Sonority Effects in the Production of Consonant Clusters by Spanish-Speaking Children

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1. Introduction

There have been numerous studies on children's acquisition of consonant clusters. The available published research shows that systematic reduction patterns are common in the process of acquiring such structures (McLeod et al., 2001; Smit, 1993). This systematicity occurs not only *within* children's sound systems, but also *across* children's sound systems, specifically in terms of the nature of the error patterns on clusters.

To be precise, there is one trend identified in the literature on cluster acquisition which is referred to as "sonority-based onset selection" (Pater and Barlow, 2003), in which the least sonorous segment of the target cluster is preserved (e.g., Barlow, 1997; Chin, 1996; Gnanadesikan, in press; Ohala, 1996; Ohala, 1999), following a sonority scale such as that in (1). To take an example, a cluster such as /br-/ would reduce to [b], while /-nt-/ would reduce to [t].

(1) Sonority scale (Blevins, 1995; Selkirk, 1984)
vowels > *glides* > *liquids* > *nasals* > *fricatives* > *stops*

The majority of evidence of this sonority pattern comes from studies of *tautosyllabic* clusters, that is, those that are part of the same syllable (e.g., /br-/ in 'bring'). Few studies have considered acquisition patterns for *heterosyllabic* clusters, that is, those that are split across two syllables (e.g., /-nt-/ in 'winter') (but see Chervela, 1981; Ohala, 1998). Furthermore, while there is some evidence in support of the sonority pattern from other languages (e.g., Fikkert, 1994; Goldstein and Cintrón, 2001; Jongstra, 2003; Lleó and Prinz, 1996; Ruke-Dravina, 1990), there is still the need for more cross-linguistic research to evaluate the pattern in other languages.

The purpose of this paper is therefore to consider children's acquisition of both tautosyllabic and heterosyllabic clusters of Spanish, for which not a lot of evidence exists. In doing so, asymmetries in reduction strategies within and across children's grammars will be considered as they compare to findings cross-linguistically. These strategies will be accounted for within an optimality theoretic framework (OT; Prince and Smolensky, 1993/2002). Under that framework, cluster reduction is attributed to high ranking syllable markedness constraints which outrank certain faithfulness constraints in children's grammars (e.g., Gnanadesikan, in press; Smolensky, 1996).

2. Data Sources

The data for this study come from three Spanish-speaking children, one who was developing in a typical fashion (BL4), and two with phonological delay (SD1 and SD2). Characteristics of these children are described briefly here; for more specific details about each child's sound system and data collection procedures, see Barlow (2003b; 2003c; in press).

Data from BL4 (female, aged 2;8) were drawn from the archives of a descriptive study of typically-developing Spanish-English bilingual children. BL4 was learning Southern Californian dialects of Spanish and English and was dominant in Spanish (which was the home language). A 120-word speech sample was obtained using picturable images or objects that represented the targeted words. The goal was to elicit a spontaneous production of the target word (without a model from the investigator) whenever possible. In some cases, however, it was necessary to elicit a delayed imitation, in which case the investigator elicited the target word (e.g., *manzana* 'apple') in the following manner: *Es una manzana. ¿Qué es?* ('It is an apple. What is it?').

Data from SD1 (female; aged 3;4) and SD2 (female; aged 3;9), were drawn from an ongoing treatment study that experimentally evaluates monolingual Spanish-speaking children's phonological acquisition following phonological treatment. Both children were acquiring a Southern California variety of Spanish. Because there are currently no standardized measures available for a quantitative diagnosis of phonological delay in Spanish-speaking children for this particular dialect, classification of these children as delayed was based on parent/teacher concern that the children's use of speech sounds was not developing appropriately. This is a method of diagnosis that has been reported to be highly reliable (Gutiérrez-Clellen and Kreiter, 2003; Restrepo, 1998). Both children were developing normally in all other respects, and this was based on formal and informal assessments of receptive and expressive language, hearing, intelligence, and oral-motor skills. Data for SD1 and SD2 were drawn from their pretreatment evaluations, prior to any experimental manipulation of their sound systems. The 214-word speech sample was elicited in the same manner as for BL4.

The productions of all three children were transcribed by two different students in the graduate program in speech-language pathology at San Diego State University. The transcribers were bilingual in Spanish and English and trained in phonetic transcription of both languages using the IPA. Interjudge transcription reliability on 20% of the data was calculate at 91% for BL4; 89% for SD1; and 88% for SD2.

3. BL4

We consider BL4's sound system first. For tautosyllabic clusters, BL4 reduces to the least sonorous singleton, following the sonority pattern. Examples of this pattern are found in (2), where both word-initial and word-internal tautosyllabic clusters are reduced.

(2) Sonority pattern in tautosyllabic cluster reduction

Target	Production	Gloss
plato	[pato]	'plate'
cumpleaños	[kumpanos]	'birthday'
bloque	[boke]	'block'
sombrero	[sombelo]	'hat'
tren	[ten]	'train'
cruz	[kus]	'cross'
chicle	[tʃike]	'gum'
negro	[nego]	'black'
tigre	[tike]	'tiger'
fresa	[fesa]	'strawberry'
flor	[fole]	'flower'

To account for this general pattern of cluster reduction within OT, it is assumed that a constraint against marked syllable structure, in this case complex onsets, outranks faithfulness constraints requiring that input and output representations be identical. These constraints are *COMPLEX and MAX, respectively, as defined in (3).

(3) *COMPLEX: No branching onsets (Prince and Smolensky, 1993/2002)
MAX: No deletion (McCarthy and Prince, 1995)

Ranking *COMPLEX over MAX only accounts for the reduction of the cluster; it does not account for *which* segment is deleted. Accounting for which segment is deleted requires an appeal to a set of sonority constraints, ranked in a universal order, that show a preference for low sonority segments in the onset (Pater and Barlow, 2003; adapted from Prince and Smolensky, 1993/2002). As shown in (4), given the fixed ranking, a glide in the onset is worse than a liquid, which is worse than a nasal, and so on.

(4) *G-ONS >> *L- ONS >> *N- ONS >> *F- ONS

A sample tableau in (5) shows how ranking *COMPLEX over MAX and the sonority constraints accounts for the sonority pattern exhibited in BL4's productions for tautosyllabic clusters:

(5) /fɾesa/ → [fesa]

/fɾesa/ 'strawberry'	*COMPLEX	MAX	*L-ONS	*F-ONS
a. [fɾesa]	*!		*	*
b. ☞ [fesa]		*		*
c. [ɾesa]		*	*!	

The tableau shows how candidate (b) [fesa] is selected over (a) [fɾesa] and (c) [ɾesa] for input /fɾesa/. Thus, violation of *COMPLEX is not tolerated in BL4's grammar, while violation of MAX is. Similarly, it is worse to violate *L-ONS than it is to violate *F-ONS.

While BL4's grammar disallows *tautosyllabic* clusters, *heterosyllabic* clusters surface target appropriately, and this is shown in the data in (6).

(6) Preservation of heterosyllabic clusters

Target	Production	Gloss
estampa	[tampa]	'stamp'
cumpleaños	[kumpanos]	'birthday'
elefante	[elefante]	'elephant'
lengua	[leŋga]	'tongue'
manzana	[manzana]	'apple'
sombrero	[sombelo]	'hat'
dulces	[dulses]	'sweets'
delfín	[elfin]	'dolphin'
falda	[falta]	'skirt'
árbol	[albol]	'tree'

To account for BL4's production of heterosyllabic consonant clusters, it is assumed that MAX is outranking the markedness constraint *CODA (defined in (7)), which prohibits the occurrence of coda consonants. Codas are allowed in BL4's sound system, given the occurrence of heterosyllabic consonant sequences (as well as word-final consonants, but see following sections for further discussion of the status of word-final consonants). This motivates the low ranking of *CODA below MAX. A sample tableau that illustrates this ranking is shown in (8).

(7) *CODA: No codas (Prince and Smolensky, 1993/2002)

(8) /dulses/ → [dulses]

/dulses/ 'sweets'	MAX	*CODA
a. ☞ [dul.ses]		**
b. [du.ses]	*!	*

The overall ranking for BL4 is shown in (9). This ranking allows for heterosyllabic clusters to surface, while tautosyllabic clusters are reduced to singletons following the sonority pattern.

(9) Overall ranking for BL4

*COMPLEX
|
MAX
/ \
*CODA *L-ONS
|
*N-ONS
|
*F-ONS

A sample tableau in (10) shows how a heterosyllabic cluster would be preserved, but a tautosyllabic cluster would be reduced. (Here only relevant segments are shown for clarity purposes, given additional changes that occur.)

(10) Illustrative tableau for BL4's grammar: /-mbɾ-/ → [-mb-]

/sombɾeɾo/ 'hat'	*COMP	MAX	*COD	*L-ONS	*N-ONS
a. [...m.bɾ...]	*!		*	*	
b. ☞ [...m.b...]		*	*		
c. [...m.ɾ...]		*	*	*!	
d. [...bɾ...]	*!	*		*	
e. [...m...]		**!			*

Let us now consider the second child, SD1, who shows the opposite patterning in her productions of tautosyllabic and heterosyllabic clusters.

4. SD1

Contrary to that of BL4, SD1's sound system allows tautosyllabic clusters to be produced intact, without reduction, as shown in (11).

(11) Preservation of tautosyllabic clusters

Target	Production	Gloss
plátanos	[plata]	'bananas'
plato	[plato]	'plate'
bloque	[bloke]	'block'
brinca	[bɾika]	'jumps'
estrella	[etɾeja]	'star'
tren	[tɾen]	'train'
chanclas	[tʃaklas]	'sandals'
chicles	[tʃikles]	'gum'
cruz	[kɾus]	'cross'
fresa	[fɾeda]	'strawberry'

To account for the preservation of clusters in onset position, it is assumed that SD1's grammar ranks MAX over *COMPLEX, allowing for the more faithful form to surface, as shown with the example of *plato* 'plate' in (12).

(12) /plato/ → [plato]

/plato/ 'plate'	MAX	*COMPLEX
a. ☞ [plato]		*
b. [pato]	*!	

Despite the fact that tautosyllabic clusters are allowed in SD1's system, heterosyllabic clusters are disallowed. In (13), SD1's productions of heterosyllabic clusters are shown. In each case, the target cluster is reduced to the least sonorous segment, regardless of the cluster type. Again, this is an example of the sonority pattern.

(13) Sonority pattern in heterosyllabic cluster reduction

Target	Production	Gloss
campanas	[kapanas]	'bells'
fuente	[fuete]	'water fountain'
gente	[exetes]	'people'
pintura	[putuɾa]	'painting'
brinca	[bɾika]	'jumps'
blanca	[blaka]	'white'
chanclas	[tʃaklas]	'sandals'
gancho	[gatʃo]	'hook'
tambor	[taboɾ]	'drum'
lengua	[legua]	'tongue'
delfín	[ofi]	'dolphin'
dulces	[duθes]	'sweets'

At first glance, it appears that this pattern in (13) could be accounted for by appealing to the same constraints that account for tautosyllabic cluster reduction patterns, namely, MAX and the sonority constraints, plus *CODA. Ranking *CODA above MAX and the sonority constraints would account for the pattern nicely, as shown in (14).

(14) /bɾiŋka/ → [bɾika]

/bɾiŋka/ 'jumps'	*CODA	MAX	*N-ONS
a. [bɾiŋ.ka]	*!		
b. ☞ [bɾi.ka]		*	
c. [bɾi.ŋa]		*	*!

However, this analysis might appear problematic when we consider that word-final consonants are allowed to occur in SD1's grammar; this is clear from her productions of *tren* 'train', *chanclas* 'sandals', *dulces* 'sweets', and other forms in (11) and (13). Assuming word-final consonants are codas, an apparent ranking paradox is observed, because MAX must outrank *CODA in order to account for those consonant-final forms, as shown in (15).

(15) /tɾen/ → [tɾen]: A ranking paradox for *CODA and MAX?

/tɾen/ 'train'	MAX	*CODA
a. ☞ [tɾen]		*
b. [tɾe]	*!	

Therefore, an alternative explanation is needed in order to account for the asymmetry between word-internal codas and word-final consonants in SD1's grammar.

SD1's grammar is similar to languages such as Luo, Yapese, and Yucatec Maya, which disallow word-internal syllables closed with a consonant, but allow final consonants (Harris and Gussmann, 2002; Kaye, 1990; Piggott, 1999). The asymmetry observed in these grammars has been explained in a variety of ways. For instance, many have proposed that word-final consonants are extraprosodic in certain languages. More recently, researchers have proposed that word-final consonants actually are onsets to syllables lacking a vowel (e.g., Goad and Brannen, 2003).

There is much disagreement regarding whether Spanish is an onset-final or coda-final language (Harris, 1983; Harris and Gussmann, 2002). Nevertheless, regardless of the status of Spanish as a fully-developed system, children's sound systems often differ from the adult systems in a variety of ways by allowing certain nonambient structures to occur while disallowing other ambient structures. Thus, it possible that a child's sound system could allow word-final onsets, even when the corresponding adult sound system does not.

In fact, Goad and Brannen (2003) propose that word-final onsets are unmarked relative to word-final codas. As a result of this markedness relationship, Goad and Brannen argue that final consonants are first analyzed by children as onsets, regardless of how they appear to pattern in the adult language (but see Lleó, 2003, for an alternative account). Their evidence comes from their evaluation of the sound systems of five children learning English, who exhibit commonly-occurring patterns of epenthesis (e.g., [ʌbʌ] 'up'), word-final aspiration (e.g., [mitʰ] 'meat'), and nasal release (e.g., [dædn̩] 'dad'). They argue that these patterns are revealing of how final consonants behave as onsets more than as codas, given that the release properties of these consonants are more similar to onsets rather than codas. Goad and Brannen assume that these children are producing relatively unmarked forms as compared to those with codas.

Returning to SD1, since no word-internal codas are allowed, but final consonants do occur, it is assumed that final consonants are onsets in her sound system. Following that assumption, it is further assumed that *CODA is in fact responsible for the heterosyllabic cluster reduction pattern, as originally considered (refer to the tableau in (14)). Accordingly, a word like *tren* 'train' would surface with a final consonant, in spite of high-ranking *CODA; but the final consonant would violate a lower-ranked constraint against empty-headed syllables, as defined in (16) and illustrated in (17).

(16) *EMPTY: Syllabic positions must be phonetically interpreted (Harris and Gussmann, 2002)

(17) Word-final onsets: /tɾen/ → [tɾen]

/tɾen/ 'train'	*CODA	MAX	*EMPTY
a. [tɾen]	*!		
b. ☞ [tɾe.n]			*
c. [tɾe]		*!	

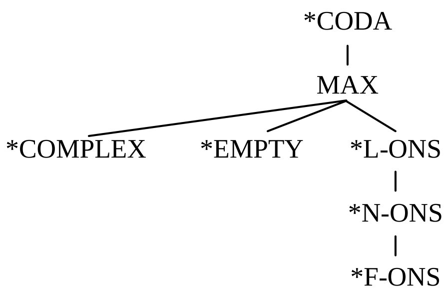
This also allows for reduction of heterosyllabic clusters, as with *tambor* [taboɾ] 'drum', shown in the tableau in (18).

(18) Illustrative tableau for SD1's grammar: /tamboɾ/ → [taboɾ]

/tamboɾ/ 'drum'	*CODA	MAX	*EMPTY	*L-ONS	*N-ONS
a. [tam.boɾ]	**!				
b. [tam.bo.ɾ]	*!		*	*	
c. ☞ [ta.bo.ɾ]		*	*	*	
d. [ta.mo.ɾ]		*	*	*	*!
e. [ta.bo]		**!			

The final ranking shown in (19) is posited to account for SD1's productions of tauto- and heterosyllabic consonant clusters.

(19) Overall ranking for SD1



Thus far, two rather systematic grammars, though with opposite cluster production patterns, have been described. While BL4 reduces tautosyllabic clusters and maintains heterosyllabic clusters, SD1 maintains tautosyllabic clusters and reduces the heterosyllabic clusters. Despite these opposing patterns of production, one factor holds constant: When reduction does occur, the sonority pattern accounts for their productions in all cases.

Next, the third child is considered. SD2 reduces *both* tauto- and heterosyllabic clusters. The sonority pattern generally accounts for this child's productions; however, in specific contexts this pattern is disrupted.

5. SD2

Starting with tautosyllabic clusters we see that, similar to BL4, SD2 also reduces tautosyllabic clusters. In each case, the reductions adhere to the sonority pattern, as shown in the data in (20).

(20) Sonority pattern in tautosyllabic cluster reduction

Target	Production	Gloss
plato	[pato]	'plate'
princesa	[pisesa]	'princess'
bloque	[boke]	'block'
libro	[libo]	'book'
bruja	[buxa]	'witch'
tren	[ten]	'train'
clavo	[kaβo]	'nail'
bisicleta	[bisiketa]	'bicycle'
crema	[kema]	'cream'
globos	[goβos]	'balloons'
grande	[gane]	'large'
flecha	[fetʃa]	'arrow'
frente	[fete]	'forehead'

It is therefore assumed that the same ranking that accounts for BL4's reduction of tautosyllabic clusters also accounts for SD2's productions, as illustrated in the tableau in (21).

(21) /fletʃa/ → [fetʃa]

/fletʃa/ 'arrow'	*COMPLEX	MAX	*L-ONS	*F-ONS
a. [fletʃa]	*!		*	*
b. ☞ [fetʃa]		*		*
c. [letʃa]		*	*!	

SD2's grammar disallows heterosyllabic clusters as well, similar to SD1. Generally, the sonority pattern of reduction is followed for these clusters, as shown in (22).

(22) Sonority pattern for most heterosyllabic clusters

Target	Production	Gloss
campana	[kapana]	'bell'
cumpleaños	[kupano]	'birthday'
gente	[xete]	'people'
llanta	[tʃata]	'tire'
pintura	[pitula]	'painting'
brinca	[bika]	'jumps'
blanco	[bako]	'white'
manzana	[masana]	'apple'
sarten	[saten]	'pan'
dulces	[duses]	'sweets'
dormida	[nomija]	'slept'

As with SD1's grammar, final consonants do occur in SD2's productions (e.g., *dulces* [duses] 'sweets', as well as other examples in (20) and (22)). This is another example of a grammar that allows final consonants but not word-internal codas. It is therefore assumed that final consonants are onsets in SD2's grammar, as with SD1's. Following that assumption, *CODA must be ranked relatively high in her grammar, while *EMPTY is ranked relatively low. Refer to the tableau in (23) for this ranking.

(23) /tɾen/ → [ten]

/tɾen/ 'train'	*CODA	MAX	*EMPTY
a. [ten]	*!		
b. ☞ [te.n]			*
c. [te]		*!	

The same ranking that accounts for SD1's reduction of heterosyllabic clusters accounts for the reduction of the majority of such clusters in SD2's grammar as well. This is illustrated in the tableau in (24).

(24) /bɾiŋka/ → [bika]

/bɾiŋka/ 'jumps'	*CODA	MAX	*N-ONS
a. [biŋ.ka]	*!		
b. ☞ [bi.ka]		*	
c. [bi.ŋa]		*	*!

While this proposed ranking accounts for *most* heterosyllabic clusters in SD2's productions, there are, however, certain cluster reduction patterns which diverge from the sonority pattern. The data in (25) show how nasal + voiced stop clusters instead reduce to the *most* sonorous segment in SD2's productions. This is a pattern that deviates from the general sonority pattern; but in fact, a similar asymmetry has been observed in diary studies of children learning Spanish and English (Hernández-Chávez et al., 1975; Macken, 1979; Smith, 1973).

(25) Reduction to most sonorous segment: nasal + voiced stop clusters

Target	Production	Gloss
grande	[gane]	'big'
bandera	[βaneja]	'flag'
llorando	[dʒolano]	'crying'
lengua	[lenua]	'tongue'
prende	[pene]	'turn on'
tamborito	[tamolito]	'little drum'

With the ranking as it currently stands, we incorrectly predict that the obstruent [d], rather than the sonorant [n] would be chosen by the grammar, as shown in (26).

(26) SD2's nasal + voiced obstruent clusters: /gɾande/ → *[gade]

/gɾande/ 'big'	*CODA	MAX	*N-ONS
a. [gan.de]	*!		
b. 👎 [gade]		*	
c. (☞) [gane]		*	*!

To account for this asymmetry in reduction for the two different types of clusters, it is necessary to assume that some constraint interaction is occurring, which is disrupting the general sonority pattern.

Since the nature of the asymmetry between the two cluster types relates to the voicing of obstruents, it is assumed that this asymmetry is the result of the interaction between the sonority constraints and segmental constraints related to voicing. Specifically, two additional constraints, defined in (27), are appealed to in order to account for these differential patterns of reduction (Lombardi, 1991; Lombardi, 1999). *VOICE, which is a markedness constraint against voiced obstruents, is in conflict with IDENT-VOICE, a faithfulness constraint requiring preservation of voice feature specifications.

(27) *VOICE: No voiced obstruents
IDENT-VOICE: Preserve voice features

Independent motivation for *VOICE and IDENT-VOICE can be found in cross-linguistic patterns related to laryngeal phenomena. For instance, voicing plays a role in the differential patterning of certain heterosyllabic clusters in fully developed languages. Voiced nasal + consonant (NC) clusters, such as [nd], [mb], tend to be preferred cross-linguistically over voiceless NC clusters, such as [mp], [nt] (e.g., Archangeli et al., 1998; Pater, 1999). Yet, NC devoicing patterns also have been observed (Hyman, 2001); and, furthermore, a preference for voiceless versus voiced NC clusters have also been observed in acquisition (Barlow, 2003a, 2003d). Thus, the relative markedness of the two types of clusters is less clear. Regardless, the asymmetries in the patterning of these two cluster types appear to relate to voicing (Herbert 1986; Hyman 2001).

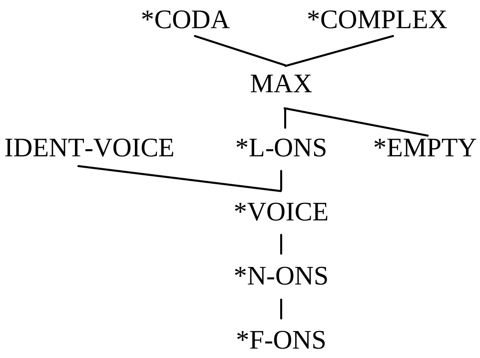
For target nasal + voiced stop clusters, SD2's grammar reduces to sonorants rather than voiced obstruents, which motivates the ranking of *VOICE over the sonority constraint *N-ONS, allowing for *lengua* 'tongue' to surface as [lenua], as shown in (28).

(28) /leŋgua/ → [lenua]

/leŋgua/ 'tongue'	*VOICE	*N-ONS
a. [le.gua]	*!	
b. ☞ [le.nua]		*

The independent rankings thus converge on the final ranking shown in (29), and two sample tableaux are shown in (30).

(29) Overall ranking for SD2



(30) Illustrative tableaux for SD2: /ɡɾande/ → [gane], /xente/ → [xete]

/ɡɾande/ 'big'	*COMP	*COD	MAX	*L-ON	*VOI	*N-ON
a. [ɡɾan.de]	*!	*		*	**	
b. [ga.de]			**		**!	
c. ☞ [ga.ne]			**		*	*
d. [ɾa.de]			**	*!	*	
e. [ɾa.ne]			**	*!		*

/xente/ 'people'	*CODA	ID-VOI	MAX	*VOI	*N-ONS
a. [xen.te]	*!				
b. ☞ [xe.te]			*		
c. [xe.ne]			*		*!
d. [xe.de]		*!	*	*	

This ranking also predicts the emergent sonority pattern for sonorant + sonorant clusters in SD2's productions, as in the case of *dormida* 'slept' shown in (31) (where only relevant segments are shown for simplicity, given additional changes that occur).

(31) Emergent sonority: /-ɾm-/ → [-m-]

/doɾmiða/ 'slept'	*COD	MAX	*L-ONS	*N-ONS
a. […oɾ.mi…]	*!			*
b. […o.ɾi…]		*	*!	
c. ☞ […o.mi…]		*		*

6. Discussion

To summarize, each child's grammar treated consonant clusters in a unique but systematic fashion. BL4 reduced target tautosyllabic clusters, but preserved both segments in her productions of target heterosyllabic clusters. This motivated the ranking of *COMPLEX over MAX, which in turn was ranked over *CODA. SD1 preserved both segments of target tautosyllabic clusters, but reduced heterosyllabic clusters. This was accounted for by ranking *CODA over MAX, which was ranked above *COMPLEX. The third child, SD2, reduced both tautosyllabic and heterosyllabic clusters to singletons, which motivated the ranking of both *COMPLEX and *CODA over MAX.

These cluster production patterns do not appear to reflect characteristics specific to bilingualism (in the case of BL4) or to phonological delay (in the case of SD1 or SD2), given that these patterns have been reported to occur in the speech of other monolingual Spanish-speaking children, not to mention children from other language backgrounds. Of course, other aspects of BL4's sound system may be reflective of her bilingualism (e.g., cases of transfer as reported in Barlow, 2003b). And, indeed, SD1 and SD2 differ from normally developing children in that they required phonological treatment to help eliminate their error patterns. To address the cluster production patterns specifically, a child such as SD1 would require treatment on syllable-final consonants, while a child like SD2 would require treatment on both syllable-final consonants and complex onsets. This would result in the subsequent demotion of relevant markedness constraints (*CODA and *COMPLEX) below the faithfulness constraint MAX, thereby bringing the children's sound systems more in line with the adult Spanish grammar. (For a detailed evaluation of the longitudinal change in SD2's grammar following phonological treatment, see Barlow, 2003c.)

Importantly, since the reduction of heterosyllabic clusters was independent of the reduction of tautosyllabic clusters, it appears that there is, not surprisingly, no universal ranking between the markedness constraints *COMPLEX and *CODA with respect to the faithfulness constraint MAX. To be more precise, BL4, SD1, and SD2 represented three possible rankings of the three constraints, which are similar to grammars of fully-developed systems (Blevins, 1995). Some examples of this are shown in the table in (32). Specifically, BL4's grammar is not unlike those of Cairene and Finnish, which have coda consonants but not complex onsets. SD1's grammar resembles that of Arabela and Mazateco, which have onset clusters but not coda consonants. SD2's grammar is similar to Fijian, which does not allow complex onsets or codas. Of course, adult Spanish, allowing both types of clusters to occur, represents a fourth grammar, and this is the grammar that all three children are expected to settle on once acquisition is complete.

(32) Cluster typology

Ranking	*Cluster status*	*Child*	*Language*
a. *COMP >> MAX >> *CODA	*tautosyllabic √heterosyllabic	BL4	Cairene Finnish
b. *CODA >> MAX >> *COMP	√tautosyllabic *heterosyllabic	SD1	Arabela Mazateco
c. *COMP, *CODA >> MAX	*tautosyllabic *heterosyllabic	SD2	Fijian
d. MAX >> *COMP, *CODA	√tautosyllabic √heterosyllabic	all 3 (later)	Spanish English

Recall that SD1 and SD2 both produced word-final consonants. Despite that fact, we assumed that *CODA ranked high in both their grammars, given that heterosyllabic clusters reduced to singletons. To account for the asymmetry between word-internal codas and word-final consonants, it was proposed that word-final consonants in these two children's sound systems were actually onsets, thus motivating the ranking of *CODA over *EMPTY. As stated previously, SD1's and SD2's grammars resemble other fully developed grammars, such as that of Yucatec Maya (Harris and Gussmann, 2002), by allowing final consonants but not word-internal codas.

There are likewise languages that allow both word-internal codas and final consonants (e.g., English), or neither such forms (e.g., Zulu) (Harris and Gussmann, 2002). Assuming that those languages that have both word-internal codas and final consonants also vary in terms of how those final consonants pattern (as codas or as onsets), we have all possible rankings of *CODA and *EMPTY. It remains to be determined if all such rankings are observed in acquisition as well.

We cannot be certain whether final consonants were analyzed as codas or onsets by BL4's grammar, given that both word-internal codas and final consonants occurred in her productions. Therefore, it is also uncertain where *EMPTY ranks in her grammar. According to Goad and Brannen

(2003), we might predict that, early on in development, final consonants patterned as onsets in her grammar, following the assumption that they are relatively unmarked.

Recall that all three children showed a general preference for low sonority in the onset position, which appears to be a general cross-linguistic preference. As mentioned previously, the sonority pattern has been established as a pattern for acquisition of a variety of languages. Thus, despite differences in constraint rankings, all three children in this study showed reduction patterns that resulted in syllable unmarkedness, which is common in developing grammars and is accounted for generally within optimality theory by ranking markedness constraints over faithfulness constraints (e.g., Gnanadesikan, in press; Smolensky, 1996).

Yet, SD2 showed an asymmetry in terms of her reduction patterns. For the tautosyllabic clusters and most of the heterosyllabic clusters, she generally followed the same sonority pattern as BL4 and SD1, where the least sonorous segment was maintained. However, SD2's productions showed a different pattern of reduction for target nasal + voiced stop clusters, which reduced to the most sonorous segment. This required an appeal to segmental constraints noted to be responsible for the differential patterning of voiced and voiceless obstruents cross-linguistically (*VOICE and IDENT-VOICE).

Similar such deviations from the sonority pattern have been observed for phonological acquisition of English, due to effects of markedness constraints against fricatives and dorsals, as well as faithfulness constraints pertaining to place (Pater and Barlow, 2003) or manner (Barlow, 2003a, 2003d). In each of these cases, as with the present one, the more general pattern that prevailed was the sonority pattern.

Given the constraints appealed to in the present study, it might be predicted that other types of cluster asymmetries may emerge. For example, the ranking in (29) allowed for nasal + voiced stop clusters to reduce to the most sonorous segment. Other rankings are also predicted to occur as shown in the typology in (33). We have evidence for these rankings for the three children in the present study, and a child in a related study (Fabiola, discussed in Barlow, 2003a, 2003d). BL4 and SD1 show no asymmetries with respect to the reduction of sonorant + voiced versus voiceless obstruent clusters, which motivated the relatively low ranking of *VOICE. SD2, on the other hand, shows an asymmetry with respect to nasal + voiced versus nasal + voiceless obstruent clusters, while other sonorant + obstruents show no such asymmetry. This motivated the ranking of *VOICE above *N-ONS, but below *L-ONS. Finally, a third child, Fabiola, discussed in Barlow (2003a, 2003d), showed an asymmetry for all sonorant + voiced versus voiceless obstruent clusters, and this motivated the ranking of *VOI above *L-ONS.

(33) Factorial typology of *VOICE and sonority constraints

	/lt/	/ld/	/nt/	/nd/	
a. *VOI >> *L-ONS >> *N-ONS	t	l	t	n	Fabiola
b. *L-ONS >> *VOI >> *N-ONS	t	d	t	n	SD2
c. *L-ONS >> *N-ONS >> *VOI	t	d	t	d	BL4, SD1

For future research, it is necessary to continue to evaluate typological predictions such as this, not only in acquisition of Spanish, but also in other languages. In fact, there is still much to learn about cross-linguistic patterns of cluster acquisition. Further establishment of the sonority pattern as a general pattern, as well as the corresponding deviations, is especially warranted. Finally, further evaluation of the status of final consonants, and even final clusters and the way in which they pattern in acquisition, is also necessary.

Notes

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