Form and Substance in Phonological Development

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1. Introduction

If we adopt the standard assumption that a phonological grammar is appropriate for expressing regularities in child speech (cf. Hale and Reiss 1998), we are faced with the question of what type of grammar is best suited to this task, as well as the more basic issue of how the relationship between theory and child speech is to be conceived. In generative phonology, connections between theory and child phonology have been made at a formal level and a substantive level (cf. Jakobson 1941/1968 as a precursor). In rule-based theory, formal connections were made by arguing that the phonological generalizations in child speech are best captured in terms of a mapping from an Underlying to a Surface Representation, rather than simply in terms of statements of surface regularities, and that this mapping is accomplished by ordered rules (e.g. Smith 1973, Stampe 1973).

Substantive connections were motivated by parallels between the content of child language rules and those found in the languages of the world. For example, learners of English devoice syllable-final voiced obstruents, in a stage that resembles languages like Russian and German. To capture such parallels, Stampe (1973) proposes that there is a set of innate processes that constrains early phonology. Final devoicing would apply in the early phonologies of all learners, would continue to remain in force in the fully developed phonologies of Russian and German speakers, but would be overcome by learners of English.

It was quickly recognized that using a purely rule-based framework to deal with child phonology meets the same conspiracy problem that

* All of the research presented here is collaborative. Section 1 presents work done jointly with Jessica Barlow (Barlow 1997, Pater and Barlow 2002, to appear). Section 2 builds on work done jointly with Adam Werle (Werle 2001, Pater and Werle 2001), and on discussion with Paul de Lacy. I am solely responsible for faults in this presentation. Thanks to A.J. Compton for sharing his data with me. Section 1 also incorporates data gathered with support from a grant from the National Institutes of Health to Indiana University, DC01694.

 WCCFL 21 Proceedings, ed. L. Mikkelsen and C. Potts, pp. 348-372. Somerville, MA: Cascadilla Press.

Kisseberth (1970) raises for phonological theory in general. Smith (1973) points out that several of the rules he posits for Amahl's phonology serve the purpose of simplifying clusters, but that the shared output target is not expressed in the rules. This is one of the factors that led many child phonologists to adopt constraint-based approaches (see e.g. Menn 1980).

The proposal that child speech is governed by a set of innate processes also meets with problems, chief among them being the observation that there are processes that apply in child speech that lack an analogue in the languages of the world (Drachman 1976, Menn 1976, Kiparsky and Menn 1977, Vihman 1980). The most famous example is that of assimilation of major place of articulation between non-adjacent consonants, which remains to this day attested only in child data. This leads Kiparsky and Menn (1977: 75) to reject Stampean innatism and to adopt a "constructivist" approach to child phonology, in which the rule-based formalism is maintained, but the substantive connection is severed.

Formal and substantive connections continue to be drawn in studies of phonological acquisition cast in Optimality Theory (see McCarthy 2002 and Kager *et al.* to appear for overviews and references). At the formal level, child phonology is still conceived of as a mapping from Underlying to Surface Representation, usually renamed Input and Output, as is the convention in OT. However, this mapping is accomplished by ranked constraints, rather than by ordered rules, which has the immediate benefit of yielding an account of conspiracies.

Substantive connections are made by positing a set of innate constraints, arrayed in an initial Markedness >> Faithfulness ranking (that is, constraints placing well-formedness demands on Output structures above those demanding a match between Input and Output). For example, final devoicing obtains from a constraint against voiced obstruents in codas ranked above a constraint demanding that segments maintain their voicing specification between Input and Output. However, child-specific processes have led some to adopt a "constructivist" view of constraint genesis; that at least some constraints are constructed in response to articulatory, perceptual or motor planning pressures (Pater 1997, Hayes 1999).

Framing phonological acquisition in Optimality Theory thus yields predictions inherent to the constraint ranking formalism, as well as ones derived from particular views of the substance of the constraint set. The predictions of the former type are given in (1):

(1) **Prediction 1:** Factorial typology (weak version)
All rankings of the posited constraints should yield possible *child* phonologies

Prediction 2: Non-uniform constraint activity
Any given constraint can apply non-uniformly, as well as being "on" or "off"

Under the assumption that there is a single child-adult constraint set, the first prediction can be modified as follows:

(2) **Prediction 3:** Factorial typology (strong version)
Child phonology should exactly mirror cross-linguistic phenomena

In this paper, I discuss these predictions in the context of a study of two domains in child phonology. In the first part of paper, I show that between-child differences in cluster reduction patterns can be ascribed to different rankings of conflicting constraints, constraints that are motivated by other child processes. This is as would be predicted by factorial typology. Further, I show that these constraints do show non-uniformity in their application. In the second part, I turn to the prototypical case of a child-specific process, child consonant harmony. Adopting the weaker version of factorial typology, I argue that study of child typology yields insight into the formulation of the relevant constraints, and winds up suggests striking formal parallels with constraints that are active in adult phonology. I conclude by pointing out some benefits of using ranked constraints as opposed to rules or inviolable constraints for the analysis of child speech.

2. Child Phonology as Constraint Ranking: Cluster Reduction

The reduction of onset clusters to singletons in child language can be captured by a ranking of the markedness constraint *COMPLEX-ONSET (Prince and Smolensky 1993) above the faithfulness constraint MAX (McCarthy and Prince 1999):

(3) *COMPLEX-ONSET: An onset consists of a single consonant
MAX: Every Input segment has an Output correspondent

*COMPLEX-ONS >> MAX

/slip/	*COMPLEX-ONS	MAX
[sip]	*!	
☞ [sip]		*
☞ [lip]		*

As this tableau shows, while this ranking rules out the onset cluster, it does not choose which of the consonants to delete. A common pattern is for the least sonorous member of the adult cluster to surface (e.g. Ohala 1996, Barlow 1997, Gnanadesikan to appear, Goad and Rose to appear). This pattern is illustrated in the following data from a normally developing English learning child. An obstruent-sonorant cluster reduces to the obstruent (4a), and a fricative-stop cluster reduces to the less sonorant stop.

(4) Gitanjali (age 2;3 - 2;9; Gnandesikan to appear)
a. **obstruent + sonorant → obstruent**
[kin] *clean* [dɒ] *draw* [piz] *please*
[so] *snow* [sɪp] *slip* [fɛn] *friend*
b. **fricative + stop → stop**
[gaɪ] *sky* [gɪn] *skin* [bɪw] *spill*

Several child phonologists have analyzed the preference for low sonority onsets as being due to a fixed ranking of constraints relating sonority to onset position (Barlow 1997; Gnanadesikan to appear; Ohala 1996; cf. Prince and Smolensky 1993). In (5), one version of this fixed ranking is supplied (Pater 1997), along with tableaux illustrating its effects.

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

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

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

Factorial typology can be applied to make predictions about other children's patterns of reduction in the following way. Given that other constraints conflict with the onset sonority constraints, to produce the sonority pattern, they must rank beneath the onset sonority constraints. Ranked above (some of the) onset sonority constraints, the conflicting constraints will produce deviations from the sonority pattern. Here I will show that three independently motivated constraints play a role in cluster reduction: *FRICATIVE, *DORSAL, and MAX-LABIAL.

2.1. *FRICATIVE effects in cluster reduction

Children’s early productions often display “stopping”, whereby fricatives are realized as stops, as in the following data from Amahl at 2;2 (Smith 1973):

(6) [b̥ʌt] *bus* [d̥u:] *zoo* [maip] *knife*
[b̥ʌt] *brush* [ʌdə] *other* [b̥at] *bath*

Since stopping applies in all environments (coda and onset), instead of *F–ONS, a context-free markedness constraint is needed (Barlow 1997):

(7) *FRICATIVE
Segments may not be *[+cont, -son]

In cross-linguistic phonology, this constraint would account for languages that lack fricatives entirely, as many Australian languages do (e.g. Kayardild: Evans 1995). To produce the sonority pattern, *FRICATIVE must be ranked beneath *N-ONS, as demonstrated in the following tableaux:

(8) a. *N-ONS >> *FRICATIVE

/snoʊ/	*N-ONS	*FRIC
[noʊ]	*!	
☞[soʊ]		*

b. *FRICATIVE >> *N-ONS

/snoʊ/	*FRIC	*N-ONS
☞ [noʊ]		*
[soʊ]	*!	

The mapping /sn/ → [s] in (8a) is the sonority pattern. The mapping /sn/ → [n] is also attested in many children’s productions. Here we see it in naturalistic diary-style data from Julia and Trevor, two American English learning children (see Compton and Streeter 1977, Pater 1997 on data collection procedures).

(9) **Julia: Reduced fricative-nasal clusters**

/sn-/ [mami + nis] *mommy sneeze* 1;9.5 [nek] *snake* 1;11.22
/sm-/ [wʌs ai mɛʊ] *what (do) I smell?* 2;4.28

Trevor: Reduced fricative-nasal clusters

/sn-/ [næ] *snap* 1;1.4 [ni:z] *sneeze* 1;10.5
[mæp] *snap* 1;8.12

Fricative-liquid clusters, however, reduce to the fricative:

(10) **Julia: Reduced fricative-liquid clusters**

/fl-/	[faʊwɚ]	*flowers*	1;11.23	/sl-/	[sip]	*sleep*	1;8.27
/fr-/	[fɔgi]	*froggy*	2;0.23				

Trevor:Reducedfricative-liquidclusters

/fl-/	[fəwə]	*flower*	1;7.6	/sl-/	[sip]	*sleep*	1;8.26
/fr-/	[fa:g]	*frog*	1;10.5				

Thus, *FRICATIVE ranks above *N-ONS, as in (8b), but beneath *L-ONS:

(11) *L-ONS >> *FRICATIVE

/slip/	*L-ONS	*FRICATIVE
☞ [sip]		*
[lip]	*!	

When *FRICATIVE ranks higher relative to the onset sonority hierarchy, it has more dramatic effects, as in these data from LP65, an English learning child aged 3;8 with a phonological delay (see Barlow 1997 for further subject details). LP65 produces the sonorant of fricative-sonorant clusters:

(12) **LP65: Target fricative-sonorant clusters**

/fr-/	[wɛnd]	*friend*	[wʊ:t]	*fruit*
/sl-/	[jip]	*sleep*	[jɛd̥]	*sled*
/sn-/	[ni:d]	*sneeze*	[noʊmən]	*snowman*
/ʃr-/	[wɪn:t]	*shrink*	[wɛ:d̥]	*shred*
/sw-/	[wɪ:n]	*swing*	[wɪəm]	*swim*
/sm-/	[mɛʊ]	*smell*	[maɪjʊ]	*smile*
/θr-/	[wi]	*three*	[woʊ]	*throw*

For LP65, *FRICATIVE dominates the entire onset sonority hierarchy. The tableau in (13) shows the need for it to dominate *G–ONS (an undominated *LIQUID constraint forces all liquids to surface as glides; Barlow 1997)

(13) *FRICATIVE >> *G-ONS

/slip/	*FRICATIVE	*G-ONS
[sip]	*!	
☞ [jip]		*

Fricatives are entirely absent from LP65's productions; outside of the context of cluster reduction, he produces them as stops (e.g. [ni:d] *sneeze*). This conspiracy between deletion of fricatives from clusters, and stopping of singletons is produced by *FRICATIVE dominating both the onset sonority constraints and IDENT-CONT:

(14) IDENT-CONTINUANT (IDENT-CONT)
Segments in correspondence are identical in continuancy

*FRICATIVE >> IDENT-CONT

/sniz/	*FRICATIVE	IDENT-CONT
[niz]	*!	
☞ [nid]		*

To complete the account of the conspiracy, deletion must be ruled out for singletons, and stopping for clusters, as follows:

(15) MAX >> IDENT-CONT

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

IDENT-CONT >> *G-ONS

/slip/	IDENT-CONT	*G-ONS
[d̥ip]	*!	
☞ [jip]		*

In LP65's system, as well as in Julia and Trevor's, we have thus seen that the independently motivated *FRICATIVE constraint plays a role in cluster reduction, as predicted by factorial typology.

2.2. *DORSAL effects in cluster reduction

Another constraint that conflicts with sonority based onset selection is *DORSAL (Prince and Smolensky 1993, Barlow 1997):

(16) *DORSAL: Consonants are not specified as dorsal (velar)

In the languages of the world, we do find inventories lacking velar stops, such as Tahitian. In child phonology, this constraint is responsible for "velar fronting", as in the following examples from LP65:

(17) **LP65: Velar fronting data**

[d̥ɔb]	*cob*	[dʌt]	*duck*
[deɪ:]	*gate*	[wædin]	*wagon*
[doʊ:]	*girl*	[bʊt]	*book*

The sonority pattern depends on *DORSAL being dominated by onset sonority constraints, as in (18):

(18) *L-ONS >> *DORSAL

/klin/	*L-ONS	*DORSAL
[lin]	*!	
☞[kin]		*

LP65's pattern of cluster reduction exemplifies the reverse ranking:

(19) **LP65: Target velar-initial clusters**

/gl-/	[jʌ:]	*glove*	[joʊb]	*globe*
/kl-/	[jin]	*clean*	[joʊ:]	*clothes*

The conspiracy evident here can be analyzed in a fashion parallel to that with fricatives. As shown in the tableaux in (20), *DORSAL dominates both *G–ONS and IDENT(PLACE), leading to velar deletion from clusters and fronting of singletons, respectively. The further rankings are responsible for ruling out fronting in clusters, and deletion of singletons

(20) IDENT(PLACE): Correspondent segments must be identical in place specification

*DORSAL, IDENT(PLACE) >> *G-ONS

/gloʊb/	*DORSAL	IDENT(PLACE)	*G-ONS
☞ [joʊb]			*
[goʊb]	*!		
[d̥oʊb]		*!	

*DORSAL, MAX >> IDENT(PLACE)

/kʰɔb/	*DORSAL	MAX	IDENT(PLACE)
☞ [d̥ɔb]			*
[g̊ɔb]	*!		
[ɔb]		*!	

For Julia (as well as Gitanjali and Trevor) *DORSAL has no effect. Since /sk/ surfaces as [k], *DORSAL ranks beneath *F–ONS.

2.3. MAX-LABIAL effects in cluster reduction

Faithfulness to labials plays a role in two areas in child phonology. In consonant harmony, coronals, but not labials, often assimilate to velars; we will examine this in depth in section 3. In initial stressless syllable deletion, labials are often retained over other consonants (Smith 1977, Fikkert 1994). We find evidence of the same effect in Julia'a data, though relevant cases are somewhat sparse once we remove those that can be explained on the basis of sonority (e.g. [bun] *balloon*).

(21) **Julia: Labial selection in initial stressless syllable deletion**

[pedo]	*potato*	2;0.25	[peto]	*potato*	2;1.20

The operative constraint is in (22) (Barlow 1997, Pater and Barlow 2002).

(22) MAX-LABIAL
An Input labial segment must correspond to an Output labial segment

In cluster reduction, MAX-LABIAL conflicts with the onset sonority constraints whenever the adult cluster is made up of a non-labial obstruent and a labial sonorant. I take American English [w] and [r] to both contain a labial specification (see Gnanadesikan to appear and Pater and Barlow 2002 for child language evidence for the labiality of [r]). The sonority pattern requires this constraint to be dominated, as in (23).

(23) *G-ONS >> MAX-LAB

/draɪv/	*G-ONS	MAX-LAB
☞ [daɪv]		*
[waɪv]	*!	

Both Julia and LP65 provide evidence of the other ranking:

(24) **Julia: Reduced non-labial obstruent + labial sonorant clusters**

/dr-/	[wɪk]	*drink*	1;9.19	[wapˀt ət]	*dropped it*	1;10.23
	[waɪv]	*drive*	1;9.14			
/gr-/	[rəni]	*Grundy*	1;8.19	[wʌni]	*Grundy*	1;8.18
	[wæmə]	*grandma*	1;9.14			
/kr-/	[wips]	*grapes*	1;9.18	[wækə]	*cracker*	1;8.7
/sw-/	[wɪŋ]	*swing*	1;7.1			

Julia also displayed coalescence and the sonority pattern with this cluster type, though this labial selection pattern was the most common, occurring 53% of the time (24/45). LP65 consistently applied labial selection:

(25) **LP65: Reduced non-labial obs + labial son clusters**

/dr-/	[waɪb]	*drive*	/gr-/	[woʊ]	*grow*
/tr-/	[wʌt]	*truck*	/kr-/	[waɪ]	*cry*

The ranking in (26) thus holds for LP65 and, perhaps variably, for Julia.

(26) MAX-LAB >> *G-ONS

/draɪv/	MAX-LAB	*G-ONS
[daɪv]	*!	
☞ [waɪv]		*

2.4. Non-uniform effects of onset sonority constraints

We have at this point an essentially complete account of Julia and LP65's systems of cluster reduction (see further Pater and Barlow 2002). The hierarchies in (27) illustrate the placement of the conflicting constraints with respect to the onset sonority constraints.

(27) **a. Julia**

MAX-LABIAL
|
*G-ONS
|
*L-ONS
|
***FRICATIVE**
|
*N-ONS
|
*F-ONS
|
***DORSAL**

b. LP65

MAX-LABIAL ***FRICATIVE** ***DORSAL**
|
*G-ONS
|
*L-ONS
|
*N-ONS
|
*F-ONS

When dominant, the conflicting constraints cause the onset sonority constraints to be violated. However, Optimality Theory predicts that effects of dominated constraints can emerge when higher ranked constraints are not decisive. For example, MAX-LABIAL fails to be decisive when neither of the target onset segments is a labial, or when both are labial:

(28) MAX-LABIAL >> *L-ONS

/klin/	MAX-LAB	*L-ONS
☞ [kin]		
[lin]		*!

MAX-LAB >> *G-ONS

/prɪɾi/	MAX-LAB	*G-ONS
☞ [pɪɾi]	*	
[wɪɾi]	*	*!

As predicted, Julia's productions do follow the sonority pattern under these circumstances:

(29) **Julia: Non-labial clusters**

/gl-/	[dædi+gæθəs]	*daddy's glasses* 1;10.10				
/kl-/	[kinəp]	*clean up*	*1;10.25*	[gak]	*clock*	*1;8.11*
/st-/	[ʌpəteəs]	*up the stairs*	*1;9.5*	[tiv]	*Steve*	*1;11.24*

/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*

Julia: Two-labial clusters

/br-/	[bʌʃ]	*brush*	1;9.4	[baɪən]	*Brian*	1;7.20
/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

Since the onset sonority constraints are dominated by more conflicting constraints in LP65's phonology, their effects are more limited. English non-labial clusters are either fricative-initial or velar-initial, so the higher ranked constraints only fail to decide for two-labial clusters. But here we see do the expected outcome

(30) **LP65: Two-labial clusters**

/br-/	[bɛd]	*bread*	[bʌʔ]	*brush*
/pr-/	[b̥ɪɾi]	*pretty*	[b̥aɪ]	*prize*

This sort of nonuniform constraint behavior is as expected when constraints are ranked and violable; it is difficult to express if constraints can only be "on" or "off" (on child phonology, see further Gnanadesikan to appear and Pater 1997, amongst others). Other nearby examples include *FRICATIVE for Julia and Trevor (/sn/ → [n], but /sl/ → [s], /s/ → [s]), and onset sonority for Gitanjali (/sw/ → [s], but /w/ → [w]); see Pater and Barlow (2002, to appear) and Gnandesikan (to appear) for analysis.

3. Child consonant harmony and typology

It is difficult to know how closely the typologies of cluster reduction in child and adult phonology line up, given the scarcity of cross-linguistic data, though as Gnanadesikan (to appear) points out, the sonority pattern is nicely matched in data from Sanskrit reduplication (cf. Wilson 2001 for some indication that adult typology may be more constrainted than child). Consonant harmony, however, provides a clear case of a child-adult mismatch. In child phonology, non-adjacent consonants are often subject to assimilation in major place of articulation (e.g. [gɔg] *dog*). Despite the attention that long-distance assimilation has received since the advent of autosegmental phonology, not a single case of this type has been found cross-linguistically (see recently Hannson 2001, Rose and Walker 2001). If in accounting for child consonant harmony we maintain a homogeneous child-adult constraint set, then we will necessarily overgenerate cross-linguistically. Simply saying that the relevant constraint becomes low-ranked is insufficient, since as we have seen, low-ranked constraints can exert their effects under the right circumstances.

An alternative is to maintain only the weaker version of child Factorial Typology, that all re-rankings of the posited constraints should yield possible child phonologies. This does require taking out a promissory note on an account of the genesis, and extinction of the consonant harmony constraint(s) (see Pater 1997 and Hayes 1999 for initial payments). However, this seems a reasonable cost for a more restrictive theory of both child and adult phonological typology (cf. Goad 1997, Rose 2000).

3.1. Data

The table in (31) presents some examples of consonant harmony from Trevor. Here we see that coronals (31a-d,h,i), or labials (31e.,f.), can undergo harmony, that can be regressive (31a,d,e,g,i) or progressive (31 b,c,f,h), that it can be triggered by velars (31a-g) or labials (31h,i), and that it can traverse vowels of various types.

(31) **Trevor: consonant harmony**

a.	[gɔg]	*dog*	1;5.14	f.	[kʌk]	*cup*	1;5.13
b.	[kok]	*coat*	1;5.18	g.	[gɪgʊ]	*pickle*	1;9.2
c.	[kæ:g]	*cat*	1;3.4	h.	[bɛ:p̚]	*bed*	1;6.17
d.	[gɪ:gu:]	*tickle*	1;7.26	i.	[pap]	*top*	1;6.8
e.	[gʌg]	*bug*	1;5.18				

Many authors have noted tendencies about which types of consonant harmony are more common, that coronals are preferred undergoers, that regressive is the usual direction, and that velars are most often the triggers (e.g. Smith 1973, Vihman 1978, Cruttenden 1978, Stoel-Gammon and Stemberger 1994, Stoel-Gammon 1996, Bernhardt and Stemberger 1998). I will illustrate these generalizations with longitudinal data from Trevor, as well as from one stage of Amahl’s development.

For Pater and Werle (2001), we extracted all of the words Trevor produced whose adult forms had the shape C_1(C)V_1(C)C_2(C)(V)(C), where:

(32) a. C_1 and C_2 are both oral stops
b. Either C_1 or C_2 is a velar or a labial
c. Only V_1 is stressed

Other word types were eliminated so as to control factors other than those under study (e.g. the manner of the trigger or undergoer, stress placement). As shown in (33), the words are divided into 6 classes, based on the place of C_1 and C_2 (see Pater and Werle 2001 on vowel place). It should be emphasized that along with monosyllables like those exemplified in (33), initially stressed bisyllables were included.

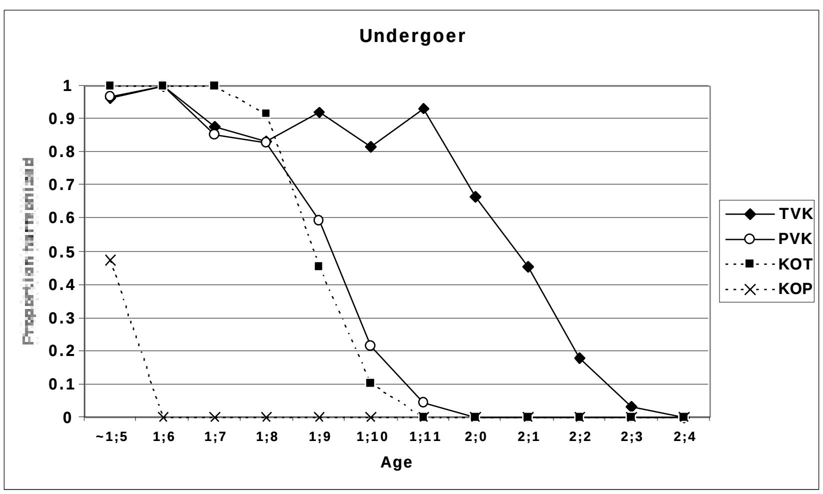
(33) TVK PVK KVT KVP TVP PVT
(Where T = coronal, K = velar, P = labial, V=vowel)

TVK	[gɔg]	*dog*	KVP	[kʌk]	*cup*
PVK	[gʌg]	*bug*	TVP	[pap]	*top*
KVT	[kok]	*coat*	PVT	[bɛ:p̚]	*bed*

For each of the word types the proportion of harmonized vs. non-harmonized forms were measured for the time period up to 1;5, and each individual month through 2;4. A comparison across word types shows the influence of the generalizations stated above; harmony lasts longer, and is more consistent with the preferred undergoer/trigger/direction.

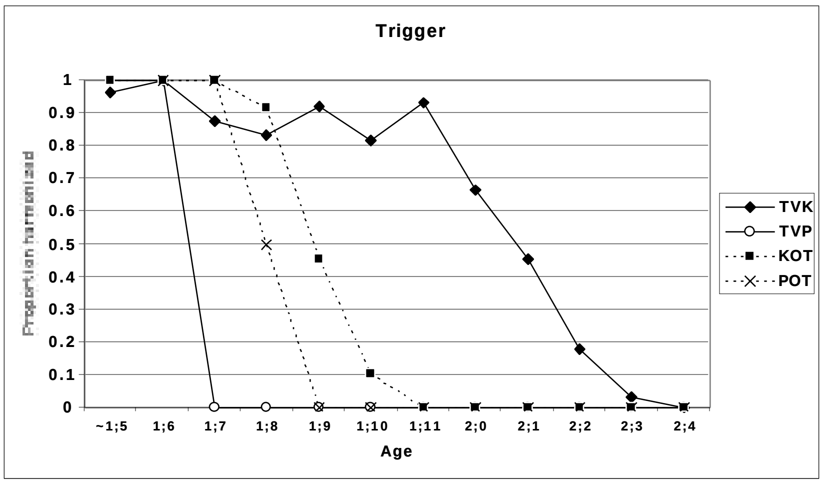
The first chart compares labial and coronal undergoers (labial harmony never targets velars in Trevor's data). Harmony affects TVK words longer than PVK, and KOT longer than KOP (where O=back vowels; front vowels strongly influence harmony in KVT words; see Pater 1997)

(34) Undergoer: Coronal > Labial



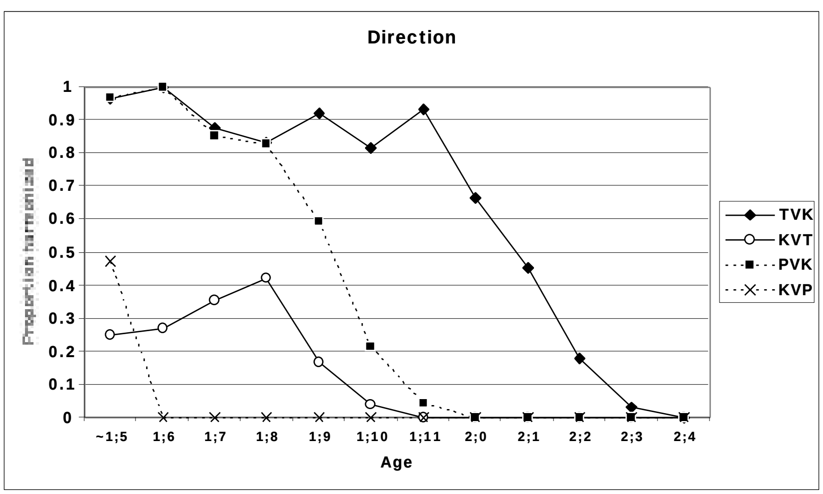
In the chart in (35), velar and labial triggers are compared. Here we see that harmony is more robust in TVK words than PVK, and somewhat marginally, in KOT than POT.

(35) Trigger: Velar > Labial



In (36), we see that TVK words are more prone to harmony than KVT, and PVK than KVP, thus confirming the directionality generalization.

(36) Direction: Regressive > Progressive



We can divide Trevor's data into 3 basic stages in the application of consonant harmony (cf. Pater and Werle 2001 for a more fine-grained approach to velar harmony). The chart in (37) shows the percentage of harmonized forms for each word type in each stage, along with the raw numbers from which it is derived.

(37) *Velar harmony* *Labial harmony*

	TVK	PVK	KVT	KVP	TVP	PVT
~ 1;9.2	96 % 69/72	95 % 125/132	42 % 33/79	18 % 9/51	25 % 5/20	44 % 48/108
1;9.19- 1;10.11	94 % 29/31	38 % 33/86	10 % 3/31	0 % 0/20	0 % 0/6	0 % 0/55
1;10.13- 2;03	93 % 41/44	5 % 5/93	0 % 0/33	0 % 0/10	0 % 0/14	0 % 0/62

Adopting the criteria that > 80% = consistent application, 20 - 80% = variable application, and < 20 % = non-application, we get the following descriptions of the stages:

(38) <u>Stage 1</u>
Consistent regressive velar harmony to labial and coronal undergoers
Variable progressive velar harmony to coronals
Variable regressive and progressive labial harmony to coronals
<u>Stage 2</u>
Consistent regressive velar harmony to coronals
Variable regressive velar harmony to labials
<u>Stage 3</u>
Consistent regressive velar harmony to coronals

The evidence for regressive directionality comes from velars; progressive labial assimilation does last slightly longer than regressive, but the data are too sparse to merit firm conclusions. Amahl's data (Smith 1973, Goad 1997, Rose 2000) provides clearer evidence for a preference for regressive direction for labials since labial harmony is never progressive. The following is a description of his earliest stage; regressive velar harmony is also the last to disappear (as in Trevor's Stage 3):

(39) Amahl's Stage 1 (2;2)
Consistent regressive velar harmony to coronal undergoers
Variable progressive velar harmony to coronals
Variable regressive labial harmony to coronals

Across these child systems we can draw the implications in (40).

(40) Undergoer: Non-coronal implies Coronal
Trigger: Labial implies Velar
Direction: Progressive implies Regressive

3.2. Analysis

To provide an analysis of these implicational generalizations, I will build on the fixed ranking analysis of Pater and Werle (2001) using de Lacy's (2002) approach to markedness scales (see also de Lacy 1997, Prince 1997 *et seq*. on constraints in stringency relations). In this theory, a key property of constraints that refer to scales is the following:

(41) Marked Reference Hypothesis (MRH)
If a constraint C that refers to scale S mention category c in S, then C also mentions all categories k where k is more marked than c.

De Lacy assumes the following markedness scale for oral place of articulation (cf. Prince and Smolensky 1993):

(42) Dorsal > Labial > Coronal

Given this scale, the faithfulness constraints that result from applying the MRH are as in (43). I continue to use the alphabetical abbreviations for place of articulation (e.g. K = Dorsal). These constraints encode the generalization that coronals are preferred undergoers of harmony. There is no constraint that applies only to coronals, and hence no way of blocking assimilation for them alone.

(43) FAITH(K), FAITH(KP), FAITH(KPT)
Any correspondent of an Input segment specified as X must be homorganic with the Input segment

This approach to a typology of undergoers is adopted directly from de Lacy's work on local place assimilation (see Kiparsky 1994 and Jun 1995 for fixed ranking precedents, and Goad 1997, Pater 1997 and Pater and Werle 2001 on child consonant harmony). For the typology of triggers, I follow de Lacy in deriving it from the MRH and the scale in (42), and for the account of directionality, I reformulate Pater and Werle's (2001) fixed ranking of AGREE constraints into constraints in a stringency relation:

(44) **Constraints driving harmony**

←K Any consonant preceding a dorsal is homorganic

←K→ Any consonant preceding/following a dorsal is homorganic

←PK Any consonant preceding a dorsal or labial is homorganic

←PK→ Any consonant preceding/following a dorsal or labial is homorganic

The additional ←PKT and ←PKT→ constraints would have no effects distinguishable from ←PK→ in the cases we are looking at.

To illustrate this approach, I provide rankings generating each of the three stages of Trevor's development, along with Amahl's Stage 1. To obtain variation, I assume that unranked constraints are placed in a random fixed order each time the grammar evaluates an Input-Output mapping (see e.g. Anttila 1997). When unranked constraints are in crucial conflict, this yields variation between optimal outputs, indicated here by a pointing finger for both candidates. Inputs undergoing harmony are placed in bold.

(45) Trevor's Stage 1

Input	Output	F(K)	←K	F(KP)	←PK→	F(KPT)
TVK	TVK		*!		*	
	☞ KVK					*
PVK	PVK		*!		*	
	☞ KVK			*		*
KVT	☞ KVT				*	
	☞ KVK					*
KVP	☞ KVP				*	
	KVK			*!		
TVP	☞ TVP				*	
	☞ PVP					*
PVT	☞ PVT				*	
	☞ PVP					*

In stage 1, almost all of the word-types undergo harmony: TVK and PVK consistently, and KVT, TVP, and PVT variably. In stage 2 FAITH(KPT) is fixed in rank above ←PK→, blocking harmony for the latter three word-types, while FAITH(KP) is now unranked with ←K, so that PVK varies.

(46) Trevor's Stage 2

Input	Output	F(K)	←K	F(KP)	F(KPT)	←PK→
TVK	TVK		*!			*
	☞ KVK				*	
PVK	☞ PVK		*			*
	☞ KVK			*	*	
KVT	☞ KVT					*
	KVK				*!	
KVP	☞ KVP					*
	KVK			*!		
TVP	☞ TVP					*
	PVP				*!	
PVT	☞ PVT					*
	PVP				*!	

Finally, in stage 3, FAITH(KP) has been fixed in rank above ←K, so that only TVK words undergo harmony:

(47) Trevor's Stage 3

Input	Output	F(K)	F(KP)	←K	F(KPT)	←PK→
TVK	TVK			*!		*
	☞ KVK				*	
PVK	☞ PVK			*		*
	KVK		*!		*	
KVT	☞ KVT					*
	KVK				*!	
KVP	☞ KVP					*
	KVK		*!			
TVP	☞ TVP					*
	PVP				*!	
PVT	☞ PVT					*
	PVP				*!	

Amahl's Stage 1 provides an example of active ←KP and ←K→ constraints. Both of these constraints are unranked with FAITH(KPT), yielding variation for KVT and TVP words.

(48) Amahl's Stage 1

Input	Output	F(KP)	←K	F(KPT)	←KP	←K→
TVK	TVK		*!		*	*
	☞ KVK			*		
PVK	☞ PVK		*		*	*
	KVK	*!		*		
KVT	☞ KVT					*
	☞ KVK			*		
KVP	☞ KVP				*	
	KVK	*!		*		*
TVP	☞ TVP				*	
	☞ PVP			*		
PVT	☞ PVT					
	PVP			*!		

These tableaux show that these constraints are able to capture the different patterns that do exist in Amahl and Trevor's data. They are also useful in showing that these constraints cannot express unattested patterns. If one compares the violations incurred by the outputs for TVK versus those for PVK, TVP, and KVT, it should be apparent that no reranking will produce only non-coronal undergoers, only labial triggers, or only progressive directionality. This is because no faithfulness constraint is specific to non-coronals, and no markedness constraint applies only to labials, or only progressively. Rankings including other constraints, such as *DORSAL, will produce other patterns, such as dorsals assimilating to labials, as has been claimed to occur in some children's speech. It must be left to further research to determine whether these patterns exactly match the child data.

3.3. Local and non-local place assimilation

The undergoer, trigger and direction generalizations for major place assimilation that we have been discussing for child language do generally hold cross-linguistically as well, in interactions between adjacent consonants (Cho 1990, Ohala 1990, Mohanan 1993, Kiparsky 1994, Jun 1995, de Lacy 2002).

Korean place assimilation provides some striking parallels with Trevor's Stage 1: labials and coronals assimilate to velars (49a), coronals assimilate to labials (49b), and coronals do not trigger assimilation.

(49) a. /əp+ko/ → [əkko] 'bear on the back + conj.'
/namkik/ → [naŋkik] 'the South Pole'
/pat + ko/ → [pakko] 'receive and'
/han + kaŋ/ → [haŋkaŋ] 'the Han river'
b. /kot + palo/ → [koppalo] 'straight'
/han + bən/ → [hambən] 'once'

As de Lacy (2002) points out, this pattern requires a constraint against heterorganic clusters that is specific to dorsals, like ←K, which is also motivated by Trevor and Amahl's data (see Jun 1995 for another approach). In fact, to produce the Korean pattern, the analysis of Trevor's Stage 1 must only be slightly modified: ←KP→ must be changed to ←KP, so that it does not target PT sequences, and fixed in rank above FAITH(KPT), so that assimilation applies consistently, not variably. And of course, the constraints against heterorganicity must apply only locally.

Besides locality, there are also more subtle differences between the typologies of place assimilation in child and adult language. Cross-linguistically, the pressure for regressive assimilation seems more pronounced. For example, in Diola Fogny, coronal, velar and labial nasals assimilate to a following oral or nasal stop, be it coronal, labial or velar (Itô 1989, Jun 1995). This pattern of regressive assimilation with all places of assimilation as triggers seems unattested in child language. It cannot be generated by constraints posited here, since assimilation of a non-coronal (e.g. KT → TT) is harmonically bound by that of a coronal (KT → KK):

(50) The failure to generate coronal triggering

Input	Output	←KPT	←KP→	F(K)	F(KP)	F(KPT)
KT	KT	*	*			
	TT				*	*
	KK					*

The standard account of regressive local assimilation in OT invokes positional faithfulness (e.g. Jun 1995, Casali 1997, Beckman 1998, Lombardi 1999). F(PLACE)-ONS is defined in (51), along with a tableau showing how it would force regressive assimilation from a coronal:

(51) F(PLACE)-ONS

A segment's Input place specification must be preserved when its Output correspondent is in onset position

Input	Output	←KP→	F(PLACE)-ONS	F(KP)
KT	KT	*!		
	☞ TT			*
	KK		*!	

Because consonant harmony in child language usually applies between consonants in both CVC and CVCV words, this constraint could not generate regressive harmony. One does wonder, however, why F(PLACE)–ONS never produces progressive harmony in just CVC words.

Clara, a child learning Québecois French, does have a pattern of assimilation that is plausibly an effect of positional faithfulness (see Rose 2000 for the data and alternative analysis). In her data, C_1 assimilates in place to C_2 in CVCV (except that labials do not assimilate), and assimilation is completely blocked in CVC words. Since French has final stress, a faithfulness constraint specific to stressed syllables will block both progressive assimilation, and assimilation in CVC words (Nordstrom 2001). It should be noted though that the blocking of assimilation of labials seems to require a FAITH-P constraint, which would require enrichment of de Lacy's (2002) system presented above (as might the data in section 2).

There are some remaining issues in comparing the child consonant harmony to cross-linguistic local place assimilation. For example, coronals are sometimes exempt as undergoers (Hume and Tserdanelis 1999, McCarthy 2001, de Lacy 2002), but child language analogues seem to be lacking. Manner restrictions on targets and triggers are not well studied in child language, but it seems unlikely that nasals are as targeted for assimilation to the extent that they are cross-linguistically. Nonetheless, there is sufficient resemblance between the two sets of facts to call for an explanation; here I have derived them both from constraints that obey the formal demands of the MRH, but that differ in their domain of application.

4. Conclusions

As a framework for the study of phonological development, as for the study of phonology in general, Optimality Theory differs from rule-based theories

(RT) and constraint-based theories that do not use ranking (CT) in the ways listed in (52).

(52) i. Provides accounts of conspiracies (cf. RT)
ii. Makes predictions about the typology of a process based on constraints posited for other processes (cf. RT and CT)
iii. Allows for non-uniform constraint behavior (cf. CT)

All of these formal features were made use of in the analysis of onset cluster reduction, and figure in many other analyses of child speech. Here it was additionally argued that when confronted with child specific processes like consonant harmony, taking child phonology on its own terms, and applying the basic formal principles of Optimality Theory to establish the constraint set, allows insight into the substantive and formal makeup of the child language constraints, and opens up new perspectives on the relationship between child and adult phonology

References

Barlow, Jessica. 1997. *A Constraint-Based Account of Syllable Onsets: Evidence from Developing Systems*. Ph.D. dissertation, Indiana University.
Beckman, Jill. *Positional Faithfulness*. Ph.D. dissertation, University of Massachusetts, Amherst.
Bernhardt, Barbara and Joseph Stemberger. 1998. *Handbook of Phonological Development from the Perspective of Constraint-Based Nonlinear Phonology*. San Diego CA: Academic Press.
Casali, Roderic F. 1997. Vowel elision in hiatus contexts: Which vowel goes? *Language* 73, 493-533.
Cho, Young-mee Yu. 1990. *Parameters of Consonantal Assimilation.* Ph.D. dissertation. Stanford University.
Compton, A.J. and Mary Streeter. 1977. Child Phonology: Data Collection and Preliminary Analyses. *Papers and Reports on Child Language Development* 7. Stanford University.
Cruttendon, Alan. 1978. Assimilation in child language and elsewhere. *Journal of Child Language* 5, 373-378.
De Lacy, Paul. 2002 The formal expression of markedness. Ph.D. Dissertation, University of Massachusetts.
Drachman, G. 1976. Child Language and Language Change: A Conjecture and Some Refutations. In J. Fisiak, ed. *Recent Developments in Historical Phonology.* Mouton, The Hague, The Netherlands.
Evans, Nick. 1995. Current Issues in the Phonology of Australian Languages. In J. Goldsmith, ed. *Handbook of Phonological Theory*. Basil Blackwell.
Fikkert, P. (1994). *On the acquisition of prosodic structure.* The Hague, The Netherlands: Holland Academic Graphics.

Gnanadesikan, Amalia. To appear. Markedness and Faithfulness Constraints in Child Phonology. In Kager *et al.* (eds.)

Goad, Heather. 1997. Consonant harmony in child language: an Optimality-Theoretic account. In S.J. Hannahs and Martha Young-Scholten (eds). *Generative Studies in the Acquisition of Phonology*. John Benjamins.

Goad, Heather, and Yvan Rose. To appear. Input Elaboration, Head Faithfulness and Evidence for Representation in the Acquisition of Left-Edge Clusters in West Germanic. In Kager *et al.* (eds.)

Hale, Mark, and Charles Reiss. 1998. Formal and empirical arguments concerning phonological acquisition. *Linguistic Inquiry* 31, 157-169.

Hansson. Gunnar. 2001. *Theoretical and Typological Issues in Consonant Harmony*. Ph.D. Dissertation, University of California, Berkeley.

Hayes, Bruce. 1999. Phonetically-Driven Phonology: The Role of Optimality Theory and Inductive Grounding. In Michael Darnell, Edith Moravscik, Michael Noonan, Frederick Newmeyer, and Kathleen Wheatly, eds., *Functionalism and Formalism in Linguistics, Volume I: General Papers*. John Benjamins, Amsterdam, pp. 243-285.

Hume, Elizabeth, and Georgios Tserdanelis. 1999. Nasal place assimilation in Sri Lankan Portugues Creole: Implications for Markedness. Ms., Ohio State University.

Itô, Junko.1989. A prosodic theory of epenthesis. *NLLT* 7. 217-259.

Jakobson, Roman. 1941. *Child Language, Aphasia and Phonological Universals*. Trans. A. Keiler 1968. The Hague: Mouton.

Jun, Jongho. 1995. *Perceptual and Articulatory Factors in Place Assimilation: An Optimality Theoretic Approach*. Ph.D. dissertation, UCLA.

Kager, René, Joe Pater, and Wim Zonneveld (eds.). To appear. *Fixing Priorities: Constraints in Phonological Acquisition*, CUP.

Kiparsky, Paul. 1994. Remarks on markedness. Paper presented at TREND 2, Stanford University.

Kiparsky, Paul, and Lise Menn. 1977. *On the Acquisition of Phonology*. In J. Macnamara, ed. Language Learning and Thought, Academic Press, New York.

Kisseberth, Charles. 1970. On the functional unity of phonological rules. *Linguistic Inquiry* 1, 291-306.

Lombardi, Linda. 1999. Positional faithfulness and voicing assimilation in Optimality Theory. *Natural Language and Linguistic Theory*17, 267–302.

McCarthy, John 2001. Comparative Markedness. Ms., University of Massachusetts, Amherst.

McCarthy, John. 2002. *A Thematic Guide to Optimality Theory*. Cambridge University Press.

McCarthy, John, and Alan Prince 1999. Faithfulness and identity in Prosodic Morphology. In R. Kager, H. v. d. Hulst and W. Zonneveld (eds.) *The Prosody-Morphology Interface*. Cambridge: Cambridge University Press. 218-309.

Menn, Lise. 1976. *Pattern, Control, and Contrast in Beginning Speech: A Case Study in the Development of Word Form and Word Function.* Ph.D Dissertation, University of Illinois, Champaign.

Menn, Lise. 1980. Phonological Theory and Child Phonology. In G. Yeni-Komshian, J. Kavanagh, and C. Ferguson, eds. *Child Phonology: Vol. 1, Production*. Academic Press, New York.

Mohanan, K.P 1993. Fields of attraction in phonology. In John. Goldsmith (ed). *The Last Phonological Rule*. University of Chicago Press.

Nordstrom, Barrett. 2001. A Study In Child Consonant Harmony. Ms, University of Massachusetts, Amherst.

Ohala, Diane. 1996. *Cluster reduction and constraints in acquisition*. Ph.D., University of Arizona.

Ohala, John. 1990. The Phonetics and Phonology of Aspects of Assimilation. In J. Kingston and M. Beckman (ed.) *Papers in Laboratory Phonology I: Between the Grammar and Physics of Speech*. Cambridge University Press: Cambridge.

Pater, Joe. 1997. Minimal Violation and Phonological Development. *Language Acquisition* 6. 201-253.

Pater Joe and Jessica Barlow. 2002. Constraint Conflict in Cluster Reduction. Ms, University of Massachusetts, Amherst and San Diego State University.

Pater Joe and Jessica Barlow. To appear. A Typology of Cluster Reduction: Conflicts with Sonority. In the *Proceedings of the 26th Annual Boston University Conference on Language Development*.

Pater, Joe and Adam Werle. 2001. Typology and variation in child consonant harmony. In Caroline Féry, Antony Dubach Green and Ruben van de Vijver (eds.), *Proceedings of HILP*5, University of Potsdam. 119-139.

Prince, A. 1997. Stringency and Anti-Paninian Hierarchies, Handout from LSA Institute.

Prince, Alan and Paul Smolensky. 1993. *Optimality Theory: Constraint Interaction in Generative Grammar.* Rutgers Center for Cognitive Science.

Rose, Sharon, and Rachel Walker. 2001. A typology of consonant agreement as correspondence. Ms, University of California, San Diego and University of Southern California.

Rose, Yvan. 2000. *Headedness and Prosodic Licensing in the L1 Acquisition of Phonology*. Ph.D. dissertation, McGill University.

Smith, N.V. 1973. The Acquisition of Phonology: A Case Study. Cambridge University Press.

Stampe, David. 1973. *A Dissertation on Natural Phonology.* Ph.D. Dissertation University of Chicago (Published by Garland 1979).

Stoel-Gammon, Carol. 1996. On the acquisition of velars in English. *Proceedings of the UBC International Conference on Phonological Acquisition*. Somerville, MA: Cascadilla Press. 201–214.

Stoel-Gammon, Carol and Joseph Stemberger 1994. Consonant harmony and underspecification in child speech. In M. Yavas (ed). *First and Second Language Phonology*. San Diego: Singular Publishing group.

Vihman, Marilyn. 1978. Consonant harmony: its scope and function in child language. In J.H. Greenberg (ed). *Universals of Human Language. Stanford University Press*. 281–334.

Vihman, Marilyn. 1980. Sound Change and Child Language. In E. Traugott, R. Labrum and S. Shepard, eds. *Papers from the 4th International Conference on Historical Linguistics*, John Benjamins, Amsterdam, The Netherlands.

Wilson, Colin. 2001. Consonant cluster neutralization and targeted constraints. *Phonology* 18, 147