Lengthened affricates as a test case for the phonetics–phonology interface

Anne Pycha

Institute for Research in Cognitive Science
University of Pennsylvania
pycha@sas.upenn.edu

Many phonetic and phonological processes resemble one another, which has led some researchers to suggest that phonetics and phonology are essentially the same. This study compares phonetic and phonological processes of consonant lengthening by analyzing duration measurements collected from Hungarian speakers ($n = 14$). Affricates, which crucially possess a two-part structure, were placed in target positions. Results show that affricates regularly undergo phonetic lengthening at phrase boundaries, and the affected portion of the affricate is always that which lies closer to the boundary. Affricates also regularly undergo phonological lengthening when next to a geminating suffix, but the affected portion of the affricate is always the stop closure. Thus, while phonetic lengthening observes a strict respect for locality, phonological lengthening does not, and we conclude that the two processes are in fact quite different from one another.

1 Introduction

A peculiar characteristic of the interface between phonetics and phonology is that processes on either side of the divide often resemble one another. The resemblances, pointed out most explicitly by Flemming (2001), can be seen by examining, for example, the effects of a nasal consonant on a neighboring vowel. In some languages, such as English, the vowel becomes partially nasalized; in other languages, such as Bengali and Nupe, the vowel becomes fully nasalized and undergoes neutralization with respect to phonemic nasalized vowels (Cohn 1993). We call the first process coarticulation and refer to it as phonetic, while we call the second process assimilation and refer to it as phonological. Yet insofar as both these processes involve the contextual influence of one sound upon another, there is undeniably some sense in which they are 'the same'. Flemming (2001) lists many other processes that look 'the same'; whether we agree with his particular approach to these processes or not, we must acknowledge that the phonetics–phonology interface does indeed raise pressing problems of redundancy, and that it does so to a degree that is not found in other interfaces, such as those between phonology and morphology or syntax and semantics (for further perspectives on this redundancy issue see J. Ohala 1990; Steriade 1997, 2001; Blevins & Garrett 1998; Barnes 2002; Blevins 2004; and many others).

Consonant lengthening is a phenomenon that has received much attention as a phonetic process, and also separately as a phonological process, but to date little or no research has considered the relationship between the two. Are these two processes the same? Consider

International Phonetic Association (2009) 39/1
doi:10.1017/S0025100308003666

phonetic lengthening. A large body of work has established that consonants can lengthen due to their position in a syllable, word, or phase (e.g. Klatt 1976, Fougeron & Keating 1997, Cho & Keating 2001, Lavoie 2001, Keating et al. 2003, Byrd et al. 2000, 2005). The changes effected by this type of lengthening vary, but are usually limited: in English, for example, consonants in phrase-final position exhibit durations approximately 30% greater than their medial counterparts (Klatt 1976: 1217). Because such a limited increase in duration does not change the phonemic status of the consonant, we refer to this type of lengthening as phonetic (for further discussion on distinguishing between phonetic and phonological processes, see Keating 1984, Pierrehumbert & Beckman 1988, and Cohn 1993).

Of course, phonological lengthening of consonants has also received a great deal of attention (see e.g. Kenstowicz 1982; Hyman 1985; Hayes 1986a, b; McCarthy 1986; Schein & Steriade 1986; Inkelas & Cho 1993; Rose 2000; Ham 2001; Muller 2001). This process, usually referred to as gemination, typically effects rather large changes: in Hungarian, for example, underlying geminates exhibit durations that are 180% to 300% greater than their singleton counterparts (Ham 2001; see also Magdics 1969: 80, Szende 1974, Kassai 1980, Tarnóczy 1987: 267). These duration increases change the phonemic status of the consonant from singleton to geminate, and can therefore be considered phonological.

Phonetic lengthening and phonological lengthening seem to perform the same basic operation (increasing duration) on the same representation (a consonant), so it seems reasonable to ask if there are some unnoticed differences between the two. The current study addresses this question, and it does so in a particular way: by examining the behavior of affricates. Affricates are complex segments which, on the surface, consist of a stop closure followed by frication (e.g. Clements & Keyser 1983; Lombardi 1990; Sagey 1990; Steriade 1993, 1994; Clements 1999). This means that any given process which affects an affricate actually has not one, but two potential targets. Different lengthening processes can, in theory, treat these targets differently. The null hypothesis is that both processes treat the complex structure of the affricate in the same manner, e.g. by increasing the duration of each portion to a certain degree. This would provide evidence that phonetic and phonological lengthening are basically the same. The alternative hypothesis, however, is that different lengthening processes treat affricates differently, e.g. phonetic lengthening increases the duration of frication only while phonological lengthening increases duration of closure only. Such a result would provide evidence that the two processes are actually rather different.

I investigate these hypotheses in a speech production study that uses near-minimal pairs for phonetic and phonological lengthening. For example, to characterize phonetic lengthening, I compare the durations of closure and frication in a target affricate that is phrase-medial with those of a target affricate that is phrase-final, as schematized in (1).

(1) Phonetic lengthening
   a. Medial: [...Vtʃ... $]_{\text{Phrase}}$
   b. Final: [...Vtʃ$]_{\text{Phrase}}$

Based on the research on phonetic lengthening cited above, we expect the target consonant in phrase-final position to exhibit an increased overall duration relative to its phrase-medial counterpart. In the current study, I seek to elaborate this expectation by asking which PORTION of the target affricate, if any, increases its duration the most.

Similarly, to characterize phonological lengthening, I compare the durations of closure and frication for a singleton affricate with those for a geminate affricate, (2).

(2) Phonological lengthening
   a. Singleton: [...VtʃV...$]_{\text{Word}}$
   b. Geminate: [...VttʃV...$]_{\text{Word}}$

Based on previous research examining the correlates of gemination, we expect geminate consonants to exhibit longer duration than singleton counterparts, even if duration is not the sole cue distinguishing the two (see Lahiri & Hankamer 1988 on Turkish and Bengali;

Local & Simpson 1988, 1999 on Malayalam; Ladd & Scobbie 2003 on Sardinian; Payne 2005 on Italian; Arvaniti & Tserdanelis 2000 and Payne & Eftychiou 2006 on Cypriot Greek; Ridouane 2007 on Tashlhiyt Berber). But again I seek to elaborate this expectation, by asking which PORTION of the affricate increases its duration the most.

The conceptual questions that motivate the current study could conceivably be pursued with speech production data from any number of different languages. Here, I pursue them with data from Hungarian, for three reasons. First, Hungarian has strident affricates at two different places of articulation, alveolar ([ts], [dz]) and postalveolar ([tʃ], [dʒ]). This fact obliges us not to over-simplify the representation of the affricate, a point to which I will return in section 5 below. Second, in addition to affricates, Hungarian has a series of palatalized consonants [tʲ dʲ nʲ]. These consonants also have a complex structure (stop closure plus glide articulation), and therefore serve as a useful point of comparison with the strident affricates. Third and finally, Hungarian possesses an unusually rich inventory of phonological processes that create geminate affricates. Only one such process will be directly investigated here, but the other processes give us important supporting evidence about the nature of lengthening.

Section 2 describes the methods of the current study. Section 3 reports the results of experiments examining phonetic lengthening, while section 4 examines phonological lengthening. Section 5 considers how linguistic theory should capture the difference between these lengthening processes, and concludes that the difference is not one of representations, but of basic operations.

2 Methods

2.1 Stimuli

To investigate phonetic lengthening, two target affricates, alveolar [ts] and postalveolar [tʃ] (Hungarian orthographic ⟨c⟩ and ⟨cs⟩, respectively, see Szende 1994), were embedded in carrier sentences modeled after those found in Beckman, Edwards & Fletcher (1992) and Byrd et al. (2000). Two word positions (initial versus final) were cross-cut with two phrasal positions (final or initial versus medial) such that each affricate appeared in a total of four positions. The target affricate was always intervocalic. Stimuli for phonetic lengthening are shown in tables 1 and 2.

To investigate phonological lengthening, stimuli were constructed from the same Hungarian noun roots, *becs* ‘honor’ and *teknőc* ‘tortoise’. Each root was combined with two different suffixes, to create two different experimental conditions. Stimuli are shown in table 3.

The singleton condition consisted of the root plus the superessive case suffix *-en* ∼ *-ön* ∼ *-on* ∼ *-n,* which adds a meaning ‘on’ or ‘on top of’ (Kenesei, Vago & Fenyvesi 1998: 235ff.; see also Vago 1980).[1] This suffix, like most suffixes of the Hungarian nominal paradigm, combines with the root without triggering lengthening. The lengthened condition consisted of the root plus the instrumental case suffix *-el* ∼ *-al* ∼ *-vel* ∼ *-val*, which adds a meaning ‘with’ (Kenesei et al. 1998: 210). This suffix conditions phonological lengthening of the root-final consonant; cf. *vassal* ‘iron-INSTR’, *bajjal* ‘trouble-INSTR’, *ketreccel* ‘cage-INSTR’ (Kenesei

[1] The modal-essive case suffix has the same -VC shape as the superessive, but lacks a rounded allomorph. In theory, then, if we combined the root *teknőc* with the modal-essive, the *-en* allomorph would provide a phonological environment that is more similar to that created by the instrumental *-el*. However, the distribution of the modal-essive is quite restricted: it is used with language names, certain qualitative adjectives (*halk-an* ‘quietly’), and in partitive constructions (*a gyerek-ek közül néhány-an* ‘some of the children’; Kenesei et al. 1998: 220, 229). Because of this restricted distribution, the superessive case suffix, which provides the next-best minimal pair with the instrumental, was used instead.

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

Table 1 Stimuli for target affricate ⟨cs⟩ [tʃ] in intervocalic position.

Word-final										
a. Phrase-medial	Nem	nagy	be**cs**	ülni	a	sarokban.				
	[nɛm	nɔdʲ	bɛ**tʃ**	ylni	ɔ	ʃɔrokbɔn]				
	not	great	honor	to.sit	the	in.corner				
	'Not a great honor to sit in the corner.'									
	Ez	igazán	nagy	be**cs**.	Ülök	a	székben	és	mindenki	kiszolgál.
	[ɛz	igɔzaːn	nɔdʲ	bɛ**tʃ**]	[yløk	ɔ	seːkbɛn	eːʃ	mindɛnki	kisolgaːl]
	this	really	great	honor	I.sit	the	in.chair	and	everyone	waits.upon
	'This is a really great honor. I sit in the chair and everyone waits upon me.'									
Word-initial										
a. Phrase-medial	Kell	még	ebbe	**cs**ülök	is.					
	[kɛll	meːg	ɛbbɛ	**tʃ**yløk	iʃ]					
	need	also	into	pig's.feet	too					
	'It also needs pig's feet.'									
b. Phrase-initial	Hús	kell	a	levesbe.	**Cs**ülök	meg	kolbász.			
	[huːʃ	kɛll	ɔ	lɛvɛʒbɛ]	[**tʃ**yløk	mɛg	kolbaːs]			
	meat	need	the	in.soup	pig's.feet	and	sausage			
	'The soup needs meat. Pig's feet and sausage.'									

Table 2 Stimuli for target affricate ⟨c⟩ [ts] in intervocalic position.

Word-final									
a. Phrase-medial	Nagyon	sok	teknő**c**	él	ebben	a	tóban.		
	[nɔdʒon	ʃok	tɛknøː**ts**	eːl	ɛbbɛn	ɔ	toːbɔn]		
	very	many	tortoise	lives	in.this	the	in.lake		
	'There are very many tortoises living in this lake.'								
b. Phrase-final	Errefelé	a	leggyakrabban	előforduló	állat	a	teknő**c**.	Él	
	[ɛrrɛfɛleː	ɔ	lɛdʲdʲɔkrɔbbɔn	ɛløːforduloː	aːllɔt	ɔ	tɛknøː**ts**]	[eːl	
	here	the	most.frequently	appearing	animal	the	tortoise	lives	
	még	itt	krokodil	is.					
	meːg	itt	krokodil	iʃ]					
	also	here	crocodile	too					
	'The most frequent animal here is the tortoise. Crocodiles also live here.'								
Word-initial									
a. Phrase-medial	A	musttal	teli	teknő	**c**élként	lebegett	előtte:	már	csak
	[ɔ	muʃttɔl	tɛli	tɛknø	**ts**eːlkeːnt	lɛbɛgɛtt	ɛløːttɛ	maːr	tʃɔk
	the	with.must	full	tub	as.goal	hover	in.front.of.him	only	ten
	tíz	vödör	szőlőt	kell	szednie.				
	tiːz	vødør	søːløːt	kɛll	sɛdniɛ]				
	bucket	grape	he.must	pick					
	'His goal, a tub full of must, was hovering in front of his eyes: he only needs to pick ten buckets of grapes.'								
b. Phrase-initial	Látod,	ott	egy	teknő.	**C**élozd	meg	egy	labdával.	
	[laːtod	ott	ɛdʲ	tɛknøː]	[**ts**eːlozd	mɛg	ɛdʲ	lɔbdaːvɔl]	
	see	there	a	tub	aim	PARTICLE	a	with.ball	
	'See, there is a tub there. Aim at it with a ball.'								

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

Table 3 Stimuli for phonological lengthening.

	ROOT	PLAIN SUFFIX superessive *-en*	GEMINATING SUFFIX instrumental *-el*
Postalveolar [tʃ]	becs 'honor (n).' [bɛtʃ]	becsen [bɛtʃɛn]	beccsel [bɛttʃɛl]
Alveolar [ts]	teknőc 'tortoise' [tɛknøːts]	teknőcön [tɛknøːtsøn]	teknőccel [tɛknøːttsɛl]

Table 4 Comparison of lengthening types.

Process	Trigger location (◇)	Trigger
Phonetic	becs◇ teknőc◇	# (phrase boundary)
Phonological	becs◇ teknőc◇	*-el* (suffix)

et al. 1998: 437). Gemination is represented in the Hungarian orthography by ⟨ccs⟩ for the postalveolar affricate and ⟨cc⟩ for the alveolar affricate. For phonological lengthening, then, the comparison of interest is between two affricates in word-medial, intervocalic position, one singleton and the other geminate.

As shown in table 4, the gemination process is as similar as possible to that of the phonetic lengthening processes (specifically, of phrase-final lengthening). The input is a singleton consonant. The output is a lengthened version of that consonant. And crucially, the conditioning environment (i.e. the suffix itself) lies to one side of the target consonant. We can see this if we schematically compare phonetic and phonological lengthening processes for Hungarian words such as *becs* 'honor' and *teknőc* 'tortoise'. In one case the trigger location is a phrase boundary, while in the other it is a suffix, but in both cases the environment lies in the same place – to the right of the affricate.

Suffix-conditioned geminates present an advantage over geminates from other sources, such as those created by the juxtaposition of two singletons, those created by assimilation, or those which exist underlyingly. These types of geminates, all of which are also found in Hungarian, have dominated the literature on the formal representation of consonant length in phonology (see e.g. Kenstowicz 1982; Hyman 1985; Hayes 1986a, b; McCarthy 1986; Schein & Steriade 1986) and certainly warrant instrumental investigation in their own right (for explicit comparison of geminates arising from different sources, see Lahiri & Hankamer 1988 on Turkish and Bengali; Local & Simpson 1988, 1999 on Malayalam; Ladd & Scobbie 2003 on Sardinian; Payne 2005 on Italian; Payne & Eftychiou 2006 on Cypriot Greek). But these other geminates make for a less direct comparison with the process of phonetic lengthening and therefore fall outside the realm of the current study.

Suffix-conditioned geminates also present an advantage over geminates created by phrasal conditioning, as in the Italian process of *Raddoppiamento Sintattico* (RS). At first blush, this kind of phonological lengthening might seem to make a good comparison with phonetic lengthening because the conditioning environment for both processes relates to position in the phrase. In reality, however, the conditioning environment for RS is quite complex, depending partly on the stress and length of the preceding vowel (Saltarelli 1970), partly on a phrasal constituent that is initially derived from syntactic structure but then deviates from it (Nespor & Vogel 1986) and partly on the presence of specific lexical items, at least for some dialects (e.g. Bullock 2000). By contrast, the conditioning environment for suffix-triggered geminates is simple, and its linear structure is analogous to that of phonetic lengthening. The current study therefore focuses on suffix-triggered geminates in Hungarian.

2.2 Procedure

A list of sentences was prepared, containing five repetitions of each target sentence ($5 \times 8 = 40$), additional target sentences which were analyzed for a separate study ($= 40$), and filler sentences ($= 28$). Following the sentences was a list of words, which contained four repetitions of each of the four target words (*becsen*, *beccsel*, *teknőcön*, *teknőccel*; $4 \times 4 = 16$), additional target words which were analyzed for a separate study ($= 16$), and fillers ($= 17$). The order of the 108 total sentences was randomized, although adjustments were then made to ensure that filler sentences, and not stimulus sentences, occupied the first and last item of every printed page. The order of the 49 total words was similarly randomized.

Subjects were asked to familiarize themselves with the sentences and words, and to read each one aloud for practice before recording began. During recording, which used a Marantz digital recorder and a head-mounted microphone, subjects were asked to read the sentences and words at a natural pace. When they mispronounced a word or a sentence, they were asked to repeat the stimulus item from the beginning. Ten subjects were recorded in a sound-proof booth, the remaining four were recorded in a quiet room in their homes.

2.3 Subjects

Subjects were adult native speakers of Hungarian ($n = 14$), all but two of whom live in the Bay Area of California. The remaining two live in Hungary, but visited California during the study. All were paid for their participation. Eight were female, and six were male. Their ages ranged from 18 years to approximately 50 years. Of those who lived in the U.S., their length of residence ranged from two months to eleven years. They came from various locations in Hungary and Romania. In interpreting the results that follow, the varied backgrounds of the subjects as well as their (sometimes prolonged) contact with American English should be borne in mind.

2.4 Measurements

For phonetic lengthening, a total of 560 tokens were analyzed (2 affricate types $\times$ 2 word positions $\times$ 2 phrase positions $\times$ 5 repetitions $\times$ 14 speakers $= 560$). One subject accidentally skipped one token during the session; the missing data were replaced with the means for that cell. For phonological lengthening, a total of 220 tokens were analyzed (2 affricate types $\times$ 2 suffix types $\times$ 4 repetitions $\times$ 14 speakers $= 224$, minus four tokens which were discarded). One subject mispronounced three tokens during the session. These tokens were excluded from the data set; in order to maintain balanced numbers across all conditions for statistical analyses, a fourth additional token for this subject was removed.

The duration of each portion of each target affricate was measured using waveforms and spectrograms produced by Praat software (Boersma & Weenink 2007). Segmentation procedures were as follows. The closure portion began when the preceding vowel displayed no more periodicity, and ended just before the release burst, if any. The frication portion began at the onset of aperiodic energy, and ended at the cessation of aperiodic energy. In those cases where the stop portion of an affricate displayed a release burst, the burst was included in the following fricative portion.

Figures 1 and 2 show waveforms and spectrograms of sample tokens that occurred in phrase-final position. In this position, the target affricate was almost always followed by pause, as in figure 1. In such cases, the frication portion ended when the waveform exhibited no further evidence of aperiodic energy, and declined to a silent state. The cessation of high frequency energy in the spectrogram also provided a segmentation cue to the end of the

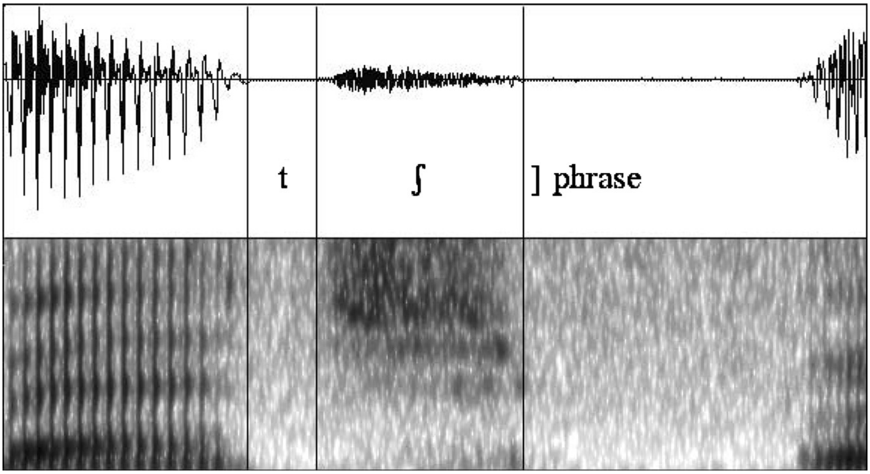


Figure 1 Segmentation of the postalveolar affricate [tʃ] in *be**cs*** 'honor' in phrase-final position.

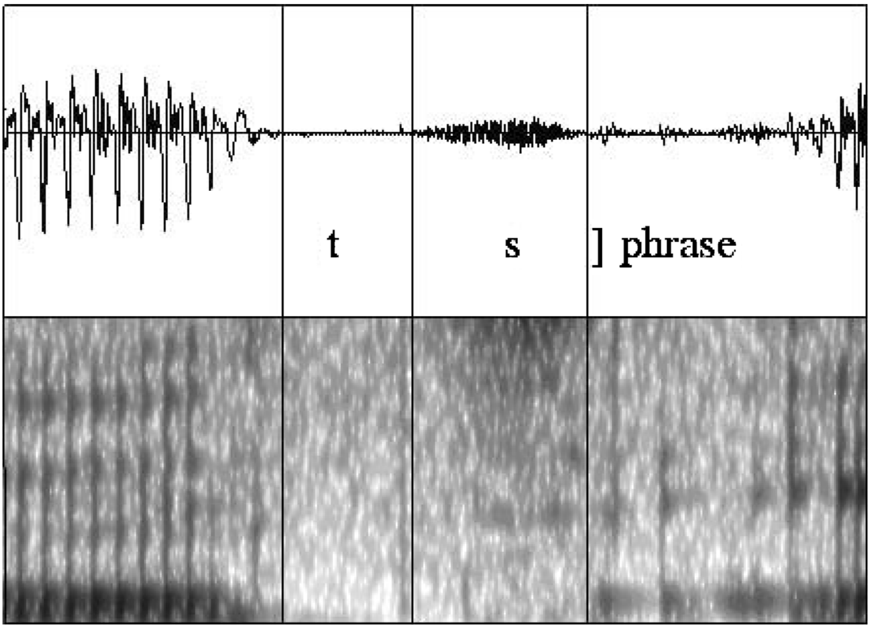


Figure 2 Segmentation of the alveolar affricate [ts] in *teknőc* 'tortoise' in phrase-final position.

fricative, particularly for the postalveolar [tʃ]. In a few phrase-final cases, the target affricate was followed by cues associated with the following phrase, as in figure 2, where there is evidence of creaky voice following [ts]. In these cases, segmentation was aided by the cues associated with the following phrase, but the criteria for segmentation were the same – that is, the frication portion ended when the waveform exhibited no further evidence of aperiodic energy.

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

2.5 Limitations

In this study, 'phonetic lengthening' will usually mean phrase-final lengthening – that is, we will be concerned with a comparison between the phrase-medial and phrase-final near-minimal pairs. This is for two reasons. First, the companion phonological lengthening process is triggered by a suffix – in other words, the triggering environment lies to the right side of the affricate. In phrase-final lengthening, the triggering environment (i.e. the phrase boundary) also lies to the right side of the affricate, making for a reasonably direct comparison between the two processes, which is the primary goal of this study. Second, the closure portion of a voiceless affricate cannot be measured accurately in phrase-initial position because it is preceded by silence. Therefore, we cannot paint a complete picture of phrase-initial lengthening. The frication portion can, however, be measured in phrase-initial position, and both portions can be measured in word-initial, phrase-medial positions. These latter measurements will therefore afford us a partial, but still valuable, characterization of lengthening in initial positions.

Hungarian also has voiced affricates, [dz] and [dʒ], at corresponding places of articulation. These are not included in the current study because their distributions are not regular. Siptár & Törkenczy (2000: 88–89) summarize the distributional evidence concerning /dz/ and conclude that '[t]he existence of /d^z/ as an underlying segment . . . is not supported by any valid argument at all'. As for [dʒ], Siptár & Törkenczy conclude that it probably is an underlying segment. But its intervocalic and final occurrences tend to be exclusively long (geminate), with just a few exceptions. Without a robust singleton counterpart, [dʒ] is a poor candidate for analysis in the current study.

For these reasons, this study examines voiceless affricates only. One consequence of this decision is that our results can be more profitably compared with previous production and perception studies of affricates, which have overwhelmingly focused on voiceless affricates (Cutting & Rosner 1974; Repp et al. 1978; Dorman, Raphael & Isenberg 1980; Howell & Rosen 1983; Miller-Ockhuisen & Zec 2002; Thurgood & Demenko 2003; Hölterhoff 2006; Mitani, Kitama & Sato 2006; but see Faluschi & Di Benedetto 2001, which includes both voiceless and voiced Italian affricates).

Note that in the word-final condition, the word containing the target postalveolar affricate, *becs* 'honor', is monosyllabic with a short vowel preceding the target, while the word containing the target alveolar affricate, *teknőc* 'tortoise', is disyllabic with a long vowel preceding the target. Ideally, these words would contain the same number of syllables and the same vowel length, but this was not possible. The difficulty lies in matching an affricate-final word with a minimally different word that lacks the affricate, as in *teknő***c** 'tortoise' versus *teknő* 'tub'. The frequency of Hungarian words containing any affricate is low to begin with. The relative frequency of words containing either a singleton or geminate ⟨cs⟩, in any position, is 0.62%. For ⟨c⟩, the figure is 0.23% (Tarnóczy 1987: 256). For final position, *Reverse-Alphabetized Dictionary of the Hungarian Language* (Papp 1969) lists only 279 words ending in singleton ⟨cs⟩ [tʃ], of which 244 are polysyllabic. It lists only 301 words ending in singleton ⟨c⟩ [ts], of which 254 are polysyllabic. Of these, only a small handful have minimally different counterparts lacking an affricate, and an even smaller handful can be embedded in a meaningful, minimally-different phrasal pair. The stimuli used in this experiment therefore represent the best compromise possible, given the natural restrictions of the Hungarian lexicon.

In the discussion that follows, then, it should be borne in mind that a difference in the lengthening behavior of postalveolar and alveolar affricates could be attributable to place, number of syllables, vowel length, or position relative to stress (which is always initial in Hungarian) or some combination of these factors. Given previous work on these issues, however, we do not expect such differences to be large. For place, Tarnóczy (1987: 267) reports nearly identical durations for both the stop and frication portions of ⟨cs⟩ and ⟨c⟩ (postalveolar closure: 0.104 sec, postalveolar frication: 0.106 sec, alveolar closure: 0.104 sec, alveloar frication: 0.113 sec), suggesting that the internal timing of these two affricates is the

Table 5 Mean duration measurements, mean differences, and ratios for affricates in phonetic and phonological lengthening contexts.

PHONETIC	Medial	Final	Difference (Final–Medial)	Ratio (Final:Medial)
Total	107.1 (20.6)	179.0 (35.7)	71.9	1.7
Closure	37.6 (14.5)	62.1 (19.3)	24.5	1.7
Frication	69.5 (19.1)	117.0 (31.6)	47.5	1.7
PHONOLOGICAL	Plain	Geminate	Difference (Gem–Plain)	Ratio (Gem:Plain)
Total	149.3 (19.9)	223.6 (32.8)	74.3	1.5
Closure	59.0 (17.6)	123.8 (40.7)	64.8	2.1
Frication	90.3 (17.0)	100.0 (25.0)	9.7	1.1

same (although see Magdics 1969, who reports bigger differences). For position relative to stress, it is usually the consonant in PRE-STRESSED position that undergoes the most change in duration (Klatt 1976, Lavoie 2001). Consonants in POST-STRESSED position, such as the ⟨cs⟩ in *becs* 'honor' are not known to change markedly, suggesting they may be reasonably compared with consonants in non-post-stressed position, such as the ⟨c⟩ in *teknőc*. It should also be noted that in most instances, Hungarian permits sequences of long vowels followed by a geminate consonant (see Kenesei et al. 1998: 419), so there should be no vowel-based restriction on the lengthening of ⟨c⟩ in *teknőc*.

3 Results: phonetic lengthening

The overall results, including both phonetic and phonological lengthening conditions, are summarized in table 5. The effect of lengthening on the total duration of the affricate appears to be roughly similar in both phonetic and phonological conditions, which exhibit increases of 71.9 ms and 74.3 ms, respectively. However, the effect of lengthening on the closure and frication portions of the affricate appears to differ greatly across the conditions. In phonetic lengthening, both closure and frication show increases in duration; for phonological lengthening, only closure seems to show a substantial increase.

The following sections discuss these results in more detail. All results use repeated-measures Analysis of Variance (ANOVA), with subject as the error term. This means that each subject serves as his or her own control, and the significance results may therefore be considered normalized across subjects (see e.g. Anderson 2001: chapter 6; Johnson 2008: chapter 4).

3.1 Phrase-final lengthening

3.1.1 Overall duration

Our first concern is to establish that phonetic lengthening does, in fact, occur in phrase-final positions. Therefore, we will focus initially on measurements for the total duration of the affricate. Recall our expectation, which is that affricates in phrase-final position should exhibit longer durations than those in phrase-medial position. This expectation was met, as can be seen in figure 3.

Affricates in phrase-medial position show a mean duration of 107.1 (20.6) ms, while those in phrase-final position show a mean duration of 179.0 (35.7) ms. This difference is significant: a repeated-measures ANOVA shows a main effect of phrasal position ($F(1, 13) = 131.25$,

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

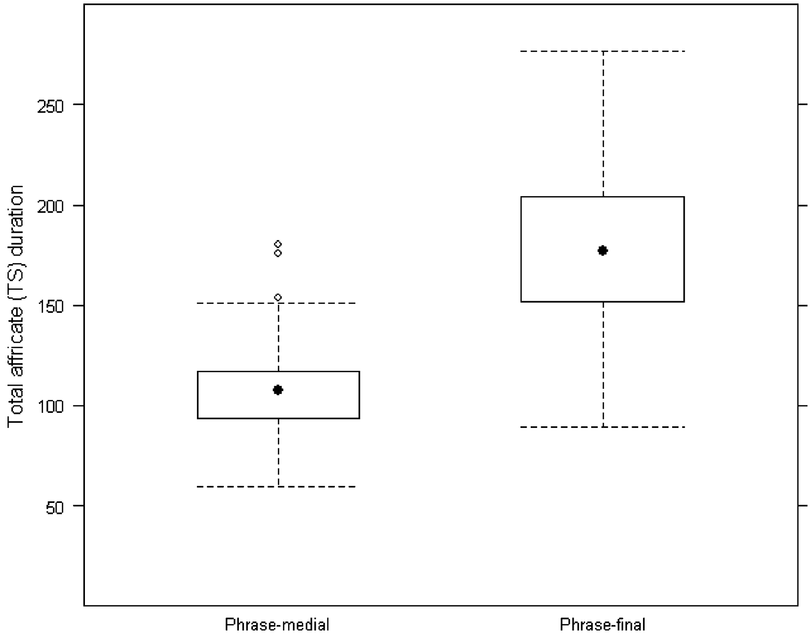


Figure 3 Distributions of total affricate durations in different phrasal positions, in milliseconds.

$p < .001$) on the total duration of the affricate. There is no effect of place of articulation and no interaction between phrasal position and place of articulation. The boxes in figure 3 (and subsequent box-and-whisker figures) enclose 50% of the durations; note that the distribution of durations in phrase-final position is relatively wide by comparison with the distribution in phrase-medial position.

We can conclude that phonetic lengthening occurs in our data set. Furthermore, each individual subject exhibits a pattern of increased durations in final position, as can be seen from consideration of figure 4. The mean ratio of durations in final versus medial position is 1.7, and individual subject ratios range from 1.4 to 1.9, except for Subject 5 who exhibited a ratio of 2.5. Thus, despite their variation in age, place of origin, and degree of contact with English, subjects exhibited remarkably consistent patterns of phonetic lengthening.

3.1.2 Component durations

Given that phonetic lengthening does occur, we can now ask HOW it occurs. We do this by individually examining the durations of the affricate components, closure and frication. Figure 5 shows the relative contribution of each component to the mean duration in each phrasal position. Figures 6 and 7 show the duration distributions of each component in each phrasal position.

In absolute terms, we see a modest difference in closure duration across the two phrase positions. Phrase-medial affricates have a mean closure of 37.6 (14.5) ms, while phrase-final affricates have a mean closure of 62.1 (19.3) ms. This difference is significant: a repeated-measures ANOVA shows a main effect of phrasal position on the closure duration ($F(1, 13) = 72.45$, $p < .001$). There is no effect of place of articulation, and no interaction between place of articulation and phrasal position. In relative terms, the mean ratio of durations in final versus medial positions is 1.7, and individual subject ratios range from 1.3 to 2.0 (except for Subject 6, whose ratio is 2.7).

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

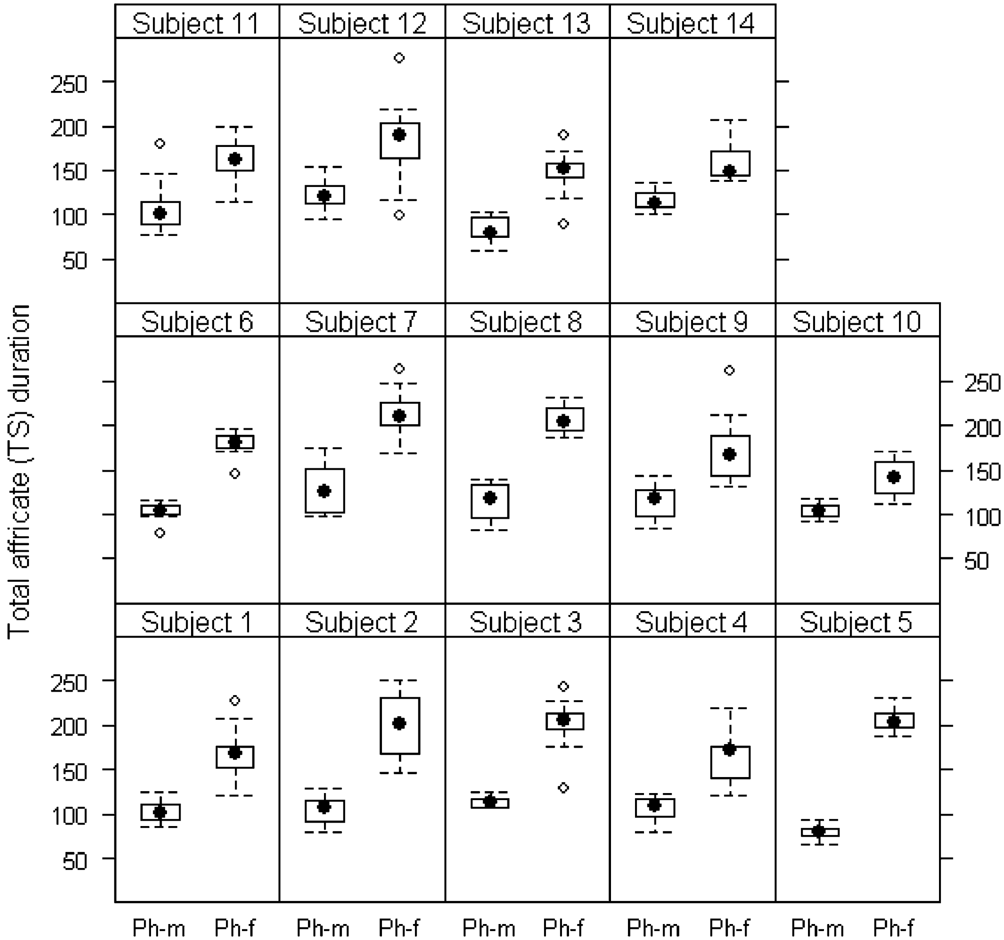


Figure 4 Distributions of total affricate durations in different phrasal positions (Ph-m = phrase-medial, Ph-f = phrase-final), for each individual subject (n = 14).

Again in absolute terms, we see a much greater difference in frication duration. Medial affricates have a mean frication of 69.5 (19.1) ms, while final affricates have a mean frication of 117.0 (31.6) ms. This difference is significant: a repeated-measures ANOVA shows a main effect of phrasal position on frication duration ($F(1, 13) = 80.75$, $p < .001$). Again, there is no effect of place of articulation, and no interaction between place of articulation and phrasal position. In relative terms, the mean ratio of durations in final versus medial position is 1.7, and individual subject ratios range from 1.3 to 2.1 (except for Subject 5, whose ratio is 3.0).

There are two ways in which we might interpret these results. In relative terms, it seems that the relationship between the closure and frication portions of the affricate remains nearly constant; phrase-final lengthening increases the duration of both closures and frications by a factor of about 1.7. This suggests a 'constancy' hypothesis: when affricates lengthen phonetically, the internal organization of the affricate remains essentially untouched. In absolute terms, however, the results indicate that it is the frication portion of the affricate which increases its duration the most. This suggests a 'locality' hypothesis: when affricates lengthen phonetically, the prime target is that portion of the affricate which lies closest to the phrase boundary.

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

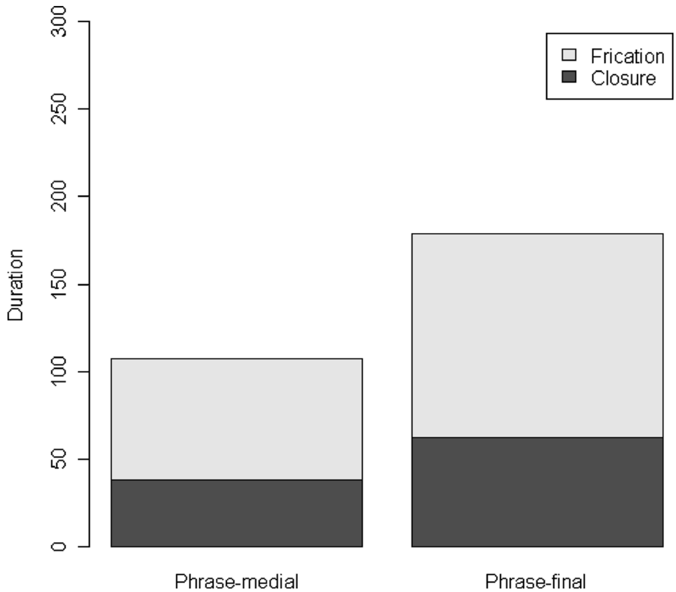


Figure 5 Mean values for closure (dark gray) and frication (light gray) durations in different phrasal positions, ms.

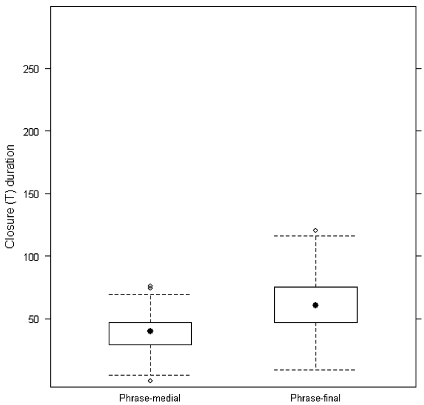


Figure 6 Distributions of closure durations in different phrasal positions, ms.

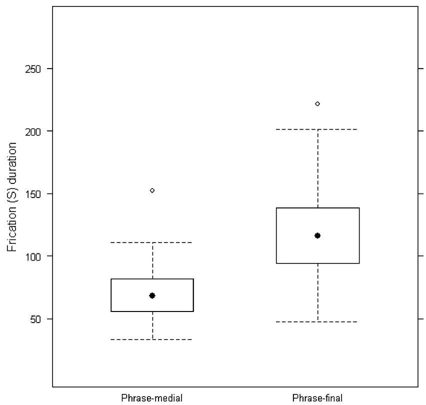


Figure 7 Distributions of frication durations in different phrasal positions, ms.

Correlations between component and total durations offer one way to evaluate these competing hypotheses. Figure 8 shows closure durations as a function of the total affricate duration, and figure 9 shows frication durations as a function of total affricate duration, both for phrase-final positions only. The constancy hypothesis would predict that both closure and frication duration should correlate equally tightly with total affricate duration. But this is not the case. Closure shows only a modest correlation with total affricate duration (Pearson's $r = 0.47$), while frication duration shows a much closer correlation (Pearson's $r = 0.84$). This result supports the locality hypothesis because it suggests that when an affricate lengthens in phrase-final position, the frication portion must be the primary target while the closure portion is only a secondary target.

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

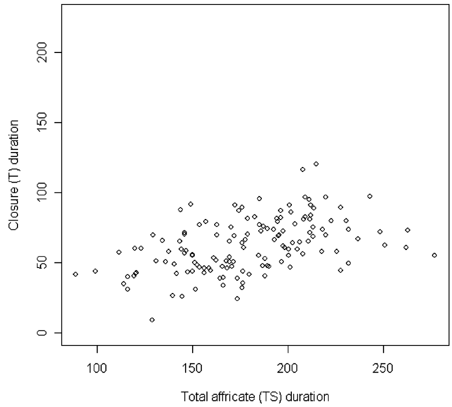


Figure 8 Phrase-final positions: relationship between total duration of the affricate and the closure portion (Pearson's r = 0.47).

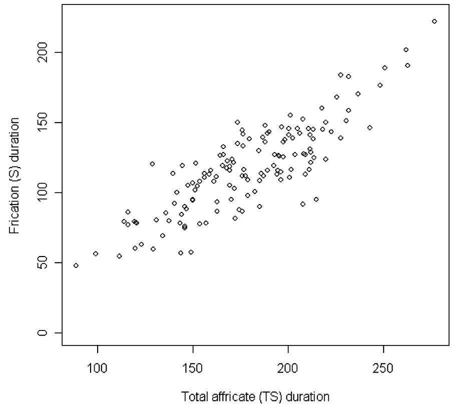


Figure 9 Phrase-final positions: relationship between total duration of the affricate and the frication portion (Pearson's r = 0.84).

3.2 Results: word- and phrase-initial lengthening

If the locality hypothesis for phonetic lengthening generalizes, then we expect that, for any phrase position, it is the affricate component closest to the phrase boundary which should undergo the biggest increase in duration. For affricates in word-initial and phrase-initial positions, then, the hypothesis predicts that CLOSURE should exhibit the biggest increases.

Our data allow us to investigate this prediction in two ways, even though we cannot measure closure durations in absolute phrase-initial position. The first way involves examining word boundaries, which also serve as a trigger for phonetic lengthening (cf. Klatt 1976: 1213). For our purposes, we want to know if the internal organization of the affricate changes as it lengthens in word-initial position (e.g. ***cs**ülök* 'pig's feet'), and whether this reorganization is the same as what we see in word-final position (e.g. *be**cs*** 'honor'). To do this, we examine correlations between measurements taken in both word-initial and word-final position, but we factor out the phrasal effect by examining only those tokens which occur in phrase-medial position (i.e. the first and third sentences from tables 1 and 2).

Figures 10 and 11 show measurements from word-initial position. Figure 10 shows closure durations as a function of the total affricate duration, and figure 11 shows frication durations as a function of total affricate duration. Closure shows a very close correlation with total affricate duration (Pearson's r = 0.93), while frication duration shows a modest correlation (Pearson's r = 0.38). This result supports the locality hypothesis because it suggests that when an affricate lengthens in phrase-initial position, the closure portion must be the primary target while the frication portion is only a secondary target. In other words, phonetic lengthening targets the component closest to the boundary, which here lies to the left of the affricate.[2]

Figures 12 and 13 show measurements from word-final position. Here, closure shows a modest correlation with total affricate duration (figure 12, Pearson's r = 0.45), while frication duration shows a closer correlation (figure 13, Pearson's r = 0.74). This pattern is reversed from what we saw in figures 10 and 11. Under the locality hypothesis, this is what we expect,

[2] For phrase-final lengthening, we first established its existence by examining the total duration of the affricate, not its components. For word-initial and word-final lengthening, we cannot meaningfully do this because we do not have word-medial counterparts against which to compare measurements.

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

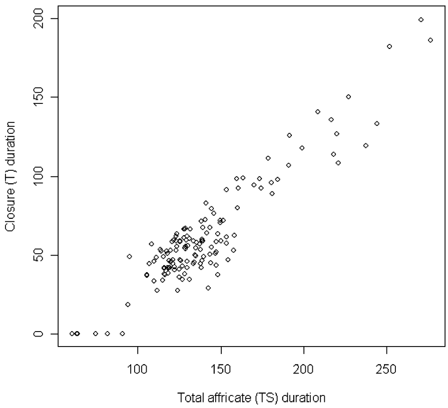


Figure 10 Word-initial positions: Relationship between total duration of the affricate and the closure portion (Pearson's r = 0.93).

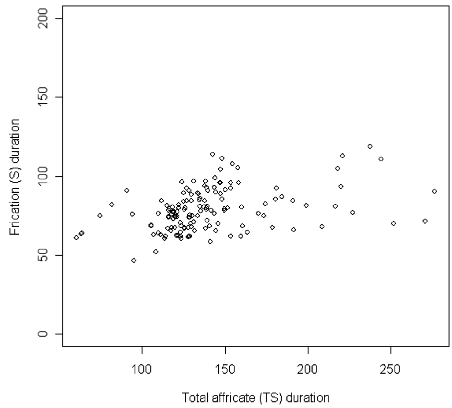


Figure 11 Word-initial positions: relationship between total duration of the affricate and the frication portion (Pearson's r = 0.38).

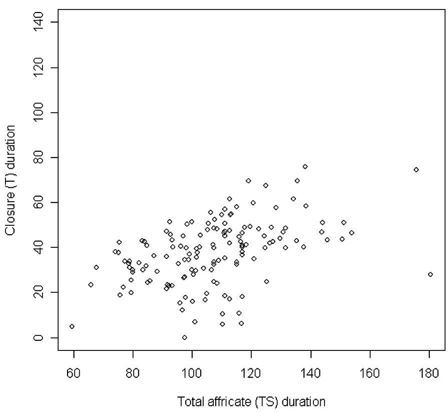


Figure 12 Word-final positions: relationship between total duration of the affricate and the closure portion (Pearson's r = 0.45).

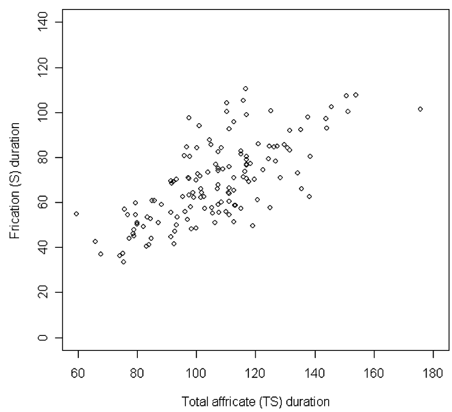


Figure 13 Word-final positions: relationship between total duration of the affricate and the frication portion (Pearson's r = 0.74).

because lengthening targets the component closest to the boundary, which now lies to the right of the affricate.

In addition to word boundaries, the second way in which we can examine our locality hypothesis is by comparing the behavior of frication durations across all four word and phrase positions.[3] We expect that the effect of phrase-final lengthening should be accomplished by increasing frication durations – this result holds true, as we have already seen in the previous section. But we also expect that the effect of phrase-initial lengthening should NOT be accomplished in this manner. This expectation appears to be borne out. A repeated-measures ANOVA shows main effects of both word position ($F(1,13) = 22.43$, $p < .001$) and phrasal position ($F(1,13) = 64.25$, $p < .001$) on frication duration, and an interaction

[3] The comparison is limited to frication durations because, as noted earlier, it is not possible to accurately measure closure durations in phrase-initial position.

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

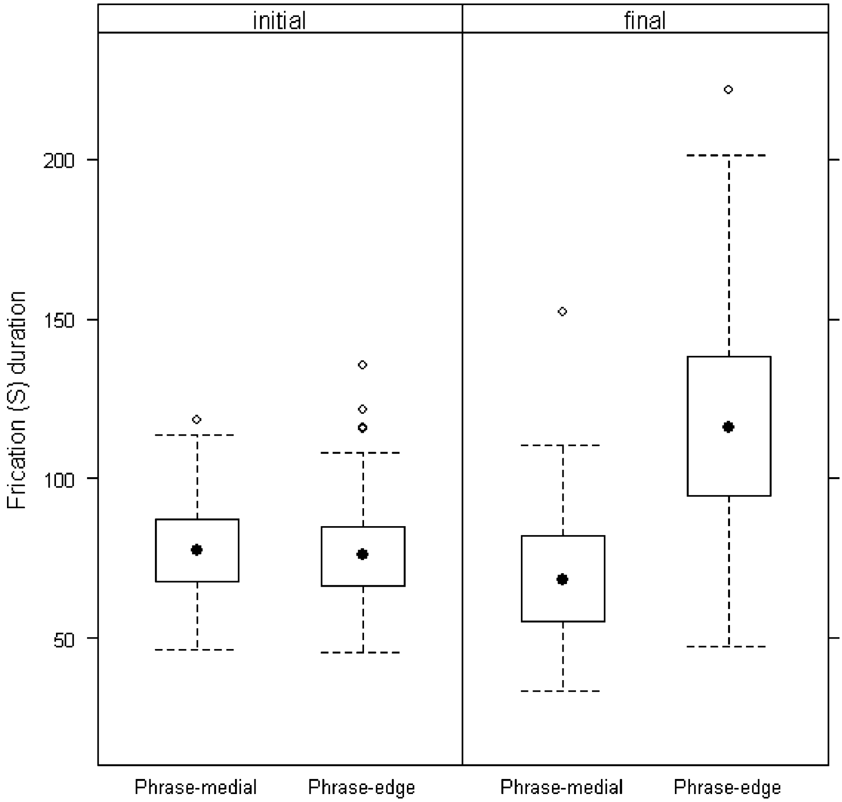


Figure 14 Distributions of frication durations in different word positions (initial versus final) and different phrasal positions (medial versus edge).

between word and phrasal position ($F(1,13) = 77.89$, $p < .001$). There is no effect of place of articulation, and no interaction between place and either word or phrasal position. A post-hoc Tukey's test reveals significant differences for every comparison except two: there is no significant difference between frication durations in phrase-initial and phrase-medial, word-initial conditions, or between frication durations in phrase-initial and phrase-medial, word-final conditions.

These results can be visualized by examining the left panel of figure 14, which shows essentially no difference in frication duration between affricates in phrase-medial and phrase-initial positions. Of course, this contrasts markedly with the results for phrase-final position (right panel), where phonetic lengthening targets frication durations almost exclusively.

3.3 Summary

The results of the phonetic lengthening experiment allow us to draw several conclusions. Lengthening in phrase-final positions is a robust effect in Hungarian. It also appears to be a gradient one, because the durations of lengthened consonants occupy a relatively wide distribution. Lengthening in phrase-final positions affects both alveolar and postalveolar affricates in similar fashion. Most importantly, phonetic lengthening targets the portion of the affricate that is closest to the word or phrase boundary. That is, initial lengthening processes target the stop closure while final lengthening processes target the frication.

The current results are consistent with previous work on phonetic lengthening in Hungarian. Olaszy (1994: 55) reports greater overall durations for words in phrase-final position, compared to phrase-medial position. Kassai (1979, 1982, cited in Hockey & Fagyal 1999) reports greater durations for both vowels and consonants in phrase-final position. Finally, Hockey & Fagyal (1999), in a corpus study of restricted spontaneous speech, found that the final CVC syllables of polysyllabic words in phrase-final position exhibited significantly longer durations than their phrase-medial counterparts. Crucially, the duration increases were not distributed equally throughout the syllable: onset consonants did not differ significantly across phrasal positions, but rhymes were somewhat longer when phrase-final, and coda consonants were significantly longer when phrase-final. The authors conclude that while some phrase-final lengthening occurs on the rhyme, most of it occurs on the final consonant, a finding that is entirely consistent with our characterization of phonetic lengthening as a strictly local process (for related work on Hungarian segmental durations, see Gósy 2001; Olaszy 2000, 2002; and the papers in Gósy 1991).

The current results are also consistent with those predicted by the prosodic boundary (π) gesture model, which Byrd and colleagues have proposed for phonetic lengthening and strengthening effects (Byrd et al. 2000, 2005). The π-gesture model predicts that those portions of the speech stream that lie closest to a prosodic boundary should undergo the most change, while those that lie farther away should undergo less. This is the effect that we see here. In phrase-final lengthening, for example, the frication portion of the affricate lies closest to the phrase boundary, and it exhibits larger increases in duration. The closure portion lies somewhat farther from the phrase boundary, and it exhibits smaller increases in duration.

Of course, the notion of locality – by which linguistic units tend overwhelmingly to be affected by those units which lie adjacent to them – is also known to be operative in phonology, the domain to which we turn next.

4 Results: phonological lengthening

We turn now to the results for phonological lengthening. Recall that we are comparing word-medial affricates followed by plain versus geminating suffixes: *be**cs**en* 'honor-SUPERESS' versus *be**ccs**el* 'honor-INSTR', and *teknő**c**ön* 'tortoise-SUPERESS' versus *teknö**cc**el* 'tortoise-INSTR'.

4.1 Overall duration

We will first establish that phonological lengthening occurs by focusing on total duration measurements. We expected that affricates which are lengthened by a geminating suffix should exhibit longer durations than affricates which are adjacent to a plain suffix. This expectation was met.

Affricates adjacent to the plain suffix show a mean duration of 149.3 (19.9) ms, while adjacent to a geminating suffix show a mean duration of 223.6 (32.8) ms. This difference is significant: a repeated-measures ANOVA shows a main effect of suffix type on the total duration of the affricate ($F(1, 13) = 235.1, p < .001$). The mean ratio of durations in geminating versus plain position is 1.5, and individual subject ratios range from 1.4 to 1.8. The ANOVA also indicates a main effect of place of articulation ($F(1, 13) = 7.4, p < .05$), and an interaction between suffix type and place of articulation ($F(1, 13) = 74.3, p < .001$). As can be seen in figure 15, the postalveolar affricates exhibit duration increases that are rather large (+92.5 ms) compared to those that the alveolar affricates exhibit (+56.0 ms). (Recall that the postalveolar stimuli *becsen*, *beccsel* and the alveolar stimuli *teknőcön*, *teknőccel* are further differentiated by number of syllables and vowel length preceding the target consonant.) Note that within each place of articulation, the distribution of durations in the geminating conditions is not much wider than the distribution of durations in the plain conditions.

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

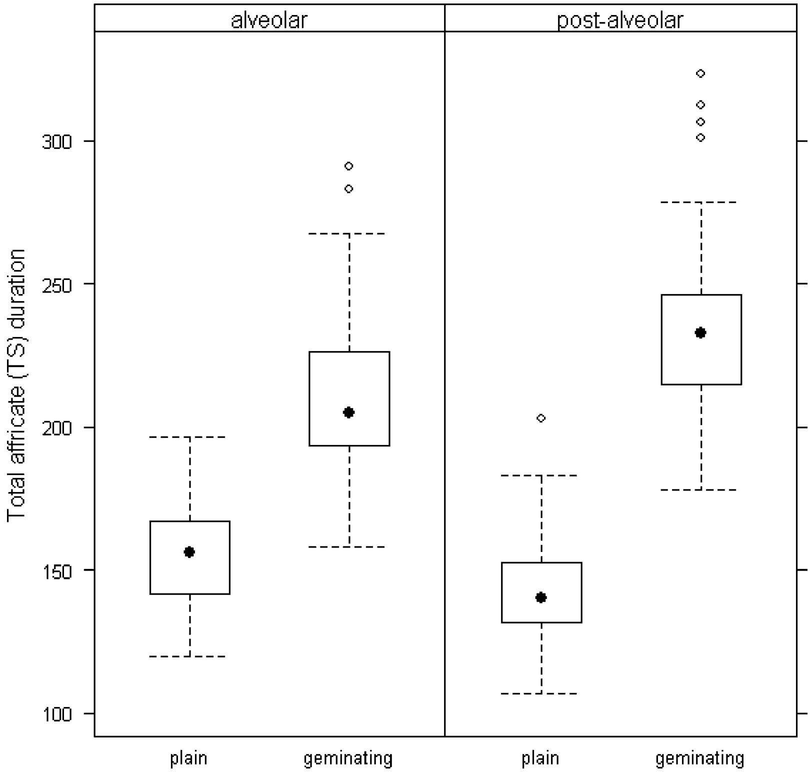


Figure 15 Distributions of total duration for different affricate places of articulation (alveolar versus postalveolar) and different suffix conditions (plain versus geminating), ms.

We may conclude that phonological lengthening occurs in our data set. Furthermore, each individual speaker exhibited a robust contrast between plain and geminating durations, as shown in figure 16. Again, despite their variation in age, place of origin, and degree of contact with English, the subjects exhibited remarkably consistent behavior. This point is important because studies of immigrant communities in the United States have shown that second-generation Hungarian speakers often lose the contrast between singleton and geminate consonants, and fail to produce geminates with the instrumental (and translative) suffixes (Fenyvesi 2005: 285–286). However, these studies also show that first-generation immigrants, unlike their younger counterparts, continue to maintain these contrasts, a conclusion that is confirmed by the current study, which included first-generation immigrants only.

4.2 Component durations

We can now ask HOW phonological lengthening occurs, and as before, we do this by examining the durations of closure and frication individually. Figure 17 shows the relative contribution of each component to the mean duration for each suffix type, and figures 18 and 19 show the duration distributions.

We see a very large difference in closure duration across the two suffix types. Affricates next to a plain suffix have a mean closure of 59.0 (17.6) ms, while those next to a geminating suffix have a mean closure of 123.8 (40.7) ms. This difference is significant: a repeated-measures ANOVA shows a main effect of suffix type on the closure duration ($F(1, 13) = 99.8$, $p < .001$). The mean ratio of durations in geminating versus plain position is 2.1, and individual subject ratios range from 1.7 to 3.0.

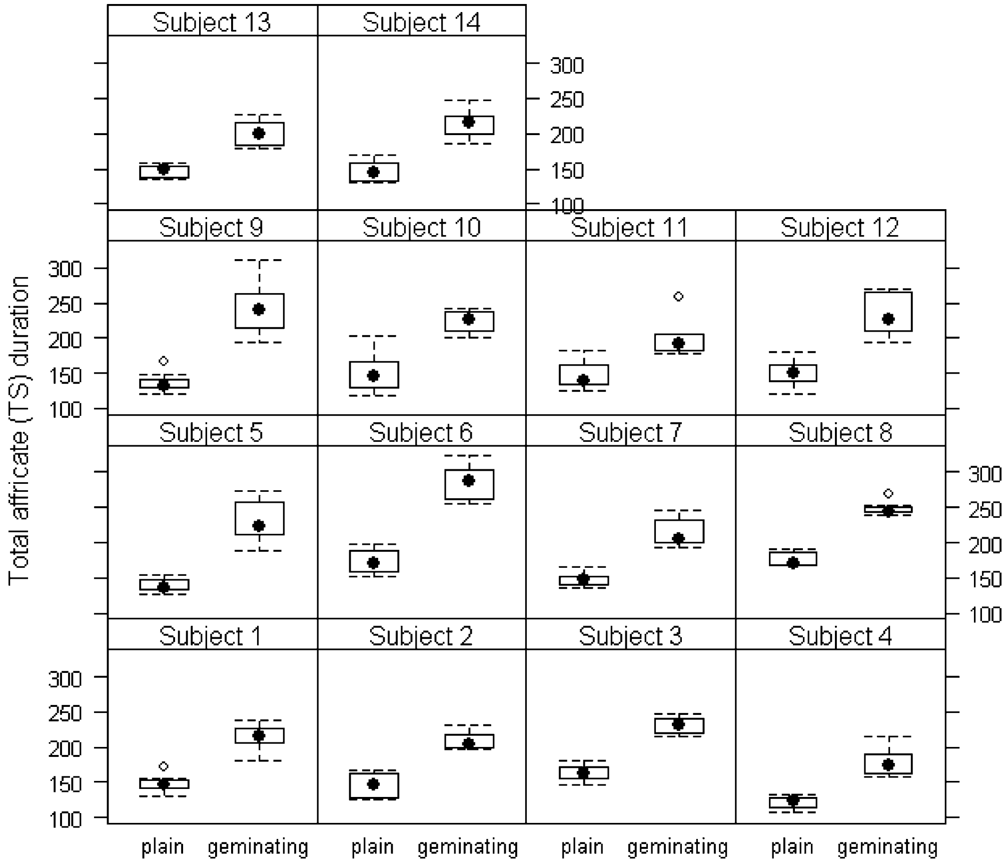


Figure 16 Distributions of total affricate durations in plain and geminating positions, for each individual subject (n = 14).

There is also a main effect of place of articulation (F(1, 13) = 36.8, p < .001), and an interaction between place of articulation and suffix type (F(1, 13) = 71.0, p < .001). This is not surprising given that the ANOVA for total duration also showed this effect and this interaction. If the bulk of affricate duration is actually due to changes in closure duration, then we expect closure duration to pattern closely with total duration.

We see just a small difference in frication duration. Affricates next to a plain suffix have a mean frication of 90.3 (17.0) ms, while those next to a geminating suffix have a mean frication of 100.0 (25.0) ms. Such a small difference may not play any linguistically meaningful role, although it is statistically significant: a repeated-measures ANOVA shows a main effect of suffix type on frication duration (F(1, 13) = 9.3, p < .01). The mean ratio of durations in geminating versus plain position is 1.1, and individual subject ratios range from 0.9 to 1.4. There is also a main effect of place of articulation (F(1, 13) = 25.3, p < .001), but no interaction between place of articulation and phrasal position.

The relative contribution of each affricate component can be seen in figures 20 and 21. These figures, which include both singleton and geminate measurements, show the closure durations and frication durations, respectively, as a function of the total affricate duration. As total duration increases, so does closure duration, and the correlation between them is strong (Pearson's r = 0.89). Frication duration, however, has a much looser relationship with total duration, and the correlation between them is quite modest (Pearson's r = 0.28).

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

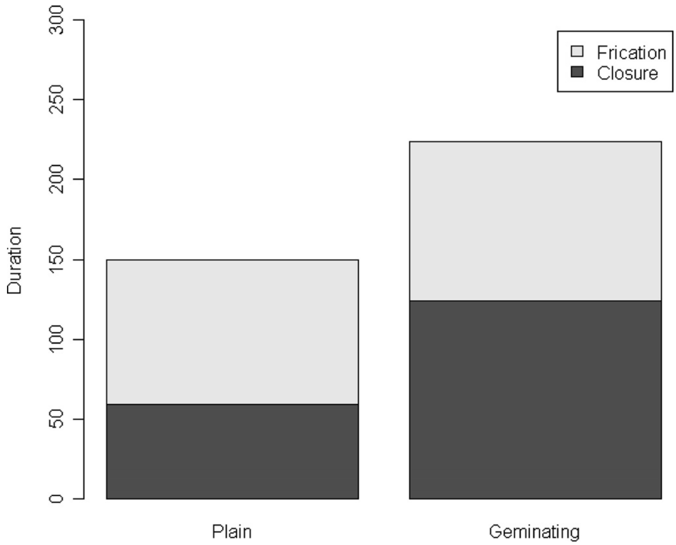


Figure 17 Mean values for closure (dark gray) and frication (light gray) durations in different suffix conditions, ms.

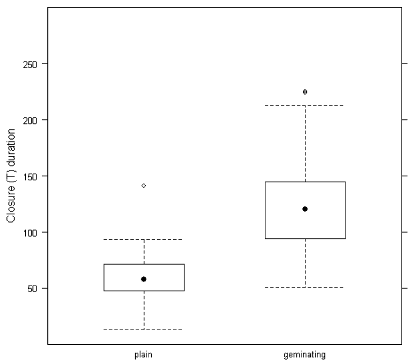


Figure 18 Distributions of closure duration in different suffix conditions, ms.

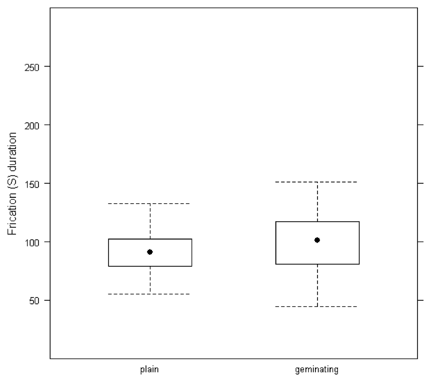


Figure 19 Distributions of frication duration in different suffix conditions, ms.

4.3 Summary

The results from phonological lengthening allow us to draw several conclusions. Suffix-triggered gemination effects duration increases on consonants. These increases appear to be categorical, in the sense that the durations of geminate consonants occupy a distribution that is just as narrow as that occupied by singletons. Most importantly, phonological lengthening overwhelmingly affects the closure portion of the affricate.

The scope of these conclusions is of course circumscribed by the fact that only two noun roots, *becs* 'honor' and *teknőc* 'tortoise', were examined. However, previous work that encompassed a larger number of Hungarian noun roots shows very similar results. Pycha (2007) reports duration measurements for thirty-two affricate-final roots with the superessive (plain) and instrumental (geminating) suffixes, exactly the same environments used here. Stimuli included monosyllabic and disyllabic roots, with final syllable shapes drawn from the

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

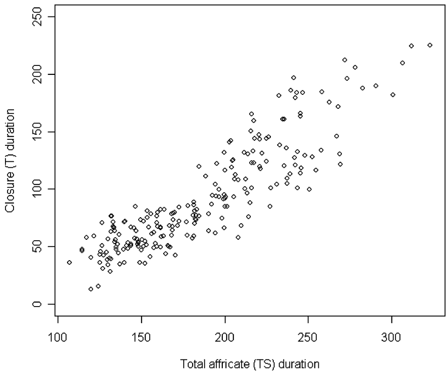


Figure 20 Singleton and geminate positions: Relationship between total duration of the affricate and the closure portion (Pearson's r = 0.89).

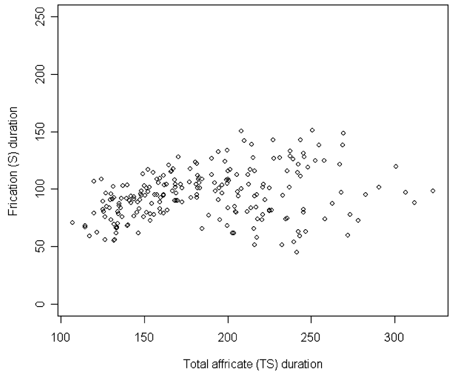


Figure 21 Singleton and geminate positions: Relationship between total duration of the affricate and the frication portion (Pearson's r = 0.28).

set CVC, CVNC, CVːC, and CVːNC, giving rise to a total of eight root shapes. The results, from three Hungarian speakers living in the United States (none of whom participated in the current study), are consistent with those presented here. The mean total duration ratios for geminating versus plain contexts was 1.3. This ratio is somewhat smaller than that reported here, most likely due to the use of a carrier sentence. For closure duration, the ratio was 1.8 and for frication duration, it was 1.1. Thus, the significant difference in duration between plain and geminating contexts occurred almost entirely in the closure portion of the affricate. Previous data on underlying singleton and geminate affricates in Hungarian also show this pattern: Kassai (1980) and Tarnóczy (1987) report measurements showing that the bulk of the duration difference occurs in the closure portion, not in the frication portion.

The current results from phonological lengthening also revealed that noun roots ending in postalveolar consonants (*becs* 'honor') are affected by phonological lengthening to a greater degree than those ending in alveolar consonants (*teknőc* 'tortoise'). Recall, however, that the two roots in question are distinguished not just by the place of articulation of the final affricate, but also by number of syllables (one for *becs*, two for *teknőc*), length of preceding vowel (short for *becs*, long for *teknőc*), and placement of the stressed syllable (always initial) relative to the target. Isolating the relevant factor is a question for future research. For now, the important point is that, in contrast to phonological lengthening, phonetic lengthening did not exhibit sensitivity to any of these factors. Thus, the behavior of phonetic and phonological lengthening clearly diverges along these lines.

Finally, recall our initial observation that the effect of lengthening on the TOTAL duration of the affricate appears to be roughly similar in both phonetic and phonological conditions. Indeed, the absolute duration increases in each condition closely parallel one another, with a mean increase of 71.9 ms for phonetic lengthening and 74.3 ms for phonological lengthening, respectively. This finding is in line with results reported in Pycha (2007) for Hungarian affricates and Hockey & Fagyal (1999) for Hungarian vowels; both studies show that phonetically lengthened segments can exhibit duration increases on a par with phonologically lengthened ones. Despite this confluence of results, the fact that phonetic and phonological lengthening should trigger similar changes in total duration is somewhat surprising, given the notion that phonetic processes should not neutralize phonological contrasts. Our focus on affricates allows us to resolve this issue. We have seen that phonetic lengthening targets the adjacent portion of an affricate, while phonological lengthening targets the closure only.

Thus, a trade-off exists between the DEGREE of lengthening, which is comparable in both conditions, and the TYPE of lengthening, which is not (see also Pycha 2007). Given that phonetic lengthening has such a radically different impact on the complex structure of the affricate, then, it seems doubtful that it would really threaten to neutralize the phonological length contrast. Future research would determine whether the phonetic lengthening of simple segments, such as vowels, could be characterized in a similar vein.

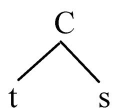
5 Discussion

The use of affricates in target position reveals a difference between phonetic and phonological lengthening that would not otherwise be evident. Although both lengthening processes are triggered by an element to the right of the affricate, and both increase the duration of the target segment, they do so in very different ways. Phonetic lengthening can increase the duration of either affricate component and does so in a strictly local fashion. But phonological lengthening exclusively increases closure duration, in a noticeably non-local fashion.

We therefore reject the hypothesis that phonetic and phonological lengthening are 'the same': that is, we reject the idea that they perform the same basic operation (increasing duration) on the same representation (a consonant). But how should we account for this lack of sameness? We could claim that the difference lies in the operation of the lengthening itself, and that the affected representations are equivalent. Alternatively, we could claim that the difference lies in underlying versus surface representations of affricates, and that the operations themselves work in an equivalent manner.

I will argue for the former claim. Phonetic lengthening, as we have seen, obeys strict locality. It always targets the nearest material in the speech stream. Phonological lengthening, on the other hand, is a more complex beast. While it generally operates according to locality, it may sometimes disregard this principle. In particular, the claim I will make here is that phonological lengthening can disregard locality (or other principles, such as input faithfulness) in order to produce outputs with long areas of maximum stricture. In other words, long consonants are preferentially long STOP consonants, not long fricatives (Elmedlaoui 1993, Kirchner 2000, Podesva 2002). As we will see, this account finds support far beyond Hungarian, in cross-linguistic patterns of gemination. Yet it also finds support within Hungarian, in patterns of geminate formation that require an underlying affricate with two ordered portions.

Let us begin by examining how this idea would apply to the Hungarian cases that have been under consideration. If there are no substantive differences between the underlying and surface forms of affricates, then the underlying form must have a two-part structure in which the stop closure and frication are ordered one after the other. This is because the surface form clearly has such a structure, visible for example in the spectrograms presented earlier in figures 1 and 2. A simple way (although certainly not the only way) to represent this ordered relationship is as in (3), which shows an alveolar affricate [ts].

(3)


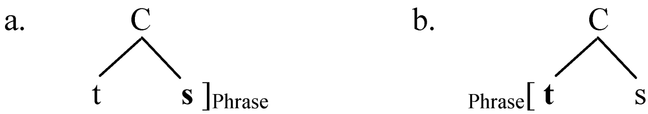
Here a single timing unit, C, is linked to two segmental units, [t] and [s] (Clements & Keyser 1983, among many others).

Phonetic lengthening can affect either edge of this two-part structure. When the trigger for lengthening is on the right (i.e. when the affricate is word-final or phrase-final), it is the frication which is affected, as shown by the bolding of [s] in (4a). When the trigger is on the

https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

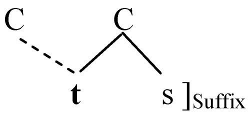
left (i.e. affricate is word-initial or phrase-initial), it is the closure which is affected, as shown by the bolding of [t] in (4b).

(4)



Phonological lengthening, on the other hand, does not have access to both edges. Even when the trigger for lengthening is on the right (i.e. when the affricate is next to a geminating suffix), it is the closure which is affected. This is because phonological lengthening is constrained by a preference to lengthen the closure rather than the frication. The representation of this constrained lengthening could take several possible forms, the choice of which is not crucial for my more general point. In (5), I show it as the non-local insertion of an empty C slot accompanied by subsequent feature spreading from [t].

(5)



There are two sources of evidence for the account that I propose. The first source comes from cross-linguistic patterns, in which a preference for geminate stop closures (versus long frications or approximant articulations) shows up in many different guises. The second source of evidence comes from independent patterns of geminate affrication within Hungarian, which show that underlying affricates must consist of two ordered portions, just like their surface counterparts.

Let us consider cross-linguistic patterns first. In Hungarian, a preference for long stop closures trumps locality. That is, phonological lengthening produces a lengthened stop closure where locality would predict a lengthened frication. In other languages, the preference for long stop closures trumps faithfulness to the input. Wolof (Ka 1994) provides a good example (see also the related language Pulaar (Niang 1997), as well as the examples from Berber cited in Elmedlaoui 1993). Wolof has a reversive suffix *-i* that triggers phonological lengthening. When the final consonant of a root is a stop, the output is a lengthened stop, as in (6).

(6)

ROOT		REVERSIVE	
ub	'to close'	ubbi	'to open'
teg	'to put'	teggi	'to remove'
lem	'to fold'	lemmi	'to unfold'
lal	'to lay'	làlli	'to take off'

When the final consonant of a root is a fricative, however, the output is also a lengthened stop, as in (7).

(7)

ROOT		REVERSIVE	
sof	'to join'	soppi	'to disjoin'
sox	'to load (a gun)'	soqqi	'to unload'

That is, phonological lengthening produces a lengthened stop closure even where input faithfulness would predict a lengthened frication.

Interestingly, in just those cases where the language can satisfy the constraint on phonological lengthening while also remaining somewhat more faithful to the input, it does so. For an input singleton /s/, the phonological lengthening produces a geminate affricate /tːs/, as in (8).

(8)	ROOT	REVERSIVE
	fas 'to tie'	fettsi 'to untie'

In other words, one portion of the fricative /s/ alternates to [t] in order to satisfy the preference for long stop closures, but the other portion surfaces as [s] in order to satisfy faithfulness to the input.

Tamil (Christdas 1988) provides additional support for this idea. In Tamil, phonological lengthening serves as a morphological marker for the derivation of nouns from verbs and of transitives from intransitives. For singleton fricatives, the output of lengthening is a geminate stop, similar to what we saw in Wolof: [perɯxɯ] 'increase', [perɯkkɯ] 'multiply'; [peesɯ] 'speak', [peeccɯ] 'speech'. In fact, Tamil extends this alternation to singletons that have even less stricture than fricatives. Thus, approximant singletons also alternate with geminate stops: [ciiʋɯ] 'comb (v)', [ciippɯ] 'comb (n)'; [uurɯ] 'ooze', [uuttu] 'spring (n)' (examples from Christdas 1988: 190, 386).

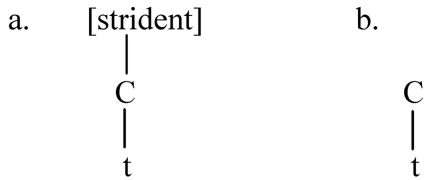
The related language Malayalam (Mohanan & Mohanan 1984, Asher & Kumari 1997) exhibits a similar pattern, and furthermore illustrates that the preference for long stop consonants seems to act specifically as a constraint on ACTIVE phonological lengthening. For example, the locative suffix *-il* triggers lengthening: [kaaʈə] 'forest', [kaaʈʈil] 'in the forest'. When the target is a singleton approximant /r/, lengthening favors a long stop closure and produces a geminate /tt/: [aarə] 'river', [aattil] 'in the river'. When two /r/ segments happen to join across a morpheme boundary, however, the preference for maximum stricture plays no role and the output is a geminate approximant /rr/: /dur-raaɳi/ → [durraaɳi] 'bad queen' (examples from Mohanan & Mohanan 1984: 582).

The idea that long consonants are preferably long stops also finds support in Podesva (2002), whose survey of 52 languages found that languages which have a geminate fricative in their phonemic inventories also have geminate stops, but not vice-versa (see also Kirchner 2000). It is also interesting to note that in some languages, an increase in stricture seems to substitute for phonological lengthening. In Cuna, for example, the geminate counterpart to singleton /s/ is not a geminate, but a singleton affricate /tʃ/ (Adelaar with Muysken 2004, Lindsey Newbold p.c.). And in Boraana Oromo, singleton affricates pattern along with geminates and consonant clusters, as evidenced by the fact that word-final affricates trigger vowel epenthesis when adjacent to another consonant (Stroomer 1995).

Many of the individual examples cited above exhibit active processes of phonological lengthening, triggered by suffixes that are similar to the Hungarian instrumental. They demonstrate that at least some phonological lengthening processes are sensitive to stricture type. But it is possible, and in fact quite likely, that more than one type of phonological lengthening exists. Some evidence for this can be found in other descriptions of geminate affricates arising from various sources. Geminate affricates that are realized with long closure portions, similar to what we have documented here for Hungarian, have also been documented for the languages Anejom (Malayo-Polynesian, Vanuatu; Lynch 2000: 24), Hindi (Indo-Iranian, India; M. Ohala 1983: 6), and Shilluk (Eastern Sudanic, Sudan; Gilley 1992: 27), to name a few. But Arvaniti & Tserdanelis (2000) report that in Cypriot Greek minimal pairs such as [ˈfitʃɐ] 'seaweed' versus [ˈfitʃːɐ] 'show off' it is the frication portion, and not the stop portion, which exhibits significantly longer durations in the geminate environment. Faluschi & Di Benedetto (2001) report that in nonsense syllables pronounced by Italian speakers, both the stop and frication portions of a geminate affricate lengthen significantly, albeit by different amounts (closure increases by 62%, frication by 28%). Finally, Thurgood & Demenko (2003) report that Polish speakers most often produce geminate affricates not with increased durations, but by double articulation. Of those geminates that were singly articulated, 44% exhibited increased duration in the frication portion. If geminate affricates take on all of these different guises, it is more likely due to a proliferation of lengthening types than to a proliferation of affricate representations.

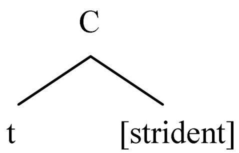
Let us now turn to the idea that underlying affricates in Hungarian must consist of two ordered portions, just like their surface counterparts. This conception of affricates has, of course, been subject to critique. Lombardi (1990), Steriade (1994), and Clements (1999) have all claimed that the representation of affricates must differ underlyingly and on the surface (see also Hualde 1988, Rubach 1994). In particular, Clements (1999) explicitly rejects the idea that affricates consist of two ordered portions. He argues instead that affricates are underlyingly simple stops, distinguished from other simple stops in terms of independently-motivated features such as [strident], [distributed], and [anterior]. Therefore, an affricate such as [ts] might have the underlying representation shown in (9a), which is distinguished from the simple stop [t] shown in (9b).

(9)



According to Clements's proposal, the feature [strident] and the features for [t] are unordered in the underlying representation. A (presumably universal) process of phonetic spell-out determines that in the surface representation, the stop closure representing [t] occurs first followed by the frication representing [strident], creating the representation shown in (10).

(10)



One advantage of Clements's proposal is that it restricts the inventory of possible segment representations. Furthermore, many, and possibly all, cases in which affricates pattern like full-blown fricatives can be analyzed as patterns that are sensitive to the feature [strident]. One such case is found in Hungarian, where regressive place assimilation among stridents encompasses not only the fricatives /s/ and /ʃ/, but also the affricates /ts/ and /tʃ/ (Siptár & Törkenczy 2000: 188–194; see also Vago 1980).

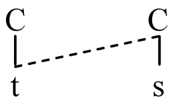
Another advantage of his proposal is that it could provide a reasonably straightforward explanation for the findings of the current study. Phonological lengthening would apply to the representation in (9a) where the closure for [t] is the only linguistic unit available for gemination. Phonetic lengthening would apply to the representation in (10), after the closure for [t] and the frication for [strident] are ordered as a sequence of events in time.

But other evidence from Hungarian suggests that an ordered, two-part structure for underlying affricates is crucial, and that an analysis which denies this ordering cannot be correct. As I mentioned briefly in the introduction, Hungarian possesses a number of processes that create geminates, and geminate affricates in particular (Kenesei et al. 1998: 442–444). For example, when an alveolar stop and a fricative come together across a morpheme boundary, a geminate affricate results, as shown in (11). (Subsequent examples, some of which show the independent effect of regressive voicing assimilation, are from Siptár & Törkenczy 2000: 193 and Kenesei et al. 1998: 442–444).

(11) *lát-szik* /t-s/ → [tts] 'seem'
barát-ság /t-ʃ/ → [ttʃ] 'friendship'
negyed-szer /d-s/ → [tts] [no gloss]
fárad-ság /d-ʃ/ → [ttʃ] 'pains'

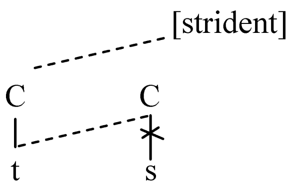
In each of these cases, two previously independent short segments, such as /t/ and /s/, rearrange their timing relationships to become a single long segment.

If, as I claim, affricates have a two-part structure, this process can be represented straightforwardly as auto-segmental spreading, in which a one-to-one relationship between segments and timing units is replaced by a many-to-one relationship, as in (12).

(12)


This analysis captures the compensatory lengthening process that occurs (Clements 1986). As the stop /t/ gets longer by virtue of association to multiple timing units, the fricative /s/ gets shorter because it no longer has a timing unit to itself.

If, on the other hand, affricates have a Clements-style simple structure, this process might be represented as the de-linking of the segment /s/ from its timing unit. This is followed by the spreading of /t/ features, and re-association of the [strident] feature that had previously been associated with /s/. A rough illustration of what this process would look like is in (13).

(13)


There are two problems here. First, the affricate geminate that results from this process can be either alveolar [ts] or postalveolar [tʃ], depending upon the place of articulation of the original fricative, i.e. alveolar /s/ or postalveolar /ʃ/. But the affricate representation in (13) does not capture differences in place. We could potentially remedy this by claiming that regressive place assimilation occurs before the delinking of /s/ or /ʃ/ from its timing unit, such that the simple stop /t/ could be rendered postalveolar, but it is much simpler to say that the underlying /s/ or /ʃ/ simply remains intact – with its stridency, place of articulation, and other features – in its original linear position within the string. Second, under a Clements-style analysis, the stridency feature of an underlying affricate is not in any linear order relative to the stop. Crucially, this predicts that geminate affricates in Hungarian should be just as likely to arise from /s-t/ and /ʃ-t/ combinations. The fact that geminate affricates do NOT arise at such junctures suggests that linear ordering of stop and frication does, in fact, play a role in affricate structure underlyingly.

Two other processes in Hungarian are also relevant to my argument. Stop and affricate combinations that occur across morpheme boundaries produce geminate affricates, as in (14). Furthermore, affricate and fricative combinations also produce geminate affricates in fast,

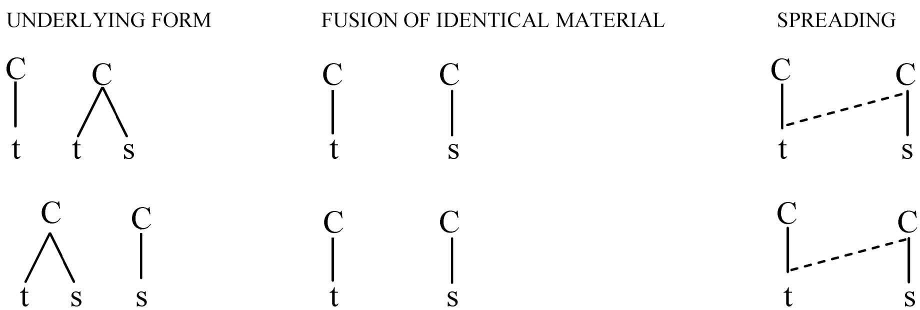
https://doi.org/10.1017/S0025100308003666 Published online by Cambridge University Press

carefree speech, as in (15) (some of the examples below also show the effect of regressive place assimilation in stridents).

(14) *hét cipő* /t-ts/ → [tts] 'seven shoe(s)'
öt csomag /t-tʃ/ → [ttʃ] 'five package(s)'

(15) *nyolc szoba* /ts-s/ → [tts] 'eight rooms'
kulcs szám /tʃ-s/ → [tts] 'key number'
arc seb /ts-ʃ/ → [ttʃ] 'facial wound'
ács segéd /tʃ-ʃ/ → [ttʃ] 'carpenter's aide'

The attested patterns show a strict sensitivity to the different sides of an affricate ('edge effects', in the terms of Lombardi 1990). Just when a stop lies to the left side of an affricate, OR when a fricative lies to the right side, a geminate affricate results. If affricates have an ordered, two-part structure underlyingly, this pattern is entirely expected, and we can analyze it as the fusion of identical, adjacent material (cf. Siptár & Törkenczy 2000: 190–193) followed by restructuring of timing relationships, as shown in (16).

(16)


As the examples show, alveolar affricates can fuse with postalveolar fricatives (*arc seb* 'facial wound'), and postalveolar affricates can fuse with alveolar fricatives (*kulcs szam* 'key number'). We can analyze these cases as having undergone regressive place assimilation, an independently-motivated alternation, prior to fusion.

If affricates have a simple structure underlyingly, however, sensitivity to the different sides of an affricate is not predicted. That is, if stop closure and stridency are unordered as Clements (1999) claims, geminate affricates should be just as likely to arise from the combinations /s-ts/, /ʃ-tʃ/, /ts-t/ and /tʃ-t/. But this does not occur in Hungarian.

A final piece of evidence also argues in favor of the two-part structure for underlying affricates. Hungarian has a series of palatalized consonants [t^j d^j n^j]. In precisely the same environments where geminate affricates are created, so are geminate palatalized consonants. Thus, when an alveolar stop and a glide /j/ come together, a geminate results.

(17) *lát-ja* /t-j/ → [tt^j] 'see' (3SG.INDICATIVE.DEF)
ad-ja /d-j/ → [dd^j] 'give' (3SG.INDICATIVE/IMPERATIVE.DEF)
ken-je /n-j/ → [nn^j] 'smear' (3SG.IMPERATIVE.DEF)

Likewise, combinations of stop and palatalized consonants produce geminate palatalized consonants, as do combinations of palatalized consonants and glides.

(18) *hat tyúk* /t-t^j/ → [tt^j] 'six hens'
mit gyártanak /t-d^j/ → [dd^j] 'what do they produce'

(19) *báty-ja* /t^j-j/ → [tt^j] 'his brother'
hagy-ja /d^j-j/ → [dd^j] 'leave' (3SG.INDICATIVE/IMPERATIVE.DEF)
hány-ja /n^j-j/ → [nn^j] 'throw' (3SG.INDICATIVE/IMPERATIVE.DEF)

The data for palatalized consonants pattern perfectly with the data for affricates. If the distinguishing feature of affricates resides in a feature such as [strident], however, we would be forced to offer one analysis for strident consonants and a separate analysis for palatalized consonants. Such a solution obviously fails to capture the generalizations holding over both. If, on the other hand, affricates and palatalized segments both have ordered, two-part structures underlyingly, as I argue, then the same analysis that we have offered for geminate affricates can handle palatalized affricates too. Thus, the proper generalization for Hungarian must be one which recognizes, rather than ignores, the underlying complexity of some segments versus the simplicity of others.

In sum, underlying affricates in Hungarian have a two-part, ordered structure. Of course, surface affricates also have a two-part, ordered structure. This strongly suggests that the correct characterization of phonetic and phonological lengthening cannot rely on the representational differences, if any, between underlying and surface segments. Instead, the correct characterization must rely on differences between the lengthening operations themselves. I have argued that this difference has to do with a phonological preference for lengthened stop closures, an idea for which there is abundant cross-linguistic evidence.

5 Conclusion

There are two major conclusions from this study. The first is that the difference between phonetic and phonological processes can run very deep indeed, despite their apparent similarities. We cannot necessarily distinguish between them simply by saying that one produces a small degree of change while the other produces a large degree of change. In fact, the lengthening processes in this study exhibit roughly equivalent degrees of overall change; thus, it is not degree, but TYPE of change that distinguishes them. It is possible that upon closer scrutiny, other supposedly similar processes – such as coarticulation and assimilation – may turn out to be quite different, too.

The second major conclusion is that complex units still have much to tell us about the nature of linguistic processes. Affricates are just one kind of complex unit. Doubly-articulated consonants, pre- and post-nasalized consonants, palatalized and aspirated consonants, diphthongs, and contour tones all possess elaborated structures. Future work could show that their components participate in phonetic and phonological processes in different ways, revealing the nature of these processes in ways that remain hidden with simpler units.

Acknowledgements

Peter Dienes wrote the stimulus sentences, for which I am deeply grateful. Keith Johnson provided guidance at all stages. Ashlyn Moehle provided expert research assistance. The Hungarian participants gave generously of their language expertise. Diana Archangeli, Larry Hyman, Sharon Inkelas, Robert Vago, *JIPA* editor Adrian Simpson, and two anonymous reviewers provided valuable critique. Portions of this work were presented at UC Berkeley, City University of New York, the University of Georgia, the 16th International Congress of Phonetic Sciences at Saarbrücken, Stanford University, and the Linguistic Society of America annual meeting, where audiences offered useful feedback. The contributors to Praat, R, and Gimp provided not-for-profit software tools. This paper was researched and written while the author was at the University of California, Berkeley. The Linguistics Department of UC Berkeley, the UC Berkeley chapter of Phi Beta Kappa, and the Abigail Hodgen Publication Award provided crucial financial support.

References

Adelaar, Willem F. H. with Pieter C. Muysken. 2004. *The languages of the Andes*. Cambridge: Cambridge University Press.

Anderson, Norman H. 2001. *Empirical direction in design and analysis*. Mahwah, NJ: Lawrence Erlbaum.

Arvaniti, Amalia & Georgios Tserdanelis. 2000. On the phonetics of geminates: Evidence from Cypriot Greek. *6th International Conference on Spoken Language Processing, Beijing, China*, vol. 2, 559–562.

Asher, R. E. & T. C. Kumari. 1997. *Malayalam*. New York: Routledge.

Barnes, Jonathan. 2002. *The phonetics and phonology of positional neutralization*. Ph.D. dissertation, University of California, Berkeley.

Beckman, Mary, Jan Edwards & Janet Fletcher. 1992. Prosodic structure and tempo in a sonority model of articulatory dynamics. In Gerard J. Docherty & D. Robert Ladd (eds.), *Segment, gesture, prosody* (Papers in Laboratory Phonology 2), 68–86. Cambridge: Cambridge University Press.

Blevins, Juliette. 2004. *Evolutionary phonology*. Cambridge: Cambridge University Press.

Blevins, Juliette & Andrew Garrett. 1998. The origins of consonant-vowel metathesis. *Language* 74, 508–556.

Boersma, Paul & David Weenink. 2007. Praat: Doing phonetics by computer (Version 4.3.22). http://www.praat.org/.

Bullock, Barbara E. 2000. Consonant gemination in Neopolitan. In Lori Repetti (ed.), *Phonological theory and the dialects of Italy*, 45–58. Philadelphia, PA: John Benjamins.

Byrd, Dani, Abigail Kaun, Shrikanth Narayanan & Eliot Saltzman. 2000. Phrasal signatures in articulation. In Michael B. Broe & Janet B. Pierrehumbert (eds.), *Acquisition and the lexicon* (Papers in Laboratory Phonology 5), 70–87. Cambridge: Cambridge University Press.

Byrd, Dani, Sungbok Lee, Daylen Riggs & Jason Adams. 2005. Interacting effects of syllable and phrase position on consonant articulation. *Journal of the Acoustical Society of America* 118(6), 3860–3873.

Cho, Taehong & Patricia A. Keating. 2001. Articulatory and acoustic studies on domain-initial strengthening in Korean. *Journal of Phonetics* 29, 155–190.

Christdas, Prathima. 1988. *The phonology and morphology of Tamil*. Ph.D. dissertation, Cornell University.

Clements, George N. 1986. Compensatory lengthening and consonant gemination in LuGanda. In Leo Wetzels & Engin Sezer (eds.), *Studies in compensatory lengthening*, 37–77. Dordrecht: Foris.

Clements, George, N. 1999. Affricates as noncontoured stops. In Osamu Fujimura, Brian D. Joseph & Bohumil Palek (eds.), *LP '98: Item order in language and speech*, 271–299. Prague: Karolinum Press.

Clements, George N. & Keyser, Samuel Jay. 1983. *CV phonology: A generative theory of the syllable* (Linguistic Inquiry Monographs). Cambridge, MA: MIT Press.

Cohn, Abigail. 1993. Nasalization in English: Phonology or phonetics? *Phonology* 10, 43–81.

Cutting, James E. & Burton S. Rosner. 1974. Categories and boundaries in speech and music. *Perception and Psychophysics* 14, 564–571.

Dorman, Michael F., Lawrence J. Raphael & David Isenberg. 1980. Acoustic cues for a fricative-affricate contrast in word-final position. *Journal of Phonetics* 8, 397–405.

Elmedlaoui, Mohamed. 1993. Gemination and spirantization in Hebrew, Berber and Tigrinya: A 'Fortis–Lenis Module' analysis. *Linguistica Communicatio* 5, 55–64.

Faluschi, Simone & Maria-Gabriella Di Benedetto. 2001. Acoustic analysis of singleton and geminate affricates in Italian. *The European Student Journal of Language and Speech*. www.essex.ac.uk/web-sls.

Fenyvesi, Anna. 2005. Hungarian in the United States. In Anna Fenyvesi (ed.), *Hungarian language contact outside Hungary*, 265–318. Philadelphia, PA: John Benjamins.

Flemming, Edward. 2001. Scalar and categorical phenomena in a unified model of phonetics and phonology. *Phonology* 18, 7–44.
Fougeron, Cécile & Patricia A. Keating. 1997. Articulatory strengthening at the edges of prosodic domains. *Journal of the Acoustical Society of America* 101(6), 3728–3740.
Gilley, Leoma G. 1992. *An autosegmental approach to Shilluk phonology*. Arlington, TX: University of Texas at Arlington.
Gósy, Mária (ed.). 1991. *Temporal factors in speech: A collection of papers*. Budapest: Research Institute for Linguistics, Hungarian Academy of Sciences.
Gósy, Mária. 2001. The VOT of Hungarian voiceless plosives in words and in spontaneous speech. *International Journal of Speech Technology* 4, 75–85.
Ham, William H. 2001. *Phonetic and phonological aspects of geminate timing* (Outstanding Dissertations in Linguistics). New York: Routledge.
Hayes, Bruce. 1986a. Inalterability in CV phonology. *Language* 62, 321–352.
Hayes, Bruce. 1986b. Assimilation as spreading in Toba Batak. *Linguistic Inquiry* 17(3), 467–499.
Hockey, Beth Ann & Zsuzsanna Fagyal. 1999. Phonemic length and pre-boundary lengthening: An experimental investigation on the use of durational cues in Hungarian. *14th International Congress of Phonetic Sciences, Berkeley, University of California*, 313–316.
Hölterhoff, Julia. 2006. *Acoustic cues of German obstruents in the speech signal and in speech perception: A contribution to automatic speech recognition*. Ph.D. dissertation, University of Konstanz.
Howell, Peter & Stuart Rosen. 1983. Production and perception of rise time in the voiceless affricate/fricative distinction. *Journal of the Acoustical Society of America* 73(3), 976–984.
Hualde, José Ignacio. 1988. Affricates are not contour segments. *Seventh West Coast Conference on Formal Linguistics*, 143–158. Stanford, CA: Stanford Linguistics Association.
Hyman, Larry. 1985. *A theory of phonological weight*. Dordrecht: Foris.
Inkelas, Sharon & Young-mee Yu Cho. 1993. Inalterability as prespecification. *Language* 69(3), 529–574.
Johnson, Keith. 2008. *Quantitative methods in linguistics*. Boston, MA: Wiley-Blackwell.
Ka, Omar. 1994. *Wolof phonology and morphology*. Lanham, MD: University Press of America.
Kassai, Ilona. 1979. *Időtartam és kvantitaás a magyar nyelvben* [Duration and quantity in Hungarian] (Nyelvtudományi értekezések 102). Budapest: Akadémiai Kiadó.
Kassai, Ilona. 1980. A magyar affrikatákról időtartamuk alapján [Duration of the Hungarian affricates]. *Magyar Nyelvőr* 104(2), 232–245.
Kassai, Ilona. 1982. A magyar beszédhangok időtartamviszonyai [Temporal relationships of Hungarian speech sounds]. In Kálmán Bolla (ed.), *Chapters of Hungarian descriptive phonetics*, 115–154. Budapest: Akadémiai Kiadó.
Keating, Patricia A. 1984. Phonetic and phonological representation of stop consonant voicing. *Language* 60, 286–319.
Keating, Patricia A., Taehong Cho, Cécile Fougeron & Chai-Shune Hsu. 2003. Domain-initial articulatory strengthening in four languages. In Local et al. (eds.), 143–161.
Kenesei, István, Robert M. Vago & Anna Fenyvesi. 1998. *Hungarian*. New York: Routledge.
Kenstowicz, Michael. 1982. Gemination and spirantization in Tigrinya. *Studies in the Linguistic Sciences* 12, 103–122.
Kirchner, Robert. 2000. Geminate inalterability and lenition. *Language* 76(3), 509–545.
Klatt, Dennis. 1976. Linguistic uses of segmental duration in English: Acoustic and perceptual evidence. *Journal of the Acoustical Society of America* 59(5), 1208–1221.
Ladd, D. Robert & James M. Scobbie. 2003. External sandhi as gestural overlap? Counterevidence from Sardinian. In Local et al. (eds.), 164–182.
Lahiri, Aditi & Jorge Hankamer. 1988. The timing of geminate consonants. *Journal of Phonetics* 16(3), 327–338.
Lavoie, Lisa. 2001. *Consonant strength: Phonological patterns and phonetic manifestations*. New York: Garland.
Local, John, Richard Ogden & Rosalind Temple (eds.). 2003. *Phonetic interpretation* (Papers in Laboratory Phonology 6), 164–182. Cambridge: Cambridge University Press.

Local, John & Adrian P. Simpson. 1988. The domain of gemination in Malayalam. In David Bradley, Eugénie J. A. Henderson & Martine Mazaudon (eds.), *Prosodic analysis and Asian linguistics: To honour R. K. Sprigg* (Pacific Linguistics Series C – No. 104), 33–42. Canberra: Department of Linguistics, Australian National University.

Local, John & Adrian P. Simpson. 1999. Phonetic implementation of geminates in Malayalam nouns. *14th International Congress of Phonetic Sciences, Berkeley, University of California*, 595–598.

Lombardi, Linda. 1990. The nonlinear organization of the affricate. *Natural Language & Linguistic Theory* 8, 375–425.

Lynch, John. 2000. *A grammar of Anejom*. Canberra: Research School of Pacific and Asian Studies, The Australian National University.

Magdics, Klara. 1969. *Studies in the acoustic characteristics of Hungarian speech sounds* (Uralic and Altaic 97). Bloomington, IN: Indiana University Publications.

McCarthy, John J. 1986. OCP Effects: Gemination and anti-gemination. *Linguistic Inquiry* 17(2), 207–263.

Miller-Ockhuisen, Amanda & Draga Zec. 2002. Durational differences in Serbian palatal affricates. Presented at First Pan-American/Iberian Meeting on Acoustics, Cancun, Mexico.

Mitani, Shigeki, Toshihiro Kitama & Yu Sato. 2006. Voiceless affricate/fricative distinction by frication duration and amplitude rise slope. *Journal of the Acoustical Society of America* 120(3), 1600–1607.

Mohanan, K. P. & Tara Mohanan. 1984. Lexical phonology of the consonant system in Malayalam. *Linguistic Inquiry* 15(4), 575–602.

Muller, Jennifer S. 2001. *The phonology and phonetics of word-initial geminates*. Ph.D. dissertation, The Ohio State University.

Nespor, Marina & Irene Vogel. 1986. *Prosodic phonology*. Dordrecht: Foris.

Sagey, Elizabeth. 1990. *The representation of features in non-linear phonology: The Articulator Node Hierarchy*. New York: Garland.

Niang, Mamadou Ousmane. 1997. *Constraints on Pulaar phonology*. Lanham, MD: University Press of America.

Ohala, John J. 1990. The phonetics and phonology of aspects of assimilation. In John Kingston & Mary Beckman (eds.), *Between the grammar and the physics of speech* (Papers in Laboratory Phonology 1), 258–275. Cambridge: Cambridge University Press.

Ohala, Manjari. 1983. *Aspects of Hindi phonology*. Delhi: Motilal Banarsidass.

Olaszy, Gábor. 1994. Sound duration measurements in declarative sentences. *Acta Linguistica Hungarica* 42(1–2), 51–62.

Olaszy, Gábor. 2000. The prosody structure of dialogue components in Hungarian. *International Journal of Speech Technology* 3, 165–176.

Olaszy, Gábor. 2002. Predicting Hungarian sound durations for continuous speech. *Acta Linguistica Hungarica* 49(3–4), 321–345.

Papp, Ferenc. 1969. *Reverse-alphabetized dictionary of the Hungarian language*. Budapest: Akadémiai Kiadó.

Payne, Elinor M. 2005. Phonetic variation in Italian consonant gemination. *Journal of the International Phonetic Association* 25(2), 153–181.

Payne, Elinor & Eftychia Eftychiou. 2006. Prosodic shaping of consonant gemination in Cypriot Greek. *Phonetica* 63, 175–198.

Pierrehumbert, Janet & Mary Beckman. 1988. *Japanese tone structure*. Cambridge, MA: MIT Press.

Podesva, Robert J. 2002. Segmental constraints on geminates and their implications for typology. Presented at the annual meeting of the Linguistic Society of America.

Pycha, Anne. 2007. Phonetic vs. phonological lengthening in affricates. *16th International Congress of Phonetic Sciences, University of Saarland, Saarbrücken*, 1757–1760.

Repp, Bruno H., Alvin M. Liberman, Thomas Eccardt & David Pesetsky. 1978. Perceptual integration of acoustic cues for stop, fricative, and affricate manner. *Journal of Experimental Psychology: Human Perception and Performance* 4(4), 621–637.

Ridouane, Rachid. 2007. Gemination in Tashlhiyt Berber: An acoustic and articulatory study. *Journal of the International Phonetic Association* 37(2), 119–142.

Rose, Sharon. 2000. Rethinking geminates, long-distance geminates, and the OCP. *Linguistic Inquiry* 31(1), 85–122.

Rubach, Jerzy. 1994. Affricates as strident stops in Polish. *Linguistic Inquiry* 25, 119–143.

Saltarelli, Mario. 1970. *A phonology of Italian in a generative grammar*. The Hague: Mouton.

Schein, Barry & Donca Steriade. 1986. On geminates. *Linguistic Inquiry* 17(4), 691–744.

Siptár, Péter & Miklós Törkenczy. 2000. *The phonology of Hungarian*. Oxford: Oxford University Press.

Steriade, Donca. 1993. Closure, release, and nasal contours. In Marie K. Huffman & Rena A. Krakow (eds.), *Phonetics and phonology*, vol. 5: *Nasals, nasalization, and the velum*, 401–470. San Diego, CA: Academic Press.

Steriade, Donca. 1994. Complex onsets as single segments: The Mazateco pattern. In Jennifer Cole & Charles Kisseberth (eds.), *Perspectives in phonology*, 203–291. Stanford, CA: CSLI Publications.

Steriade, Donca. 1997. Phonetics in phonology: The case of laryngeal neutralization. Ms., University of California at Los Angeles.

Steriade, Donca. 2001. Directional asymmetries in place assimilation: A perceptual account. In Elizabeth Hume & Keith Johnson (eds.), *Perception in phonology*, 219–250. San Diego, CA: Academic Press.

Stroomer, Harry. 1995. *A grammar of Boraana Oromo (Kenya)*. Köln: Rüdiger Köppe Verlag.

Szende, Tamás. 1974. Intervocalic affricates in present-day Hungarian. *Annual Report of the Institute of Phonetics of the University of Copenhagen*, vol. 8, 129–131.

Szende, Tamás. 1994. Hungarian. *Journal of the International Phonetic Association* 24(2), 91–94.

Tarnóczy, Tamás. 1987. The formation, analysis, and perception of Hungarian affricates. In Robert Channon & Linda Shockey (eds.), *In honor of Ilse Lehiste*, 255–270. Dordrecht: Foris.

Thurgood, Ela & Grazyna Demenko. 2003. Phonetic realizations of Polish geminate affricates. *15th International Congress of Phonetic Sciences, Barcelona*, 1895–1898.

Vago, Robert M. 1980. *The sound pattern of Hungarian*. Washington, DC: Georgetown University Press.