Stress and Syllable Structure in English: Approaches to Phonological Variations

英語的重音和音節：如何分析語音結構的多樣性

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作者/Author： 端木三(San Duanmu);Hyo-Young Kim;Nathan Stiennon

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STRESS AND SYLLABLE STRUCTURE IN ENGLISH: APPROACHES TO PHONOLOGICAL VARIATIONS*

San Duanmu, Hyo-Young Kim, and Nathan Stiennon

ABSTRACT

We use phonological variation to refer to alternative forms that are available in a language, such as different syllable structures or word stress patterns in English. We discuss several approaches to such variations and argue for a new approach, in which all alternative forms observe a set of inviolable constraints. In particular, we propose that all English words observe four constraints: (a) a foot must be disyllabic, (b) stressed syllables must be heavy, (c) heavy syllables must have stress, and (d) the maximal syllable is CVX. We discuss the implications of our proposal for Optimality Theory and for the analysis of linguistic variation in general.

1. WHAT IS PHONOLOGICAL VARIATION?

We use phonological variation to refer to alternative forms that can be used for more or less similar purposes. For example, in English a word made of CVCVCV may have stress on the first syllable, as in *Canada*, or on the second syllable, as in *banana*. There is no reason why the stress pattern could not have been the other way round, i.e. for *Canada* to have the stress on the second syllable and for *banana* to have the stress on the first. Nor is there any reason why the stress in such words cannot be all on the first syllable, or all on the second. English just happens to use both forms. Similarly, an English word can be VC, such as *Ann*, CVC,

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such as *sit*, or CCCVC, such as *split*. There is no reason why a word must use one or another form and English just happens to use all these forms.

In addition to variations within a language, there are also variations across different languages. For example, before the nuclear vowel Standard Chinese allows CG- but not CC-, whereas English allows both CG- and CC-. Similarly, Standard Chinese only allows [–n] and [–ŋ] after the nuclear vowel, whereas English allows many more consonants. Moreover, Standard Chinese uses five underlying vowels (Duanmu 2000, not including diphthongs), whereas English uses about ten.

Indeed, linguistic variations go beyond phonology and extend to other areas, such as syntax, semantics, and the lexicon. For example, Japanese uses the word order SOV, whereas English and Chinese use SVO. Similarly, the galaxy we are in is called *the Milky Way* in English but *Yin He* 'Silver River' in Chinese, and the animal 'cat' is called [kæt] in English but [mau] in Chinese. For the learning of the content of a book and of that of a movie, English uses two different verbs—*read* for the former and *see* for the latter, whereas Chinese use the same verb *kan* for both activities.

Obviously, what distinguishes one language (or dialect) from another is the set of choices a language makes with regard to various linguistic variations. Therefore, linguistic variations are what descriptive linguists are primarily interested in.

2. APPROACHES TO PHONOLOGICAL VARIATIONS

For describing a language, it is perhaps enough to list the choices the language makes with regard to various aspects of linguistic variations, such as the lexicon, the word order, the consonant and vowel inventories, syllable structures, stress patterns, and so on, assuming that we already know what kind of linguistic variations there are.

For theoretical linguists, additional questions can be raised. For example, for a given aspect of variation, such as syllable structure, is the number of possible forms limited? And if it is, how many forms and what kind of forms are there? Specifically, does every syllable require a vowel? If in some languages every syllable requires a vowel, how many consonants may occur before the vowel in a syllable? For example, we

know that English allows three consonants before the vowel, as in the word *split*. Is it possible for a language to allow four consonants, or seven consonants, before the vowel? The answers to such questions are far from obvious.

In this article we focus on two well-known phonological variations—syllable structure and word stress, and discuss four approaches to them. For lack of space, we will focus on American English only (hereafter English), although the argument applies to variations across different languages, too. The main question for all the approaches is, is there any generalization to be made of the many patterns that are found in English syllable structure or word stress? The four approaches are given in (1).

(1) Approaches to phonological variations
   a. *The no-pattern approach*: There is no useful generalization to be made of the patterns.
   b. *The norm-and-exceptions approach*: One of the patterns is the norm for the language; others are exceptions of various sorts.
   c. *The loose-requirements approach*: All the patterns are good and conform to some loosely defined structure.
   d. *The inviolable-constraints approach*: There is a set of inviolable constraints that all patterns must satisfy. Alternative patterns are possible because the constraints can be satisfied in more than one way.

The first three approaches have been proposed before. The last is new and is what we will argue for. In what follows we illustrate the approaches with quantitative data from the English lexicon.

3. ENGLISH WORD STRESS

Most analyses, such as Halle and Vergnaud (1987) and Hayes (1995), assume that stress assignment comes after syllabification. For syllabification, most analyses follow Kahn (1976) and assume the Maximal Onset rule, according to which intervocalic consonants are syllabified as the onset of the following vowel as far as is allowed by the given language. Some examples are shown in (2), where syllable boundaries are indicated by a dot.

(2) Syllabification according to Max Onset

Canada	[kæ.nə.də]
banana	[bə.næ.nə]
pedigree	[pɛ.dɪ.gri]
committee	[kə.mɪ.ti]
essay	[ɛ.se]
alpine	[æl.pain]

Stress assignment is sensitive to the weight of a syllable, i.e. whether a syllable is heavy or light, as defined in (3), where VV is a diphthong or a tense vowel.

(3) Heavy syllable: the rhyme is VX (VV or VC)
Light syllable: the rhyme is V (a short vowel) or C (a syllabic C)

The weight patterns of the words in (2) are shown in (4), where L is a light syllable and H is a heavy one.

(4)

Words	Syllables	Weight
Canada	[kæ.nə.də]	LLL
banana	[bə.næ.nə]	LLL
pedigree	[pɛ.dɪ.gri]	LLH
committee	[kə.mɪ.ti]	LLH
essay	[ɛ.se]	LH
alpine	[æl.pain]	HH

It is worth noting that the syllabification just discussed differs from what we will argue for. We will return to this point later.

Having discussed syllable structure, let us now consider stress assignment. According to standard descriptions (e.g. Halle and Vergnaud 1987 and Hayes 1995), main stress in English words follows the rules in (5), although each rule has some exceptions. For ease of reading, the syllable with the main stress is underlined in the weight representation.

(5) English word stress: standard description

a. Stress the final syllable if it has a long vowel

Examples:	*Tennessee*	LL<u>H</u>
	decay	L<u>H</u>
	sardine	H<u>H</u>
Exceptions:	*pedigree*	<u>L</u>LH
	committee	L<u>L</u>H
	essay	<u>L</u>H
	alpine	<u>H</u>H

b. Otherwise stress the penultimate syllable if it is heavy[1]

Examples:	*agenda*	L<u>H</u>L
	Maria	L<u>H</u>L
Exceptions:	*carpenter*	<u>H</u>HL
	Julia	<u>H</u>HL

c. Otherwise stress the antepenultimate syllable

Examples:	*America*	L<u>L</u>LL
	Canada	<u>L</u>LL
Exceptions:	*Alabama*	LL<u>L</u>L
	banana	L<u>L</u>L

It would be interesting to know to what extent the standard description is true for the entire English lexicon. Alcantara (1998) offers some data, based on the CELEX lexical corpus (Baayen et al 1993), which contains some 52,000 English 'lemmas', which are basically uninflected words. The results for words that have three or more syllables are shown in (6).

[1] A reviewer asks why the vowel [i] in words like *Julia* is treated as long, since it is phonetically short. It is more reasonable to propose instead that stressed tense vowels are long (in an open syllable) and unstressed tense vowels are short, which point we will consider in more detail below. However, in previous analyses, this proposal is not available, because it would mean that syllable weight depends on stress, yet stress assignment depends on syllable weight. Therefore, to avoid the dilemma, previous analyses have assumed that tense vowels are all long at the time of syllabification.

(6) Stress distribution in CELEX for words of SSS+

	Nouns			Verbs			Adjectives		
	́σσ	σ́σ	σ̀σ́	́σσ	σ́σ	σ̀σ́	́σσ	σ́σ	σ̀σ́
HHH	33	54	11	4	11	84	34	35	30
LHH	36	53	9	58	17	25	47	52	0
HLH	77	3	17	24	6	69	56	3	40
LLH	72	7	18	62	2	34	71	8	19
HHL	35	62	1	3	91	5	3	97	0
LHL	23	73	2	6	85	8	31	67	0
HLL	74	15	8	12	60	27	51	42	6
LLL	78	15	5	36	45	18	82	17	0

In (6), only the last three syllables are shown, since that is where the main stress usually falls. The first column shows the weights of the last three syllables, where H is a heavy syllable and L is a light syllable. The syllabification is based on the Max Onset rule (Kahn 1976). Since a final CVC syllable does not always attract stress, the final syllable is coded as H only if it has a long vowel, otherwise it is coded as L. A long vowel refers to a diphthong, a tense vowel, and a stressed [r] (or [ɝ], as in *fur*), but not an unstressed [r] (or [ɚ], as in the second syllable of *worker*). The number in each cell shows the percentage of words with that stress pattern. For example, in HHH for nouns, 33% of the words take the main stress on the third last syllable, 54% of the words take the main stress on the second last syllable, and 11% of the words take the main stress on the final syllable. The three percentages for each weight pattern do not always add up to 100%, probably because in some words the main stress is not on the last three syllables. Alcantara listed nouns, verbs, and adjectives separately in order to examine another issue. For our interest, it is relevant to note that even within each word category, there is not always a dominant pattern, such as HHH for adjectives, LHH for nouns, or LLL for adjectives.

Duanmu and Stiennon (2004) offer a similar study with the CMUDICT lexicon (Weide 1998), which has some 127,000 words, including inflected words. The result is shown in (7). In the top row, '1' indicates main stress, '2' indicates secondary stress, '0' indicates no stress, and 'X' indicates any stress. The numbers in other cells show the number of words for the given weight and stress pattern. The shaded

cells show the stress patterns predicted by the standard description of English word stress in (5), and the last column shows the percentages of the shaded cells for each weight structure.

(7) Stress distribution in CMUDICT for words of SSS+

	100	102	120	122	X10	X12	XX1	Other	%
HHH	736	423	33	15	2921	83	277	67	6
HHL	2345	198	922	4	3577	16	91	400	47
HHS	310	104	43	1	605	16	47	24	53
HLH	1544	1468	118	4	746	16	286	231	7
HLL	3501	273	342	3	1420	1	100	247	60
HLS	743	216	24	0	287	0	110	44	52
LHH	443	374	5	14	2113	107	135	263	4
LHL	1592	149	95	3	4040	37	37	1466	55
LHS	247	73	3	2	787	9	26	45	66
LLH	1617	1270	4	1	555	17	167	536	4
LLL	2941	232	37	0	1427	6	68	601	55
LLS	702	130	0	0	346	0	57	100	53
Total	16721	4910	1626	47	18824	308	1401	4024	37

It is not obvious from the corpus data what the generalization for English word stress should be. In what follows we discuss four proposals.

3.1. The no-pattern approach

In this approach, there is no attempt to find a general pattern that applies to all or most words, probably because no generalization is believed to exist. For example, Daniel Jones (1972: 248) states that 'Generally speaking there are no rules determining which syllable or syllables of polysyllabic English words bear the stress.' As a result, stress patterns are simply listed in the lexicon. Any apparent trends or statistical preferences for certain patterns are probably due to historical accidents.

3.2. The norm-and-exceptions approach

This approach assumes that English has a default stress pattern, similar to what is stated in (5), although there are some exceptions. There are four slightly different versions of this approach, shown in (8).

(8) Four versions of the norm-and-exceptions approach
    a. Language typology
    b. Language parameters
    c. Rule-based theory
    d. Optimality Theory

For those who believe in language typology, there is a limited number of types for each linguistic aspect (e.g. stress, syllable, word order, etc.). For example, there is a limited number of types for word stress, such as initial vs. final stress, mora counting vs. syllable counting, and whether stress is sensitive to syllable weight. Each language chooses one type, which is the norm for that language. A language may also contain some exceptions. With regard to English stress, the norm is what is stated in (5), and the presence of exceptions is expected.

Those who believe in language parameters assume that there is a limited number of parameters for each linguistic feature, such as stress. For example, Halle and Vergnaud (1987) propose a number of stress parameters, such as whether we count syllables or rhyme segments, whether the last syllable is counted or ignored, whether a foot has initial stress or final stress, whether heavy syllables attract stress or not, and so on. Each language chooses one parameter set, which determines the normal stress pattern for that language. A language may also contain a number of other patterns, which are exceptions. Exceptions are lexically marked (memorized) and can violate the parameter settings of the given language.

The rule-based theory assumes that a grammar is a set of rules. Each language has its own set of stress rules, which determines its normal stress pattern. For example, English has one set of stress rules, and French has another set of stress rules. The rules for stress can in fact be quite limited and can be translated into parameters, as shown by Halle and Vergnaud (1987). Patterns that do not fit the rules are exceptions,

which are thought to be common in phonology (Bromberger and Halle 1989). Exceptions are lexically marked or memorized. In (9)-(11) we illustrate the rule-based analysis of English word stress, where a trochaic foot is one whose stress falls on the left of the foot.

(9) English main stress rules (ordered):

Extrametricality:	Ignore the last syllable unless it contains a long vowel
Stress heavy:	Put stress on heavy syllables
Trochee on right:	Build a trochaic foot from the right side of the word.

(10)	Rules	a.gen.da	car.pen.ter*
	Extrametricality	a.gen.<da>	car.pen.<ter>
	Stress heavy	a.gén.<da>	*exception**
	Trochee on right	a.(gén).<da>	(cár.pen).<ter>

(11)	Rules	A.me.ri.ca	A.la.ba.ma*
	Extrametricality	A.me.ri.<ca>	*exception**
	Stress heavy	n/a	n/a
	Trochee on right	A.(mé.ri).<ca>	A.la.(bá.ma)

The rules correctly assign main stress to *agenda* and *America*. The words *carpenter* and *Alabama* are exceptions, which do not undergo the same rules as other words. In particular, *carpenter* does not undergo the rule 'stress heavy', and *Alabama* does not undergo the rule 'extrametricality'. Without the provisions for exceptional cases, *carpenter* and *Alabama* would have been assigned other stress patterns.

In Optimality Theory (OT, Prince and Smolensky 1993), ordered rules are replaced with ranked constraints. Still, there is a limited number of constraint rankings for stress patterns, and each language selects one constraint ranking, which determines the normal stress pattern for that language. A language may also contain other stress patterns, which are exceptions. Exceptions are lexically marked, which quality can override the constraints for normal words. In (12)-(14) we illustrate the analysis in OT. Following Hammond (1999), an exceptional word has a lexically marked stress, and the constraint Lex-Stress requires it to be realized.

The constraint ranking shows one possible analysis, although other analyses are also possible.

(12) OT constraints

Lex-Stress (Lex):	Lexical stress must be realized
Trochee (Tro):	Stress is on the left of the foot
Foot-Binarity (FB):	A foot must have two syllables
Non-Finality (NF):	A right-side foot boundary should not be a word boundary
Foot-Right (FR):	Build a trochaic foot from the right end of the word.

Ranking: Lex>>Tro>>FB>>NF>>FR

(13)

/America/	Lex	Tro	FB	NF	FR
Ame(rica)				*!	
(Ame)rica					**!
√ A(meri)ca					*
Ame(ri)ca			*!		*

(14)

/Alabáma/	Lex	Tro	FB	NF	FR
√ Ala(báma)				*	
(Ala)bama	*!				**
A(laba)ma	*!				*
Ala(bá)ma			*!		*
A(labá)ma		*!			*

It is worth noting that one can in principle lexically mark stress for all words, but then most constraints become useless.

There are two general problems for the norm-and-exceptions approach. First, it is not always obvious which pattern should be chosen as the norm. For example, one can choose *banana* and *Alabama* as the norm and *Canada* and *America* as exceptions, or the other way round. In principle either way is possible. One might suggest that we should look at the statistical patterns and choose the most frequent pattern to be the norm. However, as we saw in the corpus data earlier, as far as English word stress is concerned, it is not obvious whether there is always a

dominant pattern for a given weight type, or whether the dominant patterns for different weight types form a coherent group for the language. The second problem for the norm-and-exceptions approach is that it is not clear whether there is any constraint that holds for all words, or for all languages. For example, in the parameter-based analysis, one may choose binary feet or ternary feet, and so neither foot type is universally required. Similarly, in the OT approach, one may rank Foot-Binarity (or any other constraint) high or low, and so it is not required for all words. Indeed, the norm-and-exceptions approach explicitly assumes that exceptions are possible, and so there is in principle no constraint that must hold for all words. This position contrasts sharply with the standard practice in syntax, such as Chomsky (1981), where true constraints (known as 'principles') are inviolable for all languages.

3.3. The loose-requirements approach

Burzio (1994) offers an analysis of English stress in which all words have normal stress patterns, with no exceptions as far as main stress is concerned (there are some problems with secondary stress, which we do not review here; see Kim 2000 for more discussion). However, the analysis is achieved by assuming flexible foot structures. In particular, Burzio assumes two general foot patterns, each including several sub-cases, shown in (15), where H is a heavy syllable, L is a light syllable, σ is either H or L, and Ø is an empty syllable. All feet are trochaic and have initial stress.

(15) Burzio's foot types
(Hσ): (HL), (HH), (HØ)
(σLσ): (HLH), (HLL), (LLH), (LLL)

A crucial assumption in Burzio's analysis is that syllabification is sensitive to stress (or foot structure). In addition, syllabification and stress are not carried out in sequence but are checked simultaneously. Specifically, a CVCV sequence is not always syllabified as CV.CV, but can be CVC.CV if stress is on the first syllable; in this case the medial C is thought to be a geminate, although little evidence is provided. An analysis of some sample words is shown in (16).

(16)	*potato*	L(HL)	σσ́σ
	period	(HH)L	σ́σσ
	Juliet	(HH)(HØ)	σ̀σσ́
	alpine	(HH)	σ̀σ
	sardine	(ØH)(HØ)	σ̀σ́
	city	(HL)	σ́σ
	citizen	(LLL)	σ́σσ

A few comments are in order. First, a light syllable at the end of a word can be left unfooted, as in *period*. Second, a final [i] is treated as a short vowel, as in *city*, following Chomsky and Halle (1968). Third, a heavy syllable need not be stressed, such as the second syllable in *alpine*, although in most analyses it has a secondary stress. Burzio argues that the perceived prominence on such a syllable is not due to stress, but to the fact that the vowel is unreduced. Fourth, in *sardine*, Burzio assumes that the first syllable forms an iambic foot with an empty syllable. It is unclear why Burzio does not think it is simply unfooted, similar to the second syllable in *alpine*. If he does, there is no need to assume iambic feet.

In summary, in Burzio's analysis all English words are regular as far as main stress is concerned. There are no exceptions because all the feet conform to the two general foot types. However, the success is achieved by allowing flexible foot types, and sometimes flexible syllabification. For example, it is unclear what relation there is among the list of allowable feet, such as that between (HL) and (LLH). Burzio argues that all the feet are related because they are similar in some kind of 'total weight', yet the definition of total weight seems to be complicated and the calculation seems to be *ad hoc*. In addition, some proposed feet are rather unusual cross-linguistically, such as (LLL) and (HLH). For more comments on Burzio's analysis, see Kim (2000).

3.4. The inviolable-constraints approach

The approach we argue for differs from previous ones in a major way. While other analyses assume that all phonological generalizations can in principle have exceptions, we believe that there are truly

inviolable phonological constraints that hold for all words. In addition, while most previous analyses are formulated in such a way as to pick out one of the alternative forms as the norm, we believe that it is possible to have multiple forms that all satisfy the same set of inviolable constraints and so are all good.

To see how different forms can all satisfy the same set of constraints, consider a case of foot formation, illustrated in (17) and (18).

(17) Constraints on foot structure:
A foot must be disyllabic.
An empty syllable Ø can occur in final position only.

(18)

Length	Possible and impossible foot structures
σ	(σØ), *(σ), *(Øσ)
σσ	(σσ), σ(σØ), *(Øσ)(σØ), *(Øσ)(σ), *(σØ)(σ) …
σσσ	(σσ)σ, σ(σσ), (σσ)(σØ), *(Øσ)(σσ), *(σØ)(σσ) …

If we assume the constraints in (17), then for each word length, there can be one or more foot structures that are equally good, in the sense that they all satisfy the given constraints, and structures that are bad, in the sense that they violate one or more of the constraints. In addition, there is no need to assume that one of the good forms for a given word length is necessarily better than the others.

Now if a given word length can have several good structures, does it mean that all of them can be used for the same word? For example, since σσσ has three good structures, (σσ)σ, σ(σσ), (σσ)(σØ), can we pronounce a word like *Canada* in three different ways? The answer is no, obviously. Each word must choose one of the possible forms upon its creation, and this form is memorized along with the word itself. This is similar to saying that when a word is created, we could choose any vowel(s) and consonant(s) for the given language to represent the pronunciation, but once the choice is made, it is memorized along with the word.

Another question is that, when a new word is created, are all the possible forms equally likely to be chosen? The answer is no. We believe that the choice of how to represent a new word does not always depend on phonological factors. Instead, it can be influenced by statistical effect or completely accidental. This is similar to saying that when a new word

is created, there is no way to predict, based on phonological theory, which consonants and vowels it will use. All we can say is that the consonants and vowels must be drawn from the sound inventory of the given language. Similarly, the foot structure of the new word must be drawn from one of the good forms for the given word length.

As another example of how different forms may all satisfy the same set of constraints, consider a case of syllabification, illustrated in (19) and (20), where V represents a stressed vowel and v an unstressed one.

(19) Constraint on syllabification:
Stressed syllables must be heavy.

(20)

Word	*civic*	*Japan*	*asset*
Good	CVC.vC	Cv.CVC	CVC.VC
Bad	*CV.CvC	CvC.VC	*CV.CVC

If we assume just the constraint on syllabification in (19), then we predict three possible ways to syllabify CVCVC, including a case where syllabification is ambiguous (for *Japan*). Of course, additional constraints can resolve the ambiguity, which point we will leave open.

Let us now consider the analysis of main stress in English words. We assume that syllabification and stress are not sequentially ordered, but are inter-dependent and simultaneously checked. We propose the constraints in (21), which are the same as what we have discussed earlier.

(21) Constraints on stress and syllabification:
A foot must be disyllabic.
An empty syllable Ø can occur in final position only.
Stressed syllables must be heavy.
(Heavy syllables must have stress.)

Foot binarity is well-known in phonology and is not further justified here. The empty syllable has also been proposed by many people (e.g. Abercrombie 1967, Liberman 1975, Selkirk 1984, Giegerich 1985, Hogg and McCully 1987, Burzio 1994). Our assumption is more specific in that the empty beat is only available in final positions, where it is realized as either a pause or the lengthening of the preceding syllable

(Klatt 1975, 1976). The relation between syllabification and stress has also been recognized in the literature for a long time (Prokosch 1939, Fudge 1968, Bailey 1978, Selkirk 1982, Blevins 1995, Hammond 1999, and others). The last constraint is what Prince (1990) calls the Weight-to-Stress Principle. We put it in parentheses because there are some apparent counter-examples, to be discussed later.

Let us now consider some examples. First, consider those in (22) and (23). Following previous analyses, we assume that an unstressed [r] is short, as in the last syllable in *carpenter*.

(22) Heavy syllables need not have stress:

Japan	L(HØ)	σσ́	CV.CVC.Ø
minister	(HL)L	σ́σσ	CVC.V.CCV
civic	(HH)	σ́σ	CVC.VC
carpenter	(HH)L	σ́σσ	CVC.CVC.CV
potato	L(HH)	σσ́σ	CV.CVV.CVV
period	(HH)H	σ́σσ	CVV.CVV.VC
Juliet	(HH)(HØ)	σ̀σσ́	CVV.CVV.VC.Ø
city	(HH)	σ́σ	CVC.VV
citizen	(HL)H	σ́σσ	CVC.V.CVC

(23) Heavy syllables must have stress:

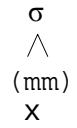
civic	(HL)	σ́σ	CVC.V.C
carpenter	(HL)L	σ́σσ	CVC.CN.CV
potato	L(HL)	σσ́σ	CV.CVV.CV
period	(HL)L	σ́σσ	CVV.CV.V.C
Juliet	(HL)(HØ)	σ̀σσ́	CVV.CV.VC.Ø
city	(HL)	σ́σ	CVC.V
citizen	(HL)L	σ́σσ	CVC.V.CN

In (22), every tense vowel is treated as long. For example, the second syllable of *city* has a long vowel, which is unstressed, because a heavy syllable does not have to carry stress. In addition, the final VC is treated as forming a heavy syllable. For example, the second syllable of *civic* is heavy, although it does not carry stress, again because a heavy syllable does not have to carry stress. If we assume that heavy syllables must carry stress, some words must be analyzed differently, as shown in (23),

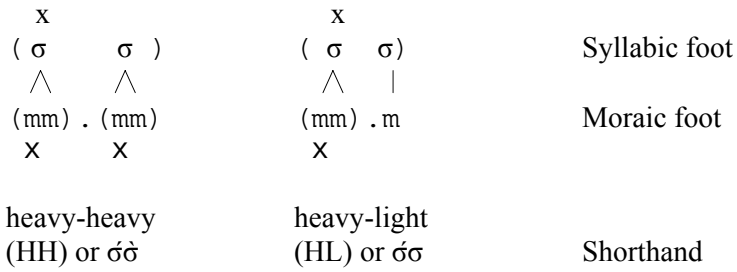
which differs from (22) in three ways. First, a tense vowel, especially [i], may be analyzed as short when it has no stress (Pike 1947, Chomsky and Halle 1968, Hammond 1999). Thus, *city* is (HL) instead of (HH). Second, a final C need not be in the same syllable as the preceding V. For example, in *civic*, the final C is either left unsyllabified or is the onset of an empty vowel (Burzio 1994, Lowenstamm 1996); thus, *civic* is (HL) or (HL)Ø, instead of (HH). Third, the rhyme of the second syllable in *carpenter* is not VC but a syllabic N, so that the syllable is not H but L. The same applies to the third syllable in *citizen*.

We have shown how our analysis works for main stress in some sample words. Let us now consider secondary stress as well. First, we need to take a closer look at foot structure. Unlike the traditional assumption, according to which a language uses either moraic feet or trochaic feet, we believe that English uses both moraic feet and syllabic feet (Duanmu 1999, Kim 2000). Specifically, following the constraint that a foot must be binary and the constraint that a stressed syllable must be heavy, there is one possible moraic foot, shown in (24), and two possible syllabic feet, shown in (25). Since each syllabic foot also contains at least one moraic foot, we call it the 'dual-trochee'.

(24) Moraic foot (moraic trochee):



(25) Syllabic foot (the dual-trochee):



It is worth noting that since (HH) has two moraic feet, both syllables carry stress, which is (σ̀σ́). Some examples are shown in (26).

(26)

sardine	H(HØ)	σ̀σ́
alpine	(HH)	σ́σ̀
panda	(HL)	σ́σ
Canada	(HL)L	σ́σσ
bike	(HØ)	σ́

The analysis distinguishes three degrees of stress: (a) H in the first syllable of a syllabic foot, which carries main stress, (b) other Hs, which carry secondary stress, and (c) L, which carries no stress. We assume that the main stress must fall on a syllabic foot. Therefore, a monosyllabic word like *bike* is also a syllabic foot.

Let us now consider how our analysis applies to the entire lexicon. For demonstration, let us consider the CMUDICT corpus. The stress patterns under traditional syllabification are repeated in (27), where in the top row '1' means main stress, '2' means secondary stress, '0' means no stress, and 'X' means any stress.

(27) Stress distribution in CMUDICT for words of SSS+

	100	102	120	122	X10	X12	XX1	Other
HHH	736	423	33	15	2921	83	277	67
HHL	2345	198	922	4	3577	16	91	400
HHS	310	104	43	1	605	16	47	24
HLH	1544	1468	118	4	746	16	286	231
HLL	3501	273	342	3	1420	1	100	247
HLS	743	216	24	0	287	0	110	44
LHH	443	374	5	14	2113	107	135	263
LHL	1592	149	95	3	4040	37	37	1466
LHS	247	73	3	2	787	9	26	45
LLH	1617	1270	4	1	555	17	167	536
LLL	2941	232	37	0	1427	6	68	601
LLS	702	130	0	0	346	0	57	100
Total	16721	4910	1626	47	18824	308	1401	4024

Due to lack of space, we focus on only two of the twelve rows in (27), HHH and LLL. Again we consider two possibilities: (a) heavy syllables must be stressed and (b) they need not be stressed. The stress patterns of HHH are shown in (28) and (29), with one sample word for each case. The last case 'other' mostly includes compounds or suffixed words, where the main stress is not on the last three syllables.

(28) Stress patterns for HHH (H need not be stressed)

Stress	Word	Foot	Count
100	*agency*	(HH)H	736
102	*handlebar*	(HH)H	423
120	*somebody*	(HH)H	33
122	*workmanlike*	(HH)H	15
X10	*Armani*	H(HH)	2921
X12	*re-export*	H(HH)	83
XX1	*Vietnam*	HH(HØ)	277
Other	*photocopy*	(HH)(HH)	67

(29) Stress patterns for HHH (H must be stressed)

Stress	Word	Foot	Count
100	*agency*	(HL)L	736
102	*handlebar*	(HL)H	423
120	*somebody*	(HH)L	33
122	*workmanlike*	(HH)H	15
X10	*Armani*	H(HL)	2921
X12	*re-export*	H(HH)	83
XX1	*Vietnam*	LH(HØ)	277
Other	*photocopy*	(HL)(HL)	67

In (28), where H may or may not carry stress, the analysis is simple. All cases satisfy foot binarity and the requirement for stressed syllables to be heavy. In (29), every H has either main stress or secondary stress, and unstressed syllables are all L. This analysis requires some assumptions discussed earlier. In particular, unstressed tense vowels need not be long (*agency*, *somebody*, *Armani*, *Vietnam*, and *photocopy*), and some syllables contain a syllabic C without a V (*agency* and *handlebar*).

Next, consider the stress patterns of LLL, shown in (30) and (31), with one sample word for each case. The syllabification for LLL is based on Max Onset. In the present analysis, such words are not LLL but contain at least one H for the main stress. The stress pattern 122 is not found. The last case 'other' mostly includes compounds or suffixed words, where the main stress is not on the last three syllables.

(30) Stress patterns for LLL (H need not be stressed)

Stress	Word	Foot	Count
100	*abacus*	(HL)H	2941
102	*amabel*	(HL)H	232
120	*breadwinner*	(HH)L	37
122			0
X10	*banana*	L(HL)	1427
X12	*jimenez*	L(HH)	6
XX1	*minuet*	HH(HØ)	68
Other	*considerable*	H(HL)LH	601

(31) Stress patterns for LLL (H must be stressed)

Stress	Word	Foot	Count
100	*abacus*	(HL)L	2941
102	*amabel*	(HL)H	232
120	*breadwinner*	(HH)L	37
122			0
X10	*banana*	L(HL)	1427
X12	*jimenez*	L(HH)	6
XX1	*minuet*	(HL)(HØ)	68
Other	*considerable*	L(HL)LL	601

Little comment is needed for (30), where H may or may not have stress. All cases satisfy foot binarity and the requirement for stressed syllables to be heavy. In (31), every H either has main stress or secondary stress, and unstressed syllables are all L. This analysis requires treating unstressed tense vowels as short (*min<u>u</u>et*), treating some syllables as having a syllabic C without a V (*c<u>on</u>siderabl<u>e</u>*), and treating the final C after an unstressed V as extra-syllabic (*abacu<u>s</u>*).

In summary, in the present analysis, all words satisfy the constraint for foot binarity and that for a stressed syllable to be heavy. In addition, there seems to be a third constraint, too, which requires heavy syllables to be stressed and unstressed syllables to be light. We will return to this third constraint shortly.

3.5. Frequency effect

In the present analysis, all good foot structures are treated the same. However, as can be seen in the data, some structures occur more frequently than others. This fact is not reflected in the present analysis, nor is it properly reflected in previous analyses either.

It seems to us that the choice among the good structures is not always determined by phonological factors, but can be influenced by morphology, statistics, or perhaps arbitrary decisions. For example, certain suffixes (or suffix-like strings) require a fixed stress pattern, such as *–átion*,*–átic*, and *-ínski*. Similarly, when a new word is created, its stress pattern can be influenced by those of existing words that look similar. For example, if one does not know the stress for *Renado*, one might try to pronounce it as σσσ, similar to *Leonado*. Finally, consider a case of arbitrary decision. The name *Nadel* once came up at a meeting of some linguists (including one of the present authors), and none knew its established pronunciation. As a result, both σσ́ and σσ́ were used.

It is possible that a new word can look similar to different existing words in different ways. It is also possible that in this case, the stress pattern is more likely to be modeled after the form that has most existing words. If this is the case, we might expect the lexicon to be heavily skewed towards one or a few stress patterns. The reason is as follows. Suppose for CVCVCV the lexicon originally contains three stress patterns σσσ́, σσσ́, and σσσ́, at more or less the same frequencies. When a new word is created, any of the three patterns is just as likely to be chosen as another. But if for some reason one of the patterns begins to have a slightly higher frequency, then new words would be more likely to be modeled after it, and very soon this pattern would dominate the lexicon.[2]

[2] A reviewer wonders what would be examples of possible reasons for favoring one of the alternative patterns. Borrowing would be one such example. It is also possible, we

The above discussion intends to show that many factors can influence the frequency differences among alternative foot structures. It is too simplistic to assume that frequency is entirely determined by phonology and that more frequent patterns are phonologically superior to than less frequent ones.

3.6. Unstressed heavy syllables

We have suggested that there might be a constraint for all heavy syllables to be stressed. There are, however, two sets of apparent exceptions. The first involves unstressed diphthongs [ai], [au], and [oi] in the CMUDICT corpus. Consider the examples in (31), where [ai], [au], and [oi] are sometimes marked as '0' or unstressed.

(32) Unstressed diphthongs in CMUDICT

Word	CMUDICT stress
bilateral	0100
anti-war	201
out-numbered	010
out-numbers	210
Dumfounded	100
Rosenow	100
Eisenhauer	1000
Eisenhower	1020
invoice	10
appointee	001

Syllables with those diphthongs are always analyzed as being heavy. In addition, most phonologists would treat such diphthongs as having secondary stress (e.g. Chomsky and Halle 1968, Halle and Vergnaud 1987, Hayes 1995, Hammond 1999). The discrepancy between phonological practice and the CMUDICT transcription probably reflects

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speculate, that if certain words happen to be used more frequently than others during a given period, and if such words happen to favor one pattern, newly introduced words during this period might skew towards such a pattern, too. In other words, we believe that, if one of the patterns becomes dominant, the reason does not have to be phonological but can be accidental or non-linguistic.

different conventions they follow. In addition, there seems to be some inconsistencies in CMUDICT, too. For example, the syllable [au] has stress in *out-numbers* but no stress in *out-numbered*. Similarly, the syllable [au] carries stress in *Eisenhower* but no stress in *Eisenhauer*. Such differences do not seem to reflect phonological reality but rather inconsistencies by the transcriber or among different transcribers.

A second case of unstressed heavy syllables involve VC rhymes. Some examples are shown in (33), where unstressed VC rhymes are underlined.

(33) Unstressed VC rhymes

*Mac*Donald	σσ́σ
*ex*change	σσ́
*anec*dote	σ́σσ̀

In all analyses, such rhymes are VC (not a syllabic C) and unstressed. And because VC is a heavy rhyme, such syllables seem to violate the requirement for heavy syllables to be stressed. A possible solution is proposed by Pierrehumbert (1994). She argues that consonants at the end of a morpheme need not be syllabified with the preceding vowel. In addition, words like *MacDonald* and *exchange* have an internal morpheme boundary *Mac-Donald* and *ex-change*, even though it might not be semantically obvious to the speaker. Similarly, *anecdote* may be analyzed as *anec-dote*, parallel to *anti-dote*. Following this proposal, the words in (33) may be analyzed as in (34), where unsyllabified consonants are in parentheses.

(34)

Mac-Donald	[mə.(k)-don.l.(d)]	L(HL)
ex-change	[ɪ(ks)-ʧen.(dʒ)]	L(HØ)
anec-dote	[æn.ɪ(k)-do.(t)]	(HL)H

In *MacDonald*, [k] and [d] are at the end of a morpheme and need not be syllabified, and [l] is a syllabic C. In *exchange*, [ks] and [dʒ] are at the end of a morpheme and need not be syllabified. In *anecdote*, [k] and [t] are at the end of a morpheme and need not be syllabified. Thus, all unstressed syllables are light. We shall have more to say about syllabification in the next section.

4. ENGLISH SYLLABLE STRUCTURE

It is often assumed that the beginning of a syllable is similar to the beginning or a word, and the ending of a syllable is similar to the ending of a word. If so, a syllable in English can contain up to three consonants at the beginning, as in *strike*, and up to four consonants at the end, as in *texts*. If so, the maximal English syllable can be CCCVVCCCC, such as *stryexts*, [straiksts], a word that does not exist but probably does not sound too bad. English also allows a range of other syllables smaller than the maximal one.

There is another interesting fact for all analyses to consider, which is reported by Borowsky (1989). Based on an examination of the English lexicon, she found that there is a limit to rhymes that are not morpheme final. The limit is VX, which is either VV (a long vowel or a diphthong) or VC (a short vowel and a consonant). In other words, the non-final rhyme VX is much smaller than the commonly assumed maximal VVCCCC. Borowsky also found a list of exceptions to the VX limit. Let us now consider the same four approaches to the problem.

4.1. The no-pattern approach

In this approach one does not assume any general pattern that English syllables follow. One might not even assume syllable boundaries explicitly. For example, Jones (1950: 130-131) defines the syllable in terms of prominence peaks while leaving it open where the boundary is between peaks. A more recent version of this approach is that there is no syllabification per se; instead, speakers infer where syllable boundaries should be word medially based on word-edge patterns (Steriade 1999, Blevins 2003), and if word edges offer conflicting patterns, speakers are unsure where syllable boundaries are. A criticism of this approach is that it leaves some important generalizations unaccounted for, such as the limit of VX on medial rhymes.

4.2. The norm-and-exceptions approach

Many phonologists seem to assume this approach. Usually, some kind of maximal syllable size is chosen, and a list of exceptions is noted. The maximal size is usually much smaller than CCCVVCCCC, because no real CCCVVCCCC is used in English, nor are there many initial CCC- or final –CCCC clusters.

Selkirk (1982) proposes that the maximal English syllable is CCVVCC, as in the word *flounce*. With certain conditions on the CC and VV sequences (such as the sonority sequencing requirement of Selkirk 1984), smaller structures are automatically allowed. Blevins (1995) proposes that the maximal English syllable is CCVVC instead, as in *dream*. As in Selkirk (1982), smaller structures are also allowed.

There are four problems with such an approach. First, it is not obvious whether there is a principled way to determine the maximal syllable structure. One might suggest that perhaps we should look at the frequency data in the entire lexicon, but that does not seem to be what Selkirk and Blevins did. Second, both Selkirk (1982) and Blevins (1995) miss the fact that non-final rhymes are VX only (Borowsky 1989). Third, this approach has little to say about possible syllable structures in other languages. For example, can any language allow four consonants before the main vowel? Finally, this approach has little to say about whether there are inviolable constraints that hold for all syllables.

4.3. The loose-requirements approach

The proposal of Fudge (1968) may be an example of this approach. According to him, the English syllable has the structure in (35).

(35) [[[O1 O2] [P3 [C4 C5]]] T6]
O = Onset
P = Peak
C = Coda
T = Terminal
O1, C5, T6 can be [s]+C

Because O1 and T6 can each be [s]+C, and because P can be a diphthong, the structure includes CCCVVCCCC. One challenge for this approach is to exclude syllables that fit the structure but do not occur. Fudge offers a list of 'collocational restrictions'. For example, if O2 is N, then O1 must be [s], and O1O2 cannot be [tl- dl- …]. Still, one must balance the length of the list of restrictions and the number of exceptions.

Fudge's proposal cannot explain the VX limit on medial rhymes, a fact discovered twenty years later by Borowsky (1989). In addition, there is no explanation as to why the maximal structure is as such, or why there are these additional restrictions. Finally, there is no discussion of what constraints there are for all syllables.

4.4. The inviolable-constraints approach

In our analysis, the English syllable structure is a lot simpler than previously thought, and there are constraints that hold for all words. In particular, we propose that the rhyme is VX for a heavy syllable and V for a light syllable, where V can be a syllabic C. In addition, the onset is simply C and is optional. In other words, the maximal syllable is CVX. Several other assumptions are also needed, listed in (36).

(36) Assumptions for the English syllable:
- a. An initial [s] can be added
- b. The onset C can be a complex sound
- c. A morpheme-final C can be added
- d. Suffix-like Cs can be tolerated at the end of a morpheme

The presence of the initial [s] remains unexplained in our proposal, as it does in other proposals. Therefore, we have little to add here. The statement in (36b) follows the proposal of Duanmu (2002) that consonant-approximant clusters, such as [pl, pr, kw, …], are in fact complex sounds [p^{l}, p^{r}, k^{w}, …]. The reason is that only those CR clusters that are allowed by feature theory are found, and those CR clusters that are not allowed by feature theory are absent. The statement in (36c) has been proposed before (e.g. Lowenstamm 1996, Burzio 1994, Goad and Brannen 2003). The idea is that a final C, such as [k] in *desk*, may serve as the onset of an empty vowel. Another way to look at the presence of

the final C is that it can connect with a V-initial suffix, such as *-y* , *-ing*, and *-ize*. Moreover, perhaps owing to the need to keep the shape of a morpheme consistent, the final C can be kept even when the morpheme is not final or nor before a vowel, such as [k] in *desk-less*. The statement in (36d) explains why extra C's at the end of a word are limited to [s, z, t, d, θ], all of which can be suffixes. In (37) we offer the analysis of a few sample words.

(37)	text	[tɛk.st]	[-st] are suffix-like
	pride	[p^{r}ai.d]	[-d] is suffix-like
	grasp	[g^{r}æs.p]	[-p] is final
	spike	[s.pai.k]	[-k] is final
	spikes	[s.pai.ks]	[-k] is final and [-s] is suffix

Let us now consider to what extent the present proposal is true for the entire English lexicon. For this purpose we examined the 52,447 words in the CELEX corpus (Baayan et al 1993). CELEX offers a number of 'fields' for each word, some of which are shown in (38) for the word *abandon*. CELEX uses its own symbols for phonetic transcription, which need not concern us.

(38)	Field	Content
	Word	*abandon*
	Phonetic	@-'b{n-d@n
	Syllable	[V][CVC][CVC]
	Phonetic-syllable	[@][b&n][d@n]

The fields provide an easy way for us to process the lexicon. Some steps are shown in (39), along with their results.

(39)	Step	Result
	Start	52,447
	Remove compounds	42,089
	Extract VXX+	4,193
	Remove affixed words	166

We started with 52,447 words. Then we removed compounds (based on the hyphen), because each word of a compound also appears individually. Next, we extracted words that contain a non-final rhyme that is VXX (i.e. VVC or VCC) or longer, based on the 'syllable' field. This gives us 4,193 words. Then we removed all words that contain affixes in order to isolate true medial VXX rhymes. This gives us 166 words.

It is quite impressive to have just 166 exceptions (0.3%), out of a lexicon of 52,447. It confirms Borowsky's (1989) finding that nonfinal rhymes are limited to VX. Borowsky also found some exceptions and simply listed them. In addition, she proposes that extra C's in word-final positions will join the preceding syllable at a later level. For example, a word like *text* would start out as [tɛk.(st)], where [st] is unsyllabified, but will end up as [tɛkst], where all the sounds are in the same syllable.

We believe that the VX restriction is stronger than Borowsky thought. Therefore, it is necessary to take a close look at the exceptions and see if they are real. In addition, there is no need to assume that the VX restriction is relaxed at a later level. First, consider the list of 166 exceptions. There are three cases where the word is a compound or contains an affix, as exemplified in (40).

(40) Compounds (without hyphen)
fowlpest, WHO, weltanschauung, feldspar, portfolio, portmanteau

Prefix *ex-*
exchange, exchange, excogitate, excoriate, exhume, expatriate, expatriate, expropriate, extravagance

Suffix *-y*
schmaltz-y

There are three other cases where VXX rhymes can be analyzed as VX rhymes, as exemplified in (41).

(41) VXC][CV → VX][CCV
surplus [sr:p][ləs] → [sr:][pləs]
scherzo [skɛrt][so] → [skɛr][tso]

VNC] → ṼC]
symptom [sɪmp][təm] → [s□p][təm]

VVC] → VC] (for tense vowels)
aesthetic [i:s][θɛ][tɪk] → [is][θɛ][tɪk]
almost [ɔ:l][most] → [ɔl][most]

After excluding the cases in (40) and (41), we are left with just three words that have a VXX rhyme, shown in (42).

(42) *ordnance*
arctic
seismic

The words *arctic* and *seismic* probably have a perceived morpheme boundary *arc-tic* and *seis-mic*. We have little to say for *ordnance*. We suspect that it is either perceived as made of two morphemes *ord-nance*, or pronounced as three syllables *or-dn-ance*, but we do not have clear evidence at this point.

It should be pointed out that while the CELEX lexicon is fairly large, it is not complete. As a reviewer notes, two interesting words are missing from the CELEX lexicon: *deixis* and *deictic*; they each contain a VXX rhyme [aik]. In our analysis, the words may contain a perceived morpheme boundary *deix-is* and *deic-tic*, since both *–is* and *-tic* are used as real suffixes.

In summary, other than a few questionable words, there does not seem to be any word that contains a nonfinal syllable that is larger than CVX.

4.5. Morpheme-final consonants

Both Borowsky (1989) and Pierrehumbert (1994) have observed the lack of morpheme-medial consonant clusters. Therefore, they propose that the English syllable normally allows just one coda consonant so that word-final consonants are not part of the normal syllable structure. Still, both Borowsky and Pierrehumbert assume that the extra consonants

ultimately will join the preceding syllable (albeit as 'appendices' for Pierrehumbert).

Unsyllabified consonants in English are often either deleted, such as the initial [p] in *Ptolemy* and [k] in *knight*, or given an extra vowel to form a separate syllable, such as the first C in *Tbilisi* [təb…] and *Nkomo* [əŋk…]. This has led to the belief that every sound, if it is pronounced, must belong to a syllable (Ito 1986). This belief may be the reason why both Borowsky and Pierrehumbert assume that morpheme-final consonants will ultimately join the preceding syllable. However, if the syllable can accommodate more sounds anyway, why can it not do so medially? Ito (1986) suggests that word-final consonants need not be subject to deletion, even if they are not syllabified, but the reason why the word-edge can offer special exemption remains unclear.

In our view, there are two different reasons for keeping a morpheme-final C. First, consonant suffixes, such as [s] and [t], may be kept, even if they cannot be syllabified, such as *risk-s* and *risk-ed*. Their ability to stay, in our view, is justified by the fact that they are suffixes (or suffix-like), instead of being syllabified. Second, a morpheme-final C can form a syllable with a V-initial suffix or stem. For example, the final C in *ex-* [ɪgz] (if *ex-* is a prefix) can serve as the onset of the following vowel in *exact*, *example*, *exasperate*, etc., and the final C in *risk* can serve as the onset of the following vowel in *risky* and *risking*. When a morpheme-final C is not followed by V, such as [k] in *dark-ness*, it can still stay, not because it is now syllabified with the preceding syllable (or incorporated into any other higher prosodic category), but because English tends to avoid changing the shape of the morpheme (the 'anti-allomorph' effect).[3] When an extra C is not suffix-like and has no chance of being syllabified (i.e. it is not at the edge of a morpheme), we predict that it will be deleted, as other analyses do.

[3] A reviewer wonders if an extra C must belong to any higher prosodic category, if it is to be pronounced. Our view is that it does not have to. In other words, we do not assume the view of prosodic licensing. Instead, morphological licensing (the need to pronounce a morpheme) and anti-allomorph can also license a free C.

5. CONCLUSIONS

We have reviewed the variations in English word stress and syllable structure and discussed several approaches to the data. Despite the variations, there seem to be a set of inviolable constraints that all words satisfy, which we summarize in (43).

(43) Constraints on stress and syllabification:
A foot must be disyllabic.
Stressed syllables must be heavy.
Heavy syllables must have stress.
The maximal syllable is CVX.

If our proposal is on the right track, there are some important implications. First, the idea that there are inviolable constraints in phonology raises questions for the most fundamental assumption of Optimality Theory, namely, that all constraints can in principle be violated. Our proposal argues for an approach to phonology that is similar to the standard approach to syntax, which focuses on universal constraints.

Second, our approach suggests a new way of looking at linguistic variation. Instead of assuming that one of the variants is better or more grammatical than others (an assumption that is quite common in phonology), we believe that there can be multiple well-formed structures in the sense that they all satisfy the same linguistic constraints. A language can choose one or more of these structures, and it is necessary to describe which choices a given language makes. It is equally important, if not more so, to consider the constraints themselves so as to understand the range of possible variations in human languages.

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San Duanmu
Department of Linguistics
University of Michigan
Ann Arbor, MI
USA
duanmu@umich.edu

Hyo-Young Kim
Kookmin University
Seoul
Korea
hyk8392@yahoo.co.kr

Nathan Stiennon
University of Michigan
Ann Arbor, MI
USA
nstienno@umich.edu

英語的重音和音節：如何分析語音結構的多樣性

端木三　　Hyo-Young Kim　　Nathan Stiennon
美國密西根大學　韓國 Kookmin 大學　美國密西根大學

語音的多樣性指多種語音形式同時在一個語言裡出現，比如英語有多種音節形式，還有多種詞重音形式。前人的分析一般認為，不同的語音形式來自于不同的語音規則。我們認為所有語音形式都遵循同樣的基本原則。在英語裡，我們認為有四條基本原則：（1） 每音步必須有兩排，（2）有重音的音節必需是長音節，（3）長音節必需有重音，（4）音節最大不超過 CVX。根據本文的分析，我們討論如何重新評估優選論 (Optimality Theory) 的一些假設，並討論如何分析語言裡的其它多樣性問題。