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Constraint conflict in cluster reduction*

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ABSTRACT

When children reduce onset clusters to singletons, a common pattern is for the least sonorous member of the adult cluster to be produced. Within OPTIMALITY THEORY (Prince & Smolensky, 1993), this pattern has been accounted for in terms of a fixed ranking of onset constraints that evaluate a segment's degree of sonority, whereby onset glides violate the highest ranked constraint, and onset stops the lowest. Not all children follow the sonority pattern, however. In this paper, we apply two fundamental principles of optimality theory to yield predictions about other children's cluster reduction patterns. The first principle is that of FACTORIAL TYPOLOGY, according to which all rankings of constraints should yield possible languages. To produce the sonority pattern, all conflicting constraints must rank beneath the onset sonority constraints. If they rank above the onset sonority constraints, these other constraints will force deviations from the sonority pattern. In this paper, we show how divergences from the sonority pattern are caused by three

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well-motivated conflicting constraints: *Fricative, *Dorsal, and Max-Labial. This is documented in the speech of two normally developing children (about 1;6–2;3) and a child with a phonological delay (3;8). The second principle we appeal to is that of emergent constraint activity, according to which the effects of violated constraints can be observed when higher ranked conflicting constraints are not at issue. We show that even when the onset sonority constraints are outranked by the conflicting constraints, under the right circumstances the sonority pattern does emerge in the forms produced by these children.

INTRODUCTION

When children reduce onset clusters to singletons, they are usually systematic in terms of which consonant from the cluster they retain. A common pattern is for the least sonorous member of the adult target cluster to surface (Ohala, 1996; Barlow, 1997; Gnanadesikan, in press; Goad & Rose, in press). A simple sonority scale is given in (1), arranged from the most to least sonorous segment type (see Blevins, 1995 for a more elaborate sonority scale, and general discussion of the role of sonority in syllabification):

(1) Vowel > Glide > Liquid > Nasal > Fricative > Stop

This 'sonority pattern' of cluster reduction is illustrated in the following data from a normally developing child (Gitanjali, age 2;3–2;9; Gnanadesikan, in press), and from a child with a developmental delay (Subject 25, age 4;10; Barlow, 1997), both learning American English:

(2) Sonority pattern of cluster reduction

a. obstruent + sonorant → obstruent

Gitanjali:	[kin] 'clean'	[dɒ] 'draw'	[piz] 'please'
	[so] 'snow'	[sɪp] 'slip'	[fɛn] 'friend'
Subject 25:	[din] 'queen'	[do] 'grow'	[bei] 'play'
	[sowɪŋ] 'snowing'	[sip] 'sleep'	[sip] 'sweep'

b. fricative + stop → stop

Gitanjali:	[gaɪ] 'sky'	[gɪn] 'skin'	[bɪw] 'spill'
Subject 25:	[bun] 'spoon'	[daɪ] 'sky'	[dov] 'stove'

In all of the forms in (2), the child produces the least sonorous segment from the adult cluster. Obstruents are chosen instead of sonorants (2a), and when the target cluster consists of a pair of obstruents, the stop is chosen instead of the more sonorous fricative (2b).

Within optimality theory (Prince & Smolensky, 1993), several child phonologists have analysed the preference for low sonority onsets as being due to the activity of a set of constraints that relate sonority to syllable position, whose ranking is universally fixed (Ohala, 1996; Barlow, 1997; Gnanadesikan, in press; *cf*. Prince & Smolensky, 1993). One version of such a constraint hierarchy (Pater, 1997) is shown in (3).

(3) *G-ONS >> *L-ONS >> *N-ONS >> *F-ONS
(Where G = Glide, L = Liquid, N = Nasal, F = Fricative)

Position in this fixed ranking is correlated with the segments' sonority. Glides, being the most sonorous consonants, violate the highest ranked onset sonority constraint, and oral stops, being the least sonorous, violate no onset sonority constraint at all (or, alternatively, the lowest ranked of these constraints – we omit it for space considerations). When all else is equal, this hierarchy of constraints will select the lowest sonority onset as optimal, yielding the data pattern in (2) (see SONORITY-BASED ONSET SELECTION for more detailed exposition).

Not all children follow the sonority pattern, however. In this paper, we provide an account of divergences from the sonority pattern in terms of the interaction of conflicting constraints. Constraints that conflict with the onset sonority constraints in (3) are motivated by other processes in child phonology, as well as by phenomena in the phonologies of the world's languages. In order for the sonority pattern to obtain, such constraints must rank beneath the onset sonority constraints; when ranked above (some of) them, the sonority pattern is disrupted. Here we show that the three constraints listed in (4) play a role in cluster reduction:

(4) Constraints conflicting with onset sonority
*FRICATIVE *DORSAL MAX-LABIAL

We will discuss each of these constraints in more detail in the following sections. Briefly, the first two constraints are responsible for the common child processes of 'stopping' (e.g. /s/→[t]) and 'fronting' (e.g. /k/→[t]), respectively. In cluster reduction, they favour deletion of fricatives and velars, which, in some circumstances, will conflict with a sonority-based choice. For example, for a target /kl-/ cluster, *DORSAL would be satisfied by deletion of the velar, while *L-ONS would be satisfied by deletion of the liquid. The ranking of these two constraints will determine the outcome for a particular child's phonological system. The last constraint, MAX-LABIAL, is responsible for the preferential retention of labials in assimilation and deletion processes. In a target cluster in which the obstruent is non-labial and the sonorant is a labial (e.g. /sw-/), MAX-LABIAL and onset sonority make conflicting demands. If MAX-LABIAL prevails, the sonorant will be retained, while if onset sonority wins out, the obstruent will be kept.

Optimality theory predicts that all rankings of constraints, besides those in a universally fixed ranking, will be attested (termed FACTORIAL TYPOLOGY by Prince & Smolensky, 1993). Thus, along with the sonority pattern, which is produced if the onset sonority constraints outrank all conflicting constraints, we should also find evidence of the reverse rankings, which produce deviations from the sonority pattern. In the first part of this paper, we show that this expectation is met in cluster reduction patterns of normally developing and phonologically delayed children learning American English. We analyse these children's data in terms of ranked constraints, and point out where other analyses would meet with difficulties.

In optimality theory, when a constraint is outranked, it is not 'turned off'. In circumstances in which the dominant constraint does not conflict with it, the lower ranked constraint can exert its influence. We follow McCarthy & Prince (1994) in terming this EMERGENT CONSTRAINT ACTIVITY. In the final section of this paper, we show that the lower-ranked onset sonority constraints do continue to play a role in these children's systems, in exactly those instances in which the higher ranked constraints fail to decide the outcome of cluster reduction.

Sonority-based onset selection

For expository purposes, we assume that the markedness constraint responsible for cluster reduction is *COMPLEX (Prince & Smolensky, 1993), defined in (5), though /s/-initial clusters may in fact be targeted by another constraint (see e.g. Barlow, 2001):

(5) *COMPLEX: Onsets are limited to a single segment

This constraint conflicts with a faithfulness constraint that prohibits segmental deletion, MAX, defined in (6) (McCarthy & Prince, 1999):

(6) MAX: Every Input segment must have an Output correspondent

The INPUT in optimality theory is basically equivalent to the traditional 'Underlying Representation', and the OUTPUT to 'Surface Representation', which in child phonology are taken to correspond to the child's stored lexical representation and the produced form, respectively. If, as is likely, children do perceive and store clusters accurately, then cluster reduction involves a violation of MAX, since an Input segment lacks a corresponding Output segment.

Cluster reduction results from a ranking of *Complex above Max, while accurate production of clusters is due to the reverse ranking, Max >> Complex. In Tableau 1 and Tableau 2, we illustrate the effects of child and adult rankings:

TABLEAU 1. *Early child English:* *Complex>>Max

/pliz/	*Complex	Max
a. ☞ [piz]		*
b. [pliz]	*!	

TABLEAU 2. *Adult English:* Max>>*Complex

/pliz/	Max	*Complex
a. [piz]	*!	
b. ☞ [pliz]		*

Both tableaux have the same Input, /pliz/, and the same Output candidates, [piz] and [pliz]. These candidates violate Max and *Complex, respectively (violations are marked with asterisks). When *Complex is ranked above Max, as in Tableau 1, [pliz] is ruled out in favour of [piz] (the fatal violation incurred by [pliz] is highlighted with an exclamation mark, and the optimality of [piz] is indicated with a pointing finger). With the ranking reversed, as in Tableau 2, [pliz] becomes optimal, since [piz] is ruled out by its violation of the higher ranked constraint. The child ranking of *Complex >> Max is an instance of the dominance of Markedness constraints over Faithfulness constraints, which captures the tendency for child systems to contain structures that are unmarked relative to the adult language (Smolensky, 1996; Gnanadesikan, in press).

While the ranking of *COMPLEX >> MAX accounts for the fact that a singleton rather than a cluster is produced, it does not say anything about which of the two consonants will surface (that is, [liz] and [piz] would fare equally well in Tableau 1). Cluster reduction amongst English-learning children is derived from an initial Markedness >> Faithfulness ranking, rather than from observed alternations in the language. Therefore, the ambient phonology does not produce a preference for one reduction outcome over another. The claim in this paper is that the ranking of other universal constraints determines which consonant is retained. There is no evidence for the ranking of these constraints in the ambient language, so children will differ in which ranking they adopt, thus producing different patterns of cluster reduction.

As mentioned in the INTRODUCTION, the 'sonority pattern' of cluster reduction has received much attention within optimality theory. Adapting a proposal by Prince & Smolensky (1993), a fixed ranking of constraints is used to derive the preference for low sonority onsets shown in forms such as those in (2) above (Ohala, 1996; Barlow, 1997, 2001; Gnanadesikan, in press). The version of that ranking from Pater (1997) is repeated in (7):

(7) Onset sonority hierarchy
*G-ONS >> *L-ONS >> *N-ONS >> F-ONS
(Where G = Glide, L = Liquid, N = Nasal, F = Fricative)

Assuming that stops are the least marked onsets, there is no need for a constraint that specifically targets them. The fixedness of the ranking means that the relative ranking of these constraints cannot be changed, although other constraints can be interspersed between them.

To show the effect of these constraints, we present Tableau 3 and Tableau 4, which have inputs that have different onset sonority profiles. We consider only outputs with singleton onsets, assuming that clusters are ruled out by *COMPLEX >> MAX.

TABLEAU 3. *L-ONS>>*F-ONS

/slip/	*L-ONS	*F-ONS
a. [lip]	*!	
b. ☞ [sip]		*

TABLEAU 4. *L-ONS>>*F-ONS (*activity of dominated constraint*)

/skaɪ/	*L-ONS	*F-ONS
a. ☞ [kaɪ]		
b. [saɪ]		*!

When the choice is between a fricative and a liquid as in Tableau 3, the ranking *L-ONS >> *F-ONS leads to the fricative surfacing in the output. On the other hand, when the Input provides a choice between a fricative and a stop as in Tableau 4, the lower sonority stop is chosen. In Tableau 3, violation of *F-ONS is forced by dominant *L-ONS; in Tableau 4, *L-ONS is not at issue, so *F-ONS determines the outcome. Most constraint-based theories, including templatic accounts of child phonology, implicitly assume that a constraint is either 'on' or 'off', fully satisfied or freely violable. For example, to say that a child has a CV syllable template implies that constraints such as *COMPLEX and NOCODA (Prince & Smolensky, 1993) are inviolable. Situations in which a constraint is violated (or satisfied) only under particular conditions are straightforwardly captured with ranked and violable constraints, yet are awkward to express with inviolable constraints. Here the pair of onset selection cases illustrated in Tableau 3 and Tableau 4 would seem to provide contradictory information about the activity of an inviolable *F-ONS constraint. This contradiction is resolved under the optimality theoretic view that constraints are not simply 'on' or 'off', but that they are minimally violable, violated only when necessary to satisfy a higher ranked constraint (see Pater, 1997; Gnanadesikan, in press, for further discussion in the context of child phonology).

That the onset sonority constraints are not uniformly satisfied in some child grammars is further attested to by the data in (8) from Gitanjali (Gnanadesikan, in press), produced at the same time that she was displaying sonority-based onset reduction (*cf.* (2) above):

(8) Gitanjali: Singleton approximants

[wum]	'room'	[ju]	'you'	[wuf]	'roof'
[jælo]	'yellow'	[læb]	'lab'	[jæ]	'yeah'
[wo]	'woah'				

These data are typical of children displaying the sonority pattern of onset selection. They show that when the input provides only a singleton onset, it surfaces in exactly the same environment from which it is deleted in cluster reduction.

One difference between deletion from a cluster, and deletion of a singleton, is that the latter leads to a violation of a constraint requiring that a syllable have an onset (i.e. ONSET, Prince & Smolensky, 1993). Thus, with ONSET outranking the onset sonority constraints, a singleton liquid is preserved, as in Tableau 5:

TABLEAU 5. ONSET>> *L-ONS

/læb/	ONSET	*L-ONS
a. [æb]	*!	
b. ☞ [læb]		*

In the cluster reduction cases, deletion of either consonant satisfies ONSET, so the decision of which consonant to delete is passed down to the lower ranked onset sonority constraints, as in Tableau 6:

TABLEAU 6. ONSET>> *L-ONS (*activity of dominated constraint*)

/pliz/	ONSET	*L-ONS
a. ☞ [piz]		
b. [liz]		*!

Because the onset sonority constraints are dominated by conflicting constraints, their effects are emergent, visible only when the higher ranked constraints are not at issue. In the next sections, we will see that in other children's systems their effects can be further obscured by the dominance of other constraints, leading to the disruption of the sonority pattern. Nonetheless, where the higher ranked constraints do not apply, the emergent effects of the onset sonority constraints can still be seen, as we show in the final section of the paper.

*Fricative effects in cluster reduction

Children's early productions often display a pattern of 'stopping', whereby fricatives are realized as stops, as shown in the data from Amahl (Smith, 1973) at age 2;2 in (9):

(9) 'Stopping' in Amahl's speech

[b̥ʌt]	'bus'	[d̥uː]	'zoo'	[maip]	'knife'
[b̥ʌt]	'brush'	[ʌdə]	'other'	[b̥at]	'bath'

Since stopping applies in all environments (coda and onset), *F-Ons cannot be responsible for this pattern. Therefore, a context-free markedness constraint such as that in (10) is needed (Barlow, 1997):

(10) *Fricative: Segments may not be [+cont, −son]

This constraint is also active cross-linguistically. Its most extreme effect is in languages that lack fricatives entirely, such as in many Australian languages (Evans, 1995).

To obtain the sonority pattern, *Fricative must be ranked beneath the onset sonority constraints. For example, if *Fricative is ranked above *N-Ons, nasals will be chosen instead of fricatives. Tableau 7 and Tableau 8 compare the effects of the two rankings of these constraints.

TABLEAU 7. *N-Ons>> *Fricative

/snoʊ/	*N-Ons	*Fricative
a. [noʊ]	*!	
b. ☞ [soʊ]		*

TABLEAU 8. *Fricative>> *N-Ons

/snoʊ/	*Fricative	*N-Ons
a. ☞ [noʊ]		*
b. [soʊ]	*!	

The mapping of /sn/ to [s] in Tableau 7 is part of the sonority pattern (see (2) for examples from Gitanjali and Subject 25). The mapping of /sn/ to [n] in Tableau 8 is also attested in many children's productions (see Smit, 1993).

The data from normally developing children that we present here come from a corpus of phonetically transcribed utterances collected in a diary fashion by the children's mothers, speech-language pathologists with special training in transcription of child speech (Compton & Streeter, 1977; Pater, 1997). The children were learning American English, and had no perceptual or articulatory impairments or delays. Compton & Streeter (1977) checked the reliability of samples of the parental transcriptions by comparing them with transcriptions done simultaneously by the principal investigator, and by taping some sessions, so that they could also be transcribed by both the parent and the principal investigator. Compton & Streeter's (1977: 100) reliability calculations showed an approximate agreement of 90% for consonants transcribed.

Most of our discussion will focus on one child, Julia, who had a particularly interesting pattern of cluster reduction. However, both she and another child, Trevor, provide evidence of the same ranking of *FRICATIVE relative to the onset sonority constraints. In (11) and (12) we present examples of their reduced fricative + nasal clusters. Both children deleted the fricative, rather than the nasal, in conformity with the ranking in Tableau 8, and contrary to the sonority pattern:

(11) Julia: Reduced fricative-nasal clusters

Type	*Child form*	*Adult target*	*Age*
sn	[mami + nis]	'mommy sneeze'	1;9.5
	[nek]	'snake'	1;11.22
sm	[ʍʌs ai mɛʊ]	'what (do) I smell?'	2;4.28

(12) Trevor: Reduced fricative-nasal clusters

Type	*Child form*	*Adult target*	*Age*
sn	[næ]	'snap'	1;1.4
	[mæp]	'snap'	1;8.12
	[no mæn]	'snow man'	1;11.14
	[niːz]	'sneeze'	1;10.5

For this cluster type, Julia produces only this pattern of reduction, while Trevor produces this pattern in 35/36 cases, with one instance of reduction to the fricative. For fricative + liquid clusters, however, Julia and Trevor always follow the sonority pattern, as in (13) and (14).

(13) Julia: Reduced fricative + liquid clusters

Type	*Child form*	*Adult target*	*Age*
sl	[sip]	'sleep'	1;8.27
	[saɪːt]	'slide'	1;11.16
fl	[faʊwɚ]	'flowers'	1;11.23
fr	[fɔgi]	'froggy'	2;0.23

(14) Trevor: Reduced fricative-liquid clusters

Type	*Child form*	*Adult target*	*Age*
sl	[sip]	sleep	1;8.26
fl	[fəwə]	flower	1;7.6
fr	[faːg]	frog	1;10.5

This pattern requires *Fricative to rank between *L-Ons and *N-Ons; Tableau 9 illustrates the need for *L-Ons to dominate *Fricative:

TABLEAU 9. *L-Ons>> *Fricative

/slip/	*L-Ons	*Fricative
a. ☞ [sip]		*
b. [lip]	*!	

Thus far, we have seen two different *Fricative rankings relative to the onset sonority hierarchy:

(15) a. Sonority pattern (Gitanjali, Subject 25)
*G-Ons >> *L-Ons >> *N-Ons >> *F-Ons, ***Fricative**
b. Partially subverted sonority pattern (Julia, Trevor)
*G-Ons >> *L-Ons >> ***Fricative** >> *N-Ons >> *F-Ons

When *Fricative ranks higher relative to these constraints, it has more dramatic effects. Such effects can be seen in the following elicited data from LP65, an English learning child aged 3;8 with a functional nonorganic phonological disorder (see also Barlow, 1997), whose data were drawn from the archives of an ongoing research study on phonological development and disorders at Indiana University. LP65's *Goldman-Fristoe Test of Articulation* (Goldman & Fristoe, 1986) percentile score was < −1, though he had normal hearing, and normal vocabulary (score of 102 on the *Peabody Picture Vocabulary Test – Revised*; Dunn & Dunn, 1981). The data were collected prior to treatment using a picture elicitation task (see Barlow, 1997 for additional details). LP65's utterances were transcribed by two independent judges trained in the use of the International Phonetic Alphabet; the mean transcription reliability was 86·3 % (for a total of 483 consonants transcribed).

For all adult fricative+sonorant clusters, LP65 produces the sonorant, rather than the fricative, as in (16).

(16) LP65: Target fricative-sonorant clusters

Type	*Child form*	*Adult target*	*Child form*	*Adult target*
fr	[wɛnd]	'friend'	[wʊːt]	'fruit'
	[wɛnˀ waɪ]	'french fries'		
sl	[jip]	'sleep'	[jɛd̥]	'sled'
	[jaɪd]	'slide'		
sn	[niːd]	'sneeze'	[noʊmən]	'snowman'
	[naɪt]	'snake'	[naɪjʊl]	'snail'
ʃr	[wɪnːt]	'shrink'	[wɛːd̥]	'shred'
sw	[wɪːn]	'swing'	[wɪəm]	'swim'
sm	[mɛʊ]	'smell'	[maɪjʊ]	'smile'
θr	[wi]	'three'	[woʊ]	'throw'

The data pattern in (16) is produced if, as in LP65's system, *Fricative dominates the entire onset sonority hierarchy. Tableau 10 demonstrates the dominance of *Fricative over *G-Ons, the highest ranked of the onset sonority constraints. A candidate in which the liquid surfaces unchanged (i.e. [lip]) would be ruled out by an undominated *Liquid constraint, responsible for the gliding of all liquids in LP65's productions (see further Barlow, 1997).

Tableau 10. *Fricative>>*G-Ons

/slip/	*Fricative	*G-Ons
a. [sip]	*!	
b. ☞ [jip]		*

The entire factorial typology that results from the interaction of *Fricative and the onset sonority constraints is illustrated in Table 1. Beside each ranking is the segment selected from target /sC-/ clusters of various sonority profiles. As *Fricative ascends the fixed onset sonority hierarchy, segments

TABLE 1. *Factorial typology of *Fricative and onset sonority constraints*

Ranking	sw	sl	sn	st
a. *G-Ons ≫ *L-Ons ≫ *N-Ons ≫ *F-Ons ≫ ***Fric**	s	s	s	t
b. *G-Ons ≫ *L-Ons ≫ *N-Ons ≫ ***Fric** ≫ *F-Ons	s	s	s	t
c. *G-Ons ≫ *L-Ons ≫ ***Fric** ≫ *N-Ons ≫ *F-Ons	s	s	n	t
d. *G-Ons ≫ ***Fric** ≫ *L-Ons ≫ *N-Ons ≫ *F-Ons	s	l	n	t
e. ***Fric** ≫ *G-Ons ≫ *L-Ons ≫ *N-Ons ≫ *F-Ons	w	l	n	t

TABLE 2. *Patterns of cluster reduction predicted to be impossible*

Reduction pattern	Target cluster			
	sw	sl	sn	st
a.	w	l	n	s
b.	w	l	s	t
c.	w	s	n	t
d.	w	l	s	s
e.	w	s	s	t
f.	w	s	n	s
g.	s	l	n	s
h.	w	s	s	s
i.	s	l	s	s
j.	s	s	n	s

of increasing sonority are selected instead of the fricative. The sonority pattern is generated by rankings (a) and (b) in the table, the partially subverted sonority pattern of Trevor and Julia follows from ranking (c), while the fully subverted sonority pattern of LP65 is produced by ranking (e). The only ranking we have yet to find evidence for is (d).[1]

A number of putative onset selection patterns are predicted to be impossible in this account. The fixed ranking of onset sonority constraints yields the implicational prediction in (17):

(17) If a segment of a given sonority is chosen instead of the fricative, then all segments of lesser sonority will also be chosen instead of the fricative.

Hypothetical patterns of cluster reduction that run counter to the prediction in 17 are presented in Table 2. It is possible to produce some of

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[1] This gap may be due to the fact that children often produce liquids as glides, making it difficult to find evidence of them being distinguished in cluster reduction. Should the gap turn out to hold up empirically, one way of dealing with it would be to collapse *G-Ons and *L-Ons into a single *Approximant-Onset constraint, although further research would be required to determine if this would provide an adequate crosslinguistic account of onset sonority preferences.

these with the inclusion of further constraints. For example, patterns (c) and (e) in Table 2 are produced by the inclusion of MAX-LABIAL, discussed below in LABIAL FAITHFULNESS IN ONSET SELECTION. The first of these, (c), is Julia's pattern, but we have yet to find a child displaying (e). None of the other patterns is attested in the data we have seen from our archives or in published literature.

In total then, 4 of the 6 predicted patterns are in fact attested, while none of the patterns predicted to be impossible has turned up in data that we have seen, with the exception of (c), which will be discussed below. Thus, while the match between predicted and attested grammars is not perfect, it is close enough to provide an indication that this approach is on the right track.

It is in fact possible to avoid the conflict between *FRICATIVE and the onset sonority constraints by changing the input fricative into a stop. However, this would violate the faithfulness constraint in (18) (McCarthy & Prince, 1999):

(18) IDENT-CONTINUANT: Segments in correspondence must have identical [±cont] values

For LP65, IDENT-CONTINUANT (abbreviated as IDENT-CONT) must dominate *G-ONS, so that a glide surfaces rather than a 'stopped' version of the fricative. This ranking argument is illustrated in Tableau 11.

TABLEAU 11. IDENT-CONT>>*G-ONS

/slip/	IDENT-CONT	*G-ONS
a. [tip]	*!	
b. ☞ [jip]		*

The reverse ranking of onset sonority constraints and IDENT-CONT would yield selection of the fricative rather than the sonorant, with the fricative realized as a stop, as in the failed candidate in Tableau 11. This pattern is attested in the speech of Amahl (Smith, 1973; see Goad & Rose, in press for OT analyses), as well as in the following data (Subject 13, age 4;8; see also Barlow, 1997):

(19) Subject 13: Fricative + sonorant → stop

[bɔgi]	'frog (dimin.)'	[baɪ]	'fly'
[tʌp]	'shrub'	[toʊ]	'throw'

The ranking between Ident-Cont and *Fricative can be determined by whether singleton fricatives surface as stops or fricatives. Both Subject 13 and LP65 realize all singleton fricatives as stops, thus showing that *Fricative dominates Ident-Cont. The word-final consonant in Tableau 12 illustrates this ranking for LP65's production of *sneeze*.

TABLEAU 12. *Fricative>> Ident-Cont

/sniz/	*Fricative	Ident-Cont
a. ☞ [nid]		*
b. [niz]	*!	

In contrast, Trevor and Julia, as well as Gitanjali and Subject 25, realize singleton fricatives faithfully. For them, Ident-Cont dominates *Fricative, as shown in Tableau 13, which uses Julia's pronunciation of *sneeze* as [nis] as a representative example.

TABLEAU 13. Ident-Cont>> *Fricative

/sniz/	Ident-Cont	*Fricative
a. ☞ [nis]		*
b. [nit]	*!	

From a theoretical standpoint, LP65's data are interesting because they demonstrate a conspiracy (Kisseberth, 1970) between stopping of singleton fricatives and deletion of fricatives from clusters as a means of satisfying *Fricative.

To complete the account, deletion must be ruled out for singletons, which can be accomplished by ranking Max above Ident-Cont, as in Tableau 14.

TABLEAU 14. MAX>> IDENT-CONT

/sniz/	MAX	IDENT-CONT
a. ☞ [nid]	*	*
b. [ni]	**!	

The conspiracy between fricative deletion and stopping in LP65's system is thus produced by the dominance of *FRICATIVE over both the onset sonority constraints and IDENT-CONT, as in the partial hierarchy in (20).

(20) Ranking of *FRICATIVE for LP65
*FRICATIVE, *COMPLEX >> MAX >> IDENT-CONT >> *G-ONS

The ability to formally express conspiracies of this sort is an important virtue of constraint-based theories, and sets them apart from purely rule-based frameworks. This has long been noted in the child phonology literature; Smith (1973) cites it as a failing of his rule-based analysis that it did not capture the functional unity of the various rules that eliminated clusters from Amahl's surface forms.

This is also an advantage of the present analysis over the constraint-based one presented in Goad & Rose (in press), who focus on cases in which only [s] is deleted from onset clusters in contravention of the sonority pattern, while other fricatives continue to be chosen instead of sonorants. They treat avoidance of [s] in cluster reduction as being due to a 'head-faithfulness' constraint, which preserves the leftmost member of any onset cluster, with the exception of extraprosodic [s]. Not only does this fail to extend to cases where all fricatives are deleted from clusters (as in LP65's data), but it also fails to relate fricative deletion to stopping, and hence to express the conspiracy between them as a means of removing fricatives from the surface inventory.

An account based on *FRICATIVE can be extended to the cases in which [s] seems to behave differently from other fricatives, as Goad & Rose (in press) show in an analysis of Amahl's data (Smith, 1973), which they construct to compare with their head-faithfulness account. They argue against the *FRICATIVE analysis because it 'circumvents' the fixed ranking of the onset sonority constraints by 'exploiting [the] rankable equivalent' of *F-ONS. However, *FRICATIVE is not strictly speaking equivalent to *F-ONS: it applies in a context-free fashion, rather than to onsets only. As we noted at the outset of this section, 'stopping' patterns in child speech require a context-free constraint, since fricatives are eliminated from coda as well as onset position; similarly, there are fully developed languages that lack fricatives in all positions. Thus, the *Fricative constraint is required independently of *F-Ons, and factorial typology predicts that in some child systems, it will be ranked above it, just as we have found.

It might also be argued that factorial typology does not allow for *Fricative to dominate *F-Ons, on the grounds that general constraints cannot outrank more specific ones, in a recasting of the elsewhere principle (Kiparsky, 1973) within optimality theory (Dinnsen & O'Connor, 2001). However, in its standard form (Prince & Smolensky, 1993), optimality theory does not include an elsewhere condition on constraint ranking. Prince (1996) further explicitly argues that such a ranking condition is unnecessary, and de Lacy (2002) shows that rankings of general over specific constraints are even required in some cases. We thus maintain the standard position, and suggest that the richness of the child cluster reduction typology supports the absence of an elsewhere condition from optimality theory. We leave it as an open question whether the restrictions on child typology discussed in Dinnsen & O'Connor (2001) can be captured without such a ranking condition.

*Dorsal *effects in cluster reduction*

Another constraint that conflicts with sonority-based onset selection is *Dorsal (Prince & Smolensky, 1993; Barlow, 1997), defined in (21):

(21) *Dorsal: Consonants are not specified as dorsal (velar)

In child phonology, this constraint is responsible for 'fronting', in which velars are realized as coronals, as in LP65's data in (22):

(22) LP65: 'Velar fronting' data

Child form	*Adult target*	*Child form*	*Adult target*
[d̥ɔb]	'cob'	[dʌt]	'duck'
[deɪː]	'gate'	[wædin]	'wagon'
[doʊː]	'girl'	[bʊt]	'book'

As with the case of *Fricative, the most extreme case of a *Dorsal effect is in a language that lacks velars entirely, such as Tahitian (Tryon, 1970). The consonantal inventory of Tahitian, as shown in (23), consists of labials, coronals, and glottals, but no velars:

(23) Tahitian consonants

p	t	ʔ
f		h
v		
m	n	
	r	

For the sonority pattern of cluster reduction to apply to velar-initial clusters, *Dorsal must be dominated by the onset sonority constraints, as illustrated in Tableau 15:

TABLEAU 15. *L-Ons>> *Dorsal

/klin/	*L-Ons	*Dorsal
a. [lin]	*!	
b. ☞ [kin]		*

In LP65's phonology, however, this constraint dominates the onset sonority constraints, as evidenced by the data in (24):

(24) LP65: Target velar-initial clusters

Type	*Child form*	*Adult target*	*Child form*	*Adult target*
gl	[jʌː]	'glove'	[joʊb]	'globe'
kl	[jin]	'clean'	[joʊː]	'clothes'

Tableau 16 shows that LP65's production of *globe* as [joʊb] requires *Dorsal to dominate *G-Ons (an undominated *Liquid is again implicit here).

TABLEAU 16. *Dorsal>> *G-Ons

/gloʊb/	*Dorsal	*G-Ons
a. ☞ [joʊb]		*
b. [g̊oʊb]	*!	

Here we have a conspiracy between fronting and deletion as responses to *Dorsal, which can be treated in the same way as the *Fricative conspiracy. This involves appealing to the constraint Ident-Place, as defined in (25).

(25) Ident-Place: Consonants in correspondence have identical place of articulation

In Tableau 17, the analysis of velar deletion from clusters is completed by fixing the ranking of Ident-Place above *G-Ons, so as to choose velar deletion rather than fronting in this context. Notably, the reverse ranking of these constraints is also attested, as in Subject 25's pronunciation of *queen* as [din] (see further data in (2)).

TABLEAU 17. Ident-[Place]>> *G-Ons

/gloʊb/	Ident-[Place]	*G-Ons
a. ☞ [joʊb]		*
b. [d̥oʊb]	*!	

For fronting of singleton velars, *Dorsal must be ranked above Ident-Place, as must Max, the latter to rule out deletion. Tableau 18 shows the effects of these rankings.

TABLEAU 18. *Dorsal, Max>> Ident-Place

/kʰɔb/	*Dorsal	Max	Ident-Place
a. ☞ [dɔb]			*
b. [ɔb]		*!	
c. [g̊ɔb]	*!		

The conspiracy between fronting and deletion of velars in LP65's system is thus captured by having *Dorsal outrank both Ident-Place and *G-Ons, as shown in (26):

(26) Ranking of *Dorsal in LP65's system
*Dorsal, Max >> Ident-Place >> *G-Ons

LP65 thus uses deletion of particular segments from a cluster in order to satisfy *Fricative and *Dorsal. However, this strategy is not sufficient to deal with target /sk-/ clusters, which consist of both a fricative and a velar. In this case, he does alter the featural makeup of one of the segments, producing a coronal stop:

(27) LP65: Fricative + velar clusters

Child form	*Adult target*	*Child form*	*Adult target*
[d̥u]	‘school’	[d̥ʌnt]	‘skunk’
[d̥ʊːt]	‘skirt’	[d̥ɔːt˺]	‘scarf’

It is impossible to tell whether the fricative is being stopped, or the velar is being fronted. In either case, this pattern is already accounted for by existing rankings, since both IDENT-PLACE and IDENT-CONT are dominated by *DORSAL and *FRICATIVE respectively.

In Julia’s system (as well as Gitanjali’s and Trevor’s) *DORSAL has no effect. Her fricative + velar data, presented in (28), show that the constraint must rank at the bottom of the hierarchy, beneath *F-ONS, since the velar is produced instead of the fricative. A tableau illustrating this ranking argument appears in Tableau 19:

(28) Julia: Fricative + velar clusters

Type	*Child form*	*Adult target*	*Age*
sk	[ʌp + kai]	up (in the) sky	1;9.17
	[pe + ku]	play school	1;11.25

TABLEAU 19. *F-ONS>> *DORSAL

/skai/	*F-ONS	*DORSAL
a. [sai]	*!	
b. ☞ [kai]		*

Labial faithfulness in onset selection

The preceding section showed that a dispreference for dorsals can override sonority based onset selection. In this section, we show that a preference for labial place of articulation can also play a similar role.

In both child phonology and fully mature systems, a preference for labial place is often manifested in assimilation patterns. In child phonology, consonant place harmony regularly targets coronals to the exclusion of labials (Smith, 1973; Stoel-Gammon & Stemberger, 1994; Dinnsen, Barlow & Morrisette, 1997; Bernhardt & Stemberger, 1998; Pater, 2002). This is also seen in Julia's data, in which coronals, but not labials, assimilate to a following velar, as in (29) and (30):

(29) Julia's consonant harmony: coronals assimilate

Child form	*Adult target*	*Age*
[gɔgi]	'doggie'	1;7.13
[gɔgi]	'doggie'	1;5.24
[gʌk]	'duck'	1;7.12
[gʌk]	'duck'	1;7.19
[gʌk]	'duck'	1;8.0
[kak]	'socks'	1;8.17
[kɪgos]	'tickles'	1;9.28
[kɪgəs]	'tickles'	1;10.1

(30) Julia's consonant harmony: labials do not assimilate

Child form	*Adult target*	*Age*
[dædi+bʊk]	'daddy book'	1;8.2
[bʊk]	'book'	1;9.10
[baks]	'box'	1;7.24
[bak+hʌbi]	'box heavy'	1;8.23
[bʌko]	'buckle'	1;7.9
[bʌkə]	'buckle'	1;8.12

For present purposes, we take the constraint motivating consonant harmony to be AGREE defined in (31) (*cf.* Pater, 2002).

(31) AGREE: Consonants within a word must agree in place of articulation

As the labial faithfulness constraint, for now we use the informal FAITH-LAB constraint, violated by deletion or assimilation of an underlying labial (see below for formalization of this constraint).

When the initial consonant is a coronal (Tableau 20), FAITH-LAB does not apply, and AGREE chooses the candidate displaying assimilation. On the other hand, when the initial consonant is a labial (Tableau 21), the dominance of FAITH-LAB blocks assimilation.

TABLEAU 20. *Initial coronal:* FAITH-LAB>> AGREE

/dʌk/	FAITH-LAB	AGREE
a. ☞ [gʌk]		
b. [dʌk]		*!

TABLEAU 21. *Initial labial:* FAITH-LAB>> AGREE

/bʊk/	FAITH-LAB	AGREE
a. [gʊk]	*!	
b. ☞ [bʊk]		*

In fully developed languages, labials can similarly be immune to assimilation that affects other segments. De Lacy (2002), drawing on descriptive work by Owens (1985), shows that in Harar Oromo, an Ethiopic language, root-final dorsals, but not labials, assimilate to a following suffixal coronal. Suffixes are apparently all coronal-initial, so it is impossible to assess whether coronals assimilate in this environment as well, coronal-final prefixes do assimilate (de Lacy, 2002: 334). Examples of assimilation in Harar Oromo showing the asymmetry between labials and dorsals appear in (32) and (33).

(32) Assimilation in Harar Oromo: Dorsals assimilate

/meːk' + te/	→	[meːtt'e]	'you turned'
/d'iːk' + na/	→	[d'iːjnna]	'we wash'
/fiːg + te/	→	[fiːjdde]	'you escaped'
/beːx + ne/	→	[beːnne]	'we know'

(33) Assimilation in Harar Oromo: Labials do not assimilate

/k'ab + ta/	→	[k'abda]	'you have'
/tʃ'ap' + ti/	→	[tʃ'ap't'i]	'it (fem.) breaks'
/gub + tan/	→	[gubdan]	'you (pl) burn something'

Though we will not provide an analysis of the Harar Oromo pattern (*cf.* de Lacy, 2002), it can be accounted for in a manner similar to Julia's consonant harmony, with FAITH-LABIAL dominating a constraint motivating assimilation, this time applying to adjacent consonants (see Pater, 2002 for discussion of parallels and differences between child consonant harmony and adult local place assimilation, as well as an account of directionality and trigger effects).

Faithfulness to labials has also been documented in syllable truncation in child language. When an initial stressless syllable is deleted, the choice of whether the onset of the initial or the second syllable is retained is usually determined by sonority (Fikkert, 1994; Pater, 1997), but it sometimes also depends on place of articulation: labials are often chosen rather than coronals or dorsals (Smith, 1973; Fikkert, 1994). We find evidence of the same effect in Julia's data shown in (34), though as for other children, relevant cases are somewhat sparse once we remove those that can be explained on the basis of the preference for low onset sonority (e.g. [bun] *balloon*), or due to adjacency of the consonant with the stressed syllable ([medo] *tomato*).

(34) Julia's initial stressless syllable deletion: labials chosen

Child form	*Adult target*	*Age*
[pedo]	'potato'	2;0.25
[peto]	'potato'	2;1.20

Because this case is very similar to the onset cluster reduction cases we will discuss shortly, we will also not provide an explicit analysis here (see Pater, 1997 for analysis of a similar case involving Dorsal faithfulness).

For the sonority pattern to obtain, Faith-Lab must rank beneath the onset sonority constraints. Tableau 22 demonstrates this for a /sw-/ cluster (Subject 25's [sip] for *sweep*), on which Faith-Lab and *G-Ons make conflicting demands; they will similarly conflict with any other cluster consisting of a non-labial obstruent and a labial sonorant.

TABLEAU 22. *G-Ons>> Faith-Lab

/swip/	*G-Ons	Faith-Lab
a. ☞ [sip]		*
b. [wip]	*!	

Both Julia and LP65 provide evidence of the reverse ranking of these constraints. Unfortunately, Julia produces very few cases of reduced clusters in which the second member of the adult target is a labio-velar glide [w]. However, if we take the American English rhotic [r] to be underlyingly labial in at least early child phonology (Barlow, 1997; Gnanadesikan, in press), then there are considerably more data to draw on. This assumption is reasonable, given that American English [r] does involve lip rounding (Ladefoged, 2000: 55), and that it is often realized as [w] by children, including those under study here. The [w] produced by children for /r/ and /w/ may be acoustically (although not necessarily perceptually) distinct (see Sharf & Ohde, 1983 for a review of relevant literature), but the substitute for /r/ does seem to be markedly rounded. As we will see shortly, the child language data from cluster reduction do provide strong support for the assumption that /r/ is underlyingly labial.

There are three patterns in Julia's reduction of clusters consisting of a non-labial obstruent and a labial sonorant. In the first, shown in (35), the labial sonorant is chosen:

(35) Julia: Reduced non-labial obstruent + labial sonorant clusters: Pattern 1

Type	*Child form*	*Adult target*	*Age*
dr	[wɪk]	'drink'	1;9.19
	[waɪv]	'drive'	1;9.14
	[wap̚t ət]	'dropped it'	1;10.23
gr	[wæmə]	'grandma'	1;9.14
	[wips]	'grapes'	1;9.18
	[wʌni]	'Grundy'	1;8.18
	[rəni]	'Grundy'	1;8.19
kr	[wækə]	'cracker'	1;8.7
sw	[wɪŋ]	'swing'	1;7.1

These cluster types also sometimes displayed coalescence, or fusion, preserving place and continuancy of C_2, and obstruency of C_1. The data in (36) illustrate this second pattern. That coalescence between a non-labial obstruent and /r/ yields a labial obstruent would be difficult to explain without assuming that /r/ is underlyingly labial. (See below for further discussion.)

(36) Julia: Reduced non-labial obstruent + labial sonorant clusters: Pattern 2

Type	*Child form*	*Adult target*	*Age*
kr	[aʊfːim]	'ice cream'	1;8.21
	[faɪːn]	'crying'	1;10.8
	[fɔkəs]	'crackers'	1;10.10
ʃr	[moə fɪmp]	'more shrimp'	2;0.24
sw	[fin]	'swing'	1;9.14
tr	[fʌk]	'truck'	1;9.25

Finally, these same clusters also exhibited the sonority pattern, as illustrated in (37):

(37) Julia: Reduced non-labial obstruent + labial sonorant clusters: Pattern 3

Type	*Child form*	*Adult target*	*Age*
dr	[dʌm]	'drum'	1;8.24
kr	[bebi + kai]	'baby cry'	1;6.24
	[aːki.m]	'ice cream'	1;8.4
tr	[biːkʌk]	'big truck'	1;8.2

Summing across the various non-labial + labial sonorant clusters, we find the following relative frequencies of occurrence for each of the three patterns of cluster reduction:

(38) Frequencies of occurrence

Pattern 1	*Pattern 2*	*Pattern 3*
53% (24/45)	20% (9/45)	27% (12/45)

Patterns 1 and 2 were only attested of clusters of this type; other clusters, except /s/-nasal, uniformly displayed the sonority pattern (see (47) and (48) in EMERGENT SONORITY PATTERN for further data). It is impossible to know for certain whether the occurrence of these three different patterns for this cluster type is reflective of developmental stages, phonological conditioning, or simply free variation. Pattern 3 seems to occur earlier, but it overlaps in time with the others. Pattern 1 seems to occur mostly with voiced obstruents, and the others with voiceless, but there is again overlap. In this section we will account for the most frequently attested Pattern 1, and will abstract away from the voicing of the obstruent. We will return to Pattern 2 below in LABIAL-PRESERVING COALESCENCE.

For LP65, the labial is consistently chosen, again assuming that /r/ is labial. In his case, /sw-/ clusters, as well as several clusters with /r/ as a second member are uninformative, since the sonority pattern would be ruled out by *Fricative. However, for the remaining cluster types, LP65 does consistently produce the labial sonorant.

(39) LP65: Reduced non-labial obstruent + labial sonorant clusters

Type	*Child form*	*Adult target*
tw	[wɪːn]	'twins'
kw	[wiːn]	'queen'
dr	[waɪb]	'drive'
tr	[wʌt]	'truck'
gr	[woʊ]	'grow'
kr	[waɪ]	'cry'

As shown in Tableau 23 for Julia's production of *swing* as [wɪŋ], this pattern of labial selection is produced if Faith-Lab outranks *G-Ons.

TABLEAU 23. Faith-Lab>> *G-Ons

/swiŋ/	Faith-Lab	*G-Ons
a. [siŋ]	*!	
b. ☞ [wiŋ]		*

At this point, an excursus on the formalization of 'FAITH-LAB' is necessary, before we return to the analysis of the child data. The formal statement of 'FAITH-LAB' must have two properties. First, the constraint must be violated under deletion. Featural Identity constraints of the type employed above (i.e. IDENT-CONT and IDENT-PLACE) do not have this property, as they only specify that segments in correspondence must be featurally equivalent. When an Input segment is deleted, it has no Output correspondent, and so IDENT constraints are vacuously satisfied. As noted by McCarthy & Prince (1999), an alternative approach to featural faithfulness is to extend MAX-type constraints to the featural level. Several researchers have subsequently found arguments for this approach from phonologies of adult languages, such as Lombardi (2001), though others find support for the IDENT theory (e.g. Alderete, Beckman, Benua, Gnanadesikan, McCarthy & Urbanczyk, 1999; de Lacy, 2002). The arguments in each direction tend to be based on whether an analysis requires segmental deletion to entail violation of featural faithfulness. Labial selection provides child language support for a MAX-FEATURE constraint:

(40) MAX-LABIAL An Input Labial feature must have an Output correspondent

It should be noted that the cases dealt with earlier in the paper, in which deletion of the fricative or dorsal occurs instead of featural change, are more readily captured with IDENT-FEATURE (see further Bernhardt & Stemberger, 1998 on 'non-minimal deletion' in child language). In child phonology, just as in phonological theory in general, reconciliation of these opposing sets of evidence remains an outstanding issue.

The second property that this constraint must have is that it must penalize the migration of the labial feature from the sonorant to the obstruent (e.g. /tr/→[p], an attested, but different, pattern). This is a property usually associated with IDENT-FEATURE constraints, rather than MAX-FEATURE. Following Barlow (1997), we will build this into the statement of the MAX-LABIAL constraint (see also Causley, 1999), though it would also be possible to rely on an independent STAY constraint that performs this function (McCarthy, 1999).

(41) MAX-LABIAL An Input Labial segment must correspond to an Output Labial

Labial-preserving coalescence

Deletion of the non-labial is not the only means by which MAX-LAB can be satisfied. Coalescence between a labial and a non-labial (e.g. [fun] for *spoon*) is frequently attested in child language (see Smith, 1973; Chin & Dinnsen, 1992; Smit, 1993; Barlow, 1997). Amongst the children already discussed

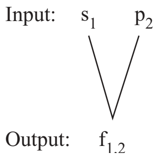

Fig. 1. Input-Output correspondence for coalesced segments.

here, labial-preserving coalescence is produced not only by Julia, but also by Gitanjali and LP65. Each of these children's coalescence patterns is different, however. In this section, we provide an analysis of the circumstances under which coalescence occurs.

Max-Lab, like McCarthy & Prince's (1999) general Max constraint, only demands that Input segments have an Output correspondent, not that there be a unique Output segment corresponding to each Input segment. In coalescence, two Input segments correspond to a single Output segment, as in Figure 1, where subscripts are used to indicate segments in correspondence. To block coalescence McCarthy & Prince (1999) invoke Uniformity:

(42) Uniformity: No segment in the Output has multiple correspondents in the Input

Outside of labial-driven coalescence, deletion, rather than fusion, occurs in the systems of all three children. Thus, we assume that Uniformity always dominates the general Max constraint in the grammars being analysed here. The effect of this ranking is demonstrated in a tableau for a /kl-/ cluster, which through coalescence could gain the less marked coronal place feature of the glide, and the less marked obstruency of the initial consonant:[2]

TABLEAU 24. Uniformity>> Max

/$k_1l_2$in/	Uniformity	Max
a. ☞ [$k_1$in]		*
b. [$t_{1,2}$in]	*!	

---

[2] It might not be necessary to use this ranking to rule out coalescence outside of Max-Lab effects, since other constraints could be invoked to ensure that the outcome resembles deletion (see Gnanadesikan, in press).

For selection of the labial sonorant to occur instead of coalescence, both MAX-LAB and UNIFORMITY must dominate *G-ONS, as shown in Tableau 25. Since the ranking between MAX-LAB and UNIFORMITY has no effect on the outcome here, they are left unranked.

TABLEAU 25. MAX-LAB, UNIFORMITY>> G-ONS

/s$_1$w$_2$ɪŋ/	MAX-LAB	UNIFORMITY	*G-ONS
a. [s$_1$ɪŋ]	*!		
b. [f$_{1,2}$ɪŋ]		*!	
c. ☞ [w$_2$ɪŋ]			*

If the ranking of *G-ONS and UNIFORMITY is reversed, coalescence will obtain. This outcome is shown for Julia's production of /swɪŋ/ as [fɪn], as shown in Tableau 26.

TABLEAU 26. MAX-LAB, *G-ONS>> UNIFORMITY

/s$_1$w$_2$ɪŋ/	MAX-LAB	*G-ONS	UNIFORMITY
a. [s$_1$ɪŋ]	*!		
b. ☞ [f$_{1,2}$ɪŋ]			*
c. [w$_2$ɪŋ]		*!	

Given that coalescence and labial selection both occur for the same word, these patterns seem to be in free variation, which can be produced by leaving *G-ONS and UNIFORMITY unranked in Julia's grammar, with a ranking between them being randomly chosen each time the grammar is deployed (see e.g. Anttila, 1997). To limit the choice to coalescence and labial selection, and to rule out the sonority pattern, MAX-LAB would have to be ranked above those two, as in (43).

(43) Ranking producing variation between deletion and coalescence
MAX-LAB >> *G-ONS, UNIFORMITY

Julia does also produce the sonority pattern on some occasions (see (37)). This pattern is mostly produced earlier than labial selection and coalescence, suggesting a developmental progression in which MAX-LAB initially ranks beneath *G-ONS, and eventually rises above it in the hierarchy. Since the data are not perfectly clear on this point, however, we will not dwell on it, and will provide an analysis only of the labial selection and coalescence patterns, which do clearly co-occur chronologically.

Gnanadesikan (in press) points out that forms that Gitanjali produced such as those in (44) provide evidence of labial preservation (see also Chin & Dinnsen, 1992 for similar patterns in delayed phonological development). When the second member of the target cluster is a labial, the output segment combines the voicing, continuancy, and obstruency of the first segment with the place of the second segment. As Gnanadesikan notes, the fact that coalescence with /r/ results in a labial supports the notion that /r/ is underlyingly labial in (child) English. The data in (44) are repeated to show the usual pattern of deletion of the more sonorous second segment:

(44) Gitanjali: Labial preservation

a.	[pi]	‘tree’	[bep]	‘grape’	[fɛw]	‘smell’	[paɪt]	‘quite’
b.	[kin]	‘clean’	[piz]	‘please’	[so]	‘snow’	[sɪp]	‘slip’
	[fɛn]	‘friend’						

Under the present approach, Gitanjali’s system would be characterized by a ranking of MAX-LAB and *G-ONS above UNIFORMITY, as in Tableau 26. Because coalescence also applies between a fricative and a nasal (i.e. [fɛw] for /smɛl/), we have evidence for it being ranked beneath *N-ONS, as in Tableau 27:

TABLEAU 27. *N-ONS>> UNIFORMITY

/s_1m_2ɛw/	*N-ONS	UNIFORMITY
a. [m_2ɛw]	*!	
b. ☞ [$f_{1,2}$ɛw]		*

In Julia's system, the ranking between UNIFORMITY and *N-ONS is indeterminate, since fricatives are already dispreferred relative to nasals due to the ranking of *FRICATIVE above *N-ONS.

Both Julia and Gitanjali display labial-preserving coalescence, which we attribute to a shared ranking of MAX-LAB and onset sonority constraints above UNIFORMITY. But what about the differences between their patterns of cluster reduction? First, Gitanjali never displays labial selection, instead always applying coalescence to non-labial obstruent+labial sonorant clusters.[3] This is due to UNIFORMITY being fixed in rank beneath *N-ONS in her system, which rules out labial selection (see Tableau 27). For Julia, UNIFORMITY variably dominates *G-ONS, so that labial selection does occur variably (see Tableau 25 and Tableau 26). In labial selection, MAX-LAB is satisfied at the expense of the onset sonority constraints; in Gitanjali's data, however, MAX-LAB and onset sonority are both respected by violating UNIFORMITY.

The second difference between their patterns concerns the outcome of coalescence for stop+approximant clusters. Julia preserves the continuancy of the approximant (e.g. [fim] *cream*), while Gitanjali preserves the continuancy of the stop ([paɪt] *quite*). As de Lacy (2002) shows, coalescence patterns vary cross-linguistically in whether the marked or the unmarked value of a feature is preserved. Here, Julia preserves the marked [+cont] value, and Gitanjali preserves the unmarked [−cont] value.[4] One way of accounting for this difference is to split IDENT-CONT into separate IDENT[+CONT] and IDENT[−CONT] constraints, as in (45a) and (45b) (see McCarthy & Prince, 1999 and Pater, 1999 for justification for this elaboration of faithfulness theory; see de Lacy, 2002 for another approach).

(45) a. IDENT[+CONT]
A correspondent of an Input segment specified as [+cont] must be [+cont]
b. IDENT[−CONT]
A correspondent of an Input segment specified as [−cont] must be [−cont]

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[3] Clusters consisting of a non-labial obstruent and a labial sonorant do sometimes follow the sonority pattern in Gitanjali's data. This occurs consistently when the following vowel is rounded (e.g. [dɒ] *draw*), and optionally when the following consonant is labial. Gnandesikan (in press) attributes this to an OCP-LABIAL constraint.

[4] A reviewer points out that this analysis requires that approximants be underlyingly specified as [+continuant] even though this feature is non-contrastive, and also that the analysis of labial selection requires /r/ to be underlyingly specified for [+labial], which would similarly appear to be non-contrastive. Within optimality theory, this is not a problem, however. Contrastiveness is determined through interaction of markedness and faithfulness constraints, and is not stipulated as a property of the lexicon (see esp. Kirchner, 1997; McCarthy, 2002). On the more specific issue of the specification of approximants as [+continuant], see Hume & Odden (1996).

In a situation in which a stop and an approximant coalesce, one of these constraints will be violated, since a [−cont] stop and the [+cont] approximant are in correspondence with a single output segment. Julia ranks Ident[+Cont] over Ident[−Cont], so that the [+cont] value of the approximant is preserved, while Gitanjali's data evince the opposite ranking. Both children rank Ident[+Cont] over *Fricative and *F-Ons, thus allowing fricatives and approximants to surface faithfully outside of the coalescence context (that is, Ident[+Cont] takes the place of Ident-Cont in Tableau 13, and elsewhere in the earlier discussion).[5]

In her analysis of Gitanjali's data, Gnanadesikan (in press) treats all cases of cluster simplification as coalescence (even the apparent cases of deletion in (44)), and then uses Ident and onset sonority constraints to determine the featural specification of the resulting consonant. In this way, an Ident-Lab constraint is able to force the retention of the labial feature of the approximant in the cases in (44b). This analysis, however, will not extend to the labial selection pattern displayed by LP65 and Julia. In labial selection, all of the features of a labial sonorant are retained (modulo gliding of liquids). One would therefore need to rank a faithfulness constraint that forces retention of a sonorant's manner features above *G-Ons. However, this would predict that sonorant features would always be kept, even when not required by labial faithfulness. As we will see in the next section, this is not the case in LP65's and Julia's data: when labial faithfulness is not at issue, the obstruent does surface. Thus, it appears that a Max-Lab constraint is indeed required to deal with labial selection.

LP65 employs coalescence to avoid a conflict between Max-Lab and *Fricative, which are both unviolated in his system. When a cluster consists of a labial fricative and a coronal sonorant, Max-Lab would prefer the preservation of the fricative, and *Fricative would prefer the preservation of the sonorant. As the data in (46) show, LP65 satisfies both of these constraints by producing a segment combining the place specification of the initial consonant with the sonorancy of the second element.

(46) LP65: Target fricative-sonorant clusters

Type	*Child form*	*Adult target*	*Child form*	*Adult target*
fl	[waɪ]	'fly'	[waʊwiː]	'flower'
	[wʊːt]	'flute'	[wɔə]	'floor'

This establishes a ranking between Max-Labial and Uniformity, as well as between *Fricative and Uniformity, both illustrated in Tableau 28.

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[5] One remaining issue here is that the ranking of Ident[−Cont] ≫ Ident[+Cont] predicts that an /sm-/ cluster should surface as [p] or [m], insofar as nasals are [−cont]; but /sm-/ in fact surfaces as [f] in Gitanjali's data. To deal with this, Ident[−Cont] could be relativized either to initial position (see e.g. Beckman, 1998), or to oral stops.

TABLEAU 28. MAX-LAB, *FRICATIVE>> UNIFORMITY

/f_1l_2aɪ/	MAX-LAB	*FRICATIVE	UNIFORMITY
a. ☞ [$w_{1,2}$aɪ]			*
b. [j_2aɪ]	*!		
c. [f_1aɪ]		*!	

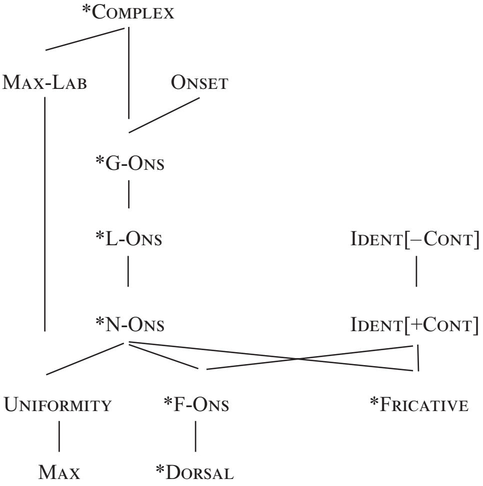

Fig. 2. Constraint hierarchy for Gitanjali.

Emergent sonority pattern

In Figures 2–4, we present hierarchies combining the rankings we have motivated for the systems of cluster reduction for Gitanjali, Julia, and LP65. The hierarchies for Julia and LP65 provide a complete account of their patterns of cluster reduction (see note 2 on the further complexities in Gitanjali's system). For Julia, we have provided the ranking that yields labial selection, rather than coalescence (see Tableau 25 and Tableau 26). For LP65, there is no evidence for the relative rank of IDENT[+CONT] and IDENT[–CONT], so we have used a single IDENT-CONT constraint. In addition to the rankings motivated above, we have also included a ranking of *LIQUID

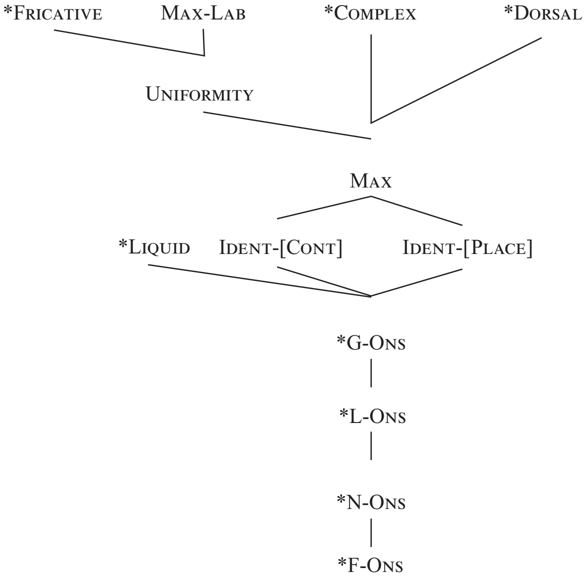

Fig. 3. Constraint hierarchy for LP65.

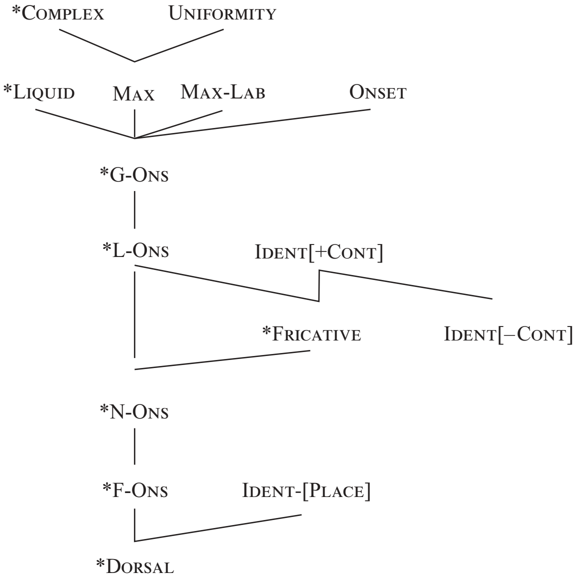

Fig. 4. Constraint hierarchy for Julia.

above *G-Ons, which is responsible for the replacement of liquids by glides in Julia's and LP65's data (/r/, /l/→[w], [j]) (see also Barlow, 1997).

In Gitanjali's system, the onset sonority constraints are free to determine the outcome of cluster reduction, because they are not dominated by any relevant conflicting constraints. In Julia's and LP65's systems, however, the conflicting constraints *Dorsal, *Fricative, and Max-Lab override the demands of onset sonority, and deviations from the sonority pattern are produced. As we pointed out above in sonority-based onset selection, though, violation does not entail inactivity in optimality theory. A constraint can be violated because of the demands of a higher ranked one, but it can still have an effect when the dominating constraint does not decide the outcome. Thus, we would predict that the effects of the onset sonority constraints should emerge in Julia's and Trevor's data when the conflicting constraints do not determine the outcome of cluster reduction.

In Julia's system, Max-Lab is satisfied at the expense of onset sonority. There are two circumstances in which Max-Lab fails to decide the outcome. The obvious one is when there is no labial in the target cluster. Because Max-Lab is not violated, the decision is passed down to the onset sonority constraints, which choose the less sonorant segment from the target cluster, as illustrated in Julia's data in (47) and in Tableau 29:

tableau 29. Max-Lab>> *G-Ons (*activity of dominated constraint*)

/klaʊn/	Max-Lab	*G-Ons
a. ☞ [kaʊn]		
b. [jaʊn]		*!

(47) Julia's sonority pattern data: non-labial clusters

Type	*Child form*	*Adult target*	*Age*
gl	[dædi+gæθəs]	daddy's glasses'	1;10.10
kl	[kinəp]	'clean up'	1;10.25
	[gak]	'clock'	1;8.11
	[kaʊn]	'clown'	1;9.9
st	[ʌpəteəs]	'up the stairs'	1;9.5
	[tiv]	'Steve'	1;11.24
	[ton]	'stone'	1;8.17

sk	[ʌp+kai]	'up (in the) sky'	1;9.17
	[pe+ku]	'play school'	1;11.25
sl	[sip]	'sleep'	1;8.27
	[sɪpʊs]	'slippers'	1;8.30
	[saɪːt]	'slide'	1;11.16

The other instance in which Max-Lab will fail to decide is when both segments are labial. In this case, candidates in which either of the consonants is deleted will both violate Max-Lab. In cases in which two candidates tie on a constraint, neither one is ruled out, and both survive to be evaluated by the lower ranked constraints, here the onset sonority constraints. In Julia's data in (48), we see that two-labial clusters do indeed reduce to the obstruent. Tableau 30 shows how the onset sonority constraint chooses the obstruent for Julia's production of *froggie*. This tableau also illustrates the need to rank *Complex above Max-Lab, since otherwise a complex onset as in candidate (a) would wrongly emerge as optimal.

(48) Julia's sonority pattern data: labial-labial clusters

Type	*Child form*	*Adult target*	*Age*
br	[bʌʃ]	'brush'	1;9.4
	[baɪən]	'Brian'	1;7.20
	[bokən]	'broken'	1;8.21
pr	[pɪdi]	'pretty'	1;8.0
	[pɪnsɛs]	'princess'	2;2.23
fr	[fɔgi]	'froggy'	2;0.23
	[ai hæf ə fɛko]	'I have a freckle'	2;1.19

TABLEAU 30. *Complex>> Max-Lab>> *G-Ons

/frɔgi/	*Complex	Max-Lab	*G-Ons
a. [frɔgi]	*!		
b. ☞ [fɔgi]		*	
c. [wɔgi]		*	*!

With the onset sonority constraints dominated by so many conflicting constraints in LP65's phonology, their effects are quite limited. They are not inactive, however: we do see their influence when the target cluster consonants are equivalent with respect to Max-Lab, *Dorsal, and *Fricative. This occurs when the consonants in the cluster are both labials, and neither one is a fricative. The data in (49) confirm the prediction of Tableau 30 that these should reduce to the stop.

(49) LP65's sonority pattern data: labial-labial clusters

Type	*Child form*	*Adult target*	*Child form*	*Adult target*
br	[bɛd]	'bread'	[bʌˀ]	'brush'
pr	[b̥ɪɾi]	'pretty'	[b̥aɪ]	'prize'

CONCLUSION

The sonority pattern of cluster reduction requires that the onset sonority constraints dominate any conflicting constraints. By factorial typology, it is predicted that other children's systems should display the effects of the reverse rankings, in which the conflicting constraints dominate onset sonority. Here we showed that three constraints, active in other child language processes and cross-linguistically, do play a role in cluster reduction: *Frica-tive, *Dorsal, and Max-Labial. Furthermore, we argued that ranking is the appropriate way to characterize the interaction of these constraints with the onset sonority constraints, since the onset sonority constraints do continue to play a role when they are dominated by these constraints.

The interaction of these constraints with onset sonority, and related faithfulness constraints, was used to account for the systems of cluster reduction of a normally developing child, Julia, and a child with a phonological delay, LP65. We also showed how reranking could characterize the relevant differences between their systems and that of another normally developing child Gitanjali, who displayed the sonority pattern along with the effects of labial faithfulness. The analyses are summarized in Table 3, which schematically depicts the effects of each of the rankings in choosing the outcome of cluster reduction, and provides references to the relevant tableaux in the paper. For conciseness, we have omitted the Ident constraints, and have included only the rankings for Julia's labial selection, and not coalescence.

Factorial typology and emergent constraint activity are unique to optimality theory, and set it apart from other constraint-based theories. Factorial typology allowed us to use constraints motivated for other child language processes to derive predictions about how children could diverge from the sonority pattern in cluster reduction. Emergent constraint activity allowed us to account for the non-uniform activity of the onset sonority constraints. Rule-based theories would fail completely to relate a process such as stopping to the avoidance of fricatives in cluster reduction. The connection between such processes is particularly evident in the conspiracies between them often seen in children's speech; above, we showed how optimality theory could deal with these conspiracies.

TABLE 3. *Constraint rankings for onset selection*

LP65			Julia			Gitanjali		
Ranking	Effect	Reference	Ranking	Effect	Reference	Ranking	Effect	Reference
*Fric ≫ *G-Ons	sw→w	Tableau 10	*L-Ons ≫ *Fric	sl→s	Tableau 9	*L-Ons ≫ *Fric	sl→s	Tableau 9
*Fric ≫ *N-Ons	sn→n	Tableau 8	*Fric ≫ *N-Ons	sn→n	Tableau 8	*N-Ons ≫ *Fric	sn→s	Tableau 7
*Dor ≫ *G-Ons	kw→w	Tableau 16	*F-Ons ≫ *Dor	sk→k	Tableau 19	*F-Ons ≫ *Dor	sk→k	Tableau 19
Uniform ≫ Max	kl→j	Tableau 24	Uniform ≫ Max	kl→k	Tableau 24	Uniform ≫ Max	kl→k	Tableau 24
Max-Lab ≫ *G-Ons	tw→w	Tableau 25	Max-Lab ≫ *G-Ons	tw→w	Tableau 25	Max-Lab ≫ Uniform	tw→p	Tableau 26
Uniform ≫ *G-Ons	tw→w	Tableau 25	Uniform ≫ *G-Ons	tw→w	Tableau 25	*N-Ons ≫ Uniform	sm→f	Tableau 27

This study does raise a number of questions for further investigation. The need to use the IDENT formulation for some faithfulness constraints, and the MAX formulation for others highlights an unresolved issue not only in child phonology, but in phonological theory in general. The bigger issue, however, concerns factorial typology. We have focused on providing evidence for the basic prediction that the constraints posited for different processes should interact with one another. However, in terms of the full factorial typology, we have only explored a subset of the possible rankings of the constraints employed here. For the interaction of *FRICATIVE with the onset sonority hierarchy, we showed that there is a reasonably good match between attested and predicted systems. It remains to be seen whether all possible permutations of these constraints yield attested systems.

In addition, it is important to consider the possibilities introduced by other constraints.[6] In terms of the place-related constraints, we have found a role in cluster reduction for a constraint that targets labials for preservation (MAX-LABIAL), and for one that targets dorsals for deletion (*DORSAL). It is generally assumed that both the place faithfulness and the place markedness constraints are in a fixed ranking, with those referring to Dorsal and Labial ranked above those referring to Coronal (on faithfulness see Kiparsky, 1994; Pater, 1997; Gnanadesikan, in press; on markedness see Prince & Smolensky, 1993; see de Lacy, 2002 on the integration of these). Thus, we would not expect to see coronal-specific faithfulness effects, or coronal-specific markedness effects. However, factorial typology would produce dorsal-specific faithfulness, and labial-specific markedness phenomena. Dorsal-specific faithfulness is documented for onset selection in truncation in Pater (1997), but we have yet to find a parallel case in onset selection in cluster reduction. This may be due to the fact that clusters do not provide the relevant segmental strings, if /w/ is considered to have a primary labial, rather than velar specification. The absence of *LABIAL phenomena in cluster reduction is a clearer gap, and we can do no more at this point than speculate that it is related in some way to the early emergence of labials in child speech.

Thus, there are a number of questions to explore concerning the predicted and attested range of child cluster reduction systems, as well as the match between child and crosslinguistic deletion patterns. For this sort of typological research to be truly meaningful, however, a much larger set of child data will be required, so this must be left for future research.[7] We hope that

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[6] See for example Bernhardt & Stemberger (1998: 385) on faithfulness constraints that would prefer retention of the initial consonant, and of the consonant adjacent to the vowel.

[7] The crosslinguistic data on initial cluster reduction seem rather sparse too. Not only do fully developed phonologies typically employ epenthesis, rather than deletion, to resolve syllable structure violations, but for alternations to occur in initial position, a language must have vowel-final prefixes, which not all do.

the data and analyses presented in this paper will help to lay the groundwork for such an undertaking.

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