Phonology and Phonetics of English Stress and Vowel Reduction

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Abstract
The reduced energy level of unstressed syllables compromises perceptibility of vowel distinctions, leading to the 'neutralization' of some of the distinctions. The difference between the collapse of most vowels into [ᴍ] 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[ᴍ]t*, a property that is reduced to the notorious 'unmarked' character of coronals: since neutralizations are to the 'unmarked', 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 reduction. The account of vowel-reduction that thus implicates V-to-C interactions 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 captured here.

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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.ri̲, a.lúm.ni̲, íncr̲e̲a̲se, persónif̲y̲, ...
        Long vowels do not reduce, thus requiring a 'Long V-stressing'
        provision.

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

    c. **Medial clashes**: èxpe̲ctátion, ... vs. cònt[M̲]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 to the analysis of vowel-reduction: reduction must meet further requirements *in addition* to simple lack of stress, prove successful. The non viable character of the provisions in (1) is in 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 (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, bisyllabic cases like
              rábbi, áthlete, sátire should have final main stress, just like
              repórt, overt, crusáde, etc.

- • Verb/ Noun alternations like *incréase/ íncrease* are exactly like those of *pervért/ pérvert*, etc., only if there is no 'Long V-stressing'. Otherwise the two types are not easily relatable.
- • The lack of stress preservation in cases like *pérson/ *pérsonify* is understandable only if -*ify* does not bear stress. Otherwise, preservation is expected, 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)da̲ck*.
- • Stress on the final syllable of *Mamároneck* would open the possibility for the primary to be on the first syllable: **(Mámaro)ne̲ck*, as in *(cátama)ràn*.
- • A final stress in disyllables like *Lákoff* is expected to be a main stress: **Laḵóff*, 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: *desí:re/ desí:rous* (SP, no shortening) vs. *blasphé:me/ blásphemous* (shortening, no SP). However, SP *never* blocks V-shortening when a medial clash would result: there are no cases like **explàinátion* (exceptions in the single digits, pace Pater 1995). 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.
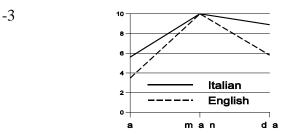
The rest of the paper is structured as follows. In the next section, I formulate

the analysis of vowel-reduction as neutralization, and 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[M]t* follows naturally from the unmarked character of coronal place. In section 3 I address the special status of sonorants in permitting reduction of a preceding vowel, and link reduced vowel energy with syllable weight, thus accounting for the fact that syllables closed by sonorants often behave like light syllables. In section 4 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 5 deals with cases like *Ár[M]b*, in which reduction occurs despite a following velar or labial, arguing that all components of the analysis are motivated independently, unlike in a stress-based approach, which would require a special destressing rule. Section 6 concludes.

2. Neutralization and Unmarked Values

Steriade (1994, 1997) has proposed 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 are at hand to avoid such markedness: enhance the distance, or reduce it to zero by neutralizing the contrast. The choice between them can be naturally managed within OT by constraint ranking within each specific grammar. 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 avoided. In the case of unstressed vowels, where the overall quality (Q) of the vowel in terms of perceived height, backness and roundness may be 'weak', replacement of such weak Q with the unmarked value for Q is naturally expected to be by way of the mid, central, unrounded vowel [M], involving the minimal articulatory effort. For further discussion of this perspective, see Steriade (1994, 1997), Boersma (1998) and, for important formal consequences, 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. The diagrams in (3) compare energy profiles for the word *amanda* as pronounced in the two languages by the author ([MmǽndM]/ [amánda]).

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In (3), the overall energy over each vowel is obtained by multiplying average energy by vowel duration. The profiles are then normalized to one-another, with energy peaks assigned the same value of 10. The common aspect of the two profiles is attributed to the modulatory effect of stress as formalized in (4) below, while the difference between them will be attributed to a difference in constraint ranking as discussed next.

-4   **?E**:   Maximize the energy difference between stressed and unstressed syllables.

Given (4), the English outcome can then be analyzed as in (5).

-5 /amanda/	?E	*WEAK-Q	IDENT (Q)
a. ⌐(M)mánd(M)			*
b. (a)mánd(a)		*	
c. a mánd a	*		

In (5), the parentheses in the candidates signify reduced energy. Candidate (c) is excluded by a violation of ?E since the unstressed vowels feature no reduction of energy, while candidate (b) is excluded by *WEAK-Q as the reduced energy on the unstressed vowels compromises the perceptibility of their quality. Candidate (a) avoids such violation by leaving vowel quality articulatorily unexpressed, and thus

proves the winner under the given ranking, despite its unfaithfulness to the input quality, violating IDENT (Q).

It is easy to see that the Italian outcome would be produced if IDENT (Q) were top-ranked, although it remains unclear whether this would be in the form of candidate (b) or candidate (c). The diagrams in (3) reveal that it is in fact neither. Energy reduction in Italian is neither zero: candidate (c), nor comparable to that of English: candidate (b). Rather, it is at some intermediate level. To account for this, we take each of ?E and *WEAK-Q in (5) to be effectively a family of constraints, each varying in rank but in opposite directions: as energy on the unstressed syllable decreases, a larger and larger portion of the ?E family is satisfied, to include more and more lower-ranked members, while a larger and larger portion of the *WEAK-Q family is violated to include more and more higher-ranked members. In Italian, then, the stressed/ unstressed energy difference can be assumed to be set at the maximal level that will keep violations of the *WEAK-Q family below any *WEAK-Q_i such that *WEAK-Q_i dominates IDENT (Q). The only formal difference needed between Italian and English is in the relative ranking of ?E and IDENT (Q), the latter being higher-ranked in Italian, forcing violations of higher-ranked members of the ?E family than in English. The interaction between energy (and hence, indirectly, ?E) and *WEAK-Q can be regarded as a property of perception, and hence language invariant. The interaction between *WEAK-Q and IDENT (Q) can also be taken to be invariant, reflecting general trade-offs between perceptibility and articulation.

Note at this point, however, that Italian, like many other languages, while not reducing its vowel inventory in unstressed position as dramatically as English, nonetheless features some reduction, merging /ɡ, e/ to [e], e.g. *b[ɟ]llo/ b[e]llíssimo* 'beautiful'/ 'very beautiful', and /], o/ to [o]. The Italian mergers involve a violation of IDENT (ATR), and can be accounted for as in (6).

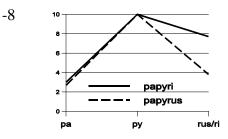| -6	/bɡllíssimo/	IDENT (Q)	?E(IT)	*WEAK-ATR	IDENT (ATR)
a.	b(ɡ)llíssimo			*	
b.	bɡllíssimo		*		
c.	b(M)llíssimo	*			
d. ⌐	b(e)llíssimo				*

In (6), candidate (c) is excluded by the fact that Italian does not permit violations of IDENT (Q), for the reasons just discussed. Candidate (b), with no energy reduction,

is excluded by the fact that, like English, Italian too reduces the energy level of unstressed syllable, though only to the more modest extent ? E(IT) as we have seen. The more modest reduction will not compromise the perceptibility of overall quality, thus not violating the same *WEAK-Q of (5), but it can, and apparently does, compromise perceptibility of subtler distinctions, specifically the one due to the ATR feature, so that candidate (a) will violate *WEAK-ATR. Candidate (d) avoids the latter violation by neutralizing the ATR distinction, and is thus optimal under the given ranking, violating only IDENT (ATR). Note that the relative ranking of IDENT (Q) and IDENT (ATR) in (6) need again not appeal to language-specific choices. Rather, it can be taken to reflect the fact that the two constraints describe different degrees of faithfulness (changing a single feature versus changing multiple features). Hence it follows entirely from the fact that Italian accepts more modest energy modulations that it will only accept more modest -if any- vowel-neutralizations. The grammar of neutralization remains the same, the rightmost three constraints in (6) mirroring exactly those of (5)

Returning now to English and taking up the noted immunity of long vowels to reduction, we attribute it to the fact that longer duration enhances perceptibility (Steriade 1997) –a factor that is likely to underlie the more general phenomenon of 'geminate inalterability' (Kenstowicz 1994, sect. 8.4). Hence, so long as the output abides by the input length, violations of *WEAK-Q can be presumed to be avoided, as indicated in (7).

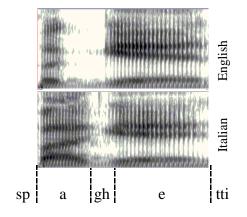| -7 /papýri:/	IDENT (long)	? E	*WEAK-Q	IDENT (Q)
a. ∟ papýri:		*		
b. papýri	*		*	

In (7), top-ranked IDENT (long) excludes candidate (b), which would in turn lose to a reduction candidate not shown. The winning candidate (a) violates ? E since vowel duration adds to the overall energy of the unstressed vowel. The diagrams in (8) illustrate this effect.

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The diagrams show that the energy reduction on the final long vowel of *papyri* is less than on the corresponding short vowel of *papyrus*, due to the extra length. That reduction is roughly comparable to the reduction typical of Italian shown in (3), whence the reported violation of ?E in (7). Note that the option *papyr[M:]* with a long and yet reduced vowel, is excluded, as is long [M] more generally, by the same dispersion-theoretic notion of 'distance' that underlies *WEAK-Q. By being central rather than peripheral, the vowel [M] is perceptually too close to other vowels, and is thus excluded from the inventory in general. The reason [M] shows up when short and unstressed is that, given the strong modulatory effect of stress in English (?E >> IDENT(Q) of (5)), 'distance' would be violated anyway by articulatorily more marked alternatives, such as candidate (5b) above *(a)mánd(a)*. This type of candidate violates *WEAK-Q, a type of constraint that effectively penalizes the conjunction of poor distance and articulatory markedness. When [M] is long, however, the violation of 'distance' is unmotivated, since the average energy that characterizes [M] will yield superior -and apparently adequate- cues to quality when sustained over a longer duration. We assume that reduction of energy below that of [M] is not viable, essentially because it may lead to syncopation, but we will not attempt a formal characterization. Similar considerations to those excluding long [M] also exclude stressed [M]: higher energy yields adequate cues, also resulting in an unmotivated violation of 'distance'.

Turning now to closed syllables, 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, with codas being particularly dependent in this regard. Consider in this connection the spectrograms in (9) relative to the mid portion of the word *spaghetti* as pronounced in English and Italian, respectively, by the author: [Mgé]/ [agé].

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		English
		Italian
sp	a	gh	e	tti

In the English version, the velar is preceded by [ɨ], 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. There are two aspects of this difference to consider: the weaker formant structure in the more static portion of the vowel, and the weaker formant structure in the more dynamical portion leading into the velar. While descriptively distinguishable in this manner, these two aspects are effectively inseparable, as the same satisfaction of ?E automatically yields both. Since the static formant structure is what provides cues to vowel quality while the formant transitions provide cues to consonant place, along with neutralization to [ɨ] we will expect a corresponding tendency for place neutralization of a following consonant. This expectation does not hold for the velar in (9) in particular, since place is here adequately cued by the following stressed vowel [é]. But it will be expected in a similar situation in which no vowel follows, as for example in the word-final position in *Adiróndack*, where we observe that, instead, the vowel fails to reduce. This specific outcome would follow from the ranking in (10).

-10 /Adiróndack/	IDENT (P)	*Weak-P	? E
a. ∟Adiróndack			*
b. Adiróndɨck		*	
c. Adiróndɨt	*		

In (10), the reduction candidate (b) violates *WEAK-P(lace) with respect to the final velar, because of the weak formant transitions within the [ɨ] that were noted for (9). Candidate (c) avoids that violation by neutralization: marked velar place is replaced

with coronal place –the least marked oral closure, as extensively documented in the literature. This hypothetical restriction of coda consonants to coronals would mirror 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 also seem possible in principle and are cross-linguistically attested. For instance, place could turn to glottal, yielding a glottal stop (with glottal being possibly even less marked than coronal. For relevant discussion of English material, see Harris 1994, sect. 4.7). Alternatively, the coda consonant could be deleted altogether. Let us assume, however, that the place cues provided by a preceding [M] are weak only in not distinguishing among oral places, but sufficient to reveal the presence of *some* oral place. Candidate (c) then satisfies *WEAK-P, but only at the cost of violating IDENT (Place), leaving the unreduced candidate (a) as the winner under the present ranking.

Now, it is clear under the analysis in (10) that the reduced candidate (c) *would* be the winner, *if* the coronal place were in the input, and this is indeed what one finds, e.g. *Connécticut*. The predicted generalization is stated in (11).

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

The facts in (12), some of which were brought to light by Ross (1972), testify to the correctness of (11). The 'ár[M]b' class of exceptions will be discussed in sect. 5 below.

(12) 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, h&peractívity, ìnspectórial,
        mìcrobactérial, rèflectívity, rèfractómeter, cònductívity, còllectívity, cònnectívity,
        s&necdóchic, dèlectátion, désignàte, ìnsigníficant, àstigmátic, ènigmátic,
        ìmpregnátion, ph&siognómic

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 (12) 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 reduction of energy on unstressed vowels compromises perceptibility of vowel quality, with consequent neutralization to the unmarked quality of [M]. However, cues to vowel quality are inseparable from cues for place of a following coda consonant. This predicts a parallel pressure on such consonants for neutralization to the unmarked place: [coronal]. But with IDENT (Place) ranked high enough, the burden will be shifted to ?E, 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 that the vowel itself will no longer turn to [M].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. Sonorants and 'Sonorant Destressing'
Unlike obstruents, sonorant codas do not exhibit a difference between coronal and other places, allowing vowel-reduction rather generally, as shown in (13).

(13) 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, trànsportátion, 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 (14).

(14) a. **Word-final sonorants** (vowel *un*reduced): Agamémn<u>o</u>n, márath<u>o</u>n
támp<u>o</u>n, pé<u>o</u>n, sámp<u>a</u>n, Íg<u>o</u>r, wígw<u>a</u>m, ág<u>a</u>r, cháo<u>s</u>, cárav<u>a</u>n, méte<u>o</u>r

b. **Word-medial sonorants** (vowel *un*reduced): òst<u>e</u>ntátion, déf<u>a</u>lcàte,
ìnc<u>a</u>ntátion, hàlic<u>a</u>rnássus, ìnc<u>a</u>rnátion, éx<u>o</u>rcìse, ínc<u>u</u>lpàte, còmplem<u>e</u>ntátion,
èxh<u>o</u>rtátion, còmp<u>a</u>rtméntal, dìsp<u>e</u>nsátion, dèp<u>a</u>rtméntal, dèp<u>o</u>rtátion, èl<u>o</u>ngátion,
èmb<u>a</u>rkátion, èm<u>e</u>ndátion, èx<u>a</u>ltátion, fèrm<u>e</u>ntátion, fràgm<u>e</u>ntátion, cónt<u>e</u>mplàte,
ìncr<u>u</u>státion, ìnf<u>e</u>státion

What this suggests is that coda sonorants are in fact also dependent on a preceding
vowel, albeit less so than obstruents. Such weaker dependency will be formally
expressible by a *WEAK-X constraint lower ranked than the *WEAK-P(lace) of (10)
above. Putting aside the exact nature of 'X' for the moment, this will allow us to
postulate both of the interactions of (15) and (16) below.

-15	/ápron/	IDENT (X)	? E	*Weak-X
a.	ápron		*	
b.	**L** áprⱮn			*
c.	áprⱮn̩	*		

In (15), *WEAK-X is violated by candidate (b), in which vowel-reduction suppresses
critical cues to the following sonorant, which is thus under pressure to neutralize to
some yet undetermined structure 'n̩' as in candidate (c). The latter candidate is
excluded by higher-ranked IDENT (X), however, while candidate (a) is excluded by
? E, also higher-ranked. Candidate (b) is therefore optimal. The variability of vowel-
reduction in these contexts can be accounted for by assuming that the relative ranking
of ? E and *WEAK-X is in fact indeterminate, such that the relevant grammar can be
thought of as ambiguous between the ranking of (15) and that of (16), which now
yields an unreduced vowel.

-16	/Agamémnon/	IDENT (X)	*WEAK-X	? E
a.	**L** Agamémnon			*
b.	AgamémnⱮn		*	
c.	AgamémnɁn̩	*		

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In (16), violation of IDENT (X) as in (c) remains excluded, but violation of ?E rather than of *WEAK-X is now optimal. Such ranking ambiguity between (15) and (16) effectively makes candidates (a, b) equally optimal, so that the choice between them can then be attributed to other constraints, not given in this grammar fragment. In particular, IO-FAITH can be taken to play the crucial role in many cases. For instance, if we take *apron* of (15) to have a reduced vowel in the input, then candidate (b) will be correctly favored by an appropriate IDENT (Q). In contrast, *Agamemnon* of (16) can be taken to have a full vowel in the input, IDENT (Q) thus favoring candidate (a). Note that input [M]'s are expected under 'Richness of the Base' (Prince and Smolensky 1993), responsibility for their output distribution falling on the grammar. We have already dealt with their exclusion in stressed position in the discussion of (7) above. Exclusion in the cases of (12a, b): **Adirónd[M]ck*, is automatic under the present analysis: since ?E dominates IDENT (Q) as in (5), and IDENT (P) dominates ?E as in (10), then IDENT (P) dominates IDENT (Q) by transitivity. Hence a velar or labial coda will force a preceding vowel to be full regardless of its input quality.

Similarly to IO-FAITH, we can also take OO-FAITH to play the arbitrating role in some cases. This will in fact account for contrasts such as the famed *cònd[e]nsátion* (base *cond[é]nse*) versus *còmp[M]nsátion* (base *cómp[M]nsàte*).

As for what 'X' in (15), (16) refers to, we may assume it concerns the type of aperture (nasal/ lateral/ rhotic). I leave open the question of exactly what neutralizations such 'Weak-X' would promote (perhaps liquids would tend to merge with glides or vowels, and nasals with non nasal stops).

With regard to the variation in (13), (14), we note further that [s] codas behave similarly to their sonorant counterparts, as shown in (17).

(17) a. **Word-final [s]**. Vowel reduced: sýllab<u>u</u>s, aspárag<u>u</u>s, ...; Vowel *un*reduced: Orést<u>e</u>s, hypóthes<u>e</u>s, ...

b. **Word-medial [s]**. Vowel reduced: órch<u>e</u>stràate, ... ; Vowel *un*reduced: dèt<u>e</u>státion, ìncr<u>u</u>státion ...

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 (18).

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

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

c. **Son**: **répertòry** ádversàry, ínventòry, prómontòry, légendàry, sécondàry, sédentàry, cómmentàry, mómentàry, 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 (18a), while if the latter is light, they stress the suffix, along with the stem penultimate, as in (18b). This variation clearly results from the general preference for stress to coincide with heavy syllables, a fact ultimately reducible to our ?E, as argued below. Now, syllables closed by sonorants behave like light syllables in this respect, as shown in (18c). Earlier literature, beginning with Kiparsky (1979), had assumed that such syllables were initially stressed like other heavy ones, but that they 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 (13) –that of permitting vowel-reduction. Assuming as seems rather natural that the formal notion of syllable 'weight' is commensurate with 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 illustrated in (3) above, and the effect in (18) will then be expected. PES (71) also notes a corresponding 'scale-down' effect on syllables that would be structurally light, which, under vowel-reduction 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. *(rúuta)(bàg[M])*, patterning like *(Cáro)(lìne)*, 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 extends to the cases in (19), some of which show that syllables closed by [s] again behave similarly.

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

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

The cases in (19a) 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 (19a) is less than fully general, however, as noted in PES, witness *párent* / *párental* (vs. *párentage*), but rather requires certain conspiring factors to bring it about (PES 306-311 and passim), as does the behavior in (18a) 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 given 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 partially dependent are able to reduce, although there is apparently enough residual dependency that those vowel may also remain unreduced under certain circumstances. Vowel-reduction scales down syllable weight, resulting in the fact that syllables closed by sonorants or [s] may function on a par with light ones under various conditions. 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 surface constraints.

4. The Structure of Final Clusters
It was also noted in PES that, unlike the stress-based account of the asymmetry between *Adirond[æ]ck* and *Connectic[M]t*, the account based on perceptual dependency directly relates to the asymmetry in word-final clusters shown in (20).

(20) a. **pt#** (non-reduced vowel): trans<u>e</u>pt, conc<u>e</u>pt, perc<u>e</u>pt, prec<u>e</u>pt, ed<u>i</u>ct, distr<u>i</u>ct, ...

    b. **kt#** (non-reduced vowel): catar<u>a</u>ct, ins<u>e</u>ct, def<u>e</u>ct, dial<u>e</u>ct, imp<u>a</u>ct, obj<u>e</u>ct, subj<u>e</u>ct, prod<u>u</u>ct, ...
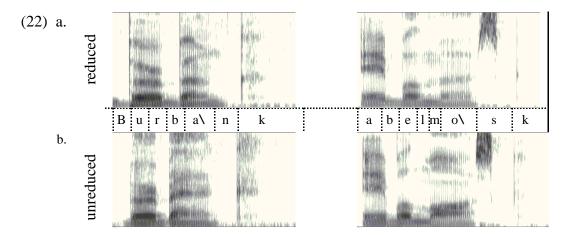
    c. **tp/ tk#**: **non-existent**

Yip (1991) correctly links the asymmetry in (20) to the special status of coronals, but not to the vowel-reduction generalization of (11) above. From the present perspective, the final clusters of (20a, 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 when it occurs by itself, as in (12a) above, while at the same time the second member will also be licensed because, being a coronal stop, its demands for perceptual cuing are modest, witness the vowel-reductions of (12c) above. In contrast, the clusters of (20c) are excluded because the dependency of velars and labials on a preceding full vowel is not satisfied. Consider that if consonants differed in whether or not they attract stress as in the tradition of Ross (1972), then consonant clusters should also just differ in the same way, with nothing else following from it.

In addition to the characteristics noted above, sonorants and [s] also appear to share the property of being transparent to the dependency relation between a stop and a preceding vowel, as shown in (21).

(21) a. **Before *p/ k*** (vowel unreduced): **Búrb<u>a</u>nk**, pód<u>u</u>nk, chípm<u>u</u>nk, óz<u>a</u>rk, áardv<u>a</u>rk, ábelm<u>o</u>sk, áster<u>i</u>sk, árim<u>a</u>sp

   b. **Before *t/ d*** (vowel reduced): **ínf<u>a</u>nt,** éleph<u>a</u>nt, élem<u>e</u>nt, lieutén<u>a</u>nt, sérp<u>e</u>nt, cómf<u>o</u>rt, órch<u>a</u>rd, bást<u>a</u>rd, éver<u>e</u>st, cátal<u>y</u>st

In (21a), the final labial or velar stop is apparently licensed by an unreduced vowel across an intervening sonorant or [s], similarly to its licensing under adjacency of (12a), and unlike the failed licensing across an intervening stop postulated for (20c). In contrast, in (21b) the coronal stop continues not to require a preceding full vowel, behaving consistently with both (12c) and (20a, b). We take this behavior 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. By being partially dependent, however, they may plausibly be seen as allowing the latter cues to be modulated by the energy level of a preceding vowel. We must note as well 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 (12a) and (20c), but their role is established by the fact that none of the final clusters of either (20a, b) or (21) are found in word-medial codas, where the release is prevented by the following onset. Release can in fact be seen as the acoustic substance of PES's final null vowels (also argued for in Harris 1994), as in *pre.ven.tø* , etc. Now

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sonorants and [s] would seem capable of 'transfering' some of the energy of a preceding vowel into the release of a following stop, judging from the data in (22).

(22) a.

In (22), 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] helps 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 (20), 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 (13) can plausibly be seen as underlying their 'transparent' character in (21). If this is correct, then the limited possibilities for word-final clusters of (20) and (21) 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 (12) and (13).

5. The 'Arab' rule

Ross (1972) and others noted a class of exceptions to the generalization that final non-coronal stops do not co-occur with reduced vowels, shown in (23a). Fudge (1984) noted further that such exceptions occur word medially as well, as shown in (23b), while (23c) gives the regular cases for contrast.

(23) a. **Word-final p/ k** (vowel reduced): **árab,** 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 generalization about the exceptional cases of (23a, b) is that the adjacent stressed syllable is here light, in contrast to the stressed heavy syllables of (12a, b) above and (23c) (that 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 ingredients are needed in particular. One is our earlier assumption that ? E constitutes a family of constraints, confronting weaker and weaker energy modulations with stronger and stronger prohibitions. The other is the assumption, introduced to deal with the 'sonorant destressing' effect, that that the formal notion of syllable weight is closely related to that of acoustic energy. When put together, these ingredients yield the analysis in (24).

-24	/Árab/	? E$_2$	IDENT (P)	*Weak-P	? E$_1$
a.	⌐ Árab	*			*
b.	ÁrMb			*	(*)
c.	ÁrMt		*		

In (24), candidate (a) violates ? E$_2$, a higher ranked member of the ? E family than the ? E of (10) above, which is given here as ? E$_1$ for comparison. The reason for this violation is that, because it is a light syllable, the stressed syllable realizes a lower level of energy than the heavy syllables of (12a, b) or (21a). This results in a smaller

and perhaps even negative energy reduction, since the final syllable with an unreduced vowel is much like a heavy syllable, its final consonant being strongly cued by the preceding vowel and only weakly by its release, while in the medial cases of (23b) the unstressed syllable is indeed just a heavy syllable. Candidate (a) in (24) thus reverses the ideal situation in which stress coincides with heavy syllables, commonly expressed by a WEIGHT-TO-STRESS constraint and its complement STRESS-TO-WEIGHT (Kager 1999, 155, 278 and Refs.). Our ?E family is in fact just the present embodiment of such constraints, and will thus duly penalize (24a) as indicated. So long as IDENT (P) is sufficiently high-ranked to block neutralization to coronal place as in candidate (c), the reduction candidate (b) will emerge the winner, despite a likely residual violation of $?E_1$ (stressed and unstressed syllables now being of roughly comparable weight),

Hence, 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.

6. 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 mirrors the distribution typical of epentheses: 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 uniquely. 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 here that the weakening of perceptual properties that causes a vowel to neutralize to an unmarked [ʌ] will correspondingly drive a consonant dependent on that vowel to also neutralize to the unmarked place: [coronal], the correct choice between failed vowel-reduction: *Adirondack* and place neutralization: *Adirondʌt following from language-specific constraint ranking within OT. This analysis correctly predicts that coronal stops will not block reduction: *Connecticʌt,* because they are 'pre-neutralized' to the unmarked place in the input, 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 a separate problem.

While the dependency between stress and vowel-reduction is thus only partial, I have also argued that -at the same time- it is in fact mutual, as vowel-reduction affects syllable weight, and in turn the position of stress. A class of exceptions to failed reductions before labials and velars: *Ár[M]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. 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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