Second Language Research 10, 3 (1994); pp. 215–240

A formal model of learning L2 prosodic phonology*

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In this article I discuss the various components necessary for a formal model of the acquisition of the prosodic phonology of a second language. I outline a model that includes an explicit theory of the representation of metrical knowledge (Dresher and Kaye, 1990; Idsardi, 1992) and the necessary learning theory to account for how those representations can be acquired. The learning theory which mediates the interaction between Universal Grammar (UG) and the linguistic environment is composed of such elements as appropriate cues, indirect negative evidence and a principle of lexical dependency.

Empirical investigations of the acquisition of English metrical parameters by native speakers of Polish, Hungarian and Spanish are reported. Group data as well as case studies are presented. The data suggest that, in the domain of prosodic phonology, both the representations (metrical structure) and processes (learning principles) evidenced in second language learners are the same as those proposed for native speakers. Interlanguage grammars can be seen as a combination of UG principles, correct L2 parameter settings (from resetting) and incorrect L1 parameter settings (from L1 transfer).

I Introduction

Much of the current work on language acquisition in the framework of UG and language learnability is being conducted in the area of syntax. Clearly, however, the issues of learnability theory are just as relevant to the domain of phonology. The notions of crosslinguistic similarities (principles) and differences (parameters) are found in phonology as well. In order to investigate the acquisition of a particular phenomenon, we must have a sophisticated model of what is being acquired. This is as true of phonology as it is of syntax; learners acquire phonological as well as syntactic competence. Just as the syntactic literature can address the acquisition of such things as gov-

*I would like to thank Allan James and two anonymous *Second Language Research* reviewers for their help in making this article clearer. As for the errors, as Prospero said, 'this thing of darkness/I acknowledge mine'.

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erning categories, verb movement and Wh-movement, so can the phonological literature address the acquisition of such things as segment structure, syllable structure, tone and stress.

In this article I would like to present some of the facets of my own research programme which attempt to establish a formal model of learning the phonology of a second language. I will concentrate on aspects of prosodic phonology, particularly stress. The language-learning process is modelled in Figure 1 (adapted from Dresher and Kaye, 1990). UG interacts with the input of the linguistic environment to establish a language-specific grammar formulated within a principles and parameters framework. The interaction between UG and the input necessitates the formalization of a learning theory. More specifically, the boxes shown in Figure 1 consist of the elements shown in Figure 2.

I will argue that if we look at the phonology of interlanguage grammars within the framework of a principles and parameters model, augmented with a learning theory that includes notions such as *appropriate cue* (Dresher and Kaye, 1990), *indirect negative evidence* (Saleemi, 1992) and *lexical dependency* (Newson, 1990), our understanding of second language acquisition is enriched.

II The grammar

The general model of grammar I am assuming is that of Chomsky's Government and Binding Theory (Chomsky, 1981). Specifically, I

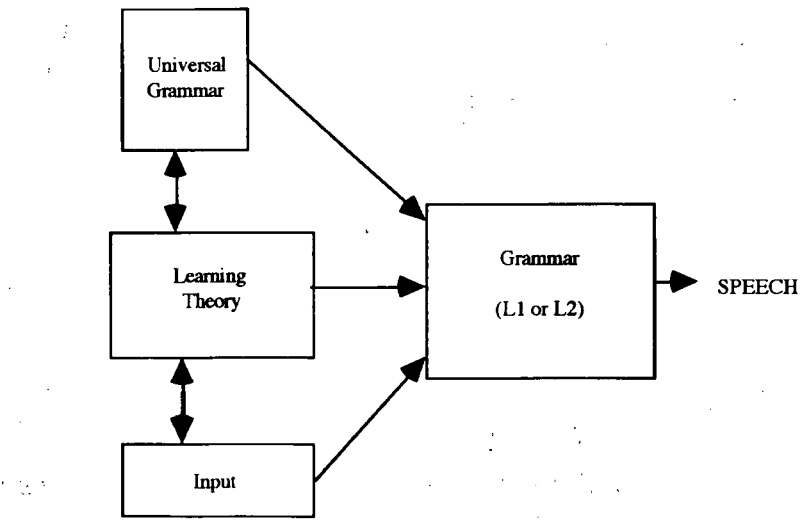


Figure 1 The language-learning process (general)

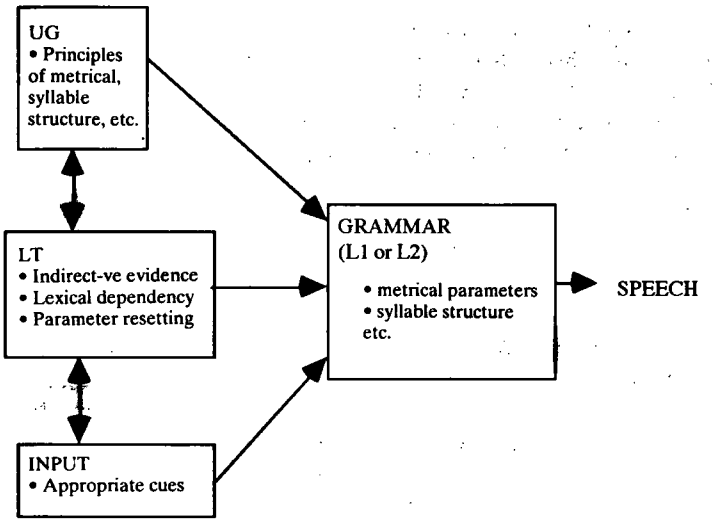


Figure 2 The language-learning process (detailed)

am assuming the kinds of representations common in the field of generative phonology regarding phonological phenomena such as metrical, syllabic and segmental structure. For useful introductions to these phenomena, see Durand (1990), Goldsmith (1990) and Kenstowicz (1994). As in other areas of linguistics, there is no clear agreement as to the best way to represent phonological competence (see Dresher and Kaye, 1990; Bromberger and Halle, 1991; Prince and Smolensky, undated). Of course, the model of the final state that we assume influences our view of the language learner. Is the learner acquiring phonological rules (Bromberger and Halle, 1991), constructing the optimal representation of an input string (Prince and Smolensky, undated) or setting parameters (Dresher and Kaye, 1990)? In this article I will be assuming a parameter-setting model of the grammar. Empirical studies of second language acquisition within other frameworks are anxiously awaited.

1 Stress

Here, though, I wish to concentrate on the acquisition of second language stress and will, therefore, present some of the necessary background to certain phenomena and theoretical machinery related to stress.

Stress has to do with the *prominence* of an element. At the word level, we note that the second syllable of a word like *banána* is prominent compared with the first and third syllables. Stress is not

an inherent quality of a syllable but can only be viewed relatively. Prominence is phonetically realized via a combination of pitch, duration, loudness and vowel quality. I will not be discussing the phonetic implementation of stress (see Flege and Bohn, 1989) but rather the phonological representation of stress. Prominence can also be manifested at the sentence level where we note that the final word in (1) is most prominent:

1) I gave the book to Paul.

I will only be discussing stress at the word level in this article.

The principles of metrical phonology are designed to account for the regularities of stress placement in a language. Let us now consider the mechanisms which determine stress placement.

Roca (1992) provides an overview of some of the issues involved in determining stress placement. In discussing the sources of word prosody, he distinguishes between 'rhythm-based' and 'lexical' stress. Lexical stresses have to be included as part of the lexical entry. I will not be considering this type of stress here. The issue of whether structure is stored lexically or computed is familiar at many levels of linguistic analysis. We generally assume that syntactic structure is computed (i.e., we do not store sentences) but that simple words (e.g., *cat*) are stored. Morphologically complex words (e.g., *bullseye*) have been argued by some to be stored and by others to be computed (Libben, 1993).

Within the domain of phonology, there appear to be languages where stress is stored as part of the lexical entry (e.g., Russian) and languages where stress is computed (e.g., English). My primary concern in this article is with the computation of prosodic structure (what Roca calls rhythm-based stress), though empirical studies involving lexical-stress languages (as either an L1 or and L2) would be informative.

For Roca, prosodic structure results from parsing the input by a universal algorithmic procedure which is regulated by a set of parameters. In Archibald (in press b) I discuss the characteristics of this universal parsing mechanism with respect to first language acquisition. Adults are engaged in a fundamentally different activity in learning the prosodic system of a second language than children are in setting up the prosodic system of the first language (though they do not set up fundamentally different grammars in terms of representation). The child has to set up a system for extracting stress from an input string and representing metrical systems. The adult second language learner has already done this, and has to discover how the L2 system differs from the L1 system (obviously, for mono-

lingual children, there is no possibility of L1 transfer). In child language acquisition, a long period of perception of prosody precedes production. This is usually not the case for adult learners. However, there may also be some similarities between child L1 and adult L2 learners. One is the sensitivity of the learner to the perception of prominent syllables. The ability to perceive stress is crucial to parsing the input in L1 (see Grosjean and Gee, 1987; Gleitman *et al.*, 1988; Echols and Newport, 1992). Adult second language learners also seem to be able to perceive a stressed vowel in an input string. In tests of both production and perception of English stress, nonnative speakers consistently performed significantly more accurately on the perception tests which involved identifying stressed syllables (Archibald, 1993a).

There are, then, three sources of word prosody: parsing the input, lexical marking and a set of parameters. Only the final source is of concern here as we look at language learners acquiring the stress system of a second language.

2 *Crosslinguistic variation in metrical parameters*

In order to illustrate the utility of a UG-based approach to second language phonological acquisition, I would like briefly to discuss the empirical studies I have conducted which have investigated the acquisition of English metrical parameters by speakers of Spanish (Archibald, 1993b), Polish (Archibald, 1992a) and Hungarian (Archibald, 1993a). In these works, I assumed the parameters[1] proposed by Dresher and Kaye (1990) shown in Table 1. I will explain briefly some of the terminology. A metrical representation is thought to consist of some sort of hierarchical structure that indicates constituency and prominence. If we consider the word *Athapaskan*, we might propose the structure in (2)[2]:

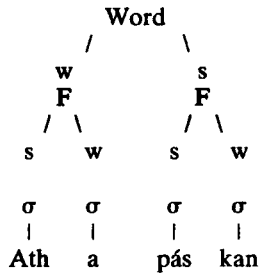
Table 1 Dresher and Kaye's (1990) metrical parameters

P1:	The word-tree is strong on the [left/right].
P2:	Feet are [binary/unbounded].
P3:	Feet are built from the [left/right].
P4:	Feet are strong on the [left/right].
P5:	Feet are quantity-sensitive (QS) [yes/no].
P6:	Feet are QS to the [Rhyme/nucleus].
P8A:	There is an extrametrical syllable [no/yes].
P8:	It is extrametrical on the [left/right].

[1]I have not included those parameters that are not directly relevant to the issues discussed in this article.

[2]The symbol σ stands for *syllable*.

3)



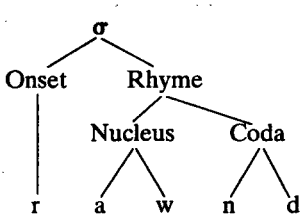
From this example, we can see that syllables (σ) are grouped together into feet (F) that, in this case, are strong (s) on the left and weak (w) on the right. The feet are grouped together into a phonological word which is strong on the right. This structure accounts for the primary penultimate stress and the secondary initial stress on the word.

The term *quantity-sensitivity* has to do with stress assignment being sensitive to aspects of syllable structure. In some of the world's languages, heavy syllables are treated differently from light syllables when it comes to stress assignment. Ignoring some complexities, the difference between heavy and light syllables is shown in (3):

3) Light syllable: CV
Heavy syllable: CVV, CVC

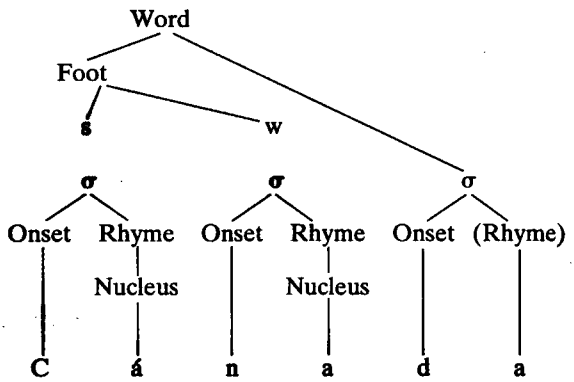
In English, we can see that heavy syllables have a tendency to attract stress. The differing stress patterns in words like *Cánada* and *agénda* can be explained with recourse to the property of quantity-sensitivity. The second syllable of *agenda* is a heavy syllable (CVC) and attracts stress. The word *Canada* has no heavy syllable to attract stress so other principles apply. The other principles have to do with the fact that English builds left-dominant, binary branching feet from the right edge of the word, and that nouns with lax vowels in the final syllable have extrametrical final rhymes. Extrametrical status means that the element is invisible to the principles of stress assignment. In order to understand what an extrametrical rhyme is, we need to illustrate internal syllable structure. This internal structure of the word *round* is shown in (4):

4)



If a rhyme is extrametrical, it does not take part in the metrical construction. The word *Canada*, then, would have the structure shown in (5):

5)



The observed stress pattern is accounted for by having the final rhyme extrametrical, and building a binary foot which is strong on the left from the right edge of the (visible) word.

Such things as extrametrically, quantity-sensitivity and, indeed, all of the parameters presented in Table 1, can vary from language to language. Table 2 shows the settings for the parameters given in Table 1 for Spanish, Polish, Hungarian and English and from it one can discern the differences among them and infer the likely places of transfer.

In Polish, P5 and P8 are major sources of transfer errors, while in Hungarian P1, P3, P6 and P8 are major sources (Archibald, 1993a). Spanish stress assignment is very much like English stress assignment, but when we look at the Spanish subjects learning English we will see evidence for the transfer of certain L1 structures that influence stress assignment.

Table 2 Parameter settings of Spanish, Polish, Hungarian and English

		Spanish	Polish	Hungarian	English
P1	(word tree)	right	right	left	right
P2	(food type)	binary	binary	binary	binary
P3	(built from)	left	left	left	left
P4	(strong on)	right	right	left	right
P5	(QI/QS)	QS	QI	QS	QS
P6	(sensitive to)	rhyme	NA	nucleus	rhyme
P8	(extrametrical)	yes	no	no	yes
P8A	(extrametrical on)	right	NA	NA	right

3 The computation of prosody

Idsardi (1992) has formulated a model for the computation of prosody that generates bracketed grids rather than metrical trees (see also Halle and Idsardi, 1992). The model has interesting implications for the study of language acquisition in that it makes a clear distinction between the universal mechanisms common to all languages and the parameters that vary from language to language.

Idsardi's model requires three universal formal devices:

1) A device for designating stress-bearing elements.
2) A device for delimiting groupings of elements.
3) A device to mark the head of a group.

He proposes a metrical plane that is orthogonal to the phonemic plane. Stress-bearing elements (usually vowels) project grid marks (x) on to this plane. Groups are delimited by parentheses. Heads are projected on to the next line of the metrical grid. For example, the prosodic structure of *autobiographic* would be generated as shown in (6), taken from Halle and Idsardi (1992: 2–3):

6)

Stress-bearing elements project grid marks	x x xx x x autobiographic	Line 0
Parentheses are projected on to Line 0 (Before every other grid mark)	(x x (xx (x x autobiographic	Line 0
Heads are projected on to Line 1 (Leftmost grid mark in a constituent)	x x x (x x (xx (x x autobiographic	Line 1 Line 0
Parentheses are projected on to Line 1 (After the rightmost grid mark)	x x x) (x x (xx (x x autobiographic	Line 1 Line 0
Heads are projected on to Line 2 (Rightmost grid mark in the word)	x x x x) (x x (xx (x x autobiographic	Line 2 Line 1 Line 0

This produces the correct stress pattern on the word (with primary stress on the penultimate).

The parameters that Idsardi proposes to account for crosslinguistic variation are given in Figure 3. Consider, for example, the regu-

Line 0 element projection
Project a line 0 element for each element that can bear stress.

Line 0 parenthesis projection
Project the { left } boundary of certain syllables onto line 0.
right

Edge Marking Parameter
Place a { left } boundary to the { left } of the { left }-most element.
right right right

Headedness Parameter

Project the { left }-most element of each constituent (onto the next higher line on the grid).
right

Iterative Constituent Construction Parameter (ICC)

Insert a parenthesis every two elements starting from the { left }-most element.
right

Figure 3 Idsardi's metrical principles and parameters

lar Polish stress pattern of penultimate stress.[3] Polish has the parameter settings shown in (7), taken from Idsardi (1992: 15):

7) Line 0: Edge: LLL ICC: R Head: L
Line 1: Edge: RRR Head: R

Note the forms of (8):

8)

	Stem	Stem + V	Stem + VCV
Project	x x x x	x x x x x	x x x x x x
	hipopotam	hipopotamu	hipopotamami
Edge, ICC	(x x (x x	(x (x x (x x	(x x (x x (x x
	hipopotam	hipopotamu	hipopotamami
Head	x	x	x
Line 1	x x)	x x x)	x x x)
	(x x (x x	(x (x x (x x	(x x (x x (x x
	hipopotam	hipopotamu	hipopotamami

I have presented both Dresher and Kaye's (1990) model of metrical trees and Idsardi's model of bracketed grids as I think they are both

[3]Some Polish words have antepenultimate stress and others have final stress. These exceptional forms can be dealt with by inserting lexical edges (see Idsardi, 1992).

potentially interesting for the study of L2 stress. The theoretical phonology literature continues to pursue the implications and adequacy of the bracketed grid model. As acquisition researchers, we should be aware of both models.

III The learning theory

In the preceding section, I have outlined two models of how stress is represented in the grammar. In this section, I would like to address the question of how these representations are learnt. In other words, the issue of a learning theory will be addressed.

Prompted perhaps by Lightfoot's (1991) accusation that linguists have displayed an almost pathological lack of attention to the nature of linguistic triggers, the acquisition literature is now beginning to address the problem of integrating a learning theory (usually domain specific) with a principles and parameters model of grammar (Dresher and Kaye, 1990; Newson, 1990; Gibson and Wexler, 1992; Saleemi, 1992; White, 1992). In Archibald (in press c) I present a more detailed discussion of 1) the types of evidence that are available in the data; and 2) the characteristics of the learning theory necessary to set the parameters correctly.

In first language acquisition research, it is widely assumed that only positive evidence (i.e., well formed strings) are available in the primary linguistic data, and that negative evidence (i.e., information as to what are ill formed strings) is not available to the child. Furthermore, when negative evidence is made available to the child, it has no effect on the child's grammar (see Pinker, 1989). Indirect negative evidence is evidence (or the assumption) that nonoccurring strings are ill formed, and is also usually assumed to be unavailable to the child.[4]

While much of this type of theoretical debate has taken place in the field of first language acquisition, it has also attracted a fair amount of attention in the field of second language acquisition. This question has recently been addressed explicitly by, among others, White (1991), Schwartz and Gubala-Ryzak (1992) and White (1992) in a series of related articles on phenomena related to verb raising. These studies have suggested that negative evidence has, at best, a short-term effect on the learner's grammar.

I would like to suggest that second language learners do have access to indirect negative evidence (see Lasnik, 1990; Saleemi,

[4]However, this may well be the mechanism responsible for children retreating from lexical overgeneralizations such as *goed*. As direct negative evidence is assumed not to be available, the child must notice that nobody is saying *goed*. People have also argued for a Uniqueness Principle that would eliminate *goed* after *went* is acquired (Marcus *et al.*, 1992).

1992; Carroll and Swain, 1993) and to combine this with the solution suggested by Dresher and Kaye (1990) that parameter resetting can only be discussed in conjunction with a discussion of the cues which are appropriate to a particular parameter.

Saleemi (1992) proposes a 'strength function' to get around the problem of knowing when indirect evidence of nonoccurrence is interpreted as positive evidence of ungrammaticality. It is modelled visually in Figure 4. Parameters will be reset when a threshold is crossed. The frequency threshold can be crossed by hearing positive examples of a form. Upon hearing a particular structure, a counter will be incremented. After so many positive examples, the threshold is crossed and the parameter is reset. Frequency effects are one of the most robust findings of psycholinguistic research. There is also a time threshold related to indirect negative evidence (Saleemi, 1992), as shown in (9):

9) If after a certain amount of time, the frequency threshold has not been crossed then assume that it will never be; once the time threshold is crossed, a decision is made.

This is a way of combining the final state mutual exclusivity of parameter settings with the transitional state elasticity commonly evidenced in second language acquisition. Clearly, one of the problems for the parameter-setting model is to account for the fact that,

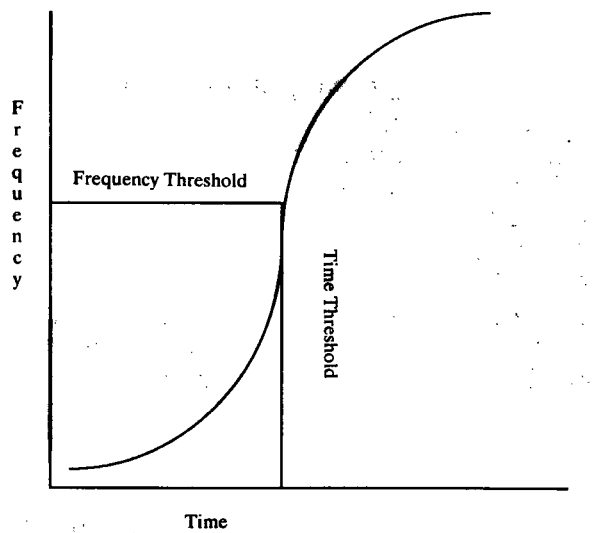


Figure 4 Frequency and time thresholds (adapted from Saleemi, 1992)

unlike native speakers, second language learners exhibit considerable variation in their realization of core grammatical structures. Consider widely discussed syntactic parameters such as verb raising or null subjects. The parameter-setting model seems to imply that a learner would have a particular parameter setting (e.g., verb raising [yes]; null subjects [no]). The problem arises when we note that some of the sentences that the subject produces (or judges, depending on the task) appear to be the product of one setting while other sentences appear to be the product of the other setting. How could the learner have both settings at the same time?

This dual threshold hypothesis has the potential of resolving this paradox by suggesting that, before a threshold is crossed, a learner has not made a decision as to which setting is correct and variation will result (transitional state elasticity). However, once a threshold has been crossed, a decision is made and a setting is chosen (final-state mutual exclusivity). I would still expect that we would see a preference for the L1 parameter setting in this transitional state. This type of variation awaits empirical investigation.

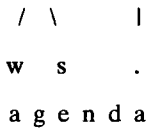
However, there are problems with allowing indirect negative evidence into the learning theory. One is that indirect negative evidence is feasible only in a restricted hypothesis space. There are, of course, many forms that do not occur in any given linguistic environment. In order to have a learner act on noticing a gap in the input, we need to be explicit as to what kinds of gaps the learner can notice. For example, we would not want a learner to have to sift through hypotheses like *I've never noticed a seven-letter word for a colour that had t as the fourth letter. Maybe that's impossible.* If the hypothesis space is not constrained, then the learning problem becomes intractable, and we could not guarantee that learners would converge on a final grammar. The hypothesis space can be constrained via the construct of appropriate cues (Dresher and Kaye, 1990). I will return to this point later.

The second problem has to do with how the learner determines *what* to reset in light of indirect negative evidence. This is the problem of *blame assignment* (Pinker, 1989). Blame assignment has to do with how a learner changes a complex system on the basis of error detection. Imagine a case where the learner notices a mismatch between the input and the output (i.e., an error). How does the learner decide which aspect of the system to change? There may be more than one change that would lead to the desired output. Even if we assume that the learner recognizes that there is a principled difference between the input being heard and the grammar being used to generate the language, the question of what exactly the learner will do to alleviate the problem remains unresolved.

Imagine a Hungarian speaker notices that a native English speaker placed the stress on the second syllable of the word *agenda* while the Hungarian speaker placed the stress on the first syllable (as would be done in Hungarian). What does the Hungarian speaker do? Within a UG framework we would like to think that the learner is going to make some change in the interlanguage grammar by resetting one of the parameters. But which one? Look at the options that are available to the learner (within Dresher and Kaye's, 1990, model).[5]

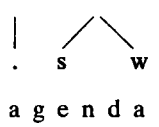
If we changed the setting of the headedness parameter (P4) from [left] to [right] this would produce the correct stress for *agenda*, as a binary branching, right-strong foot would be built from the left. The resulting structure is given in (10):

10)



If the learner changed the value of the direction of construction (P3) from [left] to [right] this would also assign stress correctly in this word, as a binary branching, left-strong foot would be built from the right, as shown in (11):

11)



How does the learner know which change to make to the grammar? Imagine the complexity involved when we deal with a system of 50 or more parameters. Considering the number of parameters proposed to describe a linguistic system, the problem of blame assignment is far from trivial.

Crucially, then, in order to develop a theory of the role of feedback, we need to pursue the notion of *appropriateness* of the cue initially proposed by Dresher and Kaye (1990). The relationship between cue and parameter can be conceived of as in (12):

12) If you find x where you were expecting y, change parameter z.

Some examples as to the possible cues which would be appropriate to particular parameters are given in Table 3 (for a more detailed

[5]Within the bracketed grid model, the same problems arise with the complexities of whether right or left parentheses are projected and whether the head is on the left or right.

Table 3 Examples of appropriate cues

Find (data)	Expecting (grammar)	Change
Primary stress	secondary stress	word-tree dominance
Secondary stress	unstressed	unbounded → bounded
Unstressed	secondary stress	bounded → unbounded
Primary stress Unstressed	unstressed primary stress	dominance (w → s) dominance (s → w)
Stress at edge	no stress at edge	direction
No stress at edge	stress at edge	extrametricality
Irregular rhythm Regular rhythm	regular rhythm irregular rhythm	QI → QS QS → QI

discussion, see Dresher and Kaye, 1990).[6] This assumes that the learner has the ability to perceive such things as primary stress, subsidiary stress, nonstress, edges and rhythm, which I think is borne out by empirical investigation (Archibald, 1993d). Developing the notion that certain input cues are appropriate to particular parameters is desirable for the following reasons:

1) It restricts the hypothesis space of the learner in terms of possible actions.
2) It acknowledgees that perception (as well as production) is governed by the mental representation of a linguistic grammar.
3) It addresses the problem of blame assignment.

A benefit of including indirect negative evidence in our learning theory is that it allows us to incorporate the process of induction into language learning. Much of the UG research into language acquisition has focused on accounting for language learning via deductive mechanisms (largely for formal reasons). If we can constrain induction then there is no reason why it cannot be a part of our learning theory. Obviously it would help us to account for the individual variation we see in both first language acquisition (see Rice and Avery, in press) and second language acquisition.

The notion of *lexical dependency* is useful in describing interlanguage change over time. Newson (1990) proposes that parameter setting may well proceed through the lexicon via a feature-copying

[6]Dresher and Kaye (1990) also discuss the *robustness* of cues, and illustrate the intricacy of the interaction between parameters. The simplified relationships I present here are in the spirit of Dresher and Kaye, but do not do justice to the sophistication of their analysis. The interested reader should consult the original.

mechanism. This is similar to the notion of lexical diffusion in historical linguistics (Wang, 1977). This would be one way to reduce the learnability problem created by Wexler and Manzini's (1987) Lexical Parameterization Hypothesis. Following lexical dependency, the learner would not actually have to set the parameters for *every* lexical item. Rather, once certain entries had been set that information could be generalized to other 'relevant'[7] lexical items via a feature-copying mechanism.

This is an appealing notion in that it recognizes that certain aspects of language acquisition involve induction while other aspects involve deduction. It also seems fitting that the domain of inductive learning in the lexicon, where arbitrary representations must be constructed. It is worth noting that we see evidence of lexical dependency in monolingual and bilingual children as well as in monolingual and bilingual adults (Archibald, in press c). See also Pater (1993) for an interesting discussion of whether second language learners can generalize metrical knowledge to nonce forms.

IV Empirical studies

While it is true that the second language acquisition of nonlinear phonology has not received as much attention as syntactic phenomena, this is not to say that there has been nothing. Hancin-Bhatt and Bhatt (1992) and Brown (1993) look at the influence of L1 segment structure on the interlanguage grammar. Broselow (1988), Kløve (1992), and Broselow and Park (in press) investigate the acquisition of L2 syllabic (and moraic) structure. Young-Scholten (1992) discusses the issue of prosodic domains in L2 phonology. For other work on L2 stress, see James (1988), Mairs (1989), Pater (1993) and Youssef and Mazurkewich (1993).

I would now like to turn to some data from empirical investigations of metrical parameters. Experiments conducted with native speakers of Polish, Hungarian and Spanish have revealed that the interlanguage grammars are governed by the same kinds of representations (in this case metrical representations) and processes (the learning theory) as primary language grammars. I will first discuss some pooled data, and then look at some case studies.

1 Pooled-data studies

The subjects in the largest of these experiments were 23 native speakers of Polish and 20 native speakers of Hungarian who were

[7]See Archibald (in press c) for a more detailed discussion of *relevance*.

learning English as a second language in Canada. The Polish subjects ranged in age from 23 to 64 (mean = 34.3). They had studied English from 1 month to 6 years (mean = 1.9 years). The Hungarian subjects ranged in age from 20 to 46 (mean = 31.7), and had studied English from 2 weeks to 5 years (mean = 1.3 years).

The research design used in these studies was to have the subjects perform both production and perception tasks related to stress assignment. First they had to read a list of words (see Appendix A) and then sentences out loud (see Appendix B). Stress placement was transcribed on the key words by two phoneticians. The subjects then listened to the same words they had produced as they were read out loud on a tape-recorder by a native English speaker. The subjects had to mark which syllable they perceived stress to be on. In both the production and the perception tasks, transfer of the L1 parameter setting into the L2 grammar was evident.

My broad conclusions from these studies suggest that 1) adult interlanguages do not violate metrical universals; 2) subjects are quite good at putting English stress on the right syllable (as discussed in Archibald, 1992b, with reference to the Critical Period Hypothesis) and, hence, are capable of resetting their parameters to the L2 setting; but 3) L1 parameter settings do transfer. Perception was significantly more accurate than production, but there was no significant difference between word and sentence tasks. Archibald (1993a) argued that their interlanguages are a combination of UG principles, correct L2 parameter settings (from resetting) and incorrect L1 parameter settings (from L1 transfer).

a Polish subjects and metrical parameters: Archibald (1992a) showed how Polish subjects learning English treated nouns and verbs differently when assigning stress. In a class of words represented by *horizon* (nouns with penultimate stress due to a heavy syllable in the penultimate), the most common error made by Polish subjects on all tasks was to stress the initial syllable (e.g., *hórizon*). However, in a class of words represented by *astonish* (verbs with penultimate stress due to a lack of a heavy syllable in the last syllable), the most common error pattern was to stress the final syllable (e.g., *astonísh*). The learners had determined that English nouns have final rhymes that are extrametrical (if the final vowel is lax) while English verbs do not. In terms of lexical dependency, this suggests that the learners are able to consult the notion of grammatical category when assigning stress; they were treating nouns and verbs differently.

Similarly, there is evidence that the subjects were treating all verbs as a coherent class. The behaviour of the Polish subjects was

consistent with a process that could be phrased as *if it's a verb stress the final syllable.* For many of the items tested (i.e., those with a heavy final syllable) this would yield the correct result, shown in (13):

13) • maintáin, appéar, eráse, decíde, achíeve
• collápse, eléct, obsérve, adápt, convínce

But for other items (i.e., those with light final syllables) this would lead to the wrong form, shown in (14):

14) • astonísh, edít, cancél, considér, interprét

I take this as further evidence that the non-native speakers are copying the representation of stress assignment to other relevant items in the lexicon. In this case the relevant class is determined by grammatical category.

The error patterns produced by the Polish subjects when dealing with English stress demonstrate that they are able to copy the representation of stress assignment parameters to other members of a relevant class.

b Hungarian subjects and metrical parameters: One of the characteristics of Hungarian stress assignment is that it is quantity-sensitive to the nucleus rather than to the rhyme (as in English). While primary stress will always appear on the initial syllable, a branching nucleus (CVV) will attract a secondary stress while a branching rhyme (CVC) will not. This type of quantity-sensitivity has an effect on the subjects' placement of primary stresses in English. This is an empirical question that can be addressed by looking at word classes with tense vowels compared to the word classes with closed syllables. If the Hungarian subjects were referring to their L1 representations to make generalizations about the L2 stress assignment, we would expect them to be more accurate on words shown in (15a) than on the words in (15b):

15) a. maintáin, appéar, eráse, decíde, achíeve (stress on CVV)
b. collápse, eléct, obsérve, adápt, convínce (stress on CVC)

This was, in fact, the case. The Hungarian subjects had much less difficulty on the final syllable when it had a long vowel in it (as in 15a) than when it was closed by a consonant (as in 15b). Thus, the Hungarian subjects are able to base their generalizations about L2 stress on their L1 lexical representations of phonological structure. Particularly, they appear to refer to their L1 domain of quantity-sensitivity when assigning English primary stress.

The data from the Hungarian subjects, then, suggest that second language learners are able to generalize their L1 parameter settings to relevant lexical items in the L2.

c Spanish subjects and metrical parameters: Archibald (1993b; 1993e) showed that native Spanish speakers learning English in Canada ($n = 7$) transferred their diacritic extrametricality markings. This can be restated in terms of lexical dependency. The L2 learner begins with a representation like that of the L1 (including the extrametricality markings). They then transfer this L1 representation to 'relevant' L2 items. In Spanish, final consonants are extrametrical in nonverbs (Harris, 1983). Consider the word 'cannibal' in Spanish, *caníbal*. The underlying representation must be as shown in (16)[8]

16) kaníbal

where the final consonant is extrametrical. Otherwise we would get the unmarked[9] stress pattern [kanibál]. When asked to produce this word in English, [kaníbal] was elicited in informal research sessions with Spanish subjects learning English. The lexical marking of extrametricality seems to have been transferred into English (see also Mairs, 1989). I take this as evidence that the learners can refer to a structural characteristic like [extrametrical consonant] when determining relevance. Further evidence comes from noncognates where we see evidence that the Spanish speakers are treating the whole coda as extrametrical[10] when they produce forms shown in (17):

17) róbust, óvert[11]

When determining the representation of English words, then, the Spanish speakers are generalizing from their L1 setting of final consonant extrametricality to an assumption that the L2 has final coda extrametricality. This is another example of a representationally based form of inductive generalization.

2 Case studies of individual learners

Archibald (1993c) presented data from two case studies of individual learners: one Polish speaker and one Hungarian speaker. It

[8]The slash overstrike indicates extrametricality.
[9]According to Harris (1983), the unmarked stress pattern for Spanish nonverbs which are consonant-final is final stress. For vowel-final nonverbs, the unmarked stress pattern is penultimate.
[10]Mairs (1989) argues that rhymes that are marked in Spanish may not be marked as extrametrical in the interlanguage grammars.
[11]If only the final C was extrametrical, the resulting final heavy syllable should attract stress (e.g., robúst).

emerged from this analysis that the interlanguage grammars of these two subjects are constrained by the same kinds of principles as grammars of other natural languages. Of all the subjects discussed in Archibald (1993a), I have chosen subjects 19 and 34 for a detailed analysis. The reason for this choice is that they are subjects with not too many errors and a reasonable symmetry of error rate across tasks. The individual profiles then are shown in (18) where the scores indicate the number of errors made on the 35 words:

18)

Subject	Word production	Sentence production	Word perception	Sentence perception	Michigan test /40	Order of presentation	L1	Vocabulary score /35
19	7	7	7	5	22	1	P	33
34	11	12	9	10	22	1	H	27

a The Polish subject: If we look at the performance of this subject by word class, the picture shown in Table 4 emerges. These charts can be summarized as in (19):

19)

Number of words with *no* errors	21	(60%)
Number of words with errors on more than one task and the *same* error pattern	6	(17%)
Number of words with errors on more than one task but with *different* error patterns	0	(0)
Number of words with errors on one task	8	(23%)
Number of classes with one error pattern	7	(100%)

We see that in classes one, two, four, five and six all the errors were on the initial syllable, while in classes three and seven all the errors were on the penultimate syllable.

b The Hungarian subject: In Table 5 the same kind of data is given for the Hungarian subject. These charts can be summarized as in (20):

20)

Number of words with *no* errors	11	(31%)
Number of words with errors on more than one task and the *same* error pattern	15	(43%)
Number of words with errors on more than one task but with *different* error patterns	0	(0)
Number of words with errors on one task	9	(26%)
Number of classes with one error pattern	6	(86%)
Number of classes with more than one error pattern	1	(14%)

We see that in classes one, two, four and five all of the errors were on the initial syllable. In class seven all of the errors were on the final syllable. In class three all of the errors were on the penulti-

Table 4 Case study of the Polish subject

Word	All correct	Incorrect syllable	No. incorrect tasks
Class 1			
aroma		initial (antepen)	3
Manitoba	✓		
arena		initial (antepen)	2
Minnesota		initial (antepen)	1
horizon		initial (antepen)	4
Note: All errors were on the initial syllable.			
Class 2			
agenda		initial (antepen)	1
consensus	✓		
appendix		initial (antepen)	4
veranda	✓		
synopsis		initial (antepen)	3
Note: All errors were on the initial syllable.			
Class 3			
cinema	✓		
javelin		penult	**1**
venison		penult	**2**
America	✓		
cabinet	✓		
Note: All errors were on the penultimate syllable.			
Class 4			
maintain		initial (penult)	1
appear	✓		
erase	✓		
decide	✓		
achieve		initial (penult)	1
Note: All errors are on the initial (penultimate) syllable.			
Class 5			
collapse	✓		
elect	✓		
observe	✓		
adapt	✓		
convince		initial (penult)	1
Note: All errors were on the initial (penultimate) syllable.			
Class 6			
astonish	✓		
edit	✓		
cancel	✓		
consider	✓		
interpret		initial (antepen)	1
Note: All errors were on the initial syllable.			
Class 7			
hurricane	✓		
antelope	✓		
candidate	✓		
matador	✓		
baritone		penult	1
Note: All errors were on the penultimate syllable.			

Table 5 Case study of the Hungarian subject

Word	All correct	Incorrect syllable	No. incorrect tasks
Class 1			
aroma		initial	**1**
Manitoba		initial	**3**
arena		initial	**2**
Minnesota		initial	**2**
horizon		initial	**2**
Note: All errors were on the initial syllable.			
Class 2			
agenda		initial	**2**
consensus		initial	**2**
appendix		initial	**2**
veranda	✓		
synopsis		initial	**2**
Note: All errors were on the initial syllable.			
Class 3			
cinema	✓		
javelin	✓		
America	✓		
cabinet	✓		
venison		penult	1
Note: All errors were an the penultimate syllable.			
Class 4			
maintain		initial	**2**
erase		initial	**1**
appear	✓		
decide	✓		
achieve	✓		
Note: All errors were on the initial syllable.			
Class 5			
collapse		initial	**1**
adapt		initial	**1**
convince		initial	**1**
elect		initial	**1**
observe	√		
Note: All errors were on the initial syllable.			
Class 6			
astonish		initial	**3**
edit		final	**2**
consider		initial	**2**
cancel	✓		
interpret		initial	1
Note: Three words had all the errors on the initial syllable; one word had all the errors on the final syllable.			
Class 7			
hurricane		final	3
baritone		final	3
antelope		final	1
candidate		final	2
matador		final	1
Note: All the errors were on the final syllable.			

mate. In class six there was a mixed pattern (the only one) where one word behaved differently from the rest of the class.

3 Summary

The preceding case studies suggest that learners are treating items within a class in the same fashion. This kind of consistency suggests that the interlanguage grammars of these subjects are constrained by the same kinds of representations and processes as have been motivated in the literature describing final-state (natural-language, primary) grammars.

V Conclusion

In this article I have tried to give an overview of the necessary components of a formal theory of second language phonological acquisition. We need an explicit theory of the relevant grammatical structures in L1 and L2 (in this case metrical or prosodic structure). We also need a learning theory. I have argued here that we need to enrich the notion of the kind of evidence readily available to the learner to include indirect negative evidence and to constrain the learning theory by including a principle of appropriateness. This reduces the hypothesis space of possible actions the learner may take when a mismatch is noted between grammatical expectations and grammatical input. Having done this, we are now free to add to the learning theory a constrained version of induction – induction constrained by the possible representations of UG and a principle of lexical dependency.

A model of this type is about to account for

1) the structural characteristics of an interlanguage grammar (metrical structure);
2) the time it takes to reset a parameter, and stages in interlanguage development when the learners are apparently allowing both settings of a parameter (indirect negative evidence);
3) the manner in which interlanguage grammars change over time (lexical dependency); and
4) the relationship between input cues and parameter resetting (appropriate cues).

The study of second language phonology within a UG framework, supplemented with a serious consideration of the necessary learning theory, promises to contribute to the field of second language acquisition to an increasing extent in the immediate future. The phono-

logical literature is rich in areas crying out for empirical testing on second language learners. We now have a detailed theoretical map that should allow us to explore previously uncharted corners of interlanguage grammars and perhaps discover the representations and processes lurking there.

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Appendix 1: Wordlists (nonrandom)

Class 1: (N: tense penult): aroma Manitoba arena Minnesota horizon
Class 2: (N: closed penult): agenda consensus appendix veranda synopsis
Class 3: (N: antepenult): cinema javelin venison America cabinet
Class 4: (V: tense V): maintain appear erase decide achieve
Class 5: (V: C cluster): collapse elect observe adapt convince

Class 6: (V: lax V): astonish edit cancel consider interpret
Class 7: (N: secondary): hurricane baritone antelope candidate matador

Class 1: Noun – penultimate stress; tense vowel in penult
Class 2: Noun – penultimate stress; consonant cluster
Class 3: Noun – antepenultimate stress; lax vowel in final
Class 4: Verb – final stress; tense vowel in final
Class 5: Verb – final stress; consonant cluster
Class 6: Verb – penultimate stress; lax vowel in final
Class 7: Secondary stress

Appendix 2: Sentences (nonrandom)

1) The thing I love about coffee is the aroma.
2) We can't talk about that, it's not on the agenda.
3) On Saturdays, I like to go to the cinema.
4) Roberta is not very easy to astonish.
5) I find that position much too tiring to maintain.
6) I really didn't think that the building would collapse.
7) Edmonton was devastated by a hurricane.
8) In the summer I like to visit Manitoba.
9) The exam committee couldn't reach a consensus.
10) When I was in school I learned to throw the javelin.
11) This new manuscript is quite difficult to edit.
12) I don't think she's as old as she might appear.
13) The delegates were still not sure who they should elect.
14) In the opera company, Bob's the best baritone.
15) The town asked for a big loan to build an arena.
16) I'm thirty years old and I still have my appendix.
17) It has a strong taste, but I really like venison.
18) I can't come on Friday, I guess I'll have to cancel.
19) You can record over the songs you want to erase.
20) You can't take part in the class, but you're allowed to observe.
21) When we all went to the zoo, we saw an antelope.
22) I have never met anyone from Minnesota.
23) When it gets hot, I like to sit on the veranda.
24) She lives in the United States of America.
25) They made Tony an offer he's going to consider.
26) The committee will support whatever you decide.
27) When I came to Canada, it was hard to adapt.
28) They asked me, but I don't want to be a candidate.
29) You can see the sun a bit above the horizon.
30) He didn't read the book, he just read a synopsis.
31) I was trying to fix the doors on the cabinet.
32) Some of the results were difficult to predict.
33) I was amazed by what you were able to achieve.
34) Don't talk to me, Bob's the person you have to convince.
35) My brother always wanted to be a matador.