Phonology and Phonetics of English Stress and Vowel Reduction*

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Abstract
The reduced energy level of unstressed vowels compromises perceptibility of vowel distinctions, leading to the 'neutralization' of some of the distinctions. The difference between the collapse of most vowels into [ə] in English, and more restricted effects in other languages is shown to be managed by constraint ranking within OT. The same factors that compromise perceptibility of V-quality are shown to also compromise perceptibility of C-place in a following coda, however, and this is argued to underlie certain failed vowel-reductions, as in the final syllable of *Àdiróndack*. Coronals differ in not comparably blocking reduction, as in *Connéctic[ə]t*, a property that is attributed to the notoriously 'unmarked' character of coronals: since neutralizations are quite generally to 'unmarked' values, coronals are -as it were- 'pre-neutralized' for place, and are thus insensitive to whether or not a preceding vowel provides good place cues, thus permitting vowel reduction. The account of vowel-reduction based on this kind of V-to-C interaction is proved superior to traditional ones based solely on lack of stress, which would not only face serious difficulties in providing just the 'right' stresses, but would also miss important links between the distribution of vowel reduction and the structure of word-final clusters, which are correctly captured here.

Keywords:
English stress
vowel reduction
perceptual cues

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1. Introduction

In my (1994) *Principles of English Stress* (PES), I argued that the traditionally held 'if-and-only-if' relation between stress and vowel-reduction in English is incorrect, and that while lack of stress is necessary for vowel-reduction, it is not sufficient. The goal of this paper is to re-assert the PES claim and analysis in the more contemporary setting of both Optimality Theory (OT) and the understanding of neutralization phenomena offered by Steriade (1994, 1997).

The traditional claim that lack of stress is sufficient for vowel-reduction leads to serious complications in the analysis of stress, listed in (1).

(1) a. **Long V-stressing**: pa.pý.ri, a.lúm.ni, íncrease, persónify, ...
Long vowels do not reduce, thus requiring a 'Long V-stressing' provision.

b. **Ross' (1972) stresses**: Adiróndack, ... vs. Connéctic[ə]t, ...
Final syllables closed by velar or labial stops fail to exhibit reduction, thus requiring some special mechanism of stress assignment sensitive to C-place, as proposed in Ross (1972).

c. **Medial clashes**: èxpectátion, ... vs. còmt[ə]mplátion, ...
Similarly, medial syllables closed by velars or labials also fail to exhibit reduction, thus requiring special provisions, especially in light of the apparent stress clashes.

The PES argument is that such complications are ultimately doomed, while alternative complications in the analysis of vowel-reduction, in the form of further requirements *in addition* to simple lack of stress, prove successful. The non-viable character of the provisions in (1) is established largely by the fact that the rest of the stress system fails to detect the presumed stresses, just as if the latter were not there. Specifically, other stresses in the word always turn up where one would expect them anyway, as described in turn in (2).

(2) a. **No Long V-stressing** (PES, 48-52):
- The stresses that would be assigned by 'Long V-stressing' never cause other stresses to shift: *papýrus/ papýri, alúmnus/ alúmni*, ...
- If long vowels were invariably stressed, disyllabic items like *rábbi, áthlete, sátire* should have final main stress, just like *repórt, ovért, crusáde*, etc.

- Verb/ Noun alternations like *incréase/ íncrease* are just like those of *pervért/ pérvert*, etc. if there is no 'Long V-stressing'. Otherwise the two types of alternation are unrelated, requiring separate accounts.
- The lack of stress preservation in cases like *pérson/ persónify* is understandable only if *-ify* does not bear stress. Otherwise, preservation is expected, just as in *óxygen/ óxygenàte*.

b. **No Ross' stresses** (PES, 78-82):
   - Feet consisting of a single overt syllable shun primary stress in the presence of a larger foot, as in *(círcum)(vènt)*. Hence, the penultimate stress of *Adiróndack,* would be expected to be a secondary if a stress was present on the final syllable: **(Ádi)(ròn)dack*.
   - Stress on the final syllable of *Mamároneck* would incorrectly open the possibility for the primary to be on the first syllable: **(Mámaro)neck*, just as in *(cátama)ràn*.
   - A final stress in disyllables like *Lákoff* would be expected to be a main stress: **Lakóff*, just as in *robúst*, etc.

c. **No medial clashes** (PES, 331):
   - 'Cyclic' Stress Preservation (SP) variably inhibits vowel-shortening when the long vowel is needed to construct a proper foot. The pattern is a roughly 50/ 50 split: *desíːre/ desíːrous* (SP, no shortening) vs. *blasphéːme/ blásphemous* (shortening, no SP). However, SP *never* blocks V-shortening when a medial clash would result: **explàinátion* (exceptions in the single digits, pace Pater 2000, (22b)). This only follows if the stress system does not tolerate medial clashes. Hence, cases like *èxpectátion* must not feature a clash (no SP from *expéct*).

In contrast to these difficulties, lack of reduction of certain unstressed vowels is correctly derivable from principles governing neutralization: long vowels do not reduce because they are perceptually more salient than short ones regardless of stress; and vowels do not reduce in certain closed syllables because the energy level within them is critical to the perceptibility of the following consonant –an interaction expected within the 'parallel' approach of both OT and PES.

The rest of the paper is structured as follows. In the next section, I formulate the analysis of vowel-reduction as neutralization. In section 3, I establish the link between such neutralization of vowel quality and neutralization of place in a following coda, showing that the co-occurrence of vowel-reduction and coronal codas as in *Connéctic[ə]t* follows naturally from the unmarked

character of coronal place. In section 4 I address the special status of sonorants in permitting reduction of a preceding vowel, and link reduced vowel energy with the formal notion of syllable weight, thus accounting for the fact that syllables closed by sonorants often behave like light syllables. In section 5 I argue that, unlike the analysis that attributes all failed reductions to stress, the present analysis based on properties of consonants automatically yields the correct generalizations about word-final clusters. Section 6 deals with cases like *Ár[ə]b*, in which reduction occurs despite a following velar or labial, arguing that all components needed for a proper analysis of these cases are already at hand in the present approach. Section 7 concludes.

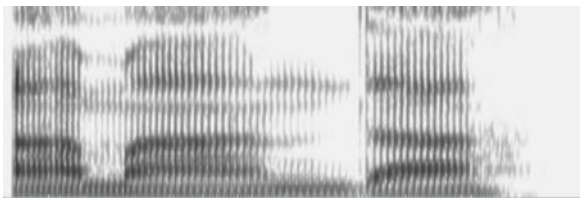
2. Neutralization and Unmarked Values

Steriade (1994, 1997), Flemming (1995) propose a 'Dispersion Theoretic' approach to neutralization phenomena: contrasts are neutralized in those positions where the perceptual distance between the members of the contrast is reduced. The prototypical positions where this occurs are coda positions for consonants and unstressed positions for vowels. To express the central claim of Dispersion Theory that maximal perceptual distance must exist among sounds (Lindblom 1986) within OT, insufficient distance must be viewed as a form of markedness (Flemming 1995; Padgett 1997, Boersma 1998). Two remedies will then be available to avoid such markedness: enhance the distance, or neutralize the contrast. The choice between them can be naturally made within OT by language-specific ranking of Faithfulness constraints: the two repairs involve different feature changes, and hence violations of different 'IDENT' constraints. When neutralization occurs, it results in the 'unmarked' value for the property that would otherwise have been weakly contrastive. For example, weak voicing distinctions for obstruents are neutralized to [-voice] ('coda devoicing'). The claim that this view embodies is essentially

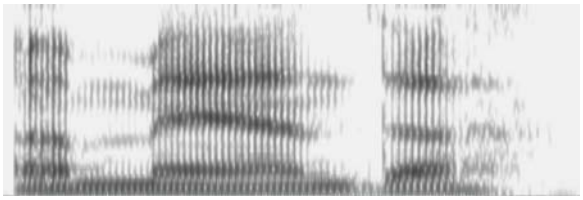
that perceptually ineffective articulatory effort is suppressed. In the case of unstressed vowels, which manifest reduced energy levels, their overall quality (Q) in terms height, backness and rounding will be perceptually weaker. A rather extreme form of repair under those circumstances will then consist of replacing the target quality with the quality that is articulatority neutral: that of mid, central, unrounded [ə], corresponding to minimal articulatory effort. For further discussion of this perspective, see Steriade (1994, 1997), Boersma (1998), Wilson (2000).

To sketch out an analysis of English vowel-reduction along the above lines, I begin by considering that English differs from other languages, like Italian, which lack it or undertake less drastic repairs. The difference between Italian and English in this domain can be appreciated in the spectrograms in (3), which represent the word 'amanda' as pronounced in the two languages by the author: [amánda]/ [ə*m*ǽnd*ə*], respectively.

(3) a. Italian



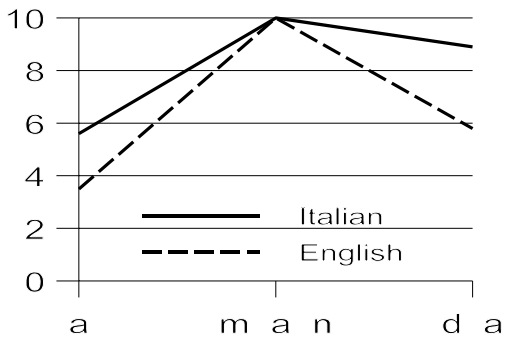
b. English



a m á n d a

In the English signal, the unstressed vowels are noticeably shorter and hence of lower overall energy than their Italian counterparts. The two signals in (3) can be compared roughly in the manner of (4), which reports relative energy levels on each of the three vowels.

(4)



Vowel-to-vowel energy profiles

The results in (4) are obtained by multiplying the average instantaneous energy of each vowel (dB) by its duration. Energy levels were measured from energy contours provided by Kay Elemetrics Multi-Speech, Model 3700 software, which also provided the spectrograms in (3). Vowel durations were estimated from those spectrograms. The profiles in (4) are normalized to one-another, with energy peaks being assigned the same value of 10. I note that such profiles can only be roughly indicative of perceptibility, since the energy values employed were indiscriminate of frequency, rather than being specific to frequency bands that may distinguish vowels from one-another. Measured in this fashion, the average instantaneous energy of each vowel across the two languages was in fact quite comparable, so that the main contributor to the differences was duration. Since duration is indeed a main contributor in the perceptibility of contrasts (Steriade 1994), it seems then sufficiently clear that the characterization in (4) would be relevant to perceptibility despite its somewhat crude basis.

Turning to an analysis of vowel reduction, I attribute the common characteristic of the two profiles in (4) – the relatively reduced energy levels of the unstressed vowels, to the modulatory effect of stress as formalized in (5).

(5) **ΔE**: Maximize the energy difference between stressed and unstressed vowels.

Other interacting constraints are formalized as in (6) and (7).

(6) ***WEAK-Q**: Non- minimal articulatory activity resulting in perceptually weak vowel quality cues is banned.

(7) **IDENT-Q**: The vowel quality specified in the input, in terms of distinctive features or their acoustic correlates, must be present in the output.

For English, the interaction of these constraints can then be characterized as in (8).

(8)	/amanda/	ΔE	*WEAK Q	IDENT-Q
a.	a mánd a	*		
b.	(a)mánd(a)		*	
c.	☞(∂)mánd(∂)			*
d.	∂ mánd ∂	*		*

In (8), it is assumed that all vowels in the input are 'peripheral' i.e. not mid-central [∂]. Alternative inputs are considered below. The parentheses around a vowel stand for a level of energy reduction that would satisfy ΔE when the vowel is unstressed. Candidates (a) and (d) then both violate ΔE, while (b) and (c) satisfy it. As a consequence of this energy reduction, however, candidate (b) will violate *WEAK-Q by featuring vowels that are articulatorily uncorrected in the face of their perceptually weak quality. Candidate (c) avoids the latter violation by resorting to articulatorily unmarked [∂], which in turn results in a violation of IDENT-Q. Since the latter constraint is bottom-ranked, candidate (c) is the winner. Note that the perceptual quality of [∂] in the winning candidate is itself also 'weak'. That, however, does not constitute a violation of *WEAK-Q, since no articulatory activity is devoted to producing such quality which is not also minimally required to produce a vowel.

It is easy to see that the outcome would not change had the unstressed vowels been /∂/ in the input, a possibility permitted under OT's 'Richness of the Base'. This would only reverse all the marks under IDENT-Q, with no consequence on the results of the competition. Unstressed vowels will thus correctly be rendered as [∂] regardless of input. Additional considerations are needed, however, to account for the fact that [∂] never appears in stressed position. Following

Flemming (1995), Steriade (1994, 1997), Padgett (1997), we take the reasons for this inability to be again Dispersion Theoretic: mid-central [ə] is perceptually too close to other central vowels like [ɛ] and [ʌ]. This can be expressed as in (9).[1]

(9) DISTANCE (ə): [ə] is perceptually too close to certain other mid-vowels.

The tableau in (10) illustrates the role of (9) in excluding [ə] from stressed positions.

(10)	/amənda/	ΔE	*WEAK-Q	DISTANCE (ə)	IDENT-Q
a.	...m ə́ n...			*	
b.	...m(ə́)n...	*			
c.	...m(á)n...	*	*		
d.	☞…m á nd...				*

In (10), candidates (b) and (c) have reduced energy levels in stressed position, in violation of ΔE, which also results in a violation of *WEAK-Q in (c). At the same time, candidate (a) is excluded via a violation of DISTANCE (ə), leaving (d) as the winner despite its violation of IDENT-Q. The output vowel is given here as *a* ([æ]) only for concreteness, as the actual output quality for an input /ə/ is unclear in the present context. Whatever the actual repair turns out to be, stressed [ə] is thus correctly excluded.

We may note in passing that the present approach entails comparing candidate outputs to other, independent, outputs of the system. Specifically, the DISTANCE (ə) constraint penalizes an output [ə] by virtue of its relation to neighboring vowels. This comparison of outputs is similar to the one performed within the 'Output-to-Output Faithfulness' approach to allomorphic variation, the two types of comparison thus corroborating each other to some extent, as argued in Burzio (2000b).

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[1] Note that (6) above *WEAK Q is plainly related to the 'distance' family of constraints of which (9) is a member, and yet not reducible to it. The reason is that the latter does not penalize weak contrasts per se, but rather only the articulatory activity that produces them.

Introduction of the new constraint in (9), however, will compel us to revisit the analysis in (8), which we thus update as in (11).

(11)	/amanda/	ΔE	*WEAK-Q	DISTANCE (∂)	IDENT-Q
a.	a mánd a	*			
b.	(a)mánd(a)		*		
c.	☞(∂)mánd(∂)			*	*
d.	∂ mánd ∂	*		*	*

This tableau shows that the correct results continue to follow, so long as DISTANCE (∂) is ranked below both ΔE and *WEAK-Q, but above IDENT-Q.

In contrast to English, Italian, which does not enforce the same ΔE, as shown in (4), will require the ranking in (12), in which ΔE is bottom-ranked.

(12)	/∂mand∂/	*WEAK-Q	DISTANCE (∂)	IDENT-Q	ΔE
a.	☞ a mánd a			*	*
b.	(∂)mánd(∂)		*		
c.	(a)mánd(a)	*		*	
d.	∂ mánd ∂		*		*

Thus formulated, the Italian grammar will correctly exclude unstressed [∂] even when the latter is in the input as shown in the tableau: the winning candidate (a) will have relatively unattenuated unstressed vowels consistently with (4) above, violating only the lowest-ranked pair of constraints ΔE and IDENT-Q. Again, output [a] is given here only for concreteness, as we only know that [∂] does not exist as an output. Had each unstressed [a] been in the input instead, the outcome would have been no different, as this would only change the marks under IDENT-Q, resulting in candidate (a) winning even more clearly.

On this analysis, the critical difference between English and Italian thus concerns the relative ranking of IDENT-Q and ΔE. In English, it is more important to satisfy ΔE than to

express input vowel quality, while in Italian the opposite is true. All other rankings can be kept constant across the two languages.

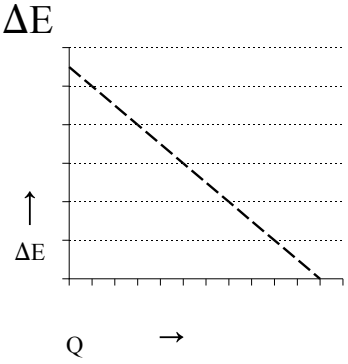
One question at this point is whether other language types are predicted by factorial typology from the constraints in (11), (12). Note that only one other type is in fact entertainable. The reason is that, while the candidates in each of (11) and (12) represent the full range of logical possibilities: a '2*2' of energy reduction and quality adjustment, it is clear that candidate (d) *[ə́mándə́]* can never win, at least in languages in which [ə] is not in the inventory. In any such language, DISTANCE (ə) will have to dominate IDENT-Q to exclude [ə] from the basic inventory. This will then result in candidate (d) always incurring more constraint violations than (a) *[amánd a]* regardless of other rankings, as is easy to see from (11) and (12). The question then reduces to whether candidate (c) in(11), (12), having the same degree of energy attenuation as English, and yet the same full vowel quality as Italian is an attested output in any language. Such output is predicted by each of the rankings in (13).

(13) Rankings yielding *[(a)mánd(a)]* (full energy reduction but unaffected vowel quality)

a. ΔE >> DISTANCE(ə) >> IDENT-Q, *WEAK-Q
b. ΔE >> DISTANCE(ə), *WEAK-Q >> IDENT-Q,

It is factually unclear to me whether a language of this sort actually exists, but it is also unclear whether the rankings in (13) are actually entertainable. Note that both rankings in (13) assert that ΔE unambiguously dominates *WEAK-Q, while those of those of (11) and (12) above postulated respectively for English and Italian are both consistent with the opposite ranking. In fact, the relative ranking of ΔE and *WEAK-Q is largely attributable to properties of the perceptual system, and to that extent it should therefore not be amenable to language-specific re-ranking. Consider in this regard that both energy differences 'ΔE' and vowel quality 'Q' are representable on continuous scales, and are relatable to one another in the inverse manner illustrated in (14).

(14) Satisfying lower and lower-ranked ΔE



When energy differentials are large: large font ΔE, perceivable quality of unstressed vowels is poor due to their low energy: small font Q, and vice-versa. To represent the continuous scales of (14) by means of OT constraints, each of ΔE (5) and *WEAK-Q (6) would have to be viewed as a constraint family, whose members stretch over the constraint hierarchy, from a lowest to a highest-ranked member. More modest ΔE's and Q's will be imposed by higher-ranked constraints, while perfect ΔE's and Q's will be imposed by the lowest-ranked constraints, as indicated for each of the axes in (14). But, given the counter-correlation expressed by the line, this will mean than any attempt at perfection on either axis will be met with stiffer and stiffer resistance on the other, thus automatically resulting in some optimal middle, just by the inherent properties of perception. If this is correct, then relative ranking of any member of the ΔE family and any member of the *WEAK-Q family will be fixed rather than language specific as would be necessary to entertain the ranking in (13), along with that of (11)-(12). In sum, there are no clear reasons to expect a third type of language in addition to the two already discussed, since there are reasons not to expect that ΔE and *WEAK-Q should be freely re-rankable with respect to one-another.

The availability of a continuous range of ΔE as in (14) rather than a single critical value is in fact supported by further considerations as well. One is that both English and Italian impose

different values of ΔE in initial syllables than in others. This is shown in (4) above: unstressed vowels in initial syllables are more attenuated than other unstressed vowels. This would follow if perception privileged initial syllables. Greater perceptibility would then allow the optimal balance between ΔE and Q to be achieved at a higher value of ΔE (and lower value of Q). Another consideration supporting a continuously valued ΔE comes from the fact that reductions of unstressed vowel inventories occur to varying degrees cross-linguistically. Languages that feature more modest inventory reductions than English will require making reference to a different value of ΔE than for English, as we see by turning to Italian again.

Standard Italian has a seven vowel system in stressed position: [i, u, e, o, ɛ, ɔ, a], but merges lax [ɛ, ɔ] with their tense counterparts [e, o] in unstressed position, as in *b[ɛ́]llo/ b[e]llíssimo* 'beautiful'/ 'very beautiful', *t[ɔ́]ro/ t[o]réllo* 'bull/bullock': a seven-to-five inventory reduction. This means that even the more moderate ΔE of Italian shown in (4), which I will refer to as 'ΔE_I', compromises perceptibility of some vowel distinctions. This effect can be characterized by assuming that, while enforcement of ΔE_I will not result in a violation of *Weak-Q –perceptibility of *overall* vowel quality remaining adequate, it will nonetheless result in a violation of what we may call *WEAK-LAX, expressing compromised perceptibility of tense/ lax distinctions, as defined in (15).

(15) ***WEAK LAX**: Articulatory activity resulting in perceptually weak laxness is banned.

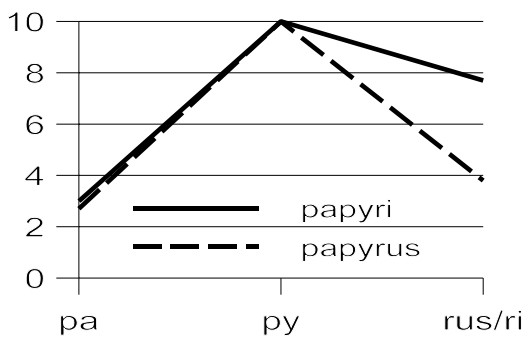
The Italian tense/ lax neutralization can then be analyzed as in (16).

(16) /bɛllíssimo/	*WEAK-Q	*WEAK-LAX	ΔE_I	IDENT-Q	ΔE
a. bɛllíssimo			*		*
b. b<ɛ>llíssimo		*			*
c. ☞ b<e>llíssimo				*	*
d. bellíssimo			*	*	*

In (16), the angled brackets stand for the energy reduction which is minimally necessary to satisfy ΔE_I, though not sufficient to satisfy the more stringent ΔE. Since all candidates have either this level of reduction or no reduction, all satisfy *Weak-Q, and all violate ΔE. The latter two constraints, given in the shaded columns, thus play no role, and are given only for comparison with previous tableaux. The two new constraints are given in the raised columns, and DISTANCE (∂) (9) is omitted because irrelevant to this particular calculation. The candidates in (16) are deliberately arranged in the same order as those in (8) above, resulting in a pattern of constraint violation which is also -mutatis mutandis- exactly the same as that in (8). This is to highlight the fact that different types of inventory reductions, while utilizing different points on the ΔE scale in (14), all employ the same mechanism that ties reduced energy to reduced perceptibility.

Returning once again to English, we now take up the noted immunity of long vowels to reduction: (1a), (2a). We attribute this to the already noted fact that longer duration enhances overall energy and hence perceptibility. This accounts for the fact noted in Steriade (1994) that in a number of languages 'Certain vocalic place contrasts are ... limited to the long vowel inventory' (see references she cites). On this assumption, then, so long as the output abides by the input length, violations of *WEAK-Q can be avoided. The energy profiles in (17), comparing the two items *papyrus*, *papyri*, would confirm this interpretation.

(17)



Vowel-to-vowel energy profiles

The diagrams show that the energy reduction on the final long vowel of *papyri* is less than on the corresponding short vowel of *papyrus*. This is due to the extra length. That reduction is in fact roughly comparable to that shown by Italian in (4). Hence, so long as vowel length is not tampered with, we will expect no more loss of vowel quality in English long vowels than generally occurs with Italian regular (short) vowels. Tableau (18) provides this result.

(18) /papýriː/	IDENT (long)	ΔE	*WEAK-Q	DISTANCE (∂)	IDENT-Q
a. ☞ papýriː		*			
b. papýr(i)	*		*		
c. papýr(∂)	*			*	*
d. papýr∂ː		*		*	*

In (18), top-ranked IDENT (long) excludes candidate (b) and (c), both with short vowels. The winning candidate (a) violates ΔE since vowel duration enhances the overall energy of the unstressed vowel, as does candidate (d). Yet, the latter, with a long [∂], loses to (a) by the additional violation of DISTANCE (∂). This consideration accounts for the fact that long [∂] does not exist at all, not only in the phonemic inventory, but also as a surface allophone, unlike short [∂]. The reason is that -as shown in (18)- extra length automatically avoids a violation of *WEAK-Q, resulting in an unmotivated violation of DISTANCE (∂). The reasons excluding long [∂] are thus totally parallel to those given above for the exclusion of stressed [∂].

Note that the high rank of IDENT (long) in (18) does not run counter to the very widespread phenomenon of vowel shortening in items derived via Latinate affixes: *na꞉ture/ natur-al, aspi꞉re/ aspir-ant, fi꞉ni꞉te/ in-finite*, etc. The latter type of vocabulary is analyzed as invoking an altogether lower-ranked system of (output-to-output) faithfulness constraints in PES and Burzio (2000a). On such an analysis, vowel shortening -which is not limited to unstressed positions: *nátural-* is an 'Emergence of the Unmarked' effect, resulting from IDENT (long) being dominated by *V꞉, while the opposite ranking holds for morphologically underived items like that in (18) (see references).

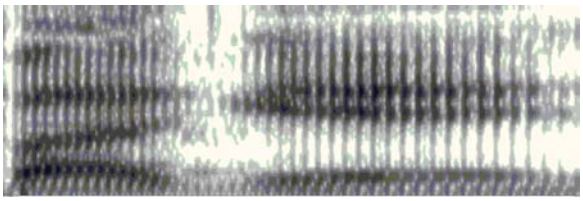
In sum, reduced energy levels in unstressed positions compromise perceptibility of vowel contrasts. Reductions in the size of vowel inventories in unstressed position result from suppression of articulatory activity that yields compromised perceptual cues. The correctness of this approach is confirmed by the fact that greater energy reductions correspond to greater reductions in inventory size: English versus Italian, and by the fact that English long vowels do not sustain inventory reductions, as their greater duration endows them with greater overall energy.[2]

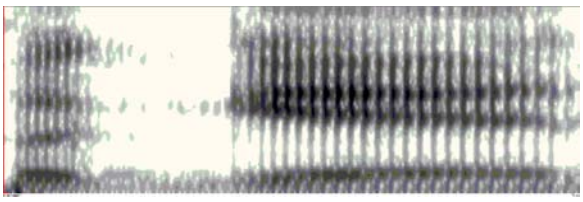
3. Vowel Quality acting on Consonant Place

Considering now the interaction of vowels and consonants, the PES claim that vowel-reduction is inhibited in certain closed syllables is based on the intuition that consonants in general are parasitic on flanking vowels. In this connection, we consider the spectrograms in (19) relative to the mid portion of the word *spaghetti* as pronounced in English and Italian again, respectively,

[2] The same mechanism is likely to underlie the more general phenomenon of 'geminate inalterability' (Kenstowicz 1994, sect. 8.4).

by the author: [agé]/ [ɔgɛ́].

(19) a. Italian 

b. English 

sp a gh é tti

In the English version, the velar is preceded by [ɔ], whose energy level is visibly lower than that of its counterpart [a] in the Italian version –the same difference that was observed in (3) above. Note in particular that formants have shorter durations both in their static portion, providing weaker cues to the quality of the vowel, and in the dynamic portion, providing weaker cues as to the nature of the following consonant. Since these two aspects are effectively inseparable, both being tied to overall vowel energy, we will expect that where vowel neutralizations occur, certain consonant neutralizations may follow suit. Harris (1994, 4.7), (1997), (2002) notes in fact that onsets of unstressed syllables undergo a number of 'lenition' phenomena not affecting stressed syllables, as for instance in *véhicle*, with an unpronounced *h*, compared with *vehícular*. This is consistent with the present perspective, but there is no reason these effects should be limited to onsets, especially since codas are independently prone to neutralization. Returning to (19), we note that notwithstanding the weakness of the preceding vowel in the English form, the velar is nonetheless well cued for place in the formant transitions into the following -stressed-vowel in both languages. We therefore need to consider a comparable situation in which no vowel follows, just as with the final velar of *Adiróndack*, where in fact that the preceding vowel

is unreduced. Such failed reduction would follow rather simply in the present approach if the English grammar rated consonant place neutralizations as worse options in than violations of ΔE. With this in mind, we then introduce the constraint in (20), modeled after *WEAK Q (6) above, which capitalizes on the widely held assumption that [coronal] is the unmarked oral place. This is given along with its obvious IDENT counterpart in (21).

(20) ***WEAK-P**: Non-minimal articulatory activity (i.e. non-coronal obstruction) resulting in perceptually weak consonant place cues is banned.

(21) **IDENT-P**: The consonant place specified in the input, in terms of distinctive features or their its acoustic correlates, must be present in the output.

The desired result will then be achieved as in (22).

(22)	/Adiróndack/	IDENT-P	*WEAK-P	ΔE
a.	☞Adiróndack			*
b.	Adirónd(∂)ck		*	
c.	Adirónd(∂)t	*		
d.	Adiróndat	*		*

In (22), the reduction candidate (b) violates *WEAK P relative to the final velar because of the weak formant transitions within the [∂] that were noted for (19). Candidate (c) avoids that violation by neutralization: marked velar place is replaced unmarked coronal place, but this is at the cost of violating IDENT-P. Candidate (d) is excluded for the same reason, in addition to a violation of ΔE. This leaves candidate (a) as the winner: it has an energetically unreduced vowel capable of properly cuing the velar, in violation of ΔE. The potential restriction of coda consonants to coronals expressed by candidate (c), which would win under a different ranking, mirrors the one actually found in other languages, e.g. Lardil (Kenstowicz 1994, 285 and Refs.; Prince and Smolensky 1993 and Refs.). More radical forms of neutralization would also seem possible in principle and are cross-linguistically attested. For instance, place could turn to glottal, yielding a glottal stop (glottal place being possibly even less marked than coronal). For

discussion of glottalization in various English dialects, see Harris (1994, sect. 4.7). Alternatively, the coda consonant could be deleted altogether (as happens to onset *h* in *vehicle,* noted above). For present purposes we may assume, however, that the place cues provided by a preceding [∂] are weak only in not distinguishing among oral places, but sufficient to reveal the presence of *some* oral place. This assumption is parallel to the one I tacitly made for vowels: the energy attenuation that goes with lack of stress compromises cues as to the nature of the vowel, but not those indicating the existence of *some* vowel.

It is now obvious from the point of view of (22) that, had the coronal place been part of the input, candidate (c) would have been the winner –indeed, just as in *Connécticut*, as illustrated in (23).

(23)	/Connécticut/	IDENT-P	*WEAK-P	ΔE
a.	Connécticuck	*		*
b.	Connéctic(∂)ck	*	*	
c.	☞ Connéctic(∂)t			
d.	Connécticut			*

The present analysis thus predicts the overall generalization in (24).

(24) **Reduction of unstressed vowels** is blocked by a following non-prevocalic *non-coronal* obstruent.

The facts in (25), some of which were brought to light by Ross (1972), testify to the correctness of (24). A systematic class of exceptions like Árab, gállop, frólic, hámmock, will be discussed in sect. 6 below.

(25) a. **Word-final velars and labials** (vowel unreduced): Adiróndack,
áztec, báobab, cárnap, sátrap, bébop, pársnip, túrnip, kídnap, kétchup, Mamároneck, hándicap, hémlock, kópeck, Lákoff, shérlock, shýlock, tármac, álmanac, lílac, slóvak, kódak, káyak, bédrock, féedback, dráwback, gímcrack, nítpick, sétback, wédlock, múskeg, húmbug, shíndig, zígzag, éggnog, nútmeg

b. **Word-medial velars and labials** (vowel unreduced): èxpectátion,
áutopsy, mácropsy, mícropsy, hýdropsy, gàstrocnémius, àrchitectónic, òlfactómeter, àdjectíval, èlectrólysis, èlectrómeter, àffectátion, hỳperactívity, ìnspectórial, mìcrobactérial, rèflectívity, rèfractómeter, cònductívity, còllectívity, cònnectívity, sỳnecdóchic, dèlectátion, désignàte, ìnsignificant, àstigmátic, ènigmátic, ìmpregnátion, phỳsiognómic

c. **Word-final coronals** (vowel reduced): Connécticut,
ídiot, lílliput, títicut, cháriot, chéviot, íliad, mýriad, pýramid, périod, ínvalid, tábanid

The lack of examples with word-medial coronal stops in (25) reflects the fact that coronal stops in word-medial codas (e.g. *Watkins*) are rare altogether –an accident, from the present perspective.

To sum up: in English, the sharp reduction of energy that occurs in general on unstressed vowels compromises perceptibility of vowel quality, with consequent neutralization to the unmarked quality of [∂]. However, cues to vowel quality are inseparable from cues for place of a following coda consonant. This predicts a parallel pressure on such consonants to neutralize to the unmarked place: [coronal]. But with IDENT-Place ranked high enough, the burden will be shifted to ΔE, and the optimal response to such pressure will consist of keeping the energy level on the unstressed vowel high –just the same response that was elicited by high-ranked IDENT-Q in Italian. The inevitable side effect of this will be that the vowel itself will no longer turn to [∂]. With coronals, however, the input structure is already in compliance with the neutralization pressure, and reduction of energy with loss of vowel-quality will thus occur normally.[3]

[3] The present analysis is partially similar though less abstract than the one in Harris (1994, 4.7) referred to in the text, and Harris (1997). The latter postulates that stress is a licensor of vowel quality and also that licensed vowels are themselves licensors for flanking consonants ('Licensing inheritance'). It remains to be seen whether further types of interactivity captured in the present energy-based analysis can also be captured within Harris' more abstract framework. These concern in particular the fact that length can remedy lack of stress: (18) above, and the fact that a stressed light syllable can influence reduction in a following unstressed one: sect. 6. below.

4. Sonorants and 'Sonorant Destressing'

Unlike obstruents, sonorant codas do not exhibit a difference between coronal and other places, allowing vowel-reduction fairly generally, as shown in (26).

(26) a. **Word-final sonorants** (vowel reduced): Wiscónsin, ápron, bálsam, amálgam, cústom, bósom, búxom, cóndom, phántom, ránsom, slálom, tránsom, bácon, uténsil, enámel, decórum

b. **Word-medial sonorants** (vowel reduced): cárpenter, còmpensátion, còntemplátion, sèrendípity, cóncentràte, àffirmátion, cònfirmátion, cònservátion, cònsultátion, cònversátion, ìnformátion, làmentátion, prèservátion, tràns**p**ortátion, ùsurpátion

We take this to reflect the fact that sonorants have inherent cues and are for this reason less dependent on a preceding vowel than obstruents. At the same time, however, sonorants also seem to permit unreduced vowels, as shown in (27).

(27) a. **Word-final sonorants** (vowel *un*reduced): Agamémnon, márathon támpon, péon, sámpan, Ígor, wígwam, ágar, cháos, cáravan, méteor

b. **Word-medial sonorants** (vowel *un*reduced): òstentátion, défalcàte, incantátion, hàlicarnássus, ìncarnátion, éxorcìse, ínculpàte, còmplementátion, èxhortátion, còmpartméntal, dìspensátion, dèpartméntal, dèportátion, èlongátion, èmbarkátion, èmendátion, èxaltátion, fèrmentátion, fràgmentátion, cóntemplàte, ìncrustátion, ìnfestátion

What this suggests is that coda sonorants are in fact also dependent on a preceding vowel, but to a lesser degree than obstruents. Although it is unclear exactly what acoustic cues to sonorants come from a preceding vowel, I will assume tentatively and for concreteness that these concern the exact type of consonantal aperture: nasal/ lateral/ rhotic, and that absent such cues, sonorants would be perceptually non distinct from other types of segments, perhaps liquids approximating glides or vowels, and nasals approximating nasal stop. Applying the usual model, this would motivate the constraint in (28) and (29).

(28) ***WEAK-A**: Non-minimal articulatory activity resulting in perceptually weak cues for consonantal aperture is banned.

(29) **IDENT-A**: The consonantal aperture specified in the input, in terms of distinctive

features or their acoustic correlates, must be present in the output.

The variability noted in (27) raises the important theoretical issue of how to construct grammatical models whose outputs are under lexical control. Although it is beyond present goals to provide a full discussion of this issue, I will outline a simple solution consistent with the general approach of PES as further developed in Burzio (1996), (2000a, b), (2002), Tantalou and Burzio (2003). This solution consists of postulating ranking indeterminacies in the grammar. Under such indeterminacies, the grammar provides co-optimal outputs, which are then evaluated by the lexicon by way of standard Input-Output faithfulness constraints. In the case at hand, the indeterminacy, or ranking ambiguity, would be as in (30).

(30) Ranking indeterminacy: (a) or (b)

a. *WEAK-A >> ΔE

b. ΔE >> *WEAK-A

The ranking of WEAK A thus contrasts with that of WEAK-P, which unambiguously dominates ΔE, as in (22) and (23) above. The ambiguity in (30) will allow us to account for the noted variation in the manner of (31) and (32) below, where the wavy line represents that ambiguity.

(31) /ápr∂n/	IDENT-A	ΔE	*WEAK-A	*WEAK-Q	DISTANCE (∂)	IDENT-Q
a. ápron		*				*
b. ☞ ápr(∂)n			*		*	
c. ápr(∂)d	*				*	
	Lexicon	Grammar				Lexicon

The present proposal is that, while input-output faithfulness constraints, here IDENT-Q and IDENT-A, in general interact with the rest of the hierarchy by way of standard ranking, when the rest of the grammar exhibits an indeterminacy, it is up to the latter constraints, representing the structure of each specific lexical item, to make the choice. Consider then the candidates in (31):

(a) violates ΔE by virtue of the unreduced unstressed [o]; (b) avoids that violation but compromises the cues to the final nasal, violating *WEAK-A; (c) corrects that violation by restructuring the nasal to -for the sake of discussion- a stop, which, however, violates top-ranked IDENT-A. *WEAK-Q is given for comparison with previous tableaux, but candidates violating are not pertinent here and are thus not shown. It is clear that, if the ranking was reflected in the left-to-right order (i.e. if the wavy line were solid), then (b) would be the unquestionable winner. However, given the ranking ambiguity, both (a) and (b) must be regarded as co-winners at the point of the hierarchy where IDENT-Q applies. The latter will then choose (b), given that the /∂/ is in the input. By the same token, then, candidate (a) would have been the winner, had the full vowel been in the input, indeed as I assume is the case with *Agamémnon* , shown (32).

(32) /Agamémnon/	IDENT-A	ΔE	*WEAK-A	*WEAK-Q	DISTANCE (∂)	IDENT-Q
a. ☞Agamémnon		*				
b. Agamémn(∂)n			*		*	*
c. Agamémn(∂)d	*				*	
	Lexicon	Grammar				Lexicon

The intuition behind this approach is that the grammar is a 'checking' device operating on lexical entries (Burzio 1994, et. seq.) such that, where the grammar tolerates multiple outcomes, a lexical entry will be deemed compliant if it matches any of those outcomes.[4]

[4] This solution generalizes to morphologically complex items under certain further assumptions. For instance, it is argued in Burzio (1993), (1994), (2000a) that a ranking indeterminacy between a ban on long vowels *V: and preservation of stress (a type of Output-Output faithfulness) results in minimal pairs like *blasphé:me/ blásphemous* (vowel shortened) versus *desí:re/ desí:rous* (stress preserved), as noted in (2c) above. The text solution correctly extends if both surface forms *blásphemous* and *desí:rous* are lexical entries in their own right, just like *blasphé:me* and *desí:re,* contra the traditional assumption that surface allomorphs are calculated from a common entry called 'Underlying Representation'(UR). As argued in the references, the traditional UR is to be rejected in a certain type of a contemporary perspective because it proves both unnecessary and insufficient. It is unnecessary because Output-Output faithfulness constraints are sufficient to account for observed surface similarities of allomorphs.

Quite similarly to the role of Input-Output faithfulness in (31), (32), we can also take Output-Output-faithfulness to play the same arbitrating role, wherever applicable. This will in fact account for contrasts such as the famed *còn**d**[e]nsátion* (base *cond[é]nse*) versus *còmp[ə]nsátion* (base *cómp[ə]nsàte*) (Chomsky and Halle 1968).

With regard to the variation in (26), (27), we note further that [s] codas behave similarly to their sonorant counterparts, as shown in (33).

(33) a. **Word-final [s]**. Vowel reduced: sýllabus, aspáragus, ...; Vowel *un*reduced: Orésteș, hypótheseș, ...

b. **Word-medial [s]**. Vowel reduced: órcheștràte, ... ; Vowel *un*reduced: dèteștátion, ìncruștátion ...

I will assume that the reasons for this are similar to those invoked for sonorants, and related to the only partial dependence of [s] on a preceding vowel, but will not attempt a more precise characterization.

Syllables closed by sonorants are known to exhibit another important property distinguishing them from syllables closed by obstruents, illustrated in (34).

(34) a. **H**: **olfáctory** refféctory, refráctory, perfúnctory, contradíctory, introdúctory, buffóonery, lampóonery, perfúmery

b. **L**: **áuditòry** heréditàry, hónoràry, plánetàry, státuàry, tríbutàry, státutòry, búdgetàry, cústomàry, úrinàry

---

It is insufficient because of the pervasive phenomenon of suppletion, e.g. *go/ went; compel/ compulsive; *arbore/ arboreal*, where surface allomorphs *must* clearly have independent inputs.

This proposal then provides a natural alternative to the claim that there are markedness constraints that are specific to individual lexical items, as proposed in Pater (2000). Applied to the text data and constraints, Pater's approach would postulate for instance a hierarchy: *WEAK-$A_{(27)}$ >> ΔE >> *WEAK-$A_{(26)}$ instead of the ambiguity in (30), with the higher-ranked *WEAK-A dedicated to the items in (27), and the lower-ranked one dedicated to those in (26). Unlike the present proposal, this kind of approach suffers from forms of the 'Duplication Problem' in so far as it requires either re-stating lexical information (a list of lexical items) in the formulation of constraints, or re-stating constraints within lexical entries (e.g. for the entry */apron/*: higher-ranked *WEAK-A applies).

c. **Son**: **répertòry** ádversàry, ínventòry, prómontòry, légendàry, sécondàry, sédentàry, cómmentàry, móméntàry, vóluntàry, dýsentèry, désultòry, óffertòry, frágmentàry

In American English, words employing the suffixes *-ary, -ory, -ery* and a few others stress the stem-final syllable if the latter is heavy as in (34a), while, if the latter is light, they stress the suffix, along with the stem penultimate, as in (34b). This variation clearly results from the general preference for stress to coincide with heavy syllables, a fact ultimately reducible to our ΔE, as I suggest below. Now, syllables closed by sonorants behave like light syllables in this respect, as shown in (34c). Earlier literature, beginning with Kiparsky (1979), had assumed that such syllables were initially stressed like other heavy ones, and were then destressed by a special rule of 'sonorant destressing'. Instead, the PES analysis (PES, 234-239) relates this phenomenon to the independent property of sonorant codas observed in (26) –that of permitting vowel-reduction. Assuming as may seem natural that the formal notion of syllable 'weight' is related to the acoustic notion of energy employed above, then syllables with reduced vowels will be less heavy than corresponding syllables with full vowels, due to their lower energy level shown in (4) above, and the effect in (34) can then be naturally accommodated: taking stressed *-ary, -ory, -ery* to be the preferred or default pattern in American English, syllables closed by sonorants will undergo reduction to accommodate that pattern, even though under different circumstances reduction may fail: (32).

PES (71) also notes a 'scale-down' effect parallel to that of syllables closed by sonorants on syllables that would be structurally light. Under vowel reduction these sometimes take on the properties of the even lighter 'weak' syllables of PES, resulting in final feet that do not bear primary stress, e.g. *(rúta)(bàg[ə])*, patterning like *(Cáro)(line)*, whose final vowel is null (a 'weak' syllable in PES), similarly to *(círcum)(vèntø)* of (2b) above.

The 'light' status of syllables closed by sonorants or [s] extends to the cases in (35).

(35) a. **Stress Preservation cases**: admínistrable, cómfortable, hárvestable, pàtentabílity, ... cávernous, párentage, òpportunístic

b. **Sundry items:** Wáshington, Rútherford, pédestal, órchestra, sácristan

The cases in (35a) differ from cases with heavy syllables closed by stops, which unfailingly attract stress as in *imprégnable*, and thus preclude preservation of the stress of their bases under comparable circumstances: *ímpregnàte/ *ímpregnable*.

The stress-preservation behavior of (35a) is less than fully general, however, as noted in PES, witness *párent* / **párental* (vs. *párentage*), but rather requires certain further conspiring factors to bring it about (PES 306-311 and passim), as does the behavior in (34a) for that matter, witness *eleméntary*, etc. (PES, 207f., 237f.). Hence unstressed syllables closed by sonorants and [s] are not quite like light syllables but effectively intermediate between light and heavy syllables, still consistently with the present reasoning. When syllables closed by sonorant or [s] are stressed, however, they perform regularly as heavy ones as expected from the non-reduced vowel, and can thus regularly bear penultimate stress: *agénda*, *paréntal*, *orchéstral*, etc.

In sum, sonorants and [s] differ from stops by possessing intrinsic perceptual cues. Hence, the vowels on which they are only partially dependent are able to reduce, and yet there is apparently enough residual dependency that those vowel may also remain unreduced under certain circumstances including lexical choice. Vowel-reduction scales down syllable weight, resulting in the fact that syllables closed by sonorants or [s] may function similarly to light ones under various conditions. We note in passing that the foregoing discussion entails that stress and vowel-reduction stand in a mutual dependency relation: stress is a determinant of vowel-reduction (if stress, no reduction), but at the same time reduction controls syllable weight, and

hence the position of stress. Such mutual dependencies are ordering paradoxes for ordered rules, and thus provide a direct argument for the parallel interaction of surface constraints, as noted in PES.

5. The Structure of Final Clusters

It was also noted in PES that, unlike the old-fashioned stress-based account of the *Adirond[æ]ck / Connectic[ə]t* asymmetry, the account based on the dependency of consonants on their flanking vowels directly relates the latter asymmetry to certain further asymmetries observable in word-final clusters illustrated in (36).

(36) a. **pt#** (non-reduced vowel): transept, concept, percept, precept, edict, district, ...

b. **kt#** (non-reduced vowel): cataract, insect, defect, dialect, impact, object, subject, product, ...

c. **tp/ tk#**: **non-existent**

Yip (1991) correctly links the asymmetry in (36) to the special status of coronals, but not to the vowel-reduction generalization of (24) above. In contrast, from the present perspective, the final clusters of (36a, b) are possible so long as the preceding vowel does not reduce, because the first member will be well cued by that vowel on a par with its occurrence by itself as in *Adirondack*, etc., while at the same time the second member will also be licensed because, being a coronal stop, its demands for perceptual cuing are modest, as shown by the vowel-reduction of *Connectic[ə]t*, etc. At the same time, the clusters of (36c) will be excluded because the stronger dependency of velars and labials on a preceding full vowel is not satisfied. In further contrast to this account, any account in the tradition of Ross (1972) will have nothing to offer with regard to possible final clusters: if individual consonants differed in whether or not they attract stress, then

consonant clusters should also just differ in the same way, with nothing else following from it.

In addition to the common characteristics of sonorants or [s] we observed above, these also appear to share a further characteristic: when they are part of a cluster, they act as if they were 'transparent' to the dependency relation between a stop and a preceding vowel, as shown in (37).

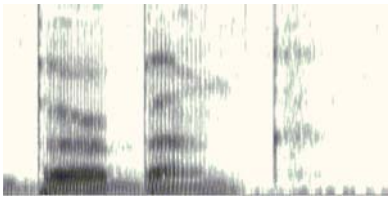
(37) a. **Before *p/ k*** (vowel unreduced): **Búrbank**, pódunk, chípmunk, ózark, áardvark, ábelmosk, ásterisk, árimasp

b. **Before *t/ d*** (vowel reduced): **ínfant,** élephant, élement, lieuténant, sérpent, cómfort, órchard, bástard, éverest, cátalyst

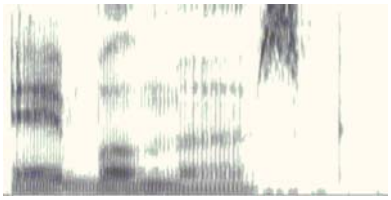
In (37a), the final labial or velar stop is apparently licensed by an unreduced vowel across an intervening sonorant or [s], similarly to its licensing under strict adjacency in *Adirondack*, and unlike the failed licensing across an intervening stop observed for (36c). In contrast, in (37b) the coronal stop continues not to require a preceding full vowel, consistently with its behavior both in *Connectic[ə]t* and in (36a, b). We take this to confirm both the partial dependency and the partial independency of sonorants and [s] from a preceding vowel. By being acoustically independent, they can be assumed to provide some perceptual cues of their own to a following obstruent. At the same time, by being partially dependent, they may perhaps be taken to allow the latter cues to be modulated by the energy level of a preceding vowel. We must note as well in this connection that some of the perceptual cues for final stops must be provided by the stop's own release. Release cues are evidently not sufficient in themselves given (25a) *Adirondack* and (36c), but their role is established by the fact that none of the final clusters of either (36a, b) or (37) are found in word-medial codas, where the release is prevented by a following onset. Release can in fact be seen as the acoustic substance of PES's and Harris' (1994) final null vowels, as in *pre.ven.tø* , etc. In this regard, sonorants and [s] would seem capable of

'transferring' some of the energy of a preceding vowel into the release of a following stop, judging from the data in (38).

(38) a. reduced

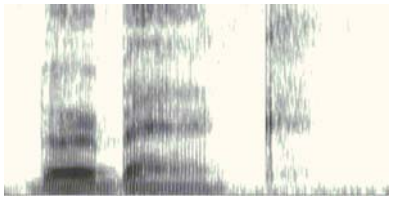


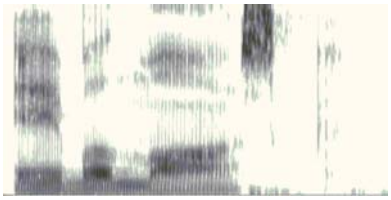
B u r b a⇓ n k



a b e l m o⇓ s k

b. unreduced





In (38), the words *Burbank*, *abelmosk* are pronounced with their last vowel either reduced (a) or unreduced (b), the arrow pointing to the attested (unreduced) pronunciation. The unreduced versions exhibit a slightly greater energy at the release of the final velar, suggesting some 'transparency' of the sonorant and [s] in this sense. The assumption that the release is critical to final stops preceded by sonorants or [s] will help account, along with the absence of clusters like *Nk*, *sk, Np, sp* in word medial codas just noted, also for the absence of more complex final clusters like *Nkt*, *skt*, *Npt*, *spt*, where the added final coronal would suppress the release of the velar or labial. This is in contrast to the simple *kt*, *pt* clusters of (36), where place cues to the velar or labial are provided by the preceding vowel directly and hence presumably more strongly, rather than through the intermediary sonorant or [s]. Final clusters *Nkt*, *skt*, *Npt*, *spt*, do occur, of course, in past-tenses: *banked*, *asked*, etc., but that behavior falls under the general phonological exceptionality of 'level 2' morphology (PES and Burzio 2002) and thus need not concern us in the present context.

In summary, the same acoustic properties that allow sonorants and [s] codas to coexist with reduced vowel nuclei as in (26) can plausibly be seen as underlying their 'transparent'

character in (37). If this is correct, then the limited possibilities for word-final clusters of (36) and (37) will indeed substantially reduce to the same considerations of obstruent-to-vowel dependency that accounted for the distribution of reduced vowels in unstressed closed syllables of (25) and (26).

6. The 'Arab' rule

Ross (1972) and others noted a class of exceptions to the generalization of (24) above that final non-coronal stops do not co-occur with reduced vowels, shown in (39a). Fudge (1984) noted further that such exceptions occur word medially as well, as shown in (39b), while (39c) gives the regular cases for contrast.

(39) a. **Word-final p/ k** (vowel reduced): **ǽrab,** dóllop, devélop, gállop, góssip, hýssop, scállop, tróllop, jálap, bárrack, búttock, cássock, dérrick, gímmick, hámmock, hássock, páddock, tráffic, hávoc

b. **Word-medial p/ k** (vowel reduced): **rècognízable**, rèsignátion, àdaptátion, stálactìte, stálagmìte

c. Vowel unreduced: **[éy]rab**, cárnap, èxpectátion

The exceptional cases of (39a, b) are in fact defined by a further generalization, which is that the adjacent stressed syllable is light, in contrast to the stressed heavy syllables of (25a, b) above and (39c) (which includes one idiolectal pronunciation of the word *Arab*, providing a close minimal pair). This effect, formerly attributed to a special destressing rule (Hayes 1985, 177), follows naturally in the present approach from assumptions already in place. Two are needed in particular. One is the earlier assumption that ΔE constitutes a family of constraints, returning stronger and stronger violations for weaker and weaker energy modulations. The other is the assumption introduced to deal with the 'sonorant destressing' effect that the formal notion of syllable weight is closely related to that of acoustic energy. The latter will imply that when a

stressed syllable is light, it will instantiate a lower energy level than if it were heavy. Non reduction in an adjacent unstressed syllable as in *Ár*[æ]*b will thus not only fail to achieve the standard ΔE of *[ə]mánd[ə]* (12) above, but even the more modest ΔE of *Adiróndack* (22), thus violating a higher-ranked member of the ΔE family. This provides the means for the analysis in (40), where ΔE_{MIN} penalizes absence of some minimal ΔE smaller than the standard ΔE employed so far for English.

(40)	/Árab/	ΔE_{MIN}	IDENT-P	*WEAK-P	ΔE
a.	Árab	*			*
b.	☞Ár(ə)b			*	(*)
c.	Ár(ə)t		*		

The rightmost three constraints are the same as used in the analysis of *Adiróndack* in (22) above, and it is easy to see that the unreduced candidate (a) would win just as in (22) if it were not for the new constraint ΔE_{min}. However, the latter now favors candidates (b) and (c), with reduced vowels. Of those two candidates, the first violates *WEAK-P (20) for having a poorly cued non-coronal obstruction, while the second violates IDENT-P for replacing labial with coronal place. Hence, so long as IDENT-P is ranked higher than *WEAK-P, candidate (b), with a reduced vowel and yet an unrepaired consonant will correctly be the winner. The latter ranking was not independently established by (22) above, but is fully consistent with it. The parenthesized asterisk in (22b) is to indicate a likely residual violation of ΔE since stressed and unstressed syllables are now rather close in weight, though ΔE_{MIN} is satisfied. The introduction of the new constraint ΔE_{MIN} will have no effect on the earlier analysis of *Adiróndack*, since the heavy status of the stressed syllable is there sufficient to ensure its satisfaction.[5]

[5] A reviewer suggest the alternative analyses: *(ærəb), (ey)ræb* where each parenthesized constituent is a 'bimoraic trochee', the syllables *rəb*, *ræb* being themselves respectively

Note that under the proposed correlation between syllable weight and energy levels suggested by the behavior of syllables with ∂ nuclei: *rép[∂]rtòry* (34c), *Ár(∂)b* (39b), our 'ΔE' constraint family will generally subsume the joint effects of the former WEIGHT-TO-STRESS constraint and its complement STRESS-TO-WEIGHT (Kager 1999, 155, 278 and refs.). The reason is that, if weight and energy correlate, ΔE will impose greater weight on stressed syllables, like STRESS-TO-WEIGHT, and less weight on unstressed syllables, like WEIGHT-TO-STRESS (as 'if weight then stress' equals 'if no stress then no weight'). The empirical difference lies in the unitary character of ΔE versus the independence of the former two constraints, and shows up precisely in the 'Arab'-type cases, which reveal the artifactual nature of the former pair. Those cases instantiate a relative violation of STRESS-TO-WEIGHT: a stressed light syllable. But there is no reason why a neighboring syllable should now more rigidly enforce WEIGHT-TO-STRESS, resulting in vowel reduction, unless the two constraints are intimately tied together rather than independent, just as in the 'ΔE' formulation.

In sum, while vowel-reduction generally fails in syllables closed by velars and labials so as not to compromise the perceptibility of place cues for the consonant, it nonetheless succeeds in 'Arab'-type contexts under compulsion from the same type of constraints that call for vowel-reduction in general and that require stress to be reflected in the energy envelope. The reason the reduction imperative is stronger in 'Arab' contexts is the more meager contribution to the ideal envelope made by the stressed syllable itself, with the demands for a suitable energy difference thus being passed on to the unstressed syllable.

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monomoraic and bimoraic. To correctly exclude (40a) **æræb* , however, one needs to stipulate that foot structure cannot split syllables. Such stipulation simply adds to the wealth of arguments in PES and the text that monosyllabic feet do not exist: if feet could be built on moras, they *would* split syllables.

7. Conclusions

If we consider that, definitionally, reduced vowels are intermediate between full vowels and no vowel, it will be less than surprising that failure of vowel-reduction in English has some of the properties of epenthesis, occurring where the vowel is needed to break up bad clusters. This simple intuition had been missed by a long tradition that insisted on linking vowel-reduction to lack of stress bi-directionally. This article has aimed to be a formal improvement on the analysis given in my (1994) 'PES', which first broke with that tradition. Specifically, I have argued that the weakening of perceptual properties that causes a vowel to neutralize to articulatorily neutral [ə] will correspondingly drive a consonant dependent on that vowel to also neutralize to the neutral oral closure: [coronal]. The choice between failed vowel-reduction: *Adirond<u>a</u>ck* and place neutralization: **Adirond<u>ə</u>t* can be straightforwardly attributed to language-specific constraint ranking within OT. This analysis correctly predicts that coronal stops will not block reduction: *Connecticət,* because they are in a sense 'pre-neutralized' for place, being thus indifferent to the pressure for neutralization. As argued in PES, this appeal to the properties of consonants not only frees the analysis of stress from the burden of several unworkable complexities, but also directly speaks to the structure of word-final clusters, which would otherwise be left as an independent problem.

While the dependency between stress and vowel-reduction is thus only partial –lack of stress not always resulting in reduction, I have argued that -at the same time- it is in fact also mutual, as vowel-reduction affects syllable weight, and in turn the position of stress: *rép[ə]rtòry*, *cáv[ə]rnous*, etc. A class of exceptions to failed reductions before labials and velars: *Ár[ə]b*, etc. has been explained in terms of the same principle responsible for reduction in general: stressed-unstressed sequences must have an energy downstep. When the stressed syllable is light, the

energy on the unstressed syllable will be clamped at the low level that yields reduction. This complex web of interactions: between vowel nuclei and coda consonants; between stress and vowel-reduction and back; between stressed and unstressed syllables, lends a sharp argument for the parallel architecture advanced in PES and Prince and Smolensky's 'Optimality Theory', and against serial alternatives.

The proposed analyses are consistent with Steriade's (1994, 1997) claim that the abstract notions of traditional syllable theory prove inadequate, and that alternative notions more firmly grounded in acoustics and perception are called for. Specifically, we have seen that not all codas are alike for licensing reduced vowels: coronals are special within stops, and sonorants are different than obstruents. Similarly, not all nuclei are alike: reduced ones yield light syllables despite a coda. We have also seen that final consonants have hybrid properties of both codas and onsets.[6]

The present analyses also further vindicate the PES claim that English has no monosyllabic feet, to the extent that cases like *Adiróndack*, *papýri*, etc. have been successfully analyzed as having just regular penultimate stress instead of consecutive stresses.

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[6] A reviewer raises the important issue of whether the reinterpretation of syllable theory along acoustic/ perceptual line should prompt a comparable reinterpretation of stress theory. The possibility for such reinterpretation is in fact opened by the ΔE constraints. In addition to subsuming WEIGHT-TO-STRESS and STRESS-TO-WEIGHT, as noted in the text, if ΔE constraints were taken to impose energy differentials on *consecutive* rather than on stressed versus unstressed syllables –a type of perceptually based 'OCP', they would effectively provide for the basic binary alternation that has been the core notion of stress theory. A fully explicit move in this direction would be a bit premature in the present context, however, since, while I have shown that some local energy levels do affect the position of stress, e.g. *rép[ɔ]rtòry* vs. *olfáctory* and discussion of (34), I have also shown that others do not, as in **Mámaron[ɛ]ck* vs. *Cátamar[æ]n* and discussion of (2), resulting in some degree of independence between stress and energy and thus preventing any straightforward reduction of one to the other. These obstacles do not seem insurmountable, but they are beyond the goals of the present work.

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