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John Archibald

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Learning to Parse Second Language Consonant Clusters

JOHN ARCHIBALD
University of Calgary

1. INTRODUCTION

In this article, I address the following broad issues: 1) how parsing procedures influence the acquisition of new phonological representations, focussing on the interaction of segmental and syllabic levels; and 2) how placing this investigation in a broader context of the cognitive architecture proposed by Carroll (2001) adds to our understanding of cross-linguistic differences in second language learning. I will present an analysis of data from Arabic learners of English to demonstrate the parsing algorithm, and then compare the acquisition of English consonant clusters by speakers of Korean and Finnish to support the model of acquisition I am proposing.

Many researchers over the years have investigated the acquisition of second language syllable structures when they differ from the first language structure (Hancin-Bhatt and Hancin-Bhatt 1997; Broselow, Chen, and Wang 1998; Hancin Bhatt 2000; Steele 2002). While clearly some aspects of the first language (L1) syllable structure transfer to the acquisition of a second language (L2), much of the research (e.g., Eckman 1991) has shown that L2 learners respect markedness relationships in their acquisition as well. In this article, I will show how a particular parsing algorithm can account for aspects of L1 transfer and for markedness facts, and reveal differences in the acquisition of clusters by speakers of two different languages which both lack clusters.

2. SYLLABLE STRUCTURE

The organization of segments into syllables has traditionally been based on the Sonority Sequencing Principle (SSP; Sievers 1881) which describes the general

I would like to acknowledge the contributions of two anonymous reviewers. Their careful reading, while initially doubling the length of the article, allowed me to flesh out and clarify my positions. In addition, the two editors of this volume, Heather and Yvan, deserve my hearty thanks for their suggestions.

tendency for more sonorous segments (such as vowels) to occur closer to a syllabic peak than those less sonorous (such as obstruents). Variations on crosslinguistic sequences are often explained using the Minimum Sonority Distance Principle (Steriade 1982). This principle requires that segments combine into clusters based on how close they are in sonority relative to each other. Languages differ in the amount of distance needed between onset members: some languages allow clusters closer in sonority while others require a greater sonority distance.

Broadly speaking, with respect to sequences of segments, we arrive at the kind of markedness scale given in (1).[1]

(1) Markedness:

Obstruent + V → Obstruent + Sonorant + V → Obstruent + Obstruent + V

Obstruent clusters are the most marked as their presence in a language implies the presence of both sonorant clusters and singleton onsets. Similarly, singleton onsets are the least marked as their presence does not imply the presence of either type of cluster.[2] Wright (1996) proposes an account of these patterns based on the perceptability of the sequences. In less marked strings (e.g., [pa]), it is easier for the listener to recover the phonological features of the first element (i.e., [p]) than in more marked strings such as [sta]. Perceptually, the listener wants as much contrast between two adjacent elements as possible.[3]

2.1. Second language acquisition of syllable structure

Let us turn now to the questions of how people acquire clusters in a second language, and whether markedness facts such as those just outlined influence their acquisition. Previous investigations have focussed on the question of how second language learners repair consonantal sequences that are not allowed in their L1. Weinberger (1988) noted that second language learners tend to repair by epenthesizing a vowel in contrast to children who tend to repair by deleting a consonant. Abrahamsson (1999) studied Spanish learners of English and Swedish and found that they modify sCC onsets more often than they modify sC onsets. He also showed that onset clusters which violated the SSP had more errors in them. Thus, it was the more marked structures which were more difficult for the subjects to produce accurately. Carlisle (1991) also looked at Spanish learners of English and showed that [st] onsets had higher error rates than [sl] and similarly argued that sequences which violate the SSP are harder to produce.

[1] Here, I am mainly focussing on onsets. There are some markedness differences between onsets and codas. For example, in onsets, C + Liquid is preferred to C + Nasal or C + Glide while in codas, Nasal + C is preferred to Liquid + C or Glide + C.

[2] See Vanderweide (2002) for a discussion of these markedness issues.

[3] I will not be addressing the range of proposals which have looked at contrast with respect to manner (Morelli 1999) or sonority.

Concerning the acquisition of codas, Tropf (1987) demonstrated that single obstruent codas are deleted more often than single sonorant codas. This reflects typological markedness facts which reveal that it is less marked to allow sonorants in a coda but more marked to allow obstruents. This type of work is also reflected in Eckman and Iverson (1993).

Finally, other studies have investigated differences between the treatment of onsets and codas. Osburne (1996) looked at Vietnamese learners of English. Vietnamese allows certain coda consonants but it does not permit clusters in any position. Osburne noted that L2 learners tended to be more accurate on initial clusters than on final clusters. Surprisingly, though, she noted, consistent with Abrahamsson (2003), that final clusters which violate the SSP are significantly *less* likely to be reduced than those which follow it. However, many of these clusters involve grammatical morphology. Reduction counter to the predictions of the SSP is thus most likely because inflectional morphology is organized into prosodic structure differently than root-final segmental content.[4]

The algorithm which I will propose will account for markedness effects, such as those summarized above, as well as for transfer.

2.2. L2 prosodic licensing

In order to consider the acquisition of new representations, we require a theoretically informed model of the target grammar, and we turn to that now. Following Government Phonology (e.g., Kaye, Lowenstamm, and Vergnaud 1990), I assume that all prosodic constituents are organized internally via a series of head/non-head relationships. Typically, heads can license a greater range of contrasts (e.g., branching onsets, or greater segmental complexity) than non-heads. I will not be delving deeply into all of the different types of licensing relationships (see Harris 1997 and Piggott 2000 for more information or Steele 2002 and Goad and Rose in press for applications to acquisition). However, I will try to make clear some of the assumptions which I feel are crucial for building the arguments here:

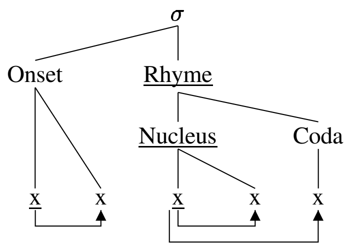
a. All phonological constituents consist minimally of a head.
b. The Rhyme is the head of the syllable, and, therefore, the Onset is a non-head. Onsets are headed.
c. Constituents are maximally binary branching (van der Hulst and Ritter 1999).

Government Phonology does not sanction word-final codas (though see Piggott 1999 for discussion). I will continue to refer to a coda position, although

[4]Note, however, that there is a difference between second language learners, who tend to omit the inflectional material in clusters, and native speakers of English, who tend to retain inflectional material in clusters, even when their dialects allow cluster simplification (Wolfram 1969).

it should be acknowledged that there is a great deal of interesting work demonstrating how these segments pattern as onsets of empty-headed syllables (see the contributions to Kaye 1990). Structurally, then, we arrive at the representation given in (2) (adapted from Steele 2002). At both syllabic and segmental levels, heads are underlined. In addition, throughout the article, heads of syllable constituents are represented by a vertical line and dependents by an oblique line.

(2)



The arrows in (2) indicate intraconstituent licensing, that is how a head can license a dependent within a constituent.[5] We will return to the role of intraconstituent licensing in second language acquisition in section 6.6.

Both Rose (2002) and Steele (2002) demonstrate that complexity emerges in heads before it does in dependents (see also Harris 1997). Rose (2002) illustrates how children learning Québec French as a first language acquire branching onsets in stressed syllables before they acquire branching onsets in unstressed syllables. He also argues that heads have greater featural complexity than non-heads for children.

2.3. Onset/coda asymmetries

Let us now address the question of why onsets and codas may behave differently (as demonstrated by Osburne 1996). I maintain that the primary reason for this asymmetry has to do with acoustic properties of the input. The input to the learners is less robust for codas than for onsets. To demonstrate this, we must discuss the notion of *perceptability*.[6]

Côté (2000) demonstrates that it is more difficult to recover the properties of a consonant in a VC sequence than in a CV sequence. Thus, the cues to recoverability of the consonants are stronger in the onset than they are in the coda. Following from this, the second language learner, attempting to process the incoming acoustic stream, will have more robust cues available to determine the identity of the onset segments than the identity of the coda segments.

[5]Again, I am making some simplifying assumptions in that I am not fully exploring the behaviour of codas (nor the relationship between a branching Nucleus and a following consonant).

[6]The interaction between perceptability and structural properties like constituent binarity is shown in section 3.

Wright (1996) observes that segments should be ordered so that transitions from one into the next provide sufficient information for the lexical item to be recovered under normal listening conditions. Perceptual salience is a function of the quantity and strength of auditory cues in a particular environment. Segments found in contexts that provide a greater number of stronger auditory cues are more perceptible than those found in environments with fewer or with weaker auditory cues. Contextual cues occur in the release phase of a segment's articulation. The burst that follows consonantal constriction has been shown to provide important acoustic cues to the perceptibility of both laryngeal and place features (Padgett 1997; Steriade 1999, among others). Segments under release, therefore, are more perceptually salient and their features more likely to be recovered. In sum, it is not the structural relationships that onsets and codas enter into that is responsible for the coda-onset asymmetries observed in L2 acquisition; the asymmetry is tied to perceptability.

3. Phonological Parsing

We turn now to address the issues involved in the parsing of segments into syllables. In the tradition of work such as Itô (1986) and Broselow (1992), I will pursue a theory of phonological parsing that is analogous to a theory of syntactic parsing. Phillips (1996), like Fodor (1999), makes the assumption that *parsing is grammar*. His model is shown in (3).

(3)

Language	=	**Grammar** Universals Language particular properties Lexicon Structure-building procedures Economy conditions	+	**Resources** Working memory Past experience World knowledge

Phillips (1996) argues that structures are built from left to right, as dictated by the condition *Merge Right*, and that structure building is subject to the economy condition *Branch Right*. These conditions are elaborated in (4a) and (4b), respectively.

(4) Parsing conditions:

a. *Merge Right*: New items must be introduced at the right edge of a structure.
b. *Branch Right*: Select the attachment that uses the shortest path(s) from the last item in the input to the current input item.

A syntactic parse succeeds if the sentence is interpretable. When we apply this machinery to phonology, we must ask the following question: what is the phonological analogue of being interpretable? If parsing is grammar, this should hold for phonology as well. At the word level, a string would be interpretable if *lexical activation* takes place. At the phrase level, the lexical activation would be checked to see if the string is interpretable in the particular syntactic context.

When second language learners whose L1 does not contain consonantal sequences are exposed to such sequences in their L2, the appropriate prosodic structures must be acquired. Specifically, learners must assign segments to particular prosodic positions. In order to investigate how this takes place, we turn to a discussion of phonological parsing. In Archibald (in press), I present the basics of a model of phonological parsing in which phonological structure is assigned on the basis of a left to right parse (unlike approaches to syllabification discussed in Broselow 1992). In this article, I elaborate the model.

Let us start with a simple case where a monolingual English subject attempts to syllabify the word *trip*. The process begins in (5).[7]

(5) Parsing *trip*:

Step 1: Link segmental content to lowest prosodic node.

Step 2: Can the first element be assigned to the Onset? [Y/N]

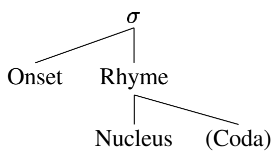
[Yes] $\rightarrow$ Assign it to the Onset.

Onset
|
[t] <rip>

At the end of step 2, only the first consonant has been parsed, by the Onset. [x] stands for a parsed element, and <x> stands for an unparsed element.

At this point, we must address the question of what determines whether or not a segment may be assigned to an Onset. Following Phillips (1996), I assume a top-down, left-to-right parsing procedure. Universal Grammar (or the L1 transferred grammar in the case of second language learners) provides the learner with syllabic structures of the kind given in (6) which is a simplified version of that in (2) which exhibits the full range of complexity permitted by UG.

(6)



Adult speakers will already have acquired the appropriate syllabic structure of their L1. In the case of second language learners, the L1 will transfer whatever status the Coda has, as sanctioned by the L1, hence the parentheses in (6).

The parsing procedure continues by attempting to assign additional segmental material to the onset position.[8]

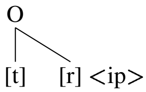
[7] To save space, I will omit step 1 from subsequent examples. In addition, only the syllable constituent that immediately dominates the segment under focus will be provided.

[8] In this discussion, I am making standard assumptions as to what types of segments may appear in syllable peaks and margins (Selkirk 1982).

(7) Parsing *trip* (continued):

Step 3: Can the next element be assigned to the Onset? [Y/N]

[Yes] → Assign it to the Onset.

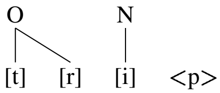


While [r] can be assigned to the Onset alongside [t], this is not the case with [i]. Thus, it is assigned to the Nucleus in step 4.[9]

(8) Parsing *trip* (continued):

Step 4: Can the next element be assigned to the Onset? [Y/N]

[No] → Assign it to the Nucleus.

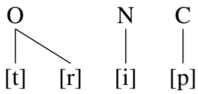


The low sonority of [p] prevents association to the Nucleus. It is thus assigned to the Coda in step 5.

(9) Parsing *trip* (continued):

Step 5: Can the next element be assigned to the Nucleus? [Y/N]

[No] → Assign it to the Coda.



Step 6 indicates that the parse for *trip* has been successful.[10]

(10) Parsing *trip* (end):

Step 6: Lexical activation. The parse succeeds.

As with any left-to-right, deterministic model of assigning structure, problems may potentially arise if decisions have to be undone (Dresher and Kaye 1991). Therefore, let us look at an example, well documented in the literature on syllabification, of a potential problem: the parsing of [s]-initial clusters. It has oft been noted that [s]-initial clusters are problematic in a variety of senses when it comes to phonological generalizations (e.g., Goad and Rose in press). There are some [s]-initial clusters that violate the SSP (e.g., [st], [sp], [sk]). In addition, [s]-initial clusters violate the constraint against homorganic place in onsets (which blocks [tl], [dl], [pm], [bm], [pw], [bw], [fw], and [vw]). Thus, we find [sl], [sn], and [st] as well formed in many languages. Kaye (1992) demonstrates that [s]-initial

[9] An anonymous reviewer has wondered why assignment to the nucleus is a "last resort". Given the machinery of a top-down, left-to-right algorithm, and the fact that not all words are vowel-initial, I maintain that this strategy is psychologically plausible.

[10] In subsequent examples, to save space, I will omit step 6.

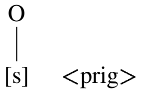
clusters behave idiosyncratically in languages around the world, and provides a number of examples to argue that these clusters are always heterosyllabic.[11] My assumption is that [s] can belong to the Onset. However, as we shall see, there are certain conditions under which the parser will end up assigning [s] to the Coda of an empty-headed syllable.

Let us examine the parsing of the string *sprig*, given in (11).

(11) Parsing *sprig*:

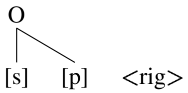
Step 2: Can the first element be assigned to the Onset? [Y/N]

[Yes] → Assign it to the Onset.



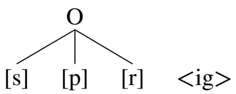
Step 3: Can the next element be assigned to the Onset? [Y/N]

[Yes] → Assign it to the Onset.



Step 4: Can the next element be assigned to the Onset? [Y/N]

[Yes] → Assign it to the Onset.



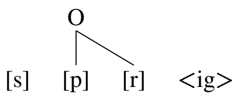
The resulting structure violates binary branching, following Government Phonology (see section 2.2), so the left-most element must be delinked.[12]

[11] His arguments range from choice of the definite article in Italian such as *il costo/lo scuro* — where words beginning with [s]-initial clusters behave like vowel-initial words — to [j]-glides in English *st[j]upid/*fl[j]uid* — where we can see that the insertion of a [j]-glide to create a three-consonantal string is blocked in *fluid* but not in *stupid*.

[12] This build-then-repair procedure is not optimal, and we could consider an alternative, incorporating a parser that has limited look ahead to a two-segment window. The algorithm would be:

a. Look one element to the right of the element being parsed. Is the next element consistent with the SSP? If [Yes], parse the first element. If [No], leave the first element unparsed.
b. Proceed to the next element.

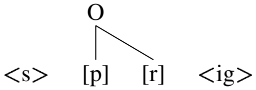
This would also result in the following at this stage of the parse:



In section 5, I will present an argument against this procedure.

(12) Parsing *sprig* (continued):

Step 5: Delink left-most element.



The result of step 5 raises the question of why, in an [spr] sequence, the leftmost consonant is delinked. Why not delink [p] or [r]? In this case, there is a straightforward perceptability argument that can be built, as illustrated in the tableau in (14). We can assume a set of constraints on outputs that include those in (13).

(13) Constraints:

a. BINARITY: Constituents are binary branching.
b. SSP: Sequences of segments respect the SSP.
c. PERCEPTABILITY: Sequences which allow for the recovery of the features of segments are preferred (following Wright 1996).

If the constraints in (13) are all high-ranking, for the input representation /spr/, we obtain the results in (14).

(14) Optimal Onset shape:

/spr/	BINARITY	SSP	PERCEPTABILITY
a. spr	*!		
b. sp		*!	
c. sr			*!
☞ d. pr			

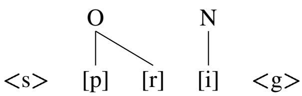
Candidate (a), [spr], is ruled out because it is not binary. The output in (b), [sp], violates the SSP, and the output in (c), [sr], does not ensure recoverability of the underlying features, as the release burst of the fricative provides less information than a preceding stop, as in candidate (d). Thus, the optimal output is [pr] with the <s> delinked from the Onset constituent.

The parser now considers the vowel [i]. Step 6 shows that this vowel cannot be assigned to the Onset. It is instead assigned to the Nucleus. Step 7 assigns [g] to the Coda.

(15) Parsing *sprig* (continued):

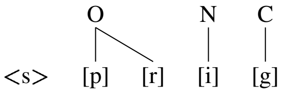
Step 6: Can the next element be assigned to the Onset? [Y/N]

[No] → Assign it to the Nucleus.



Step 7: Can the next element be assigned to the Nucleus? [Y/N]

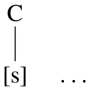
[No] → Assign it to the Coda.



Returning to the initial unparsed [s], I follow Kaye (1992) in maintaining that [s] in some clusters is a coda consonant to an empty-headed syllable. As we have seen, though, for the parser I am proposing, this is not the first assignment of the algorithm; rather, it is the state that the parser ends in. This is illustrated in step 8.

(16) Parsing *sprig* (end):

Step 8:



Before observing how the parser applies in second language acquisition, I would like to step back and consider more general aspects of cognitive architecture that will illuminate the broad questions we have asked about L2 learners' processing of input.

4. Autonomous Induction Theory

Carroll (2001) proposes a theory of induction within a modular architecture. Under this model, there is some inductive *reasoning* that takes place in the part of the mind that computes conceptual structure. Inductive reasoning is associated with problem solving at the level of conceptual structure. This type of inferencing will be drawn upon when the L2 learner is dealing with feedback, instruction, or negative evidence. We shall invoke this level of processing later when it comes to accounting for Korean learners acquiring English syllable structure. In addition, there is inductive *learning* which affects the representations within the language faculty. We will return to this when we look at the Finnish learners of English.

Carroll (2002:228) proposes the Uniform Parsers Hypothesis given in (17) to account for the behaviour of L2 learners.

(17) The Uniform Parsers Hypothesis:

Linguistic stimuli are processed by the same parsers regardless of their linguistic "origin". Initially, L1 parsing procedures apply automatically to L2 stimuli.

Inductive learning amounts to the acquisition of L2 parsing procedures. We turn now to the crucial question of what happens when parsing fails. When a parse fails, there is a learning problem which acquisition mechanisms attempt to solve. Inductive learning (i-learning) begins when the parse fails. The input to the acquisition mechanisms includes the entities that the extant parsing mechanisms cannot parse. In other words, there is a metalinguistic awareness of these unparsed elements. To come back to our discussion of the processing of consonant sequences in a second language, learners will have a metalinguistic awareness when they are not parsing consonantal sequences appropriately. Their underlying representations and parsing procedures will change over time as a function of proficiency. The creation of new parsing procedures, though, does not mean that the new procedures automatically replace the L1 parsing mechanisms. Different procedures will compete for activation, and the one with the lowest threshold of activation will prevail. I-learning is defined by Carroll (2002:229) as:

> a process that leads to the revision of perceptual and parsing procedures so that they can analyse novel stimuli made available to the organism through the perceptual systems. I-learning is not inductive reasoning. It is also different from mechanistic responses to environmental change in that the results of I-learning depend upon the contents of symbolic representations in working memory and long-term memory.

I-learning can alter parsing procedures so that those procedures can construct representations.

Let us consider how these concepts can be applied to second language phonology. The issue of phonological learnability is, of course, just as complex as syntactic learnability (Dresher and van der Hulst 1995; Dresher 1999; Fodor 1999). However, an additional complication arises in the case of phonology. As Strange (1995:5) and others have pointed out, "the problem of perceptual constancy arises because there is no one-to-one correspondence between phonemes perceived and the acoustic patterns generated by speech gestures that constitute the stimuli for speech perception." Different acoustic patterns may be categorized as the same phoneme, and similar or identical acoustic signals can sometime be categorized as different phonemes.

The question of how learners acquire structures from the units they have extracted from the acoustic stream is a focal point of the rationalist versus empiricist accounts of language acquisition. Carroll (2001) draws on a modified version of Holland et al.'s (1986) condition-action rules shown in (18).

(18) If condition C holds, then perform operation O.

The role of condition-action rules in the parsing of clusters in the L2 will be seen in section 5.

5. L2 Parsing and Autonomous Induction

I now turn to a discussion of how the parsing procedures from section 3 can be combined with Carroll's autonomous induction model. The first data come from Broselow (1992); the learner, whose L1 (Egyptian Arabic) does not allow onset consonant clusters, is acquiring an L2 (English) that does. In this section, we will consider the same words as we did in section 3. We begin with *trip* in (19).[13]

(19) Parsing *trip* in a second language (L1 = Egyptian Arabic):

Step 2: Can the first element be assigned to the Onset? [Y/N]

[Yes] $\rightarrow$ Assign it to the Onset.

```
O
|
[t]   <rip>
```

Step 3: Can the next element be assigned to the Onset? [Y/N]

[No; L1 setting] $\rightarrow$ Assign it to the Nucleus. <FAIL>

Is the string consistent with the Sonority Sequencing Principle? [Y/N]

[Yes] $\rightarrow$ Leave the current element unparsed.

```
O
|
[t]   <r> <ip>
```

Proceed to the next element.

We must address what motivates the action of leaving the current element unparsed. Why, for example, could we not assign this element to a Coda if it cannot go into an Onset? This action follows from the top-down architecture of the parser. A consonantal segment has been assigned to the Onset but nothing has been assigned to the Nucleus. Assigning [r] to the Coda at this time would violate the Branch Right condition in (4b), so any decision about [r] must be postponed. The parser will not build an illicit structure.

Before pursuing this further, let us elaborate on the role of the SSP. Thus far, we have seen that there are two different condition/action propositions, as shown in (20).

(20) a. IF consistent with SSP, THEN leave element unparsed.

b. IF inconsistent with SSP, THEN delink an element.

Importantly, an inconsistency with the SSP leads to repair that is governed, as we saw in (14), by principles of well-formed output and perceptability. In what follows, I will demonstrate that this type of algorithm is preferable to one which makes use of limited look-ahead in parsing. Let us consider an alternative parser that allows a look-ahead to the next segment in an attempt to avoid the delinking operation required by our parser. Table 1 compares the two procedures in dealing with tripartite [s]-clusters as in *street*. It shows that a contradiction ultimately arises under the look-ahead algorithm. As a result of the comparison in Table 1, I adopt the delinking version of the algorithm.

---

[13]Concerning the question in step 3 of whether the string is consistent with the SSP, I assume that L2 learners have Full Access to this kind of knowledge. In Carroll's terms, this would be a mechanism that is not under conscious control.

Table 1: Two algorithms for the tripartite [s]-cluster in *street*

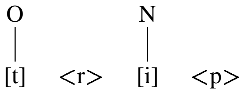
Repair strategy (delinking) algorithm	Limited look-ahead algorithm
O | [s] <trit> [s] is assigned to an Onset node.	[s | t] Working from a two-segment window, assess the first segment. In this case, the sequence is inconsistent with the SSP, so the first element would remain unparsed (as look-ahead is designed to avoid building illicit structure). An inconsistent string results in an unparsed element. <s> <trit>
O | <s> [t] <rit> Delink <s> due to the inconsistency with the SSP and assign [t] to the onset. Illicit structures are repaired.	<s> [t | r] Assess the first segment of the two-segment window. In this case, the sequence is consistent with the SSP. therefore the [t] will be parsed into the onset. A consistent string results in a parsed element. O | <s> [t] <rit>
O | <s> [t] <r> <it> <r> remains unparsed because it is consistent with the SSP.	O | <s> [t] [r | i] Assess the first segment of the two-segment window. In this case, the sequence is consistent with the SSP but the <r> remains unparsed. Hence, a contradiction arises within this algorithm: whether or not a segment is parsed or not cannot be predicted by the SSP.

Thus far, in words like *street* and *trip*, only [t] has been successfully parsed. Let us return to the steps involved in parsing *trip* in the L2. Steps 4 and 5 concern the assignment of [i] and [p] to the Nucleus and Coda, respectively.

(21) Parsing *trip* in a second language (continued):

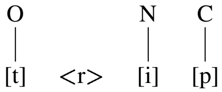
Step 4: Can the next element be assigned to the Nucleus? [Y/N]

[Yes] → Assign it to the Nucleus.



Step 5: Can the next element be assigned to the Nucleus? [Y/N]

[No] → Assign it to the Coda.

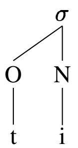


The structure in step 5 is not allowed by the grammar; the parse has failed because not all segmental material has been assigned to a higher level of prosodic structure (a licensing failure). Illicit structures must be somehow repaired. The repair strategy is as follows: the learner must fix the parse by projecting new prosodic structure (in this case a Nucleus). This is consistent with Weinberger's (1988) observation concerning L2 learners' preference for epenthesis as a repair strategy. In Carroll's terms, the condition-action rule would be as in (22).

(22) IF there is an unsyllabified element, THEN project a Nucleus to the left of the unparsed element.

This is consistent with the Branch Right property of Phillips' parser, (4b). We must insert a new element (the epenthetic [i]) and it will be attached at the right edge of the existing Onset structure, as shown in (23).

(23)



At this stage of proficiency, the learner is parsing the input (which includes a consonant cluster) and ends up inserting the epenthetic vowel. The result is that the learner's underlying representations are non-native-like in that they include the epenthetic vowel. Later on in development, the learner will be able to take advantage of a variety of cues (orthography, inductive reasoning, metalinguistic knowledge, etc.) and the nature of the underlying representation will change from the non-native-like /tirip/ to the native /trip/. This is consistent with Abrahamsson (2003) who proposes that learners proceed through the following stages when acquiring consonant clusters in an L2: (1) deletion of the illicit consonant, (2) epenthesis of a vowel to repair syllable structure, (3) acquisition of the consonant in the appropriate position.

The view espoused here proposes that, at early stages in acquisition, learners have incorrect underlying representations. Evidence that early representations are indeed inaccurate has been provided by Dehaene-Lambertz, Dupoux, and Gout (2000) who demonstrate via behavioural tasks and ERP analysis that Japanese speakers hear an epenthetic vowel between the two consonants in a string like *ebzo* (which is illicit in Japanese). The epenthetic vowel is not inserted late in a production routine; speakers actually hear it even when it is not present in the input. That is, even when there is no lexical entry available (i.e., for nonce forms) speakers perceive a vowel.

Following from this, when setting up an underlying representation for a lexical item, the learner's initial assumption will be that the underlying representation is the same as the surface representation (consistent with Lexicon Optimization). For a word containing a target cluster, the learner will thereby posit an epenthetic vowel as part of the stored form. At a later stage of proficiency, the learner will realize (through i-learning) that this vowel is not, in fact, in the underlying string, and the parse will fail. There are a few possible sources for this type of knowledge. One would be the existence of minimal pairs or near-minimal pairs related to the target CVC sequence. Examples of such pairs are given in (24).

(24)	train/terrain	trade/tirade
	claps/collapse	plate/palate
	clean/Colleen	plot/pilot
	dress/duress	plow/pillow
	drive/derive	sting/sitting

If the learner becomes aware of such pairs, then there will be an impetus to realize that the pronunciation of *drive* with an epenthetic vowel between [d] and [r] cannot be correct. It is also plausible to assume that literacy facts and orthography in languages like English play a role in making learners aware that their L1 parsing strategies are failing in the parsing of onset clusters.

Let us look at the case of the Coda-Onset cluster in forms like *ebzo* in greater detail. Knowledge of phonotactics resides in understanding which classes of segments are licensed in which positions. In Japanese, non-geminate codas must be nasal. Therefore, when a Japanese speaker hears a sequence like *ebzo*, as soon as the [b] is reached, he/she will assume that this segment is in an Onset and will expect a following vowel. The learning that has to take place is to realize that obstruents may be licensed in Coda in languages like English. This will cause the learner to consult UG (or a super-grammar) to see what changes can be made (see Fodor 1999 for more discussion of this model). If the current grammar cannot assign a structure to anything except coda nasals, then UG will provide another option (e.g., that the coda can be an obstruent). If the parse then succeeds, this new representation will be incorporated into the learner's current grammar.

We are now ready to return to our discussion of the parsing of strings by L2 learners by considering the parsing of an [s]-cluster sequence such as *street*. The two steps in (25) are repeated from Table 1.[14]

[14]Note that the delinking process in step 3 is necessary because a singleton [s] would be parsed legitimately into an Onset.

(25) Parsing *street* in L2:

Step 2: Can the first element be assigned to the Onset? [Y/N]

[Yes] → Assign it to the Onset.

O
|
[s] <trit>

Step 3: Can the next element be assigned to the Onset? [Y/N]

[No; L1 setting] → Assign it to the Nucleus. <FAIL>

Is the string consistent with SSP? [Y/N]

[No] → Delink first element and assign the current element to the Onset.

O
|
<s> [t] <rit>

Consider this process in light of the condition/action propositions from (20). *If* consistent with SSP, *then* leave element unparsed. *If* inconsistent with SSP, *then* delink an element. As indicated earlier, the issue of which segment to delink is handled by the constraints shown in (26).

(26)

/st/	BINARITY	SSP	PERCEPTABILITY
a. st		*!	
b. s			*!
☞ c. t			

The first candidate, (26a), fails on the SSP. Concerning the competition between (26b) and (26c), Wright (1996) points out that, phonetically, the transition from a stop to a following vowel is preferred over the transition from a fricative to a following vowel. Perceptability thus favours candidate (c).

(27) Parsing *street* in L2 (continued):

Step 4: Can the next element be assigned to the Onset? [Y/N]

[No; L1 setting] → Assign it to the Nucleus <FAIL>

Is the string consistent with SSP? [Y/N]

[Yes] → Leave the current element unparsed.

O
|
<s> [t] <r> <it>

Step 5: Can the next element be assigned to the Nucleus? [Y/N]

[Yes] → Assign it to the Nucleus.

O N
| |
<s> [t] <r> [i] <t>

Step 6: Can the next element be assigned to the Nucleus? [Y/N]

No → Assign it to the Coda.

```
       O            N    C
       |            |    |
<s>   [t]   <r>    [i]  [t]
```

Step 7: There are still unparsed elements. The repair strategy is as follows: the learner will fix the parse by projecting new prosodic structure, in this case, a syllabic Nucleus. The Nucleus will be projected to the left of the any unparsed element.

```
N             O    N          N    C
|             |    |          |    |
[i]   <s>    [t]  [i]   <r>  [i]  [t]
```

Note that there are still some remaining unparsed elements. As a result, a second pass occurs.

Step 8: Can the <s> be assigned to the Onset?

[No] → Can it be assigned to the Nucleus?

[No] → Assign it to the Coda.

```
N    C    O    N          N    C
|    |    |    |          |    |
[i]  [s]  [t]  [i]  <r>  [i]  [t]
```

Step 9: Can the <r> be assigned to the Onset?

[Yes]

```
N    C    O    N    O    N    C
|    |    |    |    |    |    |
[i]  [s]  [t]  [i]  [r]  [i]  [t]
```

Simple words with two or three consonants in a row would provide the second language learner with much of the information necessary to achieve the target grammar. Take medial clusters like those in *apply*, *intrude*, *abstract*, or *astronaut*. These examples would tell the learner that obstruents can be licensed in codas in English *and* that onsets can branch. Either change in the grammar would be a move closer to the target. Whether the L1 is Japanese or Arabic, there are data which would tell the learners that their current hypotheses are wrong.

5.1. Coda parsing

Let us turn now to a discussion of the parsing of elements at the right edge of a syllable, as shown in (28). We must determine that the parser can correctly assign coda status to [l] and [n] in *children* for the Egyptian Arabic learner of English.

(28) Parsing *children* in L2 (L1 = Egyptian Arabic):

Step 2: Can the first element be assigned to the Onset? [Y/N]

[Yes] → Assign it to the Onset.

```
 O
 |
[tʃ]   <ildrən>
```

Step 3: Can the next element be assigned to the Onset? [Y/N]

[No] → Assign it to the Nucleus.

```
 O     N
 |     |
[tʃ]  [i]   <ldrən>
```

Step 4: Can the next element be assigned to the Nucleus? [Y/N]

[No] → Assign it to the Coda.

```
 O     N     C
 |     |     |
[tʃ]  [i]   [l]   <drən>
```

Step 5: Can the next element be assigned to the Coda? [Y/N]

[No; L1 setting] → Assign it to the Onset.

```
 O     N     C     O
 |     |     |     |
[tʃ]  [i]   [l]   [d]   <rən>
```

Step 5 reveals a property of the parser that has been implicit until now. When a [No] answer is returned, the parser moves to the next prosodic node: Onset → Nucleus → Coda → Onset, etc. When a <FAIL> answer is returned, either the delinking or non-parsing options are pursued.

(29) Parsing *children* in L2 (continued):

Step 6: Can the next element be assigned to the Onset? [Y/N]

[No; L1 setting] → Assign it to the Nucleus <FAIL>

Is it consistent with the SSP? [Y/N]

[Yes] → Leave the current element unparsed.

```
 O     N     C     O
 |     |     |     |
[tʃ]  [i]   [l]   [d]   <r>   <ən>
```

Step 7: Can the next element be assigned into the Nucleus? [Y/N]

[Yes] → Assign it to the Nucleus.

```
 O     N     C     O            N
 |     |     |     |            |
[tʃ]  [i]   [l]   [d]   <r>    [ə]   <n>
```

Step 8: Can the next element be assigned into the Coda? [Y/N]

[Yes] → Assign it to the Coda.

```
 O     N     C     O            N     C
 |     |     |     |            |     |
[tʃ]  [i]   [l]   [d]   <r>    [ə]   [n]
```

Step 9: There are still unparsed elements. The learner will fix the parse by projecting new prosodic structure to the left of any unparsed elements.

O	N	C	O	N		N	C
|	|	|	|	|		|	|
[tʃ]	[i]	[l]	[d]	[i]	<r>	[ə]	[n]

Step 10: Can the unparsed element be assigned to the Onset? [Y/N]

[Yes] → Assign it to the Onset.

O	N	C	O	N	O	N	C
|	|	|	|	|	|	|	|
[tʃ]	[i]	[l]	[d]	[i]	[r]	[ə]	[n]

This section has demonstrated that our existing parsing algorithm can effectively deal with the syllabification of coda consonants.

6. A Comparison of Korean and Finnish Learners of English

In the final section of this article, I present data from two different languages (Finnish and Korean) which share the property of not allowing consonant clusters within a syllable. Using the machinery of the parser and the architecture of the Autonomous Induction model, I will address the different behaviours that learners from these two languages display in acquiring English consonantal sequences, and provide an analysis for these differences.

6.1. Korean phonology

The first group to consider are speakers of Korean. The Korean segmental inventory is given in (30) (from Lee 1998).[15]

(30) Korean segmental inventory:

p	t	c	k	
p’	t’	c’	k’	
p^h	t^h	c^h	k^h	
	s			h
	s’			
m	n		ŋ	
	r	j	w	

Turning to constraints on syllable structure, Korean does allow final codas [p, t, k, m, n, ŋ, l] but the distinctions among stops observed in onsets are neutralized to voiceless unaspirated. Lee (1998) argues that glides in prevocalic position are part of light diphthongs, and that Korean does not allow either branching onsets or branching nuclei.

[15] I have omitted the [l] allophone of the liquid /r/.

6.2. Finnish phonology

The Finnish segmental inventory is given in (31) (from Hakulinen 1961).

(31) Finnish segmental inventory:

p		t		k	
		d			
	v	s			h
		l, r	j		
m		n		ŋ	

Concerning Finnish syllable structure, Finnish does not allow branching onsets. It does allow coda consonants but has no final clusters (Ringen and Heinaamaakki 1999). Only dentals [t, s, n, r, l] are permitted word finally. In word-internal codas, [t, s, n, r, l, s, t, h] and the first part of geminates are found. These observations indicate that codas can only license unmarked ([coronal] or placeless) elements in Finnish.

In sum, then, both Finnish and Korean allow some coda consonants but neither language allows initial or final consonant clusters. As a result of these similarities across the two languages, if we simply looked at surface strings, we might be tempted to predict that Finnish and Korean speakers would acquire English consonant clusters in the same way. I hope to demonstrate that this is not the case.

6.3. L2 data

Broselow and Finer (1991) have presented data on the production of onset clusters from Korean learners of English. These data show that Korean subjects have greater difficulty producing some of the English clusters than others. The Korean error rates for onset clusters are given in (32).

(32) Korean error rates: Onset clusters[16]

pr	br	fr
2/383	16/384	21/382
(3%)	(26%)	(34%)

Broselow and Finer argue that a phonetically based Minimal Sonority Distance parameter can account for the differences in accuracy. In this article, I will not be looking at the differential across cluster types but, rather, will investigate the difficulty that the Korean subjects have compared to Finnish subjects. I believe that the two groups of subjects are comparable in that all subjects were residing in North America, had received English instruction in their home countries, and ranged in proficiency from high intermediate to advanced. Eckman and Iverson (1994) demonstrate that Korean subjects also have difficulty with coda clusters, producing 187 errors on 1096 opportunities, an error rate of 17.1%.

[16]Broselow and Finer did not elicit any C + lateral clusters.

Finnish subjects, on the other hand, do not seem to have difficulty, either with onset clusters or with coda clusters.[17] I have found the accuracy rates in spontaneous production tasks shown in (33).[18]

(33) Finnish error rates:

Subject number	Onset cluster accuracy		Coda cluster accuracy	
1	42/42	(100%)	113/113	(100%)
2	24/24	(100%)	47/49	(95.9%)
3	26/29	(89.7%)	32/37	(86.5%)
4	72/72	(100%)	94/94	(100%)
Total	164/167	(98.2%)	286/293	(97.6%)

I will argue that the behaviour of the second language learners can be accounted for by appealing to certain segmental properties of their first languages, ultimately having to do with the liquid inventory. Archibald (1998) argued that the presence of obstruent + liquid onset clusters in a language implies the presence of an /l/-/r/ contrast in the segmental inventory, but not vice versa. Typological support for this claim is provided in the next section.

6.4. Typological support

Maddieson (1984) lists 15 languages (Azerbaijani, Korean, Japanese, Dan, Dagbani, Senadi, Akan, Lelemi, Beembe, Teke, Vietnamese, Tagalog, Hawaiian, Mandarin, and Zoque) with a single liquid, and none of them shows robust evidence of having consonant clusters at all, and no evidence of allowing obstruent plus liquid clusters. There is also support for this claim in such typologically diverse languages as Sanuma (Borgman 1990), Kikuyu (Armstrong 1940), Ganda (Cole 1967), Nkore-Kiga (Taylor 1985), and Cayuga (Dyck, personal communication, citing Chafe 1977).

Historically, there also seems to be a connection between these two structures in that when older languages had more than one liquid (e.g., Proto-Austronesian), they allowed clusters, but their descendants (Japanese, Chinese, Korean, Vietnamese) that have one liquid have no clusters (Baldi 1991). Similarly, Proto-Aztecan had no liquids and no clusters. One descendant (Huichol) has one liquid and it has no clusters, while another descendant (Nahuatl) has two liquids and it allows clusters (Suárez 1983).

There is also a connection between children acquiring the liquid contrast in English and their acquisition of clusters (see Gierut and O'Connor 2002).

[17] As these data were collected in a naturalistic setting, I have not broken them down by cluster type. The subjects were accurate on a wide range of clusters, including two and three element clusters.

[18] For subject 3, the errors on onset clusters were /θr/ → [r], /gr/ → [kr], and /kw/ → [w].The errors on coda clusters were /vd/ → [vəd], /rz/ → [rs], /nd/ → [nt], /nθs/ → [ns] in the word *months* (which is native-like); /st/ → [s] in the phrase *just now* (which is native-like).

6.5. Finnish borrowings

Finnish is an interesting case in this respect. The inventory in (31) reveals that it has two liquids, but it allows no consonant clusters. Older loan words respect the absence of clusters. Hakulinen (1961) reports that borrowings from Germanic languages which begin with an initial cluster are reduced in Finnish, such that only the last consonant is retained, as was the case in Proto-Finnic as well. Examples of this pattern are given in (34).

(34) Older loan words:

Swedish	Finnish	
strand	ranta	'waterfront'
stol	tuoli	'chair'
klister	liisteri	'paste'

However, more recent borrowings from English seem to retain their clusters as shown in (35).[19]

(35) Recent loan words:

English	Finnish
stress	stressi
strategy	strategia

There appears to be something about Finnish which allows it to borrow words into the language and retain the clusters, and which allows Finnish speakers to acquire clusters when they are not sanctioned by the L1.

6.6. Sonorant Voice structure

Young-Scholten and Archibald (2000) argue that there is a derived sonority argument to be made for the connection between these seemingly unrelated phenomena of having a liquid contrast in the segmental inventory, and the ability to acquire L2 consonant clusters. I will not go through the argument in detail here. The basic idea is that by having a liquid contrast, the L1 has enough segmental structure to maintain a contrast between two segments in an onset or coda. Following Rice (1992), Young-Scholten and Archibald view sonority as a property that is reflected in the amount of structure under a Sonorant Voice (SV) node. English has an expanded SV node because it contrasts nasals and two liquids. Minimal Sonority Distance, under this model, refers to the relative amount of SV structure in two adjacent segments. However, because Korean lacks a liquid contrast in

[19] It goes beyond the bounds of this article to address the sociolinguistics of borrowing in Finland. My argument is that even though older borrowings were simplified, something has made Finnish susceptible to recent borrowings that are not simplified. In this respect, Finnish contrasts with languages such as Japanese and Korean, where borrowings are simplified. I therefore maintain that it is the phonemic liquid inventory of Finnish which is responsible for this pattern.

its segmental inventory, it lacks the relevant structure for arriving at the English minimal sonority distance.

In comparing Finnish and Korean learners of English, Finnish learners have the relevant structures in their L1 and simply have to learn to redeploy these structures when it comes to parsing new sequences in a second language. Learners from an L1 such as Korean have to acquire *both* new structure *and* a new parsing procedure. This added demand on the second group of learners appears to be more difficult and results in more errors.

I would maintain that the data from the Finnish subjects in (33) supports my claim that it is easier for Finnish speakers to acquire English consonant clusters than it is for Korean speakers because of the L1 liquid inventory.

6.7. A parsing comparison

In order to draw all the sections of this article together, let us compare the parsing of consonantal sequences in English by speakers of the two L1s under focus. The first steps are given in (36).

(36)

Korean	Action	Finnish	Action
<plænt>		<plænt>	
O | [p] <lænt>	Parse [p] into Onset [YES]	O | [p] <lænt>	Parse [p] into Onset [YES]
	Parse [l] into Onset [FAIL]		Parse [l] into Onset [FAIL]

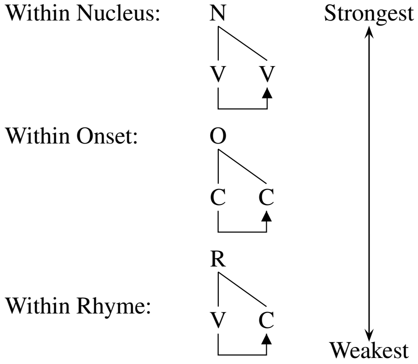
Now, let us consider what happens at this point of parsing failure in the two languages. Recall that neither L1 allows onset clusters, so the attempt to parse [l] into the Onset after [p] will fail. Some change must be made to the L2 grammar (either via I-learning or the consultation of UG). As a result, the action shown in (37) will be taken by both languages.

(37)

Korean	Action	Finnish	Action
O | \\ [p] <lænt>	License a dependent in the Onset.	O | \\ [p] <lænt>	License a dependent in the Onset.

The inductive process that will lead to this step is less obvious for the Korean learners than for the Finnish learners because the evidence for intraconstituent licensing is less robust in Korean than in Finnish. To demonstrate why this is the case, consider the intraconstituent licensing strength scale, shown in (38), which I propose reflects the ease with which head/dependent relations can be redeployed to new positions within the syllable.

(38) Intraconstituent licensing strength scale:



Modern Korean no longer has long vowels (Lee 1998). Finnish, on the other hand, has long vowels, and therefore a robust L1 instantiation of intraconstituent licensing that can be transferred to the L2. In other words, Finnish speakers can redeploy the licensing of a dependent in their L1 nuclei to acquire a weaker case of intraconstituent licensing (an onset dependent) in their L2. While Korean sanctions codas (rhyme-internal dependents), it appears that the L1 property of licensing a dependent in a weaker position on the scale does not allow the redeployment of the property to acquire a more robust position (an onset dependent) in the L2. Korean speakers will therefore have to rely on their inductive reasoning to make the necessary adjustment to their grammar. This scale is consistent with the literature which has argued that the acquisition of branching onsets (Broselow and Finer 1991) is easier than the acquisition of branching rhymes (Edge 1991).

Let us nevertheless assume that the necessary change occurs in both the Korean and Finnish interlanguage grammars and that both are in the same state, as shown earlier in (37). We come now to the question of determining which segments can be licensed in the new dependent position. Here, again, the two languages differ. Let us consider the question that the algorithm asks at this point: "Can the next element [l] be assigned to the Onset?" Having arrived at a grammar which sanctions branching onsets, the parser must now determine which segments can be licensed in that new position. The relationship between the members of an onset cluster have been described in various ways that refer to voice, place, and manner (see Steriade 1982, Rice 1992, Dresher and van der Hulst 1998). The central question is this: Is the element under focus different enough (with respect to some property or feature) to be parsed into the Onset?

Under the analysis that has been built up to this point, the Korean learners do not have the knowledge to answer that question as, recall, their L1 does not have a liquid contrast. The degree of SV structure permitted in each language is shown in (39) (based on Rice 1992).

(39) SV structure:

a. Korean:

Root
|
SV   /n/-/L/ contrast
|
Approximant

b. Finnish:

Root
|
SV   /n/-/r/-/l/ contrast
|
Approximant
|
Lateral

In Korean (39a), the feature Approximant distinguishes liquids from nasals, which are specified for SV alone. The lack of a distinction among liquids, symbolized by /L/, is reflected through the absence of Lateral, in contrast to Finnish (39b). In short, a language like Finnish which maintains a phonemic liquid contrast has more structure under the SV node. A language like Korean which does not make this contrast does not have the sonorancy representations to consult when dealing with questions about minimal sonority distance.

Let us return to the current state of our parser which is asking: Can the next element [l] be assigned to the Onset? The Korean parser is forced to answer [?] while the Finnish parser returns an answer of [Yes]. Again, the Korean learners will have to invoke changes to their grammar via I-reasoning as opposed to the Finnish learners who are able to redeploy their existing L1 representations and resources (I-learning). The current state of the parser is now as in (40).

(40)

Korean	Action	Finnish	Action
O (linked to [p] and <l>) [p] <l><ænt>	Can the [l] be assigned to the Onset? [?]	O (linked to [p] and [l]) [p] [l]<ænt>	Can the [l] be assigned to the Onset? [YES]

Blending some steps together, the parser arrives at the next state, as shown in (41).

(41)

Korean	Action	Finnish	Action
O (linked to [p] and <l>), N (linked to [æ]), C (linked to [n]) [p] <l>[æ][n]<t>	Assign the [æ] to the Nucleus; assign the [n] to the Coda (the L1 allows this).	O (linked to [p] and [l]), N (linked to [æ]), C (linked to [n]) [p] [l][æ][n]<t>	Assign the [æ] to the Nucleus; assign the [n] to the Coda. (the L1 allows this)

The remaining task is to consider the parsing of the final [t]. Both L1s, as seen in sections 6.1–6.2, sanction a [t] in Coda, but neither L1 allows coda clusters. For the sake of brevity, I would like to suggest that exactly the same arguments that we have just gone through for onsets hold for the acquisition of English coda clusters by speakers of Korean and Finnish. They will have different representations to draw on with respect to sonority and with respect to licensing that will result in the Koreans having greater difficulty with coda clusters than the Finnish speakers.

Given the perceptability facts discussed in section 2.3, we would also expect coda clusters to be acquired more slowly than onset clusters.

7. Conclusion

In this article, I have investigated a number of broad questions related to the acquisition of consonant clusters in a second language. Drawing on the structural relations and phonological principles of Government Phonology, I have argued that the behaviour of second language learners can be accounted for by a top-down, left-to-right phonological parser, similar in design to that proposed by Phillips (1996) for syntax. Invoking the cognitive architecture of Carrroll (2001), I have demonstrated that we can account for the different behaviours of speakers of languages that share the trait of lacking tautosyllabic clusters (Korean and Finnish) when they learn a language which allows such clusters (English). Properties of the L1 segmental inventory and a licensing strength scale were proposed to explain why Finnish learners had less trouble than Korean learners when acquiring English clusters.

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