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Domain-initial strengthening and the phonetics and phonology of positional neutralization

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1. Introduction

1.1 Positional Neutralization in Phonological Theory

In recent debate concerning the interaction of phonetics and phonology in the grammar, a felicitous analysis of positional neutralization phenomena has become a primary desideratum for any potential model. Positional neutralization (PN) is the asymmetrical capacity of two positions (or sets of positions) in the representation to license phonological contrasts. Specifically, one set of positions, termed "weak", allows realization of only a subset of the range of contrasts available in another set of positions, termed "strong". One well-known example of this phenomenon concerns the realization of laryngeal feature contrasts on consonants. In many languages, a number of these features (i.e. voicing, aspiration, glottalization) can be contrasted in syllable onsets, but are neutralized in syllable codas (cf. Steriade 1997 for details). Facts about phonetics are often enough implicated more or less uncontroversially in the explanation of the diachronic development of such systems. In coda position, for example, the lack of a stop burst or CV transitions following the consonant makes the features in question more difficult to perceive, and hence more prone to effacement. Less obvious, however, is the extent to which this phonetic information is necessary or desirable in a synchronic model of PN.

Some approaches to positional neutralization are largely unconcerned with the phonetic motivations for the alternations they model (Beckman 1998, Zoll 1997, inter alia). While these models differ from one another in substantive and principled ways, they share the basic assumption that positional licensing restrictions are best expressed in the grammar through constraints which have reference to a fixed set of phonological features and positions. Strong and weak positions are simply listed as such, and are freely combinable with phonological features to produce constraints generating the necessary alternations or regularities. A constraint system constructed on this principle might look

NELS 32

as shown in (1). This system has the effect of excluding mid vowels from unstressed syllables, a pattern typical of many languages with contrast-neutralizing vowel reduction.

(1) Neutralization of a Vowel Height Contrast in Unstressed Syllables

a.	Ident[hi]/σ́	>>	*MidV	>>	Ident[hi]
b.	*MidV/unstressed σ	>>	Ident[hi]	>>	*Mid

(1a) accomplishes the vowel height neutralization using positional faithfulness constraints as proposed by Beckman (1998). Here, a general constraint banning mid vowels is ranked higher than a general faithfulness constraint mandating faithful output realization of the input feature [hi]. Were this the extent of it, the grammar would generate a language with no surface mid vowels at all. The presence of the higher-ranked positional faithfulness constraint mandating faithful realization of the feature [hi] specifically in stressed syllables, however, has the effect of allowing these mid vowels alone to surface, while all others are raised.

(2a) is a positional markedness constraint of the type proposed in Zoll 1997. In this system, a general markedness constraint against mid vowels is outranked by a general faithfulness constraint preserving the input feature [hi]. This much would generate a language in which input mid vowels were always realized faithfully regardless of position. The higher-ranking positional markedness constraint banishing mid vowels from unstressed syllables has the effect of leaving intact only input mid vowels located in stressed syllables.

Otherwise significant differences between these two approaches will not be of concern here. What is noteworthy in this context rather is the arbitrary relationship between the positions "stressed syllable" or "unstressed syllable" and the features [hi] and [lo] defining mid vowels. As it happens, precisely this combination of positions and features is necessary with great frequency cross-linguistically, and thus raises few eyebrows in its formalization as above. But as far as the phonology is concerned, there is no reason why these statements should be preferred over the combination of the same positions with any other sets of features, e.g. *[anterior]/unstressed σ. Any one combination of feature with position is considered just as well-formed from the point of view of the phonology as any other combination of feature with position, whether or not there is any reason to suppose that that feature is in any way related to that position phonologically in any language.

For better or worse, there is a fairly obvious way in which this approach is missing clear generalizations. Specifically, it is manifestly not the case that all features are equally relevant or active phonologically in all positions. This observation forms the basis of the influential Licensing-by-Cue theory advanced by Steriade (1997) and implemented in numerous works of other authors adopting this approach. Steriade observes that in positional neutralization patterns, the same features appear correlated again and again cross-linguistically with the same positions, and furthermore, that this correlation follows from the specific phonetic characteristics of each position. More precisely, features are licensed preferentially in positions in which phonetic conditions make them maximally perceptually robust, and are likewise eschewed in positions where they would less robust perceptually, and hence easily overlooked. It is not then the position itself which licenses or bans features, but rather the phonetic cues themselves important for those features' perception. Certain laryngeal features could then be licensed

on stops only in the presence of release bursts and following CV transitions. Likewise certain vowel height contrasts could be permitted exclusively on vowels with sufficient phonetic durations for their accurate perception. That the above consonants happen to occupy one or another syllable position, or that the vowels with inadequate durations are often unstressed is irrelevant to the formalization of these constraints. If it turns out that not only stressed vowels but, for example, phrase-final vowels as well have enough duration to license mid vowels in some languages (cf. Barnes 2001b for details), then this approach is doubly vindicated, in that it avoids the disjunctive specification of environment which would otherwise be necessary in the phonetics-free models described above. There are, of course, problems with this model as well, to which I will return in section 5. For now however it is sufficient to note that implementation of this model requires reference to non-contrastive elements of phonetic detail in the phonology.

1.2 Phonetic Strength and Psycholinguistic Strength

One theory of PN attempting to deal with the lack of restrictiveness in earlier Positional Faithfulness/Markedness theories without wholesale importation of phonetics into phonology is that of Smith (2000). For Smith, phonological positions and features are combined as before to form PN-inducing constraints, only now, before incorporation into the grammar, they are subject to screening by a set of phonetically-sensitive substantive filters which endorse constraints reflecting articulatory or perceptual reality in some way and reject combinations of features and positions not grounded in this manner. These filters are said to constitute a sort of "meta-grammar" of constraint construction. This approach holds the specter of phonetic detail in phonology at bay while incorporating some of the restrictiveness of the Licensing-by-Cue model into the theory.

In looking thus to constrain the permissive Positional Faithfulness model of Beckman 1998, Smith takes seriously a distinction suggested in passing by Beckman that there are in fact two different kinds of strong positions, and rightly looks to identify any empirical consequences that observation may have. Beckman noted that "strong" positions may be strong by virtue either of their phonetic or their psycholinguistic salience, providing a short list of both types, but making little of the distinction. Examples given of phonetically strong positions include the stressed syllable, and the syllable onset, while psycholinguistically strong positions might are, for example the word-initial syllable. Smith defines phonetically strong positions as those with robust perceptual cues for certain contrasts. Psycholinguistically strong positions are those that "play a special role in processing/lexical access/word recognition". Smith then proposes that the two types of strong positions behave differently with respect to the licensing of features. Briefly, phonetically strong positions give privilege only to the specific features which are especially robust therein. Psycholinguistically strong positions, however, privilege all features equally, since these positions need, for reasons stemming from concerns of processing, etc., to retain as many contrasts as possible. Stressed syllables are said to license vowel features preferentially, for it is primarily vowels which are augmented phonetically in this position. Initial syllables, by contrast, are equally concerned to license consonantal and vocalic features, since both are important psycholinguistically, while neither is said have any special phonetic prominence in this position. These predictions are born out by the greater cross-linguistic frequency of PN patterns involving consonantal features in initial syllables than in stressed syllables.

This paper is an investigation into the nature of positional neutralization in initial syllables, as it concerns both the distinction between psycholinguistic and phonetic strength, and the place of phonetics in phonology in general. Along the way I present experimental evidence from English and Turkish demonstrating the language specific implementation of a process enhancing the phonetic prominence of the vowels of initial syllables, and present an analysis of one particular pattern of initial-syllable PN, progressive palatal harmony in Turkic. On the basis of this analysis I argue that the notion of psycholinguistic prominence, while obviously important on independent grounds, is irrelevant in the understanding and predicting the featural content of patterns of PN. Additionally, my analysis brings to the fore a serious problem in the implementation of Licensing-by-Cue and related theories.

1.2 The Phonetics of Initial Position

The claim that word-initial position cross-linguistically confers no additional phonetic prominence on segments realized there is simply false. A process known as domain-initial strengthening has been recognized and explored in a wide variety of phonetic studies involving a number of different languages (Byrd 2000, Dilley, Shattuck-Hufnagel and Ostendorf 1996,Fougeron 1999, Fougeron and Keating 1996, Keating, Cho, Fougeron, and Hsu 1999, Oller 1973 inter alia). Among the phonetic patterns associated with word-initial position, a variety of consonants have been shown in a number of languages (English, French, Taiwanese, Korean) to acquire strengthened articulations, such that both the magnitude of their closure gestures (evaluated in the UCLA experiments primarily by measuring linguopalatal contact), and the durations of the closures were found to be increased over those found word-internally[1]. Glottal opening gestures (and likewise VOT of aspirated stops) have also been shown to increase in magnitude in English (Pierrehumbert and Talkin 1992, as does VOT in Korean (Keating, Cho, Fougeron and Hsu 1999). This added gestural magnitude and duration is striking and consistent over a wide variety of segment types and is easily enough interpreted as a source of increased perceptual robustness in this position for many consonantal features, leading to the variety of patterns of consonantal PN found involving initial syllables. There is also some evidence that absolute word-initial vowels are realized somewhat longer than word-internal vowels in French and English (Fougeron 1999, Turk and Shattuck-Hufnagel 2000), and clear evidence that this is the case in Russian, where word-initial unstressed [a] (<- /a/, /o/) is exempted from duration-dependent reduction to schwa. A number of the experiments cited also show that these phenomena are sensitive as well to the level in the Prosodic Hierarchy of the prosodic domain within which they are initial. Thus, the effect of the strengthening is greater in higher-level constituents, such as Intonational Phrases or Phonological Phrase, and smaller in lower-level constituents such as the Phonological Word.

At this point then we can say with great confidence that many of the PN patterns involving initial syllables can be attributed to the phonetic robustness the segments involved in that particular environment. Appeal to psycholinguistic properties favoring

[1] While both magnitude and duration were found to increase in a number of the relevant experiments, correlation tests in Fougeron and Keating 1996 show that the direction or even existence of a causal relationship between these two parameters is questionable.

resistance to neutralization are no more necessary here than they are in any other phonetically strong position.

There is, however, a problem. In many languages the vowels of initial syllables may express a greater variety of contrasts than those of non-initial syllables *even when the vowel itself is preceded by a consonant and thus not actually domain-initial.* The wide attestation of progressive vowel harmonies proceeding from the initial syllable are a striking example of this. In such systems, only the initial syllable of the word realizes the language's full set of contrasts, while in non-initial syllables certain features are predictable from the specification of the vowel in the initial syllable. In languages with progressive palatal vowel harmony, such as Turkish, the frontness or backness of non-initial vowels is generally determined by the frontness or backness specification of the initial vowel. This is illustrated in (2) using several monosyllabic roots and suffixes.

(2)	gøz-ler-im	dost-lar-ɯm	dʒan-lar-ɯm	dʒep-ler-im
	eye-pl-1sg	friend-pl-1sg	soul-pl-1sg	pocket-pl-1sg
	'my eyes'	'my friends'	'my souls'	'my pockets'

The phonetic motivation for such patterns is less obvious than for those involving initial consonants. In two studies of English (Fougeron and Keating 1996 and Byrd 2000), it is demonstrated that initial-syllable vowels following onset consonants do not undergo the type of domain-initial strengthening processes that are seen in truly domain-initial segments. Which is to say, these vowels are no more prominent phonetically than any other word-internal vowels, a result which once again makes the psycholinguistic-strength analysis seem like a promising alternative explanation for the phonological patterning of initial-syllable PN. In the following two sections, however, I present empirical evidence to the contrary.

2. Experiment 1: English Initial Syllables

My first experiment was designed to verify the results of Fougeron and Keating 1996 and Byrd 2000 showing the lack of initial strengthening for initial-syllable vowels. Keating and Fougeron 1996 demonstrated that in English vowel duration is strongly correlated with degree of opening. In my experiments here I analyze only the durations of initial-syllable vowels.

2.1 Methods

The stimuli I chose were 24 actual words of English. All stimuli contained an open syllable with an /æ/ nucleus under secondary stress. The vowel /æ/ was chosen for its long inherent duration, on the assumption that any systematic temporal variation would be more readily detectable in a longer stimulus than in a shorter one. In one set of stimuli, the syllable containing the target vowel was initial in the word. In the other set, the syllable in question was second in the word. The target vowels all receive secondary stress in their words. The reason for choosing specifically this level of prosodic prominence was as follows: Since unstressed vowels in English are heavily reduced and extremely short, they would make poor candidates for the detection of small-scale

durational variations. Choosing primary stresses, however, would in effect confound two distinct loci of potential phonetic enhancement. This would be particularly detrimental in comparing vowels in a number of different prosodic constituents, since accentual lengthening is known to behave much as initial strengthening of consonants in this regard. Adjacent segments were also controlled to avoid perturbations of vowel duration stemming from these. Following segments were in all cases voiceless obstruents, while voiceless stops were avoided as preceding segments because of their long positive VOT in some environments in English. Several tokens contained syllable-initial voiceless fricatives, which in retrospect may have been an error, since these too are known to impact negatively the durations of following vowels. The number of such tokens, however, was relatively small, and evenly distributed between initial-syllable and second syllable tokens. All target vowels occurred in open syllables, again with an eye to reducing non-position-dependent durational variation. (2) shows a pair of tokens illustrating the two types of stimuli.

(2)	Syllable 1	vs.	Syllable 2
	màcerabílity		anàphrodísiac

Each token was placed in three different frame sentences selected to place the target word in initial position in a variety of prosodic domains à la Fougeron and Keating 1996. The relevant domains were Utterance, Phonological Phrase, and Phonological Word. This is shown in (3).

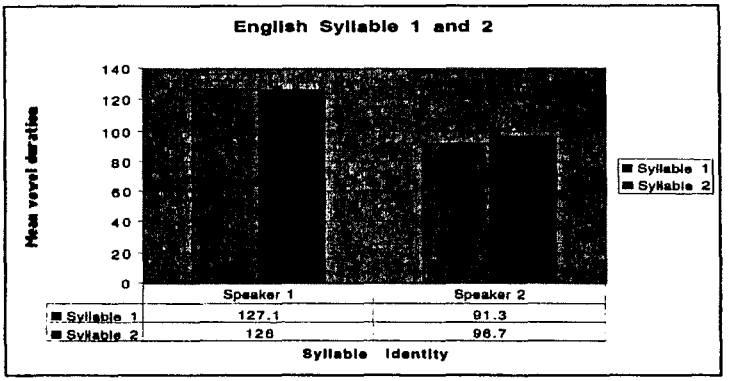
(3)	Prosodic Environments	
a.	Utterance-initial:	U[Phr[**X** is an interesting topic.
b.	Phonological Phrase-initial:	U[Phr[I think]Phr[**X** is an interesting topic.
c.	Word-initial:	U[Phr[Y **X** compound] is an interesting topic.
	e.g. fish macerability, frog anaphrodisiacs, toe lacerability, plan irrationality	

Participants were two native speakers of North American English. Speakers read the test sentences aloud from a randomized list. Sentences were uncovered one at a time by the author to insert a short pause after each sentence. Audio recordings of these sessions were digitized at 22.5 KHz., and vowel durations were measured from spectrograms and waveforms created using the Praat 3.9.5 speech analysis software (Copyright 1992-2000 by Paul Boersma and David Weenink).

2.1.4 Results

Mean vowel durations for both classes of stimuli are shown for each speaker in (4). T-test analyses revealed no significant differences between the vowels in initial and non-initial syllables. Additionally, no lengthening of the target vowels was observed in higher-level prosodic constituents either. In other words, the results of this experiment are in agreement with those of previous investigations: English vowels in initial syllables are not subject to domain-initial strengthening. Nothing new emerges from this experiment.

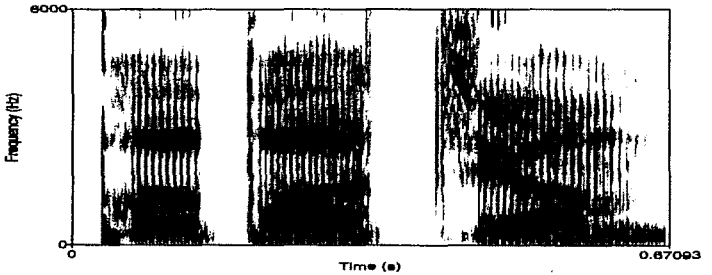
(4) Mean vowel durations for English syllables 1 and 2



3. Experiment 2: Turkish Initial Syllables

Turkish shows clear strengthening of domain-initial consonants. While a comprehensive study remains to be done, my preliminary observations over a large corpus of Turkish words recorded in isolation (created by the Turkish Electronic Living Lexicon project of Sharon Inkelas, University of California, Berkeley) suggest that at least VOT of voiceless stops, prevoicing of voiced stops and duration and energy of voiceless fricatives are significantly enhanced domain-initially. This is clearly visible in the spectrogram in (5).

(5) [$p^ha'p^hatja$] *chamomile*



In this spectrogram, the strong aspiration of the initial labial stop is clear. It is in fact substantially stronger than that found in the onset of the stressed second syllable[2]. The

[2] In Turkish as in English, both word-initial and stressed-syllable-initial voiceless stops receive strong aspiration.

longer duration of the second vowel is due to syllable structure, closed syllables hosting longer vowels than open syllables in Turkish.

This experiment investigates the phonetic durations of vowels in Turkish initial and non-initial syllables in a manner analogous to that used in Experiment 1 for English. While both that experiment and two previous ones confirm the absence of strengthening of initial-syllable vowels in English, this environment seems not to have been investigated in the studies of initial strengthening done with other languages. Turkish, as a language with progressive palatal vowel harmony, is a logical next choice for research into the realization of vowels in this position[3]

3.1 Methods

Stimuli were 85 actual trisyllabic nouns or adjectives of Turkish. In one class of stimuli, an initial closed syllable contained the vowel /a/, while in another class, a closed second syllable contained that same vowel, chosen again for its inherent duration. Turkish stress is not cued by vowel duration (Konrot 1981), and unstressed vowels do not undergo reduction, making the problems in this connection in English irrelevant here. Instead, all stimuli were had final stress, placing target vowels in either the first or second unstressed syllable. Surrounding consonantal environment was again controlled. Codas in target syllables were (in equal numbers for each class) voiceless stops and nasals. Onsets were voiced stops or sonorants. An initial version of the experiment included forms with voiceless fricative onsets, which can negatively influence following vowel duration. The majority of these were later replaced. Example stimuli are given in (6), with target vowels in boldface.

(6)	Syllable 2	vs.	Syllable 1
	CV(C).**Ca**C.CV(C)	vs.	CaC.CV(C).CV(C)
	[kaj.mak.ˈtʃɯ]	vs.	[mak.buz.ˈdʒu]

As in English, each stimulus was placed in three frame sentences, such that it would appear initially in three different prosodic constituents. The level intermediate between Utterance and Phonological Word is in all likelihood an Intonational Phrase, though to my knowledge no comprehensive study exists of prosodic phrasing in Turkish. The three prosodic environments selected are shown in (7). In each environment the target word is the initial (non-head) element in a compound. The word-initial environment makes that compound the head of an NP.

[3] Indeed, over the years a variety of Turkologists have noted some form of phonetic prominence on Turkish initial syllables. These claims are usually vague and often contradictory. In fact, there is some evidence to suggest that Proto-Turkic may have had fixed initial stress, while stress in Turkish is now regularly final in the larger part of the lexicon. It might then be concluded that any additional prominence detected on Turkish initial syllables is the lingering phonetic footprint of a long-since-shifted stress in the parent language. This analysis, discussed in Barnes 2001a, is of course impossible to confirm, though a search for strengthening patterns on initial-syllable vowels in languages lacking historical initial stresses would obviously be the correct path toward disconfirming it.

(7) Turkish Frame Sentences

Utterance-initial: U[Phr[X sokaɯ tʃok gyzel bir jerdir
street very nice one place-pred
X street is a very nice place.

Phrase-initial: U[Phr[bana sorarsan] Phr[X sokaɯ tʃok gyzel bir jerdir
I-dat ask-cond street very nice one place-pred
If you ask me, X Street is a very nice place.

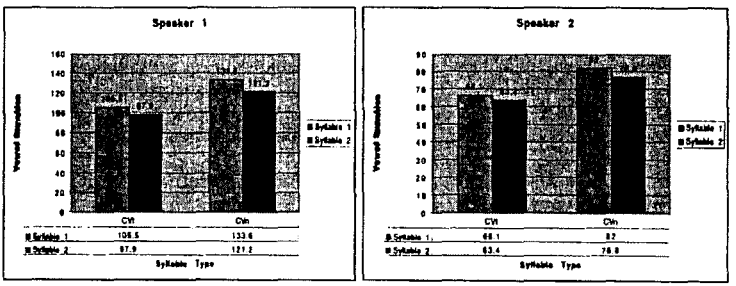
Word-initial: U[Phr[istanbuldaki W[X]sokaɯ tʃok gyzel bir jerdir
istanbul-loc-pcp street very nicel one place-pred
The X street in Istanbul is a very nice place.

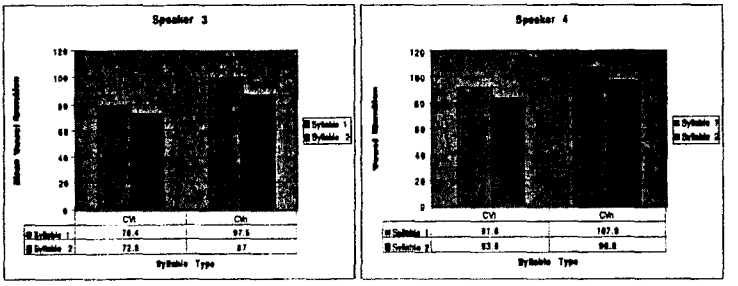
Four native speakers of Istanbul Turkish were recorded reading the stimulus sentences from a randomized list. Again, the sentences were discovered to the speakers one by one, such that a short pause was induced following each sentence. Recording sessions took place at UC Berkeley and the Bosphorus University in Istanbul. Recordings were digitized at 22.5 KHz. and vowel durations were measured from waveforms and spectrograms using the Praat 3.9.5 speech analysis software (Copyright 1992-2000 by Paul Boersma and David Weenink).

3.1.4 Results

The results of this experiment are shown in (8). It becomes clear immediately that for each speaker, mean durations of initial-syllable vowels are significantly longer than those of the vowels of second syllables. This conclusion was supported by the results of two-tailed t-tests in which analysis of the durational difference between initial and non-initial syllables for each environment and every speaker produced a main result with $p < .05$.

(8) Mean vowel durations for Turkish syllables 1 and 2





Mean vowel duration differences between syllables 1 and 2 were uniformly greater for syllables closed by nasals than for those closed by voiceless stops. This is presumably due to the fact that in Turkish vowels are longer in general before nasals than before voiceless stops, and that all things being equal longer entities tend to exhibit more durational variation than shorter entities (cf. Lehiste 1970). In this connection it is also worth noting that Speaker 2 has substantially smaller differences between vowels in initial and non-initial syllables than the other speakers. His overall vowel durations are also shorter as a result of the rapid tempo at which he read the stimuli presented to him.

The strengthening effect detected, however, was not seen to increase at the boundaries of higher-level prosodic constituents. While vowels in utterance-initial syllables were consistently shorter than others, no significant patterns emerge between phrase- and word-initial syllables. In fact, vowels in phrase-initial syllables often turned out to be shorter that their word-initial counterparts, for some speakers even with statistical significance. The same was in fact true for one of the English speakers as well. This reversal of the expected pattern might be explained by the fact that in both experiments the target words in phrase-initial contexts were both in longer sentences than the other stimuli, and farther from the beginnings of those sentences as well. These facts may have conspired to shorten the overall durations of the stimulus words at that level of the Prosodic Hierarchy, and hence of the vowels being measured as well.

While it may also be that initial strengthening in Turkish is simply not sensitive to these distinctions, it is nonetheless worth mentioning that even in the earlier studies which did detect increases at higher-level boundaries in other languages, differences were not always found for all speakers, and speakers differed frequently in their choice of boundaries playing a role. It is conceivable that a larger study of Turkish would have uncovered such an effect. It is also possible that the phrase-boundary selected for comparison with the word-boundary was insufficiently high in the hierarchy to trigger the increased strengthening effect. Further work in this direction would do well to vary the sentential contexts used, in order to control for possible problems of this type. One last problem may also have been in the choice of real-word stimuli, which, although carefully controlled, may nonetheless have introduced sufficient variation into the results to make detection of this level of durational asymmetry difficult. The studies that detected the hierarchical strengthening pattern all used single repeated stimuli and nonsense words

representing each phonetic environment under investigation. Such a strategy could prove more effective in Turkish as well.

4 Discussion

We have seen so far that Turkish, but not English, exhibits a pattern of domain-initial strengthening affecting the vowels of initial syllables. Minimally then, we can say that domain-initial strengthening is implemented to different degrees in different circumstances on a language-specific basis. This was shown in the earlier experiments as well (i.e. Keating, Cho, Fougeron and Hsu 1999), in service of the point that insofar as domain-initial strengthening varies on a language-specific basis, it cannot be relegated to the level of "universal phonetic implementation", and must receive some representation in the phonological grammars of the languages in question. Any model of phonology we adopt must then be equipped to generate both gradient non-contrastive effects of this type, and whatever patterns of PN emerge in because of them. A unified model of phonetics and phonology such as that of Flemming or Steriade would accomplish both tasks together in the same area of the grammar. Smith's model and others like it make no explicit claims concerning the location of phonetic patterns in the grammar, but they are clearly outside the phonology. I will suggest in closing that a split model of phonology recognizing both a categorical and a gradient level (possibly lexical and postlexical) à la Keating 1985, Cohn 1991, or Zsiga 1993 will ultimately be better equipped to account for the facts at hand.

Concerning the language-specific nature of domain-initial stengthening, I believe it is not by chance that it is Turkish, and not English, which exhibits initial-syllable vowel lengthening. One of the primary cues for stress placement in English is additional vowel duration in the stressed syllable. It is therefore unsurprising that English would avoid simultaneous implementation of other positionally-determined vowel-lengthening patterns, insofar as doing so would have the potential to seriously confound accurate perception of the placement of stress. This is hardly a novel argument of course; Indeed, something similar is hypothesized in Keating, Cho, Fougeron and Hsu 1999 concerning the deployment of boundary signals in English, as opposed to French and Korean, which have substantially different types of prosodic systems. They in turn cite Lehiste (1964) making a similar argument concerning vowel length and boundary signals. Continuing this line of reasoning, then, in Turkish stress is not correlated with vowel duration (Konrot 1981), leaving that phonetic resource available for use in signaling word-boundaries, which process the experiment described here in fact demonstrates. The implicational force of this analysis is, to be sure, only negative, predicting which languages should not show initial-syllable vowel lengthening. Only a more extensive experimental survey of languages with non-duration-dependent accentual systems will provide the information necessary to make any further predictions on this matter.

It might be objected at this point that English does in fact use duration to signal things other than placement of stress. Final lengthening is a well-known example[4].

[4] I do not consider durational variations induced by local segmental or syllabic environment in this connection, as these lack the culminativity associated with stress placement. In such cases duration is not being deployed in the language as the primary cue for a uniquely-identifiable prosodic positions (such as primary stress or edge). That additional duration supplied by local segmental environment can nonetheless

However, English final lengthening is consistent and robust only in the higher prosodic domains. At the word-level, it is sporadic and weak (cf. Beckman and Edwards 1990), which would tend to minimize its effect on perception of stress placement. Final lengthening is also attributed to a different articulatory mechanism than the lengthening associated with stress. Beckman, Edwards and Fletcher (1991) identify final lengthening with a general slowing down of the articulators, possibly with a concomitant decrease in the magnitude of gestures as well. This is in sharp contrast to the "localized hyperarticulation" described by de Jong (1995) in discussion of the phonetic correlates of stress. Turkish initial strengthening, unlike the final lengthening found in English, is both equally consistent in the lower and higher prosodic domains, and seems to be augmenting in nature (as preliminary observation of VOT and fricative intensity suggest).

4.1 Initial Syllables and Stressed Syllables

Based on the evidence presented here from Turkish, we can see that both the vowels of stressed and of initial syllables can be host to the type of "articulatory or perceptual privilege" thought to give rise to the positional neutralization patterns found involving phonetically strong positions. But the phonetic prominence associated with the two strong positions is far from identical. In languages with duration-cued stress, stressed vowels are generally dramatically longer than the shortened and often qualitatively reduced unstressed vowels. The initial-syllable vowel lengthening found in Turkish, however, is far less extreme, with mean differences appearing at plus or minus 10 ms. for most of the speakers measured. The vowels of non-initial syllables do not appear particularly short in comparison, and undergo no phonetic centralization, laxing, or other reduction-like processes.

I am arguing here that neutralizations of contrast observed in PN systems originate in the phonologization of phonetic patterns specific to the positions in question. If this is so, then the generalizations made above concerning the phonetics of initial- and stressed-syllable lengthening should have clear consequences in the patterns of PN we find attested in those positions. This is in fact the case.

With the caveat that we are now dealing in generalizations often admitting no small number of well-known exceptions, we can observe the following: Firstly, languages with duration-cued stress, meaning those with large durational differences between stressed and unstressed vowels (e.g. English, Russian, Brazilian Portuguese), quite commonly display patterns of phonological vowel reduction (no surface instances of certain vowels in weak positions). Reduction patterns are often said to result from a lack of sufficient duration for the accurate perception or production of some set of vowel contrasts (Details of this deficiency differ: Accounts following Lindblom 1963 focus on the articulatory "undershoot" caused by insufficient time to reach targets for vowel articulation. Steriade 1994 and others focus on a lack of adequate steady-state duration making the discrimination of contrasts difficult for the listener). In other words, the extent of the durational asymmetry between stressed and unstressed vowels in many languages results in the complete effacement of certain vowel qualities from certain positions. It is much less common to encounter in languages with duration-cued stress word-level harmony systems like that of Turkish triggered instead by the stressed

dramatically impact the structure of a stress system is of course incontrovertible, as the attraction of otherwise-edge-based stress to internal heavy syllables in many languages clearly demonstrates.

syllable[5] Such harmony systems occur in the large of majority of cases in languages without duration-cued stress. In these systems, unlike in systems of reduction, the disfavored vowels may still be realized in weak positions. They are just not contrastive there. The fact that they still are capable of surfacing at all is presumably a consequence of the fact that they are only slightly shorter than their strong-position counterparts, avoiding the more dramatic "undershoot" situation posited for the development of vowel reduction.

Phonetic differences between stressed and unstressed syllables are generally accepted to be the ultimate source of the phonological licensing asymmetries found in those positions. By now, in this and other studies, a number of phonetic asymmetries between initial and non-initial syllables have been clearly identified. I will show that these differences are sufficient to account for the specific licensing asymmetries observed between those positions as well. While the motivation for this may be clear in the case of the consonantal features discussed in earlier studies, it is admittedly less obvious how the small durational differences between initial- and non-initial-syllable vowels in Turkish could have set in motion the phonologization of a complex system of vowel harmony.

4.1 The Emergence of Turkic Palatal Harmony

It is often observed that vowel harmony and vowel reduction share many common features, most notably that they both involve the positional neutralization of vowel quality contrasts. It is additionally quite intuitive, and often suggested in a general manner, that the one type of system might be linked in some way with the other developmentally, and specifically, that the chain of assimilations imagined to give rise to systems of vowel harmony would be phonetically quite a bit more plausible were it to take place across a string of vowels whose quality had already been neutralized by some other process, to wit, vowel reduction. If the weak vowels already licensed the appearance of fewer contrasts (i.e. no mid vowels), and the vowels which did surface there were of significantly diminished duration, we could imagine they would be more susceptible to coarticulatory effects from neighboring strong vowels. Rhodes (1999), for example, observes English reduced vowels undergoing low-level gradient assimilation in roundness to neighboring back rounded vowels. Certain East Slavic dialects with robust systems of vowel reduction also display patterns of dissimilation or assimilation involving the stressed vowel and the first pretonic vowel (see Crosswhite 1999 for an OT-based analysis some of these systems). Languages with some sort of harmony system already in place are also known to add new assimilations to pre-existing ones (i.e. the gradual extension of rounding harmony in the Turkic languages, cf. Kaun 1995 for synchronic analysis of these systems).

All these cases, while not in fact instances of the development of full-blown word-domain vowel harmony systems from earlier non-harmonizing reduction systems, nonetheless suggest some validity for the reduction-then-assimilation hypothesis. For cases such as that of Turkic, however, such an analysis is implausible. There are (at least) two reasons to believe this, both of them typological in nature. Proto-Turkic is generally

[5] See Majors 1998 for a comprehensive treatment of stress-dependent harmony systems. It is importan also, in this connection, to maintain a distinction between those harmonies which spread *to* the strong syllable (as traditionally cited cases of umlaut, metaphony, and indeed most instances of stress-dependent vowel harmonies), and those which spread from it (such as Turkic).

reconstructed with some system of palatal harmony already in place, and many scholars believe there are grounds to reconstruct initial stress as well (see note 4 above). This brings us back to the oft-cited generalization that fixed-stress systems are not generally duration-cued and non-duration-cued stress-systems rarely generate robust patterns of phonological vowel reduction (a glance across the prosodic systems of the Slavic languages illustrates this point well on a smaller scale: Czech, Polish, Serbo-Croatian, Standard Macedonian with no duration-cued phonemic stress and no phonological vowel reduction, Russian, Belorussian, Bulgarian and Macedonian dialects with duration-cued phonemic stress and phonological vowel reduction, to name only the best known cases). For the reduction-first generalization to be correct for Turkic then, Pre-Proto-Turkic must have been a counterexample to this generalization. Specifically, it would have had to develop a vowel reduction system sufficiently sweeping in nature to give rise to the attested harmony system, and to do so in a system with fixed, non-duration-cued stress. This is by no means to say that such a thing is impossible, rather only that, were it true, it would be quite unusual. Alternatively, one might imagine that Turkic fixed stress was at one point duration-cued and later changed, a hypothesis which is also rather displeasing typologically, and which in any case can be neither proved nor disproved.

More damning though for the reduction-first hypothesis is the following: Recall that Turkic vowel harmony involves the neutralization of frontness/backness distinctions, which is to say, quality contrasts along the F2 dimension. In order to derive this state of affairs from an earlier system of vowel reduction, then, we must imagine that Pre-Proto-Turkic had a reduction system allowing a full range of contrasts in initial position, but neutralizing all F2 contrasts in non-initial syllables while retaining contrastive height everywhere. Among the unstressed vowel reduction systems of the world, such a system is, to my knowledge, virtually unattested. Canonical vowel reduction systems, neutralizing contrasts along the F1 or height dimension[6], make perfect sense with regard to the phonetic characteristics of unstressed syllables in the relevant languages. Durationally-deprived unstressed syllables tend not to host vowels or vowel contrasts that take a longer time to produce or apprehend. One cross-linguistically robust feature of vowels of differing heights is that they also differ in intrinsic duration, lower vowels tending to be longer. Explanations of this fact generally appeal to the time it takes to achieve the various degrees of jaw-opening associated with the different vowel heights. No similar generalization obtains for the frontness/backness distinction. It is thus clear why dramatic durational asymmetries impact precisely the contrasts they do, while leaving others systematically untouched. It follows from all the above that if Pre-Proto-Turkic did have the kind of reduction system which could have engendered the harmony reconstructed for Proto-Turkic, that reduction system would have been rather odd in a number of ways, not to say unheard of[7]. Other instances of progressive palatal harmony would presumably also require the same unlikely scenarios to have been the case at some point.

[6] Obviously not the only features involved cross-linguistically in vowel reduction. Other common ones are tenseness/laxness and perhaps to some extent rounding, at least the first of which distinctions is equally explicable according to the diachronic analysis of VR proposed here.

[7] Arguments from typological considerations are of course never conclusive, in that strange things do happen, as much in phonology as anywhere else. They can, however, be strongly suggestive, as I would argue this one is.

4.1.2 Durational Asymmetries and the Rise of Vowel Harmony

If it is not the case that Proto-Turkic palatal harmony arose from an earlier phonological vowel reduction system, to what then can its emergence be attributed? I will argue that it emerges from precisely the type of small-scale durational asymmetry between initial and non-initial syllables as this paper shows is still found in the Anatolian Turkish of today.

A widespread and intuitively plausible conception of the development of vowel harmony patterns maintains that harmony arises diachronically through the phonologization of vowel-to-vowel coarticulation. This view is defended in e.g. Ohala 1993 and 1994. Flemming (to appear) derives vowel-to-vowel assimilation patterns from coarticulation synchronically as well. Majors in her 1999 dissertation shows that in many languages vowel-to-vowel coarticulation is most robust from stressed vowels to unstressed, a fact which she argues could lead to the development of harmony patterns with stressed vowels as their triggers. Unfortunately, this information alone does not provide us with an analysis of the emergence of harmony in Turkic.

Inkelas, et al. (2001), building on work by Beddor and Yavuz 1995, demonstrate experimentally that in Modern Turkish, anticipatory vowel-to-vowel coarticulation is stronger than carryover. Furthermore, this is true regardless of the position of stress (again, usually but not always final in Turkish). These findings present a serious challenge for coarticulation-based theories of vowel harmony for the following reason: If vowel harmony is driven synchronically by vowel-to-vowel coarticulation, then stronger anticipatory coarticulation should yield right-to-left harmony patterns, rather than the left-to-right system attested in Turkish. In Turkish, coarticulation and harmony run in opposite directions. For diachrony, of course, it would be possible to conclude, with Beddor and Yavuz, that all this simply means that prosody was radically different in Proto-Turkic times. It is conceivable that at the time of the emergence of palatal harmony in Proto-Turkic, carryover coarticulation was stronger than anticipatory, and that at some point this situation reversed itself. If Proto-Turkic did in fact have fixed initial stress as some scholars hypothesize, we could imagine that, unlike in Modern Turkish, Proto-Turkic coarticulation flowed most strongly from the stressed syllable à la Majors 1999, yielding the desired direction of assimilation. This hypothesis, however, has a number of serious flaws: If Proto-Turkic did in fact have fixed initial stress, then this stress pattern obviously changed somewhere along the way to Modern Turkish, such that the language developed a fixed final stress. Now, if early fixed initial stress was in fact duration- and/or amplitude-cued[8], then the assumption of Proto-Turkic carryover coarticulation would acquire a certain phonetic naturalness (again, as per Majors 1999). The idea of a subsequent shift to stronger anticipatory coarticulation, however, in the face of the uninterrupted phonetic prominence of the initial syllable, now becomes difficult to countenance[9]. Certainly the innovation of the F0-cued accent of later Turkic is a poor candidate for the driving force behind that change. A shift in the direction of vowel-to-

[8] The alternative potential source for the modern initial syllable vowel-lengthening mentioned in note 4 above. The relationship between amplitude and stress in Modern Turkish is not straightforward, though there may be a correlation to some extent for non-final stresses (Konrot 1981). Numerous confounding factors in Konrot's experiment make this difficult to ascertain. As noted before, duration is not correlated with stress at all.

[9] Even assuming that only later did stress and coarticulation become dissociated, as they are today in Turkish.

vowel coarticulation in these circumstances seems capricious and unmotivated. On the other hand, if the earlier fixed initial stress had prosodic characteristics similar to those of the stress in Modern Turkish, then even the motivation for assuming an earlier carryover coarticulation in the first place becomes obscure.

The preferable option, of course, would be to produce an analysis that could save the coarticulation theory without recourse to the historical assumptions discussed above. To this end I propose the following: Anticipatory coarticulation, all things being equal, may well be stronger than carryover in Modern Turkish, and lacking any reason to assume otherwise, I take this to have been the case in Proto-Turkic as well. As demonstrated above, however, initial-syllable strengthening in Modern Turkish produces, independent of the position of stress, a durational asymmetry between the vowels of initial and non-initial syllables. Assuming domain-initial strengthening to have been active in the past as it is today, the same would be true of Turkic at the time of the phonologization of vowel harmony. This durational asymmetry seems not to affect the dominant direction of coarticulation in Modern Turkish (Inkelas, et al. 2001). It could, however, produce significant changes *in the perception thereof.*

Turkish vowel-to-vowel coarticulation patterns received absolute measurements in Inkelas, et al.. These were arrived at through comparison of mean formant values at vowel onsets or offsets in a coarticulated (adjacent vowel different) context with the corresponding values found in a baseline (adjacent vowels identical) context. In a relative sense, however, an absolute coarticulatory effect of a given magnitude would nonetheless occupy a smaller portion of the total duration of a longer vowel than it would of a shorter vowel. This coarticulatory effect, however strong in the absolute sense, could then still prove perceptually less salient on a longer vowel than on a shorter one. In Turkish this would mean that the overall stronger effect of anticipatory coarticulation might nonetheless fail to be perceived robustly on the lengthened vowels of the initial syllable. By the same token, carryover coarticulation, however weak overall, would receive additional salience perceptually on the shorter vowels of non-initial syllables. This durational skewing effect allows us to understand why, stronger direction of coarticulation aside, Vowel 1 of a Turkic word might still be less likely to assimilate to Vowel 2 than vice-versa.

All the foregoing, however, buys us no more than a single sound change: Vowel 2 assimilates to Vowel 1 in frontness/backness in Pre-Proto-Turkic. But this alone cannot be the full story. I am also less-than-sanguine about the plausibility of an analysis in which word-domain harmony is brought about gradually by the methodical creep of palatality across from left margin to right in the word. Rather, the sound change described here must account for only the first step in the rise of Turkic vowel harmony. The remainder of the process would then be analogical in nature.

This idea receives support from the fact that the overwhelming majority of roots reconstructed for Proto-Turkic are either one or two syllables in length. Trisyllabic roots are shadily attested at best (Johanson 1998)[10]. Assuming also the possibility of the addition of suffixes to the root in questions, we must bear in mind crucially the following word-forms in any discussion of the emergence of vowel harmony:

[10] Calculations done by Kemal Öflazer in fact suggest that the mean number of syllables per word in running text in Modern Turkish may not be any greater than this (Sharon Inkelas, p.c.).

(9) Some Crucial Proto-Turkic Word Shapes[11]

a. $[[CV.CV]_{root}]$

b $[[CV]_{root}[CV]_{suffix}]$

c. $[[CV.CV]_{root}[CV]_{suffix}]$

Assuming now that Vowels 1 and 2 in (9a-c) disagree in frontness/backness (α), the application of a sound change assimilating Vowel 2 to Vowel 1 in this respect yields the results schematized in (10):

(10) Assimilation of V2 to V1

a. $[[CV_{\alpha}CV_{-\alpha}]_{root}]$ > $[[CV_{\alpha}CV_{\alpha}]_{root}]$

b $[[CV_{\alpha}]_{root}[CV_{-\alpha}]_{suffix}]$ > $[[CV_{\alpha}]_{root}[CV_{\alpha}]_{suffix}]$

c. $[[CV_{\alpha}CV_{-\alpha}]_{root}[CV_{-\alpha}]_{suffix}]$ > $[[CV_{\alpha}CV_{\alpha}]_{root}[CV_{-\alpha}]_{suffix}]$

d. $[[CV_{\alpha}CV_{-\alpha}]_{root}[CV_{\alpha}]_{suffix}]$ > $[[CV_{\alpha}CV_{\alpha}]_{root}[CV_{\alpha}]_{suffix}]$

The sound change in (a) produces a disyllabic root with palatal harmony, meaning essentially that the overwhelming majority of roots in the language are now harmonic. The output of the change in (b) is a disyllable in which the suffix takes on the palatality specification of the root, creating another word without disharmonic vowels. Example (d) merely shows that if a suffix added to a disharmonic disyllabic root has the same [back] specification as the first syllable of the root, the output of the sound change will be a completely harmonizing trisyllabic word. The only problem among these examples, in fact, is form (c). Here the output of the sound change is a harmonized disyllabic root with a non-harmonizing suffix. The crucial analogical step occurs here.

The addition of the same suffix to [+back] and [-back] monosyllabic roots means that the sound change shown in (10) has the effect of creating an alternation, whereby the choice of suffix vowel is dependent on the identity of the root vowel. The fact that no alternation occurs when the root is disyllabic creates irregularity in the choice of suffix vocalism: Sometimes the suffix vowel harmonizes, and sometimes it does not (the addition of two suffixes to a monosyllabic root potentially creates the same irregularity). This irregularity is removed from the system simply by the generalization of the harmonizing allomorph to all forms, as illustrated in (11) where the plural suffix -lAr is taken as representative.

(11) Generalization of Suffix Alternation Pattern: Proportional Analogy

$$CV_{[\alpha]}C \ : \ CV_{[\alpha]}ClA_{[\alpha]}r \ :: \ CV_{[\alpha]}CV_{[\alpha]}C \ : \ X$$

$$X = CV_{[\alpha]}CV_{[\alpha]}ClA_{[\alpha]}r$$

At this point we have a system with all trisyllables, regardless of morphological structure, displaying palatal harmony. The extention of the alternation pattern to longer strings of suffixes is not difficult to conceive. It is worth noting that just as the generalization of the alternating allomorph is possible, we might equally well expect the reverse, viz.,

[11] These representations are highly schematic and not meant to imply consideration of open syllables only.

instances of generalization of the invariant allomorph to all forms. The fact that some suffixes are reconstructed for Proto-Turkic as non-harmonizing could be an indication that this in fact took place.

5 Conclusions

Returning at last to sychrony and discussion of the place of phonetics within a phonological model of positional neutralization, we can now make two important conclusions. First, the phenomenon of domain-initial strengthening in its multiple guises creates robust perceptual cues for a variety of phonological contrasts, both vocalic and consonantal, in word-initial syllables. Word-initial syllables, no less than stressed syllables or syllable onsets, are the locus of a phonetic strength. The fact that word-initial syllables preferentially license a different set of phonological contrasts than do, for example, stressed syllables, is a consequence of the fact that patterns of positional neutralization arise through the phonologizatioin of phonetic characteristics specific to the relevant positions. Insofar as these phonetic characteristics differ from position to position, so too will the range of contrast neutralizations observed therein. I am arguing, then, that the phonetic characteristics of initial syllables are *by themselves* sufficient to account for the featural content of Positional Faithfulness or Markedness constraints needing reference to that position. Reference in the grammar to the psycholinguistic status of initial syllables is thus superfluous in characterizing patterns of positional neutralization involving those syllables. A similar argument is made for final syllables in Barnes 2001b.

Of crucial importance to this argument is the following point: The claim that reference to the psycholinguistic prominence of initial syllables is unnecessary for modeling of PN patterns involving initial syllables *does not imply that those syllables are not in fact psycholinguistically prominent.* Experimental evidence concerning the psycholinguistic importance of word-initial syllables is compelling indeed, and nothing I have said here challenges that evidence in any way. Indeed, the phonetic prominence of initial syllables observed here may well have its origins in the very fact that those syllables do have such psycholinguistic prominence[12]. This paper seeks only to determine what factors produce the specific patterns of positional neutralization found in a given position, and why those patterns differ systematically depending on the positions concerned. For my purposes then, it matters only that the phonetic characteristics of initial syllables, and not the psycholinguistic status thereof, are the proximal cause giving rise to the specific contrast neutralizations involving those syllables. Whether initial syllables are also psycholinguistically prominent, and whether or not this fact is in any way correlated with their phonetic prominence is another question altogether, and not one I am addressing here. This claim contradicts the approach of Smith 2000, which relies on psycholinguistic prominence to derive differences between the neutralization patterns found in associated with stressed and initial syllables. I have not taken issue here with her more general theoretical innovation of substantive filters on constraint building, arguing instead only that those filters should be exclusively phonetic in nature. While I do believe there are substantial further issues that warrant discussion in connection with the idea of substantive filters, I will not undertake that discussion here. I will conclude rather with a

[12] Or, for that matter, vice versa, to invoke the chicken/egg scenario inevitable here.

note on the implications of my findings here for the Licensing-by-Cue and similar approaches to PN.

It is widely, if not generally, agreed at this point that a theory of PN which does not include phonetics at any level is simply missing a vast number of obvious generalizations involving restrictions on the types of neutralization found in each position. Licensing-by-Cue and other theories advocating the direct inclusion of phonetic detail in phonology were proposed in large part to remedy this, and in some cases (specifically those of gradient, postlexical processes), they can do so successfully. Consider, however, what such a theory could make of the link between domain-initial strengthening and palatal vowel harmony in Modern Turkish. I have detailed in this paper an account of the role of phonetics in the initial stage of phonologization of the harmony system. Implication of the durational assymetry between initial and non-initial syllables in the generation of synchronic vowel harmony, however, encounters an immediate and daunting difficulty: Vowel harmony in Turkish is simply no longer controlled by the initial-syllable vowel. Modern Turkish contains a large number of disharmonic roots which use the [back] specification of the final vowel of the root, and not the initial vowel, to determine the vocalism of suffixes[13], suggesting that further analogical changes have again restructured the system. Durational facts, while instrumental in the phonologization of progressive palatal harmony, are not sufficient to characterize its synchronic implementation. This problem reappears in case after case of PN within the lexical phonology, and must be addressed by any theory of PN advocating the inclusion of phonetic detail in the phonological grammar. The split models of phonology mentioned above, however, in which, e.g., the lexical phonology operates on categorical symbolic representations, and the postlexical on representations which are gradient and phonetic, can treat palatal harmony in the former, and initial strengthening in the latter, while the link between the two remains a fact about the diachronic development of the system, and not its driving force in the here and now.

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[13] E.g., katil, *murderer,* katiller, *murderers.*

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