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Markedness and Faithfulness Constraints in Child Phonology*

1. Introduction

This paper argues that the constraint based Optimality Theory (Prince & Smolensky 1993) provides a framework which allows for the development of a unified model of child and adult phonology and the relation between the two. In Optimality Theory (OT) an adult phonology consists of a set of ranked constraints. The ranking, but not the constraints, differs from language to language. The constraints are therefore universal. If phonological constraints are universal, they should be innate. I claim that these innate constraints are operative in child phonology. The constraints used in adult language should therefore be adequate to account for child phonology data as well, without attributing to the child more representational levels or more rules than adults have. This paper shows that this is indeed the case.

The initial state of the phonology, I propose, is one in which constraints against phonological markedness outrank the faithfulness constraints, which demand that the surface form (output) is identical to the underlying form (input, in OT terminology).[1] The result is that in the initial stages of acquisition the outputs are unmarked. The process of acquisition is one of promoting the faithfulness constraints to approximate more and more closely the adult grammar, and produce more and more marked forms. The path of acquisition will vary from child to child, as different children promote the various faithfulness constraints in different orders.

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[1] A similar proposal, namely that constraints requiring unmarked prosodic forms initially outrank constraints requiring faithfulness to input segments, is made by Demuth (1995).

In adult languages certain faithfulness constraints outrank certain markedness constraints. This is required by the need to have enough contrasts to support a large lexicon. By interspersing the markedness and faithfulness constraints in a ranked hierarchy, every adult language balances markedness and unmarkedness. Each language will differ from others in its ranking of particular constraints, and so each language will express markedness and unmarkedness in different ways. The child, who begins with dominant markedness constraints—and hence unmarked outputs—has the task of achieving the particular ranking of unmarkedness and faithfulness found in her target language.

The markedness constraints do not simply disappear when they come to be dominated by faithfulness constraints. When the requirements of a dominant faithfulness constraint conflict with those of the dominated markedness constraint the effects of the markedness constraint will naturally be obscured. There are cases where the dominating faithfulness constraint is irrelevant, however. In such cases the effects of the markedness constraint will be clearly seen. Examples of this phenomenon, known as the **emergence of the unmarked** (McCarthy & Prince 1994), provide strong evidence that adult phonology is best described by the ranking of a set of universal constraints, as proposed by OT. This paper discusses certain examples of the emergence of the unmarked in child language. These cases do not receive adequate explanation in traditional rule-based theories. The success of OT in accounting for such cases demonstrates that the ranking of constraints in OT provides the correct model of both child and adult phonology.

I restrict my attention in this paper to a single child phonology. This allows focus on a single grammar, and hence a consistent constraint ranking. The particular child phonology I will consider in this paper is that of Gitanjali (G), my daughter, a 2 year old raised in a monolingual Standard American English environment. The characteristics of her phonology discussed below have been consistent for a period of several months, roughly 2;3 to 2;9, indicating that they are properties of a semi-steady state grammar. The properties of G's phonology are consistent with those reported elsewhere for the normal acquisition of English (see, for example, Edwards & Shriberg (1983), Grunwell (1981) Ingram (1989a,b) and Stoel-Gammon & Dunn (1985)).

I will show evidence that G's inputs (underlying forms) are in general segmentally accurate, that is they contain the phonemes of the adult forms.[2] The difference between G's phonology and that of the target English lies in the fact that G still ranks certain markedness constraints above certain faithfulness constraints. It does not lie in having different segments in the inputs, different rules or constraints, or a different model of grammar.

G's grammar produces syllables which have at most one consonant in onset position. Her inputs, however, have up to three consonants in onset. In limiting onsets to one segment G's grammar displays less markedness than the target English. The unmarked structure of G's onsets is the result of ranking the markedness constraint ∗COMPLEX (the constraint forbidding complex onsets) above faithfulness. Although G's onsets are always maximally unmarked in segment number, they vary in markedness with respect to the sonority of the onset. When G's input has only one consonant available for onset it will be used regardless of how marked an onset it makes. When G's input provides a choice of onset consonants, however, her grammar selects as onset the one which is least sonorous and thus the least marked syllable onset. This selection of one onset consonant demonstrates emergence of the unmarked: low-ranking constraints on sonority have the power to select the least marked onset when there is underlyingly more than one onset consonant. The sonority constraints are too low

[2] Like other children (Macken 1980) G uses a few forms which can only be explained by assuming 'incorrect' inputs, i.e. inputs with different segments than the adults have. Presumably these forms originate in misperceptions. Such words are very few in G's speech, however. The vast majority of G's words can be systematically derived with the assumption of 'correct' inputs.

ranked to have an effect on marked underlyingly single onsets. The Obligatory Contour Principle also emerges to influence the selection of the onset consonant in some cases, but it does not rank highly enough to do so in all cases.

The onset consonants I discuss in this paper are specifically word-initial or stressed-syllable-initial. Section 3 introduces G's reduction of onset clusters, showing how ∗COMPLEX outranks faithfulness. Constraints on sonority select the least marked onset. Section 3 assumes that G has segmentally accurate (that is, adult-like) inputs. Section 4 demonstrates, based on the evidence of a dummy syllable, that G's inputs are indeed segmentally accurate. It discusses cases of onset selection in the presence of the dummy syllable, where the potential onset consonants are not underlyingly in a single cluster. Section 5 considers the behavior of labial clusters where the output onset consonant is not the same as any of the input consonants. The labial cluster data is used to show that G's preferred method of satisfying ∗COMPLEX is through coalescence. This section puts together the effects of sonority, ∗COMPLEX, faithfulness constraints on features and faithfulness constraints on segments. Section 6 looks at the exceptions to the pattern of labial coalescence in Section 5 and shows that these supposed exceptions provide a clear example of the emergence of the unmarked in the interaction between the OCP and the faithfulness constraints. The OCP is dominated and thus disabled in certain cases, but emerges to play a crucial role in others.

Before beginning the analysis of G's onsets, I present in Section 2 a brief outline of Optimality Theory and the view of faithfulness presupposed in the rest of this paper.

2. Optimality Theory and Correspondence

In Optimality Theory (Prince & Smolensky 1993) the heart of the phonology consists of a hierarchy of ranked constraints. For any given lexical input a universal function, Gen, supplies an exhaustive list of potential outputs. The hierarchy of constraints selects the candidate output which best satisfies the constraints. This winning candidate is the true phonological output.

Constraint rankings and their effects on selecting outputs are conventionally represented in tableaux. The following tableau gives a schematized example of output selection by ranked constraints.

(1)	Constraint A	Constraint B
candidate_1	*!	
√ candidate_2		*

In Tableau (1) Constraint A dominates Constraint B (abbreviated Constraint A >> Constraint B). This means that for any two candidates with otherwise identical constraint violations one which violates Constraint A will be discarded in favor of one which satisfies Constraint A and violates Constraint B instead. Constraint violations are shown with stars, and the constraint violation which eliminates a candidate from further consideration is marked with an exclamation point. Thus in Tableau (1) the violation of Constraint A by candidate_1 eliminates it as a potential output. Although it violates Constraint B, candidate_2 best satisfies the simplified constraint hierarchy in (1). It is therefore the candidate which is selected as output. This is shown by the check mark to the left of candidate_2. Since candidate_1 is eliminated by the highest constraint, the satisfaction or violation of Constraint B is *irrelevant*. Candidate2 is optimal regardless of the presence or absence of stars under Constraint B, since all competition was eliminated by

Constraint A. The irrelevance of Constraint B violations is emphasized by shading the boxes under Constraint B.

There are two basic types of constraints which are relevant to this paper. One is the markedness constraints which militate against marked structures. The other type comprises the faithfulness constraints which demand identity between input and output. The particular model of faithfulness I adopt here is the Correspondence theory of McCarthy & Prince (1995a), which expands on the notion of faithfulness developed by Prince & Smolensky (1991, 1993).

In Correspondence, the segments of two phonological representations (here input and output, but also base and reduplicant in reduplicative morphology) are seen as being related by a mapping from one to the other. Where the mapping does not describe identity between input and output (or base and reduplicant), violations occur.

For concreteness, consider two families of constraints on correspondence, MAX and IDENT[F]. MAX (specifically MAX-IO which evaluates the mapping from input to output) requires that each segment in the input have a correspondent in the output. In other words, deletion is disallowed by this constraint since deletion would result in a segment in the input that corresponds to no segment in the output. MAX-IO replaces the PARSE of the Parse/Fill model of faithfulness in Prince & Smolensky (1991, 1993).

IDENT[F] is a family of constraints which demand identity between a segment's value for some feature [F] and the value of that feature in the segment's correspondent. Thus IDENT[F]-IO requires that if an input segment possesses the feature value [αF] the output correspondent of that segment must also possess the value [αF]. IDENT[F] replaces the PARSE-FEATURE constraints of Parse/Fill versions of faithfulness, but is not identical in its effects. IDENT[F] can only be violated by a segment which has an output correspondent. If the segment is deleted, MAX is violated, but IDENT[F] is not.

For a hypothetical input /skat/ and candidate output *ska* the output incurs one violation of MAX-IO, but no IDENT[F] violations. The candidate output *ska/* does not incur a MAX violation if the final glottal stop is derived from the input *t*. It does, however, violate IDENT[Coronal], as the [Coronal] feature of the input *t* is not present on its correspondent /. The correspondence between segments which are not featurally identical can be made explicit by coindexing, as in input $s_1k_2a_3t_4$ and output $s_1k_2a_3/_4$.

3. Selection of an unmarked onset: ∗COMPLEX and sonority

In G's language syllables may begin with at most one consonant. Underlyingly complex onsets must therefore be reduced to a single segment. Examples of such reduction are shown in (2). The examples in (2) all violate faithfulness to the input in order to have wellformed onsets.

(2)	clean	[kin]
	draw	[d]
	please	[piz]
	friend	[fɛn]

Prince & Smolensky (1993) provisionally propose the constraint ∗COMPLEX to rule out more than a single consonant in onset position. Although it is sufficient for the present purposes, ∗COMPLEX as stated has the undesirable property of counting the segments in onset position. The prohibition on complex onsets is more accurately seen as related to or derived from other constraints on onset clusters which are evaluated in terms of factors such as sonority distance. The extreme case, seen in G's language, where all clusters are ruled out may be due to the effects of several constraints on clusters or of one which, say, requires a large minimal sonority distance between onset segments. Since all complex onsets in G's language are equally ruled out there is the appearance, at least, of a single constraint at work. In the absence of a more articulated theory of onset clustering, I will continue to use ∗COMPLEX.

The markedness constraint ∗COMPLEX is unviolated in G's language.[3] In order to satisfy ∗COMPLEX, the output forms in (2) are unfaithful to the input, and as such violate one of the faithfulness constraints on correspondence between input and output. For the present purposes I will identify this constraint as FAITH. Considered in isolation the data in (2) would lead to the conclusion that the FAITH constraint is MAX (IO), the constraint (described in Section 2 above) which demands that all the segments in the input have a correspondent element in the output. As Section 5 will show, however, further details lead to the conclusion that the violated constraint is not MAX.

The tableau in (3) illustrates how the ranking of ∗COMPLEX above FAITH forces violation of FAITH. Any attempt to retain both onset segments of 'please' in the output will violate the higher ranked ∗COMPLEX, so such a candidate is ruled out. The winning candidate satisfies ∗COMPLEX by losing one consonant. In the case of underlying /piz/ 'peas', however, losing a consonant results in a gratuitous FAITH violation. The winning candidate respects FAITH, and so the onset *p* is retained in the output.

(3)	∗COMPLEX	FAITH
please: pliz → pliz	∗!	
√ pliz → piz		∗
√ peas: piz → piz		
piz → iz		∗!

[3] Occasionally mimicked words show more adult-like pronunciation. This is presumably because G is phonetically capable of producing onsets that her phonology does not allow.

The situation is more complex than tableau (3) indicates, however. Since ∗COMPLEX requires simply that the onset contain maximally one segment, either the *p* or the *l* could have been deleted in 'please'. Although the first consonant is the surviving one in the examples in (2), the examples in (4) show that this is not always the case.

(4a)	sky [gay]		skin	[gIn]
	spill [bIw]		spoon	[bun]
	straw [d]		star	[dA:]
b)	snow [so]		snookie	[sUki]
	slip [sIp]		sleep	[sip]

In the examples in (4a), the initial *s* is lost. This is not true of all initial *s*'s, however, as (4b) shows. When the *s* is less sonorous than the following consonant it is retained in the output. If the *s* is more sonorous than the following consonant, it is deleted. Similarly, it is the more sonorous consonant in (2) that is deleted. Thus it is only the least sonorous of a string of onset consonants that is present in G's output. This means that G produces syllables that optimize syllable shape not only with respect to segment number (restricting to one onset consonant), but also with respect to sonority requirements. The optimal syllable begins with an onset of low sonority and is followed by a vowel.

G's reduction of multiple onset consonants to a single onset consonant in the mapping between input and output is analogous to the reduction of onset clusters in the mapping between base and reduplicant in Sanskrit. In Sanskrit reduplication a single-onset syllable is prefixed to the verb stem. The segments of the prefixal syllable are determined by the stem. With minor changes such as deaspiration the least sonorous onset consonant of the stem begins the prefix and is followed by the vowel. Examples of perfect reduplication are shown in (5a), while (5b) (5c) and (5d) show forms in the aorist, intensive and desiderative respectively (from Whitney (1889), who does not supply glosses). In the examples in the left column the first consonant is least sonorous and thus appears in the reduplicant. In the right-hand column it is the second consonant that is least sonorous and shows up in the reduplicant.

(5a) Perfect

pa - **p**rach	**t**a - s**t**Ha:
ši - **š**ri	**c**u - š**c**ut
sa - **s**na:	**p**u - s**p**Huṭ
su - **s**ru	
ši - **š**liṣ	

(5b) Aorist:

a - **t**i - **t**rasam	a - **p**i - s**p**ršam
a - **s**i - **ş**yadam	

(5c) Intensive:

ša: - **š**vas	**k**ani - ṣ**k**and ~ **c**ani - ṣ**k**and
ve - **v**li:	
po - **p**rutH	

(5d) Desiderative

šu - **š**ru:ṣa	**t**i - s**t**i:rṣa

As the examples in (5) show, the onset reduction occurs in all cases of reduplication in Sanskrit. Onset reduction is thus not a special rule of some mood or tense but rather a general property of Sanskrit reduplicants. In Correspondence theory, the reduplicant is related to the base by a mapping analogous to the mapping between the output and the input. Sanskrit reduplicants obey ∗COMPLEX at the cost of violating faithfulness to the base, while in G's language the outputs obey ∗COMPLEX at the cost of violating faithfulness to the input.

The difference between Sanskrit reduplication and G's treatment of onset clusters in (2) and (4) is that in the Sanskrit case the optimized syllable of the prefixed reduplicant stands in relation to the more complex verb stem base, while in G's speech the output unmarked syllable stands in relation to the more complex input form. G's grammar ranks ∗COMPLEX above FAITH -IO, the constraint requiring faithfulness of the output segments to the input segments. This was shown in tableau (3). In Sanskrit FAITH-IO outranks ∗COMPLEX, since underlying /stHa:/ surfaces as *stHa:* and not ∗*tHa:* or ∗*sa:*. FAITH-BR, the constraint requiring faithfulness of the reduplicant to the base, is dominated by ∗COMPLEX, with the result that the reduplicant may not have the base's complex onset.[4]

Sanskrit reduplication is a typical case of the emergence of the unmarked discussed in McCarthy & Prince (1994) (*cf*. Steriade's (1988) discussion of unmarkedness in Sanskrit reduplicants). In non-reduplicative environments Sanskrit yields no evidence for the existence of the constraint ∗COMPLEX. The grammar of Sanskrit does possess ∗COMPLEX, however, because in reduplicative environments it is clearly active. The limiting of the effects of ∗COMPLEX to reduplicative contexts can be described by the ranking of ∗COMPLEX below FAITH-IO but above FAITH-BR: FAITH-IO >> COMPLEX >> FAITH-BR.

Such cases of the emergence of the unmarked support the claim of OT that constraints are universal. Even though ∗COMPLEX appears inactive in Sanskrit bases, the reduplicants show that it is indeed active in Sanskrit in spite of being dominated by constraints such as FAITH-IO. The ranking of ∗COMPLEX in Sanskrit shows that a dominated constraint is still present in a grammar. The natural extension of the Sanskrit case is a language in which ∗COMPLEX is ranked yet lower, and so is never active. Based on this reasoning OT assumes that all constraints which are not active in a particular language are still present in the constraint hierarchy of that language. They are rendered inactive by the operation

[4] In Sanskrit FAITH-IO and FAITH-BR are respectively the MAX-IO and MAX-BR of McCarthy & Prince (1995a). I use the more general FAITH to facilitate comparison with G's language.

of the constraints which dominate them. Thus English possesses the constraint ∗COMPLEX, but it is obscured by the faithfulness constraints.

If constraints are universal, they should be innate. Therefore G's grammar possesses ∗COMPLEX in spite of the fact that she has never heard evidence for such a constraint in her target language. ∗COMPLEX is active in her language because the faithfulness constraints have not yet been promoted enough to obscure it. The difference between G's language and English is thus not the presence of the ∗COMPLEX constraint. The difference is that G ranks the markedness constraint ∗COMPLEX above FAITH-IO and English ranks FAITH-IO above ∗COMPLEX. To acquire the English phonology in this respect G will need to promote FAITH-IO above ∗COMPLEX. The relevant constraint rankings of Sanskrit, G's English and adult English are shown in (6) (The ranking of FAITH-BR in English and G's speech is indeterminable, since these languages do not employ reduplication).

(6)

a.	Sanskrit:	FAITH-IO >> ∗COMPLEX >> FAITH-BR
b.	G:	∗COMPLEX >> FAITH-IO
c.	English	FAITH-IO >> ∗COMPLEX

The constraint rankings in (6) account for the reduction of complex onsets to single segments in G's words and in Sanskrit reduplicants. What is not yet accounted for is the choice of which segment survives in the output or reduplicant. In selecting the onset, G and Sanskrit display unmarkedness. The least marked syllable onset is the least sonorous one. An optimal onset consists of a voiceless stop, followed by a voiced stop as next best, and so on down the universal Sonority Hierarchy in (7).[5]

[5] For the use of sonority to optimize syllable shapes in OT, see Prince & Smolensky (1993). For other references establishing the sonority hierarchy, see Sievers (1881), Jespersen (1904,) de Saussure (1916), Zwicky (1972), Hankamer & Aissen (1974), Hooper (1976), Steriade (1982), and Selkirk (1984) among others.

(7)	voiceless stop	e.g.	p, t, k
	voiced stop		b, d, g
	voiceless fricative		f, s, x
	voiced fricative		v, z, ˜
	nasal stops		n, m, N
	liquids		l, r
	high vowels/glides		i/y u/w
	mid vowels		e, o
	low vowels		a

In a word such as /sbun/ 'spoon',[6] the *s*, as a fricative, is more sonorous than the stop *b*. The stop is thus the best available onset, so the *s* is deleted and the *b* remains in the output *bun*. In a word like /sno/ 'snow', the *s* is less sonorous than the nasal *n*, so the *s* is retained in the output *so*. In a word like /pliz/ 'please', the stop *p* is less sonorous than the *l*, so it is the surviving output onset in *piz*.

The selection of the one least sonorous (and therefore least marked) onset is a form of emergent unmarkedness. In simple onsets, marked segments can occur freely. In Sanskrit reduplication and in G's speech syllables may begin with consonants of high sonority, including glides. When the base (in Sanskrit) or the input (in G's language) has a single onset consonant, that consonant surfaces in the reduplicant or output even when it is very sonorous. Marked onsets are thus allowed in G's language and in Sanskrit reduplication. The effect of sonority emerges only when there is a choice of consonants. In such cases G and Sanskrit both select the least sonorous consonant as onset, thus optimizing the shape of the syllable.

Gnanadesikan (1995) proposes that the preference for low sonority in onsets derives from the related preference for high sonority in moraic (non-onset) positions. If a segment is excluded from onset position on the grounds of sonority

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[6] Since G produces s+stop clusters as a simple voiced stop, I assume that she has assigned the neutralized voiceless unaspirate of this position to the voiced (unaspirated) phoneme. This is not uncommon, although children vary as to whether they treat these unapirated stops as voiced or voiceless (Bond & Wilson 1980).

it is because the segment is better parsed as moraic. The preference for sonorous segments to be moraic can be captured by the family of constraints shown in (8) where μ/Y stands for 'each Y must be parsed as a mora'.[7] For example, an *i* which is not assigned a mora in the output violates μ/i. An *m* which is assigned a mora satisfies μ/m, but is irrelevant to μ/i.

(8) μ/a >> μ/e,o >> μ/i,u >> μ/r,l >> μ/m,n >> μ/v,z >>
μ/b,d >> μ/f,s >> μ/p,t

The subhierarchy of constraints in (8) ensures that segments of a given sonority will be assigned moras preferentially over segments of lower sonority.[8] Thus *l*, for instance, will be assigned a mora preferentially over a segment such as *s*. As a result, it is worse to assign *l* to a non-moraic onset position than it is to assign *s* to an onset. That some segment must be assigned to onset position is assured by the constraint ONSET, which demands that every syllable have an onset.[9] This is demonstrated in tableau (9) for examples from G's speech (only the relevant part of the μ/Y subhierarchy is shown). The effect of ∗COMPLEX (shown above in tableau (3)) is assumed, so only candidates without complex onsets are considered. The ranking of FAITH-IO with respect to the subhierarchy of constraints in (9) is undeterminable at this time. The crucial point is that given the undominated ranking of ∗COMPLEX, FAITH-IO must be violated in complex onset cases, and the sonority constraints take advantage of this forced violation to minimize μ/Y sonority violations.

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[7] The constraint family in (8) is closely related to Prince & Smolensky's (1993) ∗Margin hierarchy which prohibits segments from being parsed as syllable margins (forcing them to be parsed as nuclei) The difference between the ∗Margin hierarchy and the μ/Y hierarchy is that by the use of moraic versus nonmoraic positions (instead of nuclear versus margin positions) the μ/Y hierarchy accounts for the fact (discussed by Zec (1988)) that codas are of high sonority relative to onsets.

[8] Given the universal nature of the Sonority Hierarchy, the ranking of the constraints in (8) should also be universal.

[9] Not resolved here is what prohibits the whole μ/Y hierarchy from outranking ONSET and thus producing a language with no onsets at all. The same open question exists in Prince & Smolensky's (1993) presentation of syllabification, since theoretically their whole ∗Margin/x hierarchy (which prohibits segments from being parsed as margins) could outrank ONSET, yielding a language with only nuclear segments.

(9)	ONSET	μ/r,l	μ/m,n	μ/v,z	μ/s,f	μ/b,d,g
sky: sga^y → sa^y					*!	
√ sga^y → ga^y						*
sga^y → a^y	*!					
snow: √ sno → so					*	
sno → no			*!			
sno → o	*!					
sleep: √ slip → sip					*	
slip → lip		*!				
slip → ip	*!					
draw: √ dr → d						*
dr → r		*!				
dr →	*!					

The tableau in (9) demonstrates a consequence of adopting the McCarthy & Prince (1995a) Correspondence interpretation of faithfulness over the Parse/Fill version in Prince & Smolensky (1993). By the Parse/Fill conception the input is literally contained in the output. Segments which appear to be deleted are considered to be actually present in the output but not heard because they are not parsed prosodically. In the Parse/Fill view segments such as the *l* in *sip* (G's output for /slip/ 'sleep') would be present in the output but not parsed. As an unparsed segment the *l* would not be associated with a mora, and so would violate μ/l. Under Correspondence, on the other hand, the *l* is missing from the output.

There is no output *l* which could fail to be parsed as a mora, and so μ/l can not be violated. The Correspondence theory thus captures the intuition that when *l* is deleted it is then exempted from constraints requiring it to be moraic.

This section has demonstrated the power of OT to capture both child and adult phonology. OT provides a set of universal constraints which are operative in both children and adults. Comparison of G's phonology with that of Sanskrit shows that G is using the same constraints as those present in adult language. This was shown by the similar action of ∗COMPLEX and the sonority constraints in Sanskrit and in G's language.

Comparison of English and G's language demonstrates the innateness of the phonological constraints. G uses the constraint ∗COMPLEX in spite of the fact that English, her target language, provides her with no evidence for its existence. English contains a high percentage of words with complex onsets, so that G would not postulate ∗COMPLEX as a property of her target language. G does use ∗COMPLEX, however, and ranks it highly enough that it is never violated in her language. By the ranking of ∗COMPLEX over FAITH-IO (as shown in tableau (3)) English *straw*, *please* and *friend* become *d* , *piz, fɛn.*

In Sanskrit ∗COMPLEX is ranked less highly. It is dominated by FAITH-IO but it outranks FAITH-BR. The result is that the effects of ∗COMPLEX emerge in reduplicants but not in bases, yielding reduplicant-base forms such as *ta-st*H*a.* Sanskrit, G and English provide a paradigm of rankings of the universal constraint ∗COMPLEX with respect to faithfulness constraints. In G's language ∗COMPLEX is undominated and hence unviolated. In Sanskrit ∗COMPLEX is dominated but still active where the dominating constraint (here FAITH-IO) is irrelevant, demonstrating emergence of the unmarked. In English ∗COMPLEX is dominated and never active.

G's ranking of ∗COMPLEX over FAITH-IO in the face of the opposite ranking in English is in keeping with the proposal made in Section 1 that initially markedness constraints outrank faithfulness constraints. To acquire the English ranking she will have to promote FAITH-IO above ∗COMPLEX. The sonority constraints are at this point already dominated by faithfulness constraints, since very sonorous consonants can be onsets. When there is a choice of onset segments, though, the effects of sonority emerge, selecting *s* in *so* 'snow', but *d* in *d* 'straw' (as shown in tableau (9)).

4. Dummy syllable, onset selection and the nature of the input

The previous section assumed that G's inputs are segmentally like those of adults, that is they contain the phonemes of the forms she hears around her. The sonority constraints and ∗COMPLEX were used to derive her less marked outputs from the more complex inputs. The assumption of generally accurate inputs is not universally accepted in child phonology (see, for example Ingram 1976 et seq., discussed in Section 7 below). The unmarked outputs of child language could theoretically be derived from unmarked inputs, obviating the need for output constraints in child phonology. This section offers evidence, based on the behavior of onsets in the presence of a dummy syllable, that G's inputs are indeed segmentally accurate. The outputs, however, are subject to interacting constraints. This strengthens the claim that the difference between child language and adult language lies in different constraint rankings, as predicted by OT.

One of the most obfuscating elements of G's language is her use of a dummy syllable *fi*-, used for word-initial unstressed syllables. Examples are shown in (10).

(10)	umbrella	[fi-bɛyˆ]	container	[fi-tenˆ]
	mosquito	[fi-giDo]	spaghetti	[fi-gɛDi]
	Christina	[fi-dinˆ]	Rebecca	[fi-bɛkˆ]
	advisor	[fi-vayzˆ]	rewind	[fi-wayn]

As the forms in (10) demonstrate, the *fi-* syllable appears in pretonic initial syllable, regardless of that syllable's phonological content in the adult language.[10] The segments of the initial unstressed syllable are deleted, but an unstressed (or secondarily stressed) syllable still occurs. This implies that G's inputs contain syllable structure. By using *fi-*, G's output is faithful to the input at the syllable level since the output has the same number of syllables as the input. At the segmental level, however, G's *fi-* outputs are wildly unfaithful to the input.[11] If G's inputs did not contain syllable structure there would be no syllables to be faithful to, and there would be no reason to insert *fi-*. G's grammatical inputs are thus closer to her perceived forms, i.e. the adult outputs, than the adults' own inputs are generally thought to be. Adult inputs are generally assumed to be unsyllabified, since syllabification is predictable from the input and the grammar.

The use of *fi-* is analogous to melodic overwriting such as that commonly seen in echo word formation (McCarthy & Prince 1986, 1990, 1995b; Steriade 1988; Yip 1992). Echo words are formed by reduplication with a fixed melody replacing part of the base melody in the reduplicative morpheme. This is shown in (11) for echo words in Kolami (from McCarthy & Prince, citing Emeneau 1955).[12]

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[10] G's use of *fi-* is remarkably similar to A's (Smith, 1973) use of the syllable *ri-* in practically the same invironment (A's was initial unstressed syllables whose vowel was *i* or «. It is hard to tell whether the vowel quality is important or not, since virtually all unstressed vowels can be reduced to «). In both cases there is a labial or labialized continuant onset followed by an *i* vowel. Like A, G shows some variation, so that G's 'piano' has been pronounced as both *pinæno* and *fi-næno*. In G's case it is my impression that the occasional non-use of *fi-* is most likely to occur in words which begin with labial consonants. I assume this is because G can pronounce an underlying labial consonant with as little violence as possible to the set *fi-* form.

[11] At an earlier stage the initial unstressed syllables were deleted, as is typical in child language (Grunwell 1981). The dummy syllable stage represents an intermediate stage where faithfulness to the *syllable* has been promoted, but faithfulness to the *segments* has not.

[12] Such melodic overwriting takes different forms in different languages, so that the form of the overwriting melody should not be considered as dictated by a universal constraint. Overwriting cases such

(11)	pal	pal-gil	'tooth'
	kota	kota -gita	'bring it!'
	iir	iir - giir	'water'
	maasur	maasur-giisur	'men'
	saa	saa - gii	'go, cont. ger.'

In Kolami, the melodic overwriting replaces the first consonant (if any) and the first vowel (long or short) of the base. Coda consonants after the first vowel remain faithful to the base. In G's language she overwrites a whole syllable whether open or closed. Thus both the *chris* in 'Christina' and the *re* of 'Rebecca' are replaced by *fi*-. The difference between adult language overwriting and G's overwriting is that in G's overwriting a whole syllable is replaced, while in adult overwriting only segments are replaced. Kolami therefore has *pal-gil*, replacing the first two segments, but leaving the coda *l* of the base to show up after the overwriting *gi*. G, on the other hand, has forms such as *fi-ten*ˆ 'container', which replaces the *con* syllable with the codaless *fi*-, rather than ∗*fi-nten*ˆ, which leaves the coda. Given that G's inputs possess prosodic structure and adult inputs presumably do not, this difference is not surprising. In G's language the initial unstressed syllable is required to stand in correspondence to a syllable whose segments are *fi*-. If adults do not have syllables in their inputs they can not overwrite whole syllables (as G does with *fi*-), but only segments.[13]

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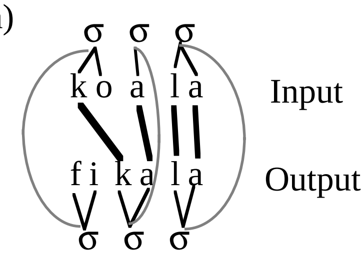
as G's *fi*- and *gi* in Kolami require some special treatment as they are not simply the insertion of default unmarked segments. In OT most epenthesis can be handled by insertion of the least marked segment in the language (the one that violates the lowest ranked markedness constraints). It is doubtful, however, that *f* and *g* should be considered the least marked consonants in G's language and Kolami (especially given the facts of Section 3 showing the preference of the sonority constraints for onset stops). This is related to the problem of *r*-insertion in Boston English discussed by McCarthy (1993) within the parse/fill model of faithfulness. McCarthy proposes a language (dialect) specific 'rule' outside the constraint system of OT that arbitrarily selects *r* as the epenthetic segment. Such language-specific statements would pick out *fi* and *gi* in G's language and Kolami.

[13] It may be possible to analyze G's use of *fi*- without positing syllable structure in the input by stating that the overwriting applies not to a syllable but to any material preceding the first foot (assigned and evaluated at the output). I assume input syllabic structure here since it allows a succinct analysis, i.e. syllabic overwriting.

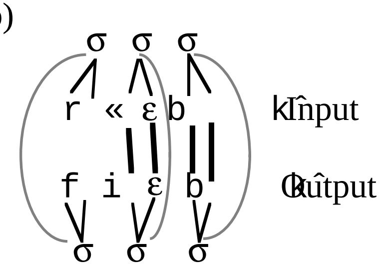
It can be determined that despite the *fi*-induced disparity between G's forms and the adult forms G still retains the segments of the first syllable in her underlying form. The evidence for this comes from the interaction of *fi*- with the sonority constraints on the onset of the stressed syllable (the first syllable that is segmentally related to the adult form). In a word like 'koala', straightforward *fi*-insertion would lead one to expect an output of ∗*fi-ala* or ∗*fi-wala*. To have no onset, as in ∗*fi-ala*, violates ONSET, while to have a glide onset, as in ∗*fi-wala*, induces a high-ranking μ/glide violation. To remedy this, G uses the onset consonant which has been removed from the first syllable to make room for *fi*-. Her output is *fi-kala*. This shows that G retains the consonants she hears in her input forms even when she does not pronounce them. When sonority constraints demand, she still has the consonants available.

In producing *fi-kala* G violates the faithfulness constraint I-CONTIG, which demands that the segments of the input which stand in correspondence to segments of the output form a contiguous string.[14] The mapping from input to output forms is shown in (12), where 'koala' is compared with 'Rebecca'. Heavy lines show segmental correspondence between input and output. Note that these are not association lines, but simply the equivalent of coindexing between input and output corresponding segments. Dotted lines show correspondence between input and output syllables. Light lines show the association of segments with syllables.

(12a)



(12b)



[14] See McCarthy & Prince (1995a) for the motivation of this constraint in adult languages, the evidence for which includes the preservation in languages such as Diyari (Austin 1981) of word-internal codas but not word-final ones in the face of a prohibition on syllable codas.

In (12) both outputs violate FAITH, but (12a) also violates I-CONTIG, since the segments of the input which participate in the correspondence from input to output do not form a contiguous string. The transfer of a better onset to the second syllable in defiance of the contiguity constraint occurs in cases where the adult syllable is onsetless or begins with a glide or liquid. It does not occur if the adult syllable begins with a nasal or an obstruent. Compare (13a) with (13b).

(13a)	balloon	[fi-bun]
	police	[fi-pis]
	below	[fi-bo]
	barrette	[fi-bɛt]
(13b)	tomorrow	[fi-mAwo]
	potato	[fi-teDo]
	Simone	[fi-mon]

Onset replacement occurs in cases where the input stressed syllable has a glide or liquid onset, but not if that onset is any less sonorous.[15] Unlike in the onset reduction discussed in Section 3 the *fi-* related onset replacement does not occur in all cases where the unstressed syllable has a less sonorous onset than the stressed syllable. This is demonstrated in forms such as 'Simone'. As Section 3 showed, contiguous *s*-nasal clusters lose the nasal in favor of the fricative *s*. As a result 'snow' is pronounced *so*. In the non-contiguous *fi-* cases a nasal remains and is not replaced by a fricative. 'Simone' is *fi-mon* not ∗*fi-son*. The data in (13) thus show that although sonority constraints are at work in both the contiguous cluster cases of Section 3 and the non-contiguous *fi-* cases, the faithfulness constraint which interacts with the sonority constraints must be different in the two types. I-

[15] A potential obstacle to this interpretation is that *h* is left in words such as *fi-hayn* 'behind', and *h* is arguably more sonorous than liquids (Gnanadesikan, 1995, in prep.) since it patterns with the more sonorous glides in processes such as nasal harmony. Although the G's liquids were realized as glides (and so weresafely more sonorous than *h*.) at the time of the transcriptions shown here, later pronunciations have onset *l*'s which are pronounced as lateral. Although *h* patterns as very sonorous in harmony processes, it is exceptional in syllablification, avoiding moraic positions and preferring onsets.

CONTIG is therefore separate, and separately ranked from the FAITH of Section 3.[16] Violation of I-CONTIG is forced by μ/glide (13a), but not by the lower-ranked μ/Y constraints (13b). FAITH-IO, on the other hand, is dominated by ∗COMPLEX and unrankable with respect to the μ/Y subhierarchy.

Tableau (14) illustrates the action of sonority requirements and I-CONTIG in the presence of *fi*-insertion. μ/glide covers both liquids and glides, as they are all glides at the output, where the constraints are operative. The mechanism responsible for the *fi-* is not included in the tableau, pending a clearer conception of melodic overwriting in OT. All candidates are assumed to have *fi-*.

(14)	ONSET	μ/glide	I-CONTIG	μ/m,n,	μ/v,z	μ/b,d
balloon: √ fi-bun			*			*
fi-yun		∗!				
Rebecca: √ fi-bɛkˆ						*
fi-wɛkˆ		∗!				

In spite of the fact that G's use of *fi-* leads to significant divergence from the segments of the adult unstressed syllable, the interaction between *fi-* and the sonority requirements on the following onset shows that G's inputs coincide segmentally with the adult forms. When required by ONSET or μ/glide, the onset of the syllable replaced by *fi-* shows up on the next syllable, demonstrating that the replaced segments are still present and available for use by the phonology.

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16 Forms discussed in Section 3, such as *piz* from /pliz/ 'please', seem to violate I-CONTIG as well, since the /l/ is absent in the output. As Section 5 will show, however, most of G's onset reductions are actually effected through coalescence, which is vacuous in a word like 'please'. As a result, the forms in Section 3 (in which the coalescing segments of the input onset cluster are themselves contiguous) do not violate I-CONTIG. The *fi-* forms do violate I-CONTIG, however, since the coalescing consonants are separated by a vowel.

Furthermore, the presence of the dummy syllable *fi-* shows that her inputs are prosodically accurate even when her outputs are segmentally divergent. Although the segmental content of the *fi-* syllable is idiosyncratic, the constraints with which it interacts are not. The constraints that this section presents as selecting G's output, namely the μ/Y constraints and I-CONTIG, are precisely those which have been independently proposed as universally existing in adult grammar.

5. Identifying FAITH: Interaction of Labials with ∗COMPLEX

Section 3 described how G's grammar selects one of a series of onset consonants as output onset, yielding unmarked syllable shape. At that time the constraint violated by cluster reduction was referred to simply as FAITH-IO. This section takes up the question of the identity of FAITH. The relevant data comes from onsets which contain labial consonants. In certain labial clusters the output onset consonant is not identical to any of the input consonants. Examples are shown in (15).

(15)	tree	[pi]	drink	[bɪk]
	cry	[pay]	grape	[bep]
	quite	[payt]	squeeze	[biz]
	string	[bɪn]	twinkle	[pɪk«w]
	sweater	[fɛDˆ]	smell	[fɛw]
	between	[fi-pin]		

In each case in (15) the last consonant in the adult onset is labial (in the case of *w*) or labialized (in the case of *r*).[17] G's output consonant is also labial. (See Allerton (1976) and Chin & Dinnsen (1992) for similar patterns of cluster simplification where [labial] dominates.) In voicing, stricture and nasality, however, it matches the least sonorous onset consonant, the one which the facts in

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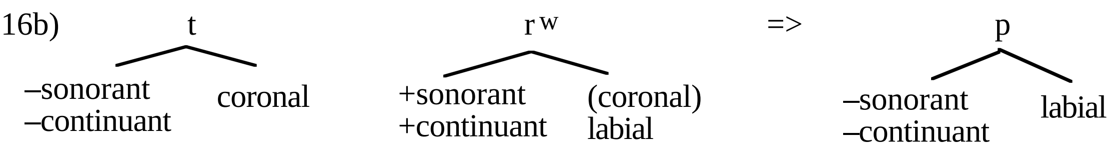
[17] G's pronounces English *r* and *w* both as [w]. I leave aside the question of whether this substitution is in the input or the output. To stress the labiality of *r*, I henceforth render *r* as r^w in G's input. In her output, of course, it is *w*.

section 3 would lead us to expect in the output. The consonants in (15) coalesce, with the sonority of one consonant showing up with the place of another. The correspondence between input and output for 'tree' is shown in (16a). The indices show that both the *t* and the r^w in the input are mapped to the *p* of the output. In (16b) is a close-up of the coalescing *t* and r^w and their affected features.

(16a) 'tree' $t_1w_2i_3$ (I)
$p_{12}i_3$ (O)

(16b)



In *pi* 'tree', the *p* corresponds to both the /t/ and the /r^w/ of the input, since it bears features of each. By coalescing the segments G can avoid deleting either one of the segments while still obeying the high-ranking ∗COMPLEX. Such a view of coalescence as a strategy to preserve the input segments is in contrast with a spreading and deletion model of coalescence (such as Chin & Dinnsen 1992) where one of the consonants in the cluster is still deleted. Since one of the segments is lost anyway, the motivation for the spreading of features is arbitrary.

In OT coalescence makes sense as a way of remaining faithful to the input segments even in the face of ∗COMPLEX. Coalescence is not a cost-free proceedure, however. In coalescing these segments G violates No-Coalescence (NO-COAL), the faithfulness constraint that requires an output segment to correspond to only one input segment.[18] The violation of NO-COAL in reducing onset clusters demonstrates that NO-COAL is lower ranked than ∗COMPLEX.

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[18] NO-COAL is part of the LINEARITY constraint of McCarthy & Prince (1995a) which serves to prohibit both coalescence and metathesis. McCarthy & Prince suggest that the two functions might need to be separated, and I have done so in this paper because G's grammar treats coalescence and metathesis separately. Specifically, μ/glide could force NO-COAL violations (in the *fi-* cases) when it could no longer force metathesis. The constraints forbidding coalescence and metathesis must be different and separately ranked to produce different ranges of application. NO-COAL is like Lamontagne & Rice's (1995a,b)

There is good evidence that these labial cases do represent a coalescence and not an error in perception. That is, the coalescence occurs in the mapping between a segmentally accurate input and G's output. It is not the case that she hears the consonant cluster as a single labial consonant and therefore has a single labial in her input onset. The evidence for grammatical coalescence comes from forms where labial coalescence occurs in the non-contiguous consonants of *fi*-words. This is shown in (17).

(17)	gorilla	[fi-biyˆ]
	giraffe	[fi-bæf]
	direction	[fi-bɛkš«n]

In (17) the input onset of the stressed syllable is labial, but it is a glide in G's language. The facts in the previous section suggest that it should be replaced by the onset of the first syllable. As in the contiguous cluster examples in (15), coalescence occurs instead of outright replacement. The onset of the first syllable and the onset of the second syllable coalesce, yielding an output onset with the sonority of the first input onset and the labial place of the second.

In these cases of long-distance coalescence G could not perceive the two consonants as one, as the adults pronounce them in separate syllables. G recognizes the two syllables as distinct, since she replaces one with *fi-*. It is also not the case that G would perceive the non-contiguous consonants as contiguous. In a word like *fi-bæf* 'giraffe', the *b* is the result of coalescence between *ǰ* and r^w, two consonants that may not occur adjacent in English. The long distance coalescence facts thus provide further evidence that G's input is segmentally accurate, since she does not perceive the two syllable onsets as either one consonant or as adjacent when they are not.[19] The coalescence in labial clusters must therefore be a grammatical process, which occurs in the mapping between input and output, rather than a perceptual error or other process that would provide G with inputs that were already coalesced.

The labial cases provide evidence that the preferred way of avoiding a ∗COMPLEX violation is through coalescence (violating NO-COAL) rather than outright deletion (violating MAX-IO). If deletion were the optimal way of avoiding ∗COMPLEX violations, labial glides in input clusters would simply disappear in the output. This implies that for G it is better to coalesce segments, violating NO-COAL, than it is to delete them and violate MAX. In terms of G's constraint ranking, MAX dominates NO-COAL. By this ranking 'tree' is *pi*, not ∗*ti*, as shown in tableau (18) (as elsewhere, the effects of undominated ∗COMPLEX are assumed).

(18)	MAX	NO-COAL
tree: √ $t_1r^w{}_2i_3 \rightarrow p_{12}i_3$		*
$t_1r^w{}_2i_3 \rightarrow t_1i_3$	∗!	

The ranking of MAX over NO-COAL would suggest that coalescence is always better than deletion and so this is always the option that G pursues. In a case such as *kin* 'clean', however, the *l* apparently has no correspondent in the output. It appears as though deletion has taken place, not coalescence. In other words, it seems that NO-COAL is not violated but MAX is. The answer to this

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∗Multiple Correspondence, except that NO-COAL refers only to segments. It is violated by segment coalescence, but not featural assimilation. This is in accord with the spirit of the McCarthy & Prince (1995a) model which distinguishes the constraints on faithfulness to segments from the constraints on faithfulness to features.

[19] The fact that 'koala' becomes *fi-kala* and not *fi-pala* suggests that G regards its stressed syllable as onsetless, rather than having a labial glide onset.

apparent paradox is in the definition of correspondence of segments. In the example below in (19), Gen, which freely generates candidates for evaluation by the constraint hierarchy, generates both the form in (19a) and that in (19b) as potential outputs of 'clean'.

(19a)	'clean'	$k_{\mathbf{1}}l_{\mathbf{2}}i_3n_4$ (I)	b)	$k_{\mathbf{1}}l_{\mathbf{2}}i_3n_4$ (I)
		$k_{\mathbf{1}}i_3n_4$ (O)		$k_{\mathbf{12}}i_3n_4$ (O)

In (19a) Gen deletes the /l/ of the input, incurring a MAX violation.[20] In (19b) Gen maps both the input /k/ and the /l/ onto the output *k*. The output *k* is thus the correspondent of both the underlying /k/ and the /l/, as emphasized by the indices. No segment has been deleted, since all input segments have an output correspondent. Therefore the candidate in (19b) violates NO-COAL but not MAX. The output (19b) also violates a number of IDENT[F] constraints, the class of constraints discussed in Section 2 which control featural faithfulness. In fact none of the *l*'s features show up on it's output correspondent, and the coalescence is vacuous.

Such flagrant violation of the IDENT[F] constraints is driven mainly by the sonority constraints mentioned earlier. The μ/Y subhierarchy will pick out the manner features of the least sonorous input segment to show up on the coalesced output segment. This leaves the place features as the only way features of the more sonorous input consonant could show up on the coalesced output consonant. In the case of the labial or labialized consonants, the labial surfaces, as in the

[20] The output in (19a) also incurs an I-CONTIG violation. In developing the ranking argument for MAX and NO-COAL in this section it is difficult to separate the effects of MAX and I-CONTIG. It is possible to separate the effects of I-CONTIG and NO-COAL enough to show that MAX does dominate NO-COAL, since in the *fi*- cases of noncontiguous onsets (where an I-CONTIG violation is unavoidable) coalescence, not deletion, is still the preferred operation (as in *fi-bæf* 'giraffe'). It is more difficult to rank MAX and I-CONTIG with respect to each other and establish the precise ranking of MAX alone. For simplicity I concentrate on MAX in this section.

examples in (15) above. As forms such as *bin* 'green' testify, IDENT[labial] is higher ranked than IDENT[dorsal].[21] This is shown in tableau (20).

(20)	IDENT[labial]	IDENT[dorsal]
green: √ $g_1r^w{}_2i_3n_4 \rightarrow b_{12}i_3n_4$		*
$g_1r^w{}_2i_3n_4 \rightarrow g_{12}i_3n_4$	*!	

Forms such as *pi* 'tree' demonstrate that IDENT[labial] outranks IDENT[coronal] as well. This is shown in (21).

(21)	IDENT[labial]	IDENT[coronal]
tree: √ $t_1r^w{}_2i_3 \rightarrow p_{12}i_3$		*
$t_1r^w{}_2i_3 \rightarrow t_{12}i_3$	*!	

The rankings in (20) and (21) assure that [labial] will show up when it is part of a coalesced sequence. The relative ranking of IDENT[dorsal] and IDENT[coronal] is demonstrated by forms such as *kin* 'clean'. IDENT[dorsal] is higher ranked than IDENT[coronal], since the [dorsal] of /k/ rather than the [coronal] of /l/ surfaces. Tableau (22) illustrates this ranking.

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21 As McCarthy & Prince (1995a) use it, IDENT[F] refers to either value (+ or –), or in privative terms presence or absence of a feature: input and output values must be the same. As Pater (1995) notes, however, the *loss* of a feature (or switch from + to –) can not always be ranked the same as the *gain* of a feature (or switch from – to +). He uses IDENT I->O [F] to rule out loss of a feature and IDENT O->I [F] to rule out the gain of a feature. Here we are concerned with IDENT I->O [Place], i.e. the set of constraints which demand the retention of underlying Place values.

(22)	IDENT[dorsal]	IDENT[coronal]
clean: √ $k_1l_2i_3n_4 \rightarrow k_{12}i_3n_4$		*
$k_1l_2i_3n_4 \rightarrow t_{12}i_3n_4$	*!	

To summarize the above tableaux, IDENT[labial] outranks IDENT[dorsal], which outranks IDENT[coronal].[22] Tableau (23) shows how the IDENT[Place] constraints interact with the sonority constraints, NO-COAL, and MAX. For reasons of space, the operation of *COMPLEX is assumed, and only the μ/Y constraints relevant to the given examples are shown. Constraints which are separated by a dotted line can not be ranked with respect to each other based on the available data. Again, since G produces liquids as glides, they are shown in the output candidates as glides.

As tableau (23) shows, NO-COAL is actually the FAITH of Section 3. The behavior of labial clusters indicates that clusters undergo coalescence to satisfy *COMPLEX. Although many of the cases look like outright deletion, these are actually cases of vacuous coalescence, where the sonority and IDENT[Place] constraints select all of one segment's features to show up in the output and none of another's.

[22] The high ranking of IDENT[lab] in G's language is confirmed by the fact that in her consonant harmony days labials did not undergo harmony, although dorsals and coronals did. Gnanadesikan (in prep) proposes for independent reasons that the ranking IDENT[labial] >> IDENT[dorsal] >> IDENT[coronal] may actually be universal due to the scalar nature of place features. The universal ranking of faithfulness to labials and dorsals over coronals (but not labials over dorsals) was proposed by Kiparsky (1994).

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G's pattern of coalescence is very similar to that found in Navajo (Lamontagne & Rice 1995a,b). In Navajo, a /d/ prefix coalesces with the onset of the stem, as shown in (24) (Lamontagne & Rice, citing Kari 1973).[23] .

(24) /na + ii + **d** + **x**aa´/ —> nei**g**aa´,

/**/**i + ii + **d** + **k**ááh/ —> **/**ii**k**ááh

By Lamontagne & Rice's account the first example is one of coalescence, with the manner of the *d* showing up with the place of the *x*, while in the second example the *d* deletes. Under the conception of coalescence developed in this section, however, both can be seen as coalescence, although in the second example it is vacuous. In both G's language and in Navajo the manner features of the least sonorous are selected, while a non-coronal place ousts a coronal place. The parallel between G's speech and Navajo is as expected given the universality of the Sonority Hierarchy (and thus of the ranking of constraints based upon it). Further, the selection of non-coronal over coronal place in both languages is as expected given the proposal by Kiparsky (1994) that faithfulness to non-coronals universally outranks faithfulness to coronals.

This section has shown that G reduces complex onsets through coalescence, with sonority and featural faithfulness constraints determining which features end up on the output segment. Her pattern of coalescence is highly similar to that of Navajo, providing another example of the fact that child and adult languages use the same set of constraints. Cases of long distance coalescence in *fi-* forms yielded further evidence that G's input is segmentally accurate and that the coalescence occurs in the mapping from input to output. As a phonological process coalescence is properly captured as the coindexation of two (or more) input segments with one output segment, governed by the interaction of ranked output

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[23] Where Navajo can form a complex segment by coalescence, it does, yielding *d* + *l* —> *dl*, etc. In such cases Navajo does not require a choice of which features to retain in the output. Since G does not allow such segments these are irrelevant for the comparison here.

constraints, such as the µ/Y constraints, the IDENT[place] constraints, and NO-COAL.

6. Labials and the OCP: the emergence of the unmarked

The constraints in tableau (23) do not describe all the properties of labial clusters in G's language. As this section shows, the Obligatory Contour Principle plays a role in determining the output shape of certain labial clusters, providing an excellent case of the emergence of the unmarked in child language. Cases such as this demonstrate that child phonology, like adult phonology, is best described by a system of ranked constraints.

Labializing coalescence of the onset consonants does not occur if the following vowel is rounded (and thus itself labial), as the following forms attest.

(25) draw [d]
straw [d]
grow [go]
stroller [doyˆ]

In most cases, the labialization is also blocked if the next consonant is labial, as in the examples in (26). The forms marked '•' were acquired after the time discussed in this paper, but while G still used the same treatment for labial clusters. I include them since they provide an excellent minimal contrast.

(26) grandma [gæmA]
• grandparent [gæmpæw«t] vs. • granddaughter [bænd tˆ]
drop [dAp]
ice cream [ays kim]
trouble [tˆbu]
but cf. grape [bep], crumb [pˆm]

The blocking of labialization is due to the ranking of the Obligatory Contour Principle in the constraint hierarchy, as described below. The OCP serves to prohibit adjacent instances of particular features. In the present case it proscribes adjacent instances of the feature Labial. OCP effects on labials are common in adult languages (Selkirk 1993), although it is more frequently effective between two consonants than between consonants and vowels. An example similar to G's use of the OCP on adjacent labials occurs in Cantonese. In Cantonese the OCP prevents sequences of rounded vowel plus labial consonant, labial consonant plus front rounded vowel, and labial consonant plus vowel plus labial consonant (Yip 1988, citing data from Hashimoto (1972) and Light (1977)). In G's case the OCP is evidently evaluated both between consonant and following vowel, and from consonant to consonant, but not from vowel to following consonant.[24] The consonant-to-consonant evaluation is weaker than the consonant-to-vowel evaluation, leading to pairs such as *tˆbu* 'trouble' versus *bep* 'grape'.[25]

The OCP in G's language is powerful enough to prevent the derivation of adjacent labials, but not powerful enough to prevent the surfacing of segments which are underlyingly labial. This is a clear instance of the emergence of the unmarked. The OCP is dominated, so it can not insist on wellformed sequences in cases of underlying labials. Thus 'room' is *wum*, 'blue' is *bu* and 'spoon' is *bun*, displaying the marked labial-labial sequences and demonstrating domination of the OCP. In the case of derived labials, however, the OCP emerges to rule out the illformed labial-labial sequences. The result is that 'draw' is *d* , not **b* , showing emergent unmarkedness due to the action of the OCP. The particular constraint

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[24] I leave open the question of whether the OCP is parameterized, thus yielding different contexts of evaluation, or whether it is not parameterized but has its application affected by other constraints which are independently rankable in different languages.

[25] This is the kind of weakening with distance that Pierrehumbert (1993) discusses. Pierrehumbert notes that in Arabic verbal roots adjacent consonants show very strong OCP place effects while nonadjacent consonants show weakened but persistant OCP effects. In her model, the OCP is not categorical but gradient, effected by similarity of manner features and proximity of the segments evaluated. An important difference between Arabic and G's English-based language is that in Arabic successive consonants are adjacent at the morphological level, while in G's language they are not.

ranking which allows the OCP to operate in some environments and not others is developed below.

The reason that the OCP can not select ∗*du* over *bu* for 'blue' through coalescence of the labial *b* and the coronal *l* is the high ranking of the IDENT[labial] constraint. IDENT[labial] requires the correspondent of an input segment which bears the feature [labial] to also bear the feature [labial]. Therefore a [coronal] place can not be chosen over [labial] in coalescence. Furthermore, in words with a single onset (and hence no coalescence) [labial] can not simply be deleted (and replaced by, say [coronal]). IDENT[labial] outranks the OCP, as illustrated in tableau (27).

(27)	IDENT[labial]	OCP
blue: √ $b_1l_2u_3 \rightarrow b_{12}u_3$		*
$b_1l_2u_3 \rightarrow d_{12}u_3$	*!	
room: √ $w_1u_2m_3 \rightarrow w_1u_2m_3$		*
$w_1u_2m_3 \rightarrow y_1u_2m_3$	*!	

IDENT[labial] thus has the power to force the correspondents of *b* and *w* to be labial in spite of the OCP.

In cases such as *go* 'grow', coalescence is blocked. Tableau (27) has demonstrated that if a labial segment undergoes coalescence the output must be labial regardless of the OCP. So if the *g* and the r^w in 'grow' coalesced the output would have to be ∗*bo*. Since this does not occur the *g* and the r^w must not be coalescing. If the r^w is deleted instead of coalescing with the *g*, IDENT[labial] is rendered irrelevant, since there is no output correspondent of r^w for the [labial] to show up on.[26] Put differently, IDENT[labial] can not be violated by a segment that is deleted. If there is a segment that can safely be deleted, the high-ranking IDENT[labial] can be bypassed. If the entire labial segment is deleted, the OCP is also satisfied. Deletion is therefore the best option in this case because it satisfies the OCP and IDENT[labial], although it violates MAX instead. This demonstrates that the OCP dominates MAX, as shown in tableau (28) (which considers only forms which do not violate IDENT[labial], based on the ranking in (27)).

(28)	OCP	MAX
grow: √ $g_1w_2o_3 \rightarrow g_1o_3$		*
$g_1w_2o_3 \rightarrow b_{12}o_3$	*!	

If labials can delete to avoid violating the OCP, one would expect the *b* to delete in *bu* 'blue', yielding **yu*. It turns out that true consonants may not delete, although glides can.[27] Compare the forms in (25) and (26), where a labial glide deletes, with those in (29), where the labial consonant coalesces.

(29)	blue	[bu]
	smoke	[fok]
	small	[f w]
	balloon	[fi-bun]

The MAX in tableau (28) must therefore be parameterized to include glides (and liquids) but not true consonants. I will call this constraint MAX(GL). It demands that all glides present in the input must be present in the output. The forms in (29) obey the constraint MAX(CONS), the analogous constraint for true consonants.

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[26] This illustrates a consequence of adopting McCarthy & Prince's (1995a) distinction between the IDENT[feature] constraints and MAX. IDENT[feature] is only violable by a segment that actually appears in the output. Therefore the same segment can not violate both MAX and IDENT[feature]. This is in contrast with views of faithfulness which use PARSE-SEGMENT and PARSE-FEATURE.

[27] Glides in glide-initial words such as *wum* 'room' can not delete because of the constraint ONSET, discussed in Section 3, which requires syllables to have an onset.

MAX(CONS) is ranked above the OCP, since true consonants can not be deleted under pressure from the OCP. This is shown in tableau (30).

(30)	MAX(CONS)	OCP
smoke: √ $s_1m_2o_3k_4 \rightarrow f_{12}o_3k_4$		*
$s_1m_2o_3k_4 \rightarrow s_1o_3k_4$	*!	

Cases such as *fi-bun* 'balloon', where a labial-round vowel sequence is derived to avoid a glide onset show that μ/glide must also outrank the OCP. This is shown in (31).

(31)	μ/Glide	OCP
balloon: b_1«$_2l_3u_4n_5$ –> fi-$y_3u_4n_5$	*!	
b_1«$_2l_3u_4n_5$ –> fi-$b_{13}u_4n_5$		*

As the cases of coalescence before front vowels (discussed in Section 5) showed, coalescence is the preferred way of satisfying *COMPLEX. As forms like *go* 'grow' attest, however, deletion of glides occurs when necessary to satisfy the highly ranked OCP. Deletion occurs in cases where the labial consonant is a glide/liquid (as in 'grow'), but it does not occur in cases where the labial is a stop (as in 'blue'). Because of the more highly ranked MAX(CONS), the *b* (unlike the r^w in 'grow') cannot be deleted to satisfy the OCP.

The diagrams in (32) illustrate the segmental correspondence of various labial clusters. As the correspondence lines show, *bin* 'green' is a straightforward case of coalescence which preserves labial place and the manner features of the least sonorous, as discussed in Section 5. *Go* 'grow' shows deletion under pressure from the OCP, as in tableau (28) In *bu* 'blue', the labial can not be deleted because it is a true consonant (as shown in tableau (30)). Instead we have coalescence, with IDENT[labial] ensuring that the labial shows up in spite of the OCP (as in (27).

(32) 'green' g r i n → b i n 'grow' g r o → g o 'blue' b l u → b u

The rankings responsible for the forms in (32) are summarized in tableau (33). Once again, only candidates satisfying ∗COMPLEX are considered, as ∗COMPLEX is never violated.

(33)	IDENT[lab]	MAX (CONS)	OCP	MAX (GL)	NO-COAL
green: √ $g_1r^w{}_2i_3n_4 \rightarrow b_{12}i_3n_4$					∗
$g_1r^w{}_2i_3n_4 \rightarrow g_{12}i_3n_4$	∗!				∗
$g_1r^w{}_2i_3n_4 \rightarrow g_1i_3n_4$				∗!	
grow: $g_1r^w{}_2o_3 \rightarrow b_{12}o_3$			∗!		∗
$g_1r^w{}_2o_3 \rightarrow g_{12}o_3$	∗!				∗
√ $g_1r^w{}_2o_3 \rightarrow g_1o_3$				∗	
blue: √ $b_1l_2u_3 \rightarrow b_{12}u_3$			∗		∗
$b_1l_2u_3 \rightarrow d_{12}u_3$	∗!				∗
$b_1l_2u_3 \rightarrow y_{12}u_3$	∗!				∗
$b_1l_2u_3 \rightarrow y_2u_3$		∗!			
$b_1l_2u_3 \rightarrow b_1u_3$			∗	∗!	

The non-coalescing cases such as *go* 'grow' provide yet more evidence for segmentally accurate inputs. Although 'green' and 'bean' are homophonous for G—both are *bin*—*gr* and *b* must be separate at underlying representation, since the OCP distinguishes between them. If the following vowel is rounded, the OCP forces a labial glide to be deleted instead of coalescing. Thus 'grow' is *go*, not **bo*. Due to the high-ranking of IDENT[lab], however, an underlying *b* surfaces, so 'boat' is *bot*. G must therefore distinguish between underlying *gr* and *b*. It can not be maintained that the difference between 'green' (which coalesces) and 'grow' (which deletes r^w) lies in perception and that the labial vowel obscures G's perception of the r^w. The same lack of labialization is often observed when the consonant after the vowel is labial. In a word like 'grandma', which G pronounces *gæm*A, the coalescence of *g* and r^w is blocked by the presence of *m* in the next syllable. *Gæm*A and *gæmpæw«t* 'grandparent' contrast clearly with *bænd t*ˆ 'grandaughter' where there is not a labial consonant after the *æ* and so coalescence does occur. Although blocking of coalescence does not always occur across vowels, it occurs quite frequently. In 'grandma', the labial r^w and the labial *m* are separated by an unrounded vowel that is stressed and therefore perceptually salient. Such cases of the OCP operating across a stressed unrounded vowel show that it is very unlikely that the two labial articulations could be heard as one. The effect of the OCP on such forms is therefore strong support for the view that G's input forms are segmentally accurate, and that G's divergence from the adult forms is due to a difference in constraint ranking. Specifically, G ranks the OCP constraint on markedness above the faithfulness constraint MAX(GL).

As the ranking of constraints in tableau (33) shows, the OCP is not a simple surface-true constraint. Rather it is a violable constraint that has its place in a whole hierarchy of constraints. Because it is dominated by the faithfulness constraints IDENT[labial] and MAX(CONS), the OCP is frequently violated. This is the case in forms such as *bu* 'blue', ∗*du*. Where IDENT[labial] is irrelevant, the effect of the OCP emerges. It then plays a crucial role in selecting the output, as in *go* 'grow', ∗*bo*.

The action of the OCP in G's language is a perfect example of the emergence of the unmarked. Optimality Theory captures such behavior by making the OCP one of a hierarchy of ranked, violable constraints. Models of phonology which rely on either unranked constraints or the serial application of rules fail to derive the emergence of the unmarked. Constraint-based models which do not employ ranking have no way of explaining why the OCP is only obeyed where it does not conflict with certain other constraints. By ranking the constraints OT can represent which constraints must be obeyed at the expense of which other constraints.

Rule-based derivational models also fail to derive the emergence of the unmarked. The simple, unmarked forms must be derived as the result of complex and arbitrary rules which can make no reference to the general constraints motivating the appearance of the unmarked forms. An attempt to describe the effects of the OCP in G's language as the result of simple, general rules would have to include a dissimilation rule which deleted the feature [labial] on an onset when it occurred adjacent to a labial vowel (or a vowel followed by a labial consonant). A default rule would presumably supply segments with the default place [coronal] where necessary. The coalescence of labial onsets would also be the result of a rule. No matter which order [labial] dissimilation and coalescence are applied in, the wrong result obtains. The two orders of application are shown in (34).

(34a)	green	grow	room	small
Input	gr^{w}in	gr^{w}o	r^{w}um	sm l
Delete Labial (+ default [cor])	gr^{w}in	go	yum	s l
Coalesce	bin	go	yum	s l
Output	bin	go	∗yum	∗s l

(b)	green	grow	room	small
Input	gr^{w}in	gr^{w}o	r^{w}um	sm l
Coalesce	bin	bo	r^{w}um	f l
Delete Labial (+ default [cor])	bin	do	yum	s l
Output	bin	∗do	∗yum	∗s l

In (34a) 'grow' undergoes dissimilation before coalescence so that labial coalescence correctly does not apply. The dissimilation wrongly targets the onset of 'room', however, yielding ∗*yum*. In 'small' the dissimilation also misapplies, bleeding the coalescence rule to produce ∗*s l*. In (34b) the opposite order does even worse. Coalescence wrongly applies to 'grow' and the r^w in 'room' is still wrongly a target of dissimilation. Coalescence applies properly to 'small', but then the dissimilation also applies, yielding ∗s l. One could remove the r^w in 'room' from the list of targets by restricting dissimilation to derived environments. Only forms which were affected by coalescence would be subject to dissimilation. This would protect the r^w in 'room'. The appeal to the derived environment, however, crucially relies on the ordering of coalescence (which provides the derived environment) *before* dissimilation. This is the order of (34b). Even if 'room' were properly given as *wum* in (34b) the ordering still fails on the derivation of 'grow' and 'small', predicting ∗*do* and ∗*s l* rather than *go* and *f l*.

The only way to make the derivation model in (34) work is to restrict the labial deletion rule in the (34a) ordering to *glides/liquids that occur as the second consonant in an onset* before a rounded vowel or unrounded vowel plus labial consonant. This is a very restricted and arbitrary rule to derive from the general motive of the OCP which looks only for successive labials. Why a child would posit such a rule is left unexplained.

OT, on the other hand, succeeds in describing the complex behavior of the OCP through the interaction of constraints which are in themselves simple and independantly motivated. It captures the emergence of the unmarked in the action the OCP because it represents the OCP not as the motivation for an idiosyncratic ordered rule or as a surface-true constraint but as one constraint among many which will be violated when it is dominated by the appropriate constraint. The dominating constraints ensure that the OCP in this case emerges only in a very restricted environment. The OCP effects in G's language show that child phonology, like adult phonology, is best described by a hierarchy of ranked, violable constraints as provided by Optimality Theory.

8. Conclusion

This paper has demonstrated that Optimality Theory succeeds in describing child phonology by ascribing to the child's grammar the same constraints and ranking properties as are required for adult languages. In particular, Section 3 showed how G's treatment of onsets is driven by the same constraints as onset simplification in Sanskrit reduplication, while Section 5 showed that G's pattern of coalescence is like that in Navajo.

An OT model of child phonology neatly accounts for the fact that the child frequently derives outputs which diverge quite strongly from the adult forms. The divergence stems from a difference in constraint rankings between the child language and the target language. It need not lie in a difference in input forms, as this child's inputs have been shown to be segmentally accurate. The evidence for this came from the facts of onset replacement in *fi-* words, described in Section 4.

The fact that the child language displays less markedness than the adult language is due to the initial state of the grammar, in which the markedness constraints are ranked above the faithfulness constraints, as proposed in Section 1. As the phonology develops, the faithfulness constraints move upward as required to approximate the adult language. At the stage of the data in this paper, G still ranked the markedness constraints of ∗COMPLEX, μ/glide and the OCP above the faithfulness constraints MAX, NO-COAL and I-CONTIG. ∗COMPLEX was at this point still undominated by any faithfulness constraints.

As children begin to promote the faithfulness constraints, their phonology is predicted to display cases of the emergence of the unmarked. This was shown to be the case for G's ranking of the OCP in Section 6. In some cases the OCP played a crucial role in selecting the output, while in others it was rendered powerless by the demands of the constraints which dominate it. G's treatment of labial clusters could not be captured using a system of unranked constraints, while a rule-based derivation was arbitrary in its connection to the OCP. Only OT, which imposes a ranking on a set of violable constraints, could account for the OCP's behavior in G's language.

This paper has shown that the application of OT to acquisition allows both child and adult language to be analyzed using the same model of phonology, and using the same constraints. This unity of approach has in general not been achieved in other models of child phonology. For comparison, consider three alternative models of child phonology. Smith (1973) considers the child's system of phonology a mapping from an adult-like underlying form to the child's surface form. Working in a rule-based framework inspired by SPE (Chomsky & Halle, 1968), he ascribes to the child a long series of 'realization rules' deriving the child's output forms from the adult-like underlying forms. By using such rules Smith attempts to describe child language in the model used for adult language. Using this model has the unsatisfactory result that the child has more phonological rules than the adults do. The child is seen as having formulated a large number of rules for which he has never received any evidence. Also, as Ingram (1976, 1989a) points out, many of these rules have the same purpose. For example, seven of 23 rules have the function of eliminating consonant clusters.

Ingram (1976, 1989a,b) avoids the proliferation of unmotivated output rules by ascribing to the child an extra phonological level. In his model the three levels of child phonology are perception, organization and production. Constraints may operate at each level. Perceptual constraints, such as the inability to perceive coda consonants, may be translated into organizational rules or production rules after the child becomes able to perceive codas. For instance, if a child is at first unable to perceive codas she may hypothesize that all words consist of CV syllables. She will then map new words onto this CV pattern at the organization level even after she has begun to perceive codas. Once the child can process and produce coda consonants at all phonological levels, the rule is suppressed.

Stampe (1973) uses a two-level model like Smith, with adult-like inputs, but the outputs are derived by a set of innate natural processes which serve to reduce markedness. In the earliest stage of acquisition the processes operate freely whenever their conditions are met. As the phonology develops, these processes are ordered (and reordered), limited in application, or suppressed as needed to approximate more and more closely the adult grammar. Thus a child with only CV syllables would derive them from adult CVC syllables by a natural process deleting coda consonants. If the child's target language has codas the natural process which deletes them is eventually suppressed.

Ingram's model is one in which constraints or rules operate on both the input (organization) and the output (production). Smith's is one in which a long series of ordered rules operate directly on the input to derive the output. Stampe's model provides universal rules, but still relies on serial derivation of the output from the input. All three give the child more tasks and hence a larger processing load than the adult has. Smith gives the child more rules, Ingram gives her an extra level, and Stampe and Ingram both ascribe to the child processes that are later suppressed. Although Stampe's model is closest to that provided by OT in that it proposes innate processes, it relies on ordering, not ranking as in OT. Such ordered derivations will fail at a natural description of the emergence of the unmarked, as noted in Section 6.

By contrast, Optimality Theory does not give the child an extra processing load. The child does not have more rules or more levels than the adult. In the OT framework the phonology is one of output constraints which are universal, and hence shared by children and adults. The output candidates evaluated by children and adults are the same, but children select different winning candidates than adults do. Reranking of the constraints provides the means by which the phonology develops. Certain rankings of the constraints will cause the child's language to exhibit emergence of the unmarked. Such cases provide strong evidence that child phonology is best modelled by a hierarchy of constraints as in OT.

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(23)	IDENT[lab]	μ/glide	MAX	IDENT[dors]	μ/b,d,g	μ/p,t,k	IDENT[cor]	NO-COAL
tree: √ $t_1r^w{}_2i_3 \rightarrow p_{12}i_3$						*	*	*
$t_1r^w{}_2i_3 \rightarrow t_{12}i_3$	*!					*		*
$t_1r^w{}_2i_3 \rightarrow t_1i_3$			*!			*		
$t_1r^w{}_2i_3 \rightarrow w_{12}i_3$		*!					*	*
$t_1r^w{}_2i_3 \rightarrow y_{12}i_3$	*(!)	*(!)						*
clean: √ $k_1l_2i_3n_4 \rightarrow k_{12}i_3n_4$						*	*	*
$k_1l_2i_3n_4 \rightarrow t_{12}i_3n_4$				*!		*		*
$k_1l_2i_3n_4 \rightarrow k_1i_3n_4$			*!			*	*	
$k_1l_2i_3n_4 \rightarrow y_{12}i_3n_4$		*!		*				*
green: $g_1r^w{}_2i_3n_4 \rightarrow g_{12}i_3n_4$	*!				*			*
√ $g_1r^w{}_2i_3n_4 \rightarrow b_{12}i_3n_4$				*	*			*
$g_1r^w{}_2i_3n_4 \rightarrow g_1i_3n_4$			*!		*			
$g_1r^w{}_2i_3n_4 \rightarrow w_{12}i_3n_4$		*!						*