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Typological predictions in developmental phonology*

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ABSTRACT

Two common and seemingly independent error patterns, namely CONSONANT HARMONY and GLIDING, are examined for their typological characteristics based on cross-sectional and longitudinal evidence from young children's developing phonologies. Data are drawn from the published literature and from the developmental phonology archives at Indiana University. An asymmetry is observed such that the occurrence of harmony is found to imply the occurrence of gliding, but not *vice versa*. While this finding would be unexpected within contemporary derivational theories, it can be shown to follow within optimality theory from a fixed universal ranking relationship among certain constraints. Optimality theory is also argued to offer a viable developmental account with clinical implications that can serve as a further test of the theory.

INTRODUCTION

Phonological theory has undergone a major paradigm shift recently with the advent of optimality theory (e.g. McCarthy & Prince, 1993; Prince & Smolensky, 1993; McCarthy & Prince, 1995). The shift has been from the more conventional rule-based derivational theories which have for many years dominated accounts of fully developed sound systems (e.g. Kenstowicz, 1994) and developing sound systems (e.g. Smith, 1973; Ingram, 1989). Optimality theory would seem to constitute a radical departure from these theories, especially given the hypothesized absence of rules, of derivations, of intermediate levels of representation, of language-specific restrictions on

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underlying representations, and of rule-ordering statements. Despite the many formal and notational differences that set it off from its predecessors, optimality theory has fared well in its initial attempts to account for facts of fully developed languages. A growing body of work has begun to demonstrate the adequacy of the new theory for many acquisition phenomena as well (e.g. Gnanadesikan, 1996; Bernhardt & Stemberger, 1998; Barlow & Gierut, 1999). Perhaps more important to the evaluation of competing theories are the different empirical predictions that they make and the new insights that they offer. This paper identifies one important area of difference and compares the competing empirical predictions against observed typological variation in developing systems. Optimality theory is argued to offer a descriptively and explanatorily adequate account of the facts of acquisition. In turn, acquisition is found to contribute in novel ways to theory.

The paper is organized as follows: in the first section, the predictions of derivational theories are spelled out relating to the occurrence of two common and seemingly independent error patterns in children's early speech. These predictions serve as claims about the range of possible grammars for children and thus yield a classification scheme or typology. The facts of cross-sectional variation are then brought to bear on the validity of those predictions. One predicted instance of the typology is found to be unattested, with its nonoccurrence claimed to be accidental within a derivational theory. The systematic nonoccurrence of this instance of the typology is, however, suggestive of a previously unnoticed implicational relationship among error patterns. An optimality-theoretic account is then formulated which provides in a principled fashion for both the occurrence and nonoccurrence of different instances of the typology. Additional support for the optimality-theoretic account is then offered from the longitudinal development of several children. Some possible experimental tests are also considered which would have direct clinical implications. The paper concludes with a brief summary.

RULE-BASED DERIVATIONAL PREDICTIONS

Background and problem

Derivational theories have characterized young children's many production errors as the result of phonological rules (or processes) in the child's grammar. When these rules are in the grammar and are applicable, they convert the child's internalized underlying representations, which have generally been assumed to be target-appropriate, into the child's errored output.[1] Similarly, the nonoccurrence of an error pattern has been attributed

[1] Some error patterns have within this framework also been attributed to the substance of the child's underlying representations. In such cases, a conventional phonological rule may or may not also contribute to the error pattern. In any event, various aspects of the

to the absence (or loss) of a rule or the suppression of a process. The rules of a grammar, and thus the error patterns, are presumed to be independent of one another. That is, a rule may apply or not apply, and its formulation and ordering (relative to some other rule) may vary across grammars. A wide range of variation in the occurrence of error patterns is thus predicted. To the extent that those predictions are borne out, the theory accrues empirical support. Along these lines, two common error patterns, consonant harmony and gliding, are examined for their conformity with the typological predictions of derivational theories.

Consonant harmony is one common and well-documented error pattern for young children with normal development as well as for other children with phonological delays or disorders (e.g. Smith, 1973; Vihman, 1978; Stoel-Gammon & Stemberger, 1994; Goad, 1997; Pater, 1997a, b; Dinnsen, 1998; Dinnsen & Barlow, 1998). In general derivational terms, consonant harmony is an assimilatory process that copies or spreads place or manner features from one consonant to either a consonant or a glide elsewhere in the word.[2]

The data in (1) and (2) are from two children with phonological delays who exhibited different varieties of MANNER HARMONY (Dinnsen, 1998). More specifically, in (1a), glides were replaced by a nasal consonant in the context of a following nonadjacent nasal, presumably as a result of some process that spread the manner feature [nasal] to the glide. In (2a), the glide /w/ was replaced by a fricative when followed by a fricative. This latter variety of harmony might have been characterized by a process that spread the obstruent manner feature [continuant] from the fricative to the preceding glide.[3] It is important to observe in both cases that the glide was not only taking on manner features as a result of harmony, but that the [−consonantal] feature of the glide was also changing to [+consonantal]. The fricative

child's underlying representations could be different from the target system, being attributed to misperceptions and/or constraints of some kind, e.g. underspecification, morpheme-structure conditions or inventory constraints. The consequence is that acquisition might also proceed by the elaboration (or restructuring) of the child's underlying representations. For a review of the evidence and argumentation along these lines, see Dinnsen (1999).

[2] Because of space considerations, we must set aside the many theoretical issues that have been associated with the characterization of this phenomenon. Briefly, however, asymmetries have been observed in what can serve as a trigger versus target of assimilation. Also, the occurrence of an intervening vowel between the trigger and target has raised concerns about whether that vowel would block assimilation. Finally, while these long-distance assimilations are common in child phonology, their relative rarity in fully developed languages has remained unexplained. Suffice it to say that all derivational accounts would attribute the error pattern to a rule of some kind that applies at some level of representation.

[3] While glides are produced with continuous air flow, we adopt Halle's (1995) assumption that the feature [continuant] is a feature of consonants and not vowels or glides. No language distinguishes vowels or glides in terms of this feature.

harmony in (2a) entailed a further change in another feature of the glide, namely a change from [+sonorant] to [−sonorant]. Any account of manner harmony must then provide for changes in these various different features. Given claims about the segment-internal organization of features, especially feature geometry (e.g. McCarthy, 1988) or feature class theory (e.g. Padgett, 1995), it is not at all obvious why these very different types of features would be implicated by one rule.

(1) Subject 23 (aged 4;8) (Dinnsen, 1998)
a. Glides as targets of nasal harmony

[sonɪŋ]	'sewing'	[blonɪŋ]	'blowing'
[fonɪŋ]	'throwing'	[nonɪŋ]	'snowing'
[fwɛnanz]	'crayon'		

b. /r/'s realized as [w]

[wid]	'read'	[wif]	'wreath'
[waɪd]	'ride'	[wʌb]	'rub'

c. Glides corresponding to /r/'s resist nasal harmony

[weɪn]	'rain'	[weɪnɪŋ]	'raining'
[wʌn]	'run'	[wʌnɪŋ]	'running'

(2) Subject 9 (aged 3;9) (Dinnsen, 1998)
a. Glides as targets of fricative harmony

[veɪv]	'wave'	[vʊf]	'wolf'

b. /r/'s realized as [w]

[wid]	'read'	[weɪn]	'rain'
[waɪd]	'ride'	[wʌb]	'rub'

c. Glides corresponding to /r/'s resist fricative harmony

[wʊf]	'roof'	[wʊfi]	'roof' (dimin.)

It is noteworthy that these two children also evidenced another common error pattern, gliding, which affected the feature [consonantal] (e.g. Ingram, 1989; Smit, 1993). That is, both children excluded /r/'s from their inventories and replaced them with the glide [w], as illustrated in (1b) and (2b). Gliding entails a change in the reverse direction (relative to the harmony process) from [+consonantal] to [−consonantal].[4]

The data in (1c) and (2c) further support the independence of gliding and harmony in that glides corresponding to liquids did not undergo harmony, even though they occurred in a context which triggers assimilation. It is evidence of this sort, namely the differential behavior of glides corresponding with glides in the target system versus those corresponding with liquid consonants, that has led many to posit target-appropriate underlying represen-

[4] The liquid consonant /l/ is also often affected by a gliding process, which may or may not result in a /w/. Because these two liquid consonants can be acquired independently, we will limit our focus throughout to the liquid consonant /r/.

tations for children. This assumption has been further supported by those cases where a child accurately perceives the relevant target distinction (e.g. Locke, 1980).

Some of the assumptions we are adopting about the featural representation of segments are summarized in (3). In some models of feature organization (e.g. feature geometry or feature class theory), the binary features [consonantal] and [sonorant] have been grouped together to constitute the ROOT of a segment (e.g. McCarthy, 1988). These two features serve to distinguish glides, sonorant consonants and obstruents from one another. These sounds can be further differentiated by another set of features that have been argued to group together to constitute a subordinate class or node, namely MANNER (Dinnsen, 1998). The relevant manner features are assumed to be monovalent and include [approximant], [nasal], and [continuant]. The feature [approximant] is correlated with nonturbulent air flow and is associated with liquid consonants and possibly also glides (Clements, 1990). We will see in what follows that glides can bear this feature under certain circumstances. The other sonorant consonants can be identified by the feature [nasal], which is correlated with a lowered velum. Obstruent consonants can be distinguished from one another by the presence versus absence of the manner feature [continuant]. This feature relates to turbulent air flow and would be associated with fricatives, but not with stops. The assumption is that obstruent stops are inherently (permanently) underspecified for manner. The underspecified character of stops (and glides under certain circumstances) has in some models of phonology been used to account for their propensity to serve as targets of assimilation.

(3) Assumptions about features and the representation of segments

Classes of sounds	*Root features*	*Manner features*
Glides	[−consonantal, +sonorant]	([approximant])
Liquids	[+consonantal, +sonorant]	[approximant]
Nasals	[+consonantal, +sonorant]	[nasal]
Obstruents		
Fricatives	[+consonantal, −sonorant]	[continuant]
Stops	[+consonantal, −sonorant]	

The fact that harmony co-occurred with gliding in these two children's systems is interesting given that both error patterns entailed changes in the feature [consonantal], albeit in opposite directions. Within derivational theories or representational theories (such as feature geometry or feature class theory), however, the co-occurrence of these two error patterns is entirely fortuitous. That is, there is no necessary connection between the two error patterns. The prediction, then, is that either could occur without the other, or that neither would occur, or that both could occur together applying in one or the other order. The application of harmony before gliding would be termed a COUNTERFEEDING order because it yields output representations where it appears a rule (harmony) should have applied but did not. The opposite order, namely gliding before harmony, would be termed a FEEDING order because one rule (gliding) creates representations to which a subsequent rule (harmony) can apply. The predicted typology associated with these two error patterns is summarized in (4).[5] To assist in the interpretation of the typology, the hypothesized realizations of two representative words, *won* and *run*, are also given. These words would be predicted to be homophonous under certain circumstances. These predictions will thus serve as a test of derivational theories.

(4) Predicted typology within a derivational theory

Error pattern(s)	*Empirical characteristics* 'won'	'run'
a. Harmony & gliding (counterfeeding order)	[nʌn]	[wʌn]
b. Gliding & harmony (feeding order)	[nʌn]	[nʌn]
c. Gliding but no harmony	[wʌn]	[wʌn]
d. No harmony & no gliding (adult English)	[wʌn]	[rʌn]
e. Harmony but no gliding	[nʌn]	[rʌn]

How well do the facts of developing systems fit with the predicted typology? In the following subsections, we will attempt to instantiate these predictions.

Harmony and gliding in a counterfeeding order

The facts in (1) and (2) exemplify that instance of the typology where harmony must be ordered before gliding in a counterfeeding relation (4a). An illustrative derivation is provided in (5) for the two words *won* and *run*.

(5) Counterfeeding derivation

Underlying representation	a. /wʌn/ 'won'	b. /rʌn/ 'run'
Harmony	nʌn	—
Gliding	—	wʌn
Phonetic representation	[nʌn]	[wʌn]

Adopting the widely held assumption of target-appropriate underlying representations (e.g. Smith, 1973; Ingram, 1989) and assuming that the

[5] The predicted range of variation is even greater if variation in the formulation of rules is considered. Derivational theories allow grammars to differ in this regard as well. We have limited the typology to consideration of a harmony rule which targets glides. Within derivational theories, however, it would also be possible to formulate a different harmony rule which restricts targets to liquid consonants (and not glides). While such a restriction might be possible, we know of no case study motivating the hypothetical harmony rule with the effect that target glides resist harmony but target liquids undergo harmony.

targets of the harmony rule are restricted to glides,[6] the word *won* in (5a) would be subject to harmony, being realized as [nʌn]. The structural description of the gliding rule would not be satisfied and thus would not apply since no liquid consonant occurred in the word. The word *run* in (5b) would, however, resist harmony because at that point in the derivation its structural description would not be met. Recall that harmony requires a glide as the target. The structural description of gliding would be satisfied and would apply to yield [wʌn]. Given this rule ordering relationship, the output of gliding could not serve as the input to harmony, resulting in [wʌn] as the actual phonetic output for *run*. It is outputs of this latter sort which illustrate the counterfeeding effect where it appears the harmony rule should have applied but did not.

Gliding and harmony in a feeding order

Another instance of the typology (4b) is exemplified by Trevor (aged 1;3–2;0) as described by Pater (1997a, b) (cf. Compton & Streeter, 1977). Some relevant data are given in (6). The liquid consonant /r/ did not occur and was replaced by a glide, as shown in (6a). Harmony was also evident with glides serving as targets of assimilation, as shown in (6b). The crucial difference relates to the forms in (6c), which show that liquid consonants also served as targets of assimilation.

(6) Trevor (aged 1;3–2;0) (Pater, 1997a, b)

a. /r/'s realized as [w]

[wæ:dɪt]	'rabbit'	[wæ:f]	'giraffe'
[gʌ:wa]	'gorilla'		

b. Glides as targets of nasal harmony

[momə]	'mower'	[nɪno:]	'window'
[kai:niŋ]	'crying'		

c. Liquids as targets of nasal harmony

[əmaund]	'around'	[ai:nən]	'iron'
[mɪmə]	'mirror'	[neni]	'raining'
[niŋ]	'ring'	[nʌn]	'run'
[sai:nən]	'siren'		

A conventional account of these facts would retain the same assumptions regarding the substance of underlying representations and the formulation of the two rules. The only difference would be in the ordering of the rules. That is, gliding would be ordered before harmony in a feeding relation. A sample

[6] Different varieties of manner harmony exhibit different restrictions on what can serve as a target. For some children, targets of harmony are restricted instead to obstruent stops. For illustrations of how these different restrictions might be accommodated in different theoretical frameworks, see Dinnsen (1998) and Dinnsen & Barlow (1998).

derivation is provided in (7) for the words *won* and *run*. The derivation for *run* in (7b) is most relevant to the feeding effect. That is, gliding is satisfied by the occurrence of /r/ in the underlying representation and applies to yield an intermediate representation with a glide. Harmony then becomes applicable to this intermediate representation, resulting in homophonous assimilated outputs for *run* and *won*.

(7) Feeding derivation

Underlying representation	a. /wʌn/ 'won'	b. /rʌn/ 'run'
Gliding	—	wʌn
Harmony	nʌn	nʌn
Phonetic representation	[nʌn]	[nʌn]

An alternate derivational account of this case based solely on the production facts might argue that there were no liquid consonants underlyingly (since they never occurred phonetically), and therefore that there was no gliding rule to feed harmony. Liquid consonants would have been internalized by the child as glides with the expectation that they would act like other target glides, that is, being realized as glides when harmony was not applicable and as nasals when harmony was applicable. Even if such an account were adopted, the generalization expressed by the gliding rule would still need to be captured, namely that liquid consonants were systematically realized as glides when harmony was not applicable. The presumed ability to perceptually differentiate target /r/ from /w/ would also remain an issue. Consequently, a gliding rule would seem to be necessary at some level of representation.

Gliding without harmony

The data in (8) are drawn from the Developmental Phonology Archives at Indiana University and relate to a child with phonological delays, Subject 5 (aged 3;8). These data exemplify the common case where gliding occurred without harmony (4c). Words such as *won* and *run* would be homophonous, being produced as [wʌn].

(8) Subject 5 (aged 3;8) (Developmental Phonology Archives at Indiana University)

a. Glides realized as glides despite following nasal or fricative

[weɪv]	'wave'	[waf]	'wash'
[sowiŋ]	'sewing'	[bowɪn]	'blowing'

b. /r/'s realized as [w]

[wid]	'read'	[waɪd]	'ride'
[wʌb]	'rub'	[wak]	'rock'

c. /r/'s realized as [w] despite following nasal or fricative

[wif]	'wreath'	[woz]	'rose'
[weɪn]	'rain'	[wʌn]	'run'

The forms in (8a) are consistent with the absence of a harmony rule inasmuch as glides were realized target-appropriately even though a nasal or a fricative consonant followed. Gliding was, however, evident in (8b) and (8c). It is perhaps not surprising that the glides corresponding to /r/'s in (8c) would resist harmony given that target glides also resisted harmony. A derivational account of these facts would thus claim that the child's grammar included a gliding rule but not a harmony rule.

No harmony and no gliding (adult English)

Adult English, of course, constitutes another instance of the typology, where neither harmony nor gliding is evident (4d).

Harmony without gliding

The prediction that does not seem to be borne out by the facts is the case where harmony occurs to the exclusion of gliding (4e). For such a case to exist, a target word such as *won* would have to be realized as [nʌn] due to harmony, but the word *run* would be produced correctly due to there being no gliding rule. A review of the published literature and the developmental phonology archives at Indiana University (including more than 200 children with phonological delays between the ages 3;0–7;0) has failed to identify any such case.

Implicational relationship

If these observations about the occurring and nonoccurring instances of the typology are correct and nonaccidental, what emerges is an implicational relationship between harmony and gliding. The implicational relationship is expressed in (9).

(9) Implicational relationship among error patterns
The occurrence of manner harmony implies necessarily the occurrence of gliding, but not *vice versa*.

There is nothing in derivational theories from which this precise relationship could or should follow. In optimality theory, however, we will argue that it is the reflex of a fixed universal ranking of certain constraints.

OPTIMALITY-THEORETIC ACCOUNTS AND PREDICTIONS

Background

Optimality theory differs from derivational theories in several important respects.[7] The hypothesis is that there are no rules and thus no rule ordering

[7] For tutorial introductions to optimality theory, see Barlow & Gierut (1999) and Kager (1999).

relationships, no derivations, no intermediate levels of representation, and no language-specific restrictions on underlying representations. Instead, for any given input (underlying representation), a ranked set of universal constraints evaluates in parallel a potentially infinite set of output candidates and selects one as optimal. The optimal candidate is the one that best satisfies the constraint hierarchy. Languages are presumed to differ solely by the ranking of constraints. Constraints are of two fundamental and often antagonistic types, namely markedness constraints and faithfulness constraints. Markedness constraints are formulated exclusively in terms of output properties and militate against marked segment types, sequences and structures. Faithfulness constraints, on the other hand, demand identity between corresponding elements in input and output strings. The conflict between constraints is resolved by language-specific constraint rankings. Some constraints will dominate or outrank other constraints. Constraints that are undominated in some language will not be violated by a winning output candidate. The many production errors that occur in early stages of development have been characterized by an initial state or default ranking of markedness constraints over the antagonistic faithfulness constraints (e.g. Gnanadesikan, 1996; Smolensky, 1996). The process of acquisition leading to target-appropriate realizations is presumed to proceed by the reranking of constraints, specifically by the minimal demotion of markedness constraints (Tesar & Smolensky, 1998).

The constraints that are relevant to the phenomena at hand are given in (10). *R is a markedness constraint disfavouring the occurrence of a relatively late acquired sound, in this case /r/. A violation of *R would be incurred by any segment where the root feature [+consonantal] co-occurred with the manner feature [approximant] in an output representation. If this constraint were highly ranked (at least above an antagonistic faithfulness constraint), the nonoccurrence of /r/ would be predicted, achieving the equivalent of the gliding rule. ALIGN is the markedness constraint that captures the essence of harmony.[8] This constraint is similar to other featural alignment constraints that have been formulated, for example, to account for vowel harmony and nasal harmony (Walker, 1999 and references therein) as well as place harmony (Goad, 1997). ALIGN favors a structural configuration in an output representation where an available manner feature is aligned or associated with the left edge of some prosodic domain such as a syllable onset. Syllable

[8] The status of alignment constraints as either markedness or faithfulness has been ambiguous at times (cf. McCarthy & Prince, 1995). Our particular alignment constraint is, however, fully consistent with the markedness interpretation given that it is formulated exclusively in terms of output properties without regard for correspondence relations.

onsets often serve as preferred or privileged contexts for licensing various features. Under the assumption that glides do not have manner features of their own, a word such as *won* would incur a violation of ALIGN for its failure to have the manner feature [nasal] of the final consonant associated with the glide at the left edge of the word. The effect of enforcing alignment in this case would cause the glide to assimilate to the final nasal. On the other hand, compliance with the constraint would not necessarily result in assimilation in certain other cases. For example, any segment in a syllable onset with an associated manner feature of its own (such as an /r/) would satisfy ALIGN without there being any assimilation. Of course, the constraint is also trivially satisfied by words that contain segment types with no manner features (e.g. 'wet' [wɛt]). The other markedness constraint, LICENSE, is adapted from Itô, Mester & Padgett (1995) and disfavors the occurrence or realization of predictable (redundant), implied features in output representations. Thus, given that glides are approximants, any [−consonantal] segment associated with the feature [approximant] would violate LICENSE. Stated differently, the feature [approximant] is implied by the feature [−consonantal] and is therefore not licensed by glides. The feature is, however, licensed by other segment types, for example, by sonorant consonants since only some are approximants and others are nasals. If this constraint were undominated, it would ensure that glides were underspecified for manner, even if the input included the manner feature [approximant]. This would enforce a type of context-sensitive underspecification (e.g. Dinnsen, 1996). The importance of LICENSE will become clear as we consider the interplay of the constraints. The two faithfulness constraints in (10) would be violated by any segment that did not accurately parse (or preserve) the input root or manner features. Given that gliding and harmony both entail changes in root features, any system with both error patterns must rank MAX[root] below the markedness constraints *R and ALIGN. MAX[manner] is relevant because it can provide the trigger to harmony, but we will see that it also plays a role in blocking harmony under certain circumstances.

(10) Constraints

a. Markedness constraints

*R:	Avoid [r]'s, i.e. the co-occurrence of [+consonantal] and [approximant].
ALIGN:	Manner features (e.g. [nasal], [approximant], [continuant]) must be aligned with the left edge of a prosodic domain.
LICENSE:	Glides do not license the feature [approximant].

b. Faithfulness constraints[9]

MAX[root]: Input root features ([consonantal], [sonorant]) must be preserved in corresponding output segments.

MAX[manner]: Input manner features ([nasal], [continuant], [approximant]) must be preserved in corresponding output segments.

Let us now turn to a demonstration of how these constraints interact to account for the typological variation in the occurrence of these error patterns.

Gliding and harmony with a feeding effect

We begin with the case where gliding and harmony co-occur with the equivalent of a feeding effect as was the case for Trevor (6).

The displays in (11) and (12) are tableaux and relate to our account of this case by illustrating how a particular candidate is selected as optimal given a specific input (or underlying representation). In all tableaux, the input representation is given in the upper left corner. For illustration purposes, we consider the input representations for the two most relevant word types, *won* and *run*. Competing output candidates are listed down the left side of the tableau. We have throughout limited the candidate set to the same four most likely competitors. The representations of candidates differ in their root features and associated manner features (indicated by an association line and the abbreviation for the relevant manner feature, A for [approximant] and N for [nasal]). Constraints are given along the top in accord with their ranking. Crucial rankings are indicated by a solid vertical line between affected constraints. Constraints that are unranked relative to one another (i.e. their ranking cannot be determined) are separated by a dotted vertical line. A candidate's violation of a constraint is indicated by a '*' in the intersecting cell. The elimination of a candidate from the competition is termed a fatal violation and is indicated by a '!' after the violation mark. The winning or optimal candidate is identified by the manual indicator '☞'.

To achieve the feeding effect for the two error patterns, these particular markedness constraints must outrank the antagonistic faithfulness constraints. The input for *won* in (11) includes a word-initial glide with no associated manner feature and a final nasal with its manner feature. The faithful candidate (a) is eliminated for its failure to associate (or align) the

[9] There have been different interpretations and implementations of featural faithfulness, depending on whether the feature is binary or monovalent and whether the faithfulness relation is bidirectional or unidirectional. Consistent with the interpretation of MAX[feature] constraints, we assume that these faithfulness constraints treat monovalent and binary features the same and that the faithfulness relation is unidirectional (i.e. that a feature in the input must appear in the output, but not vice versa). For a critical review of some of the issues relating to the interpretation of faithfulness constraints, see Pater (1999).

manner feature [nasal] with the initial glide. Candidate (b) is otherwise faithful but includes an initial glide that is also specified for the manner feature [approximant]. The specification of [approximant] satisfies ALIGN, but it is that specification that fatally violates LICENSE.[10] Thus, even if the input were assumed to be identical to candidate (b), that candidate would still be eliminated by LICENSE. Candidate (c) with an initial /r/ would comply with ALIGN and LICENSE but would still be eliminated for its violation of *R. While the assimilated candidate (d) violates MAX[root] due to the glide having changed to a [+consonantal] segment, that violation is less serious than the need to comply with ALIGN. Candidate (d) would thus survive as optimal.

(11) Input /wʌn/realized as [nʌn]
*R, ALIGN, LICENSE >> MAX[root], MAX[manner]

/wʌn/'won' (n: N)	*R	ALIGN	LICENSE	MAX[root]	MAX[manner]
a. wʌn (n: N)		*!			
b. wʌn (w: A, n: N)			*!		
c. rʌn (r: A, n: N)	*!			*	
☞ d. nʌn (n, n: N)				*	

Legend:
☞ = optimal output | or >> = crucial ranking ¦ or, = equal ranking
* = constraint violation
! = fatal violation N = [nasal] A = [approximant]

[10] Technically, this candidate incurs a violation of ALIGN because the manner feature [nasal] is not left-aligned. If [nasal] were left-aligned in some otherwise comparable candidate, the resultant structure would be a complex (or contour) segment with two associated manner features. We assume that such a candidate would be eliminated by an undominated constraint militating against branching complex segments.

The same result also obtains for the input /rʌn/, although for slightly different reasons, as shown in (12). The faithful candidate (c) is eliminated by *R. While candidate (b) complies with Align and preserves the manner feature of the /r/, it fatally violates License. Candidate (a) is eliminated for its violation of Align, but is acknowledged to also violate the lower ranked faithfulness constraints. The assimilated candidate (d) once again wins, only violating low-ranked Max[manner] by failing to parse the input manner feature [approximant] of the initial consonant.

(12) Input /rʌn/realized as [nʌn]
*R, Align, License >> Max[root], Max[manner]

/rʌn/'run' A N	*R	Align	License	Max[root]	Max[manner]
a. wʌn N		*!		*	*
b. wʌn A N			*!	*	
c. rʌn A N	*!				
☞ d. nʌn N					*

It is striking that with this ranking of constraints it matters little what is assumed about the input representation of the initial segment of either of these two target words. That is, in addition to the inputs just considered, either or both words could be assumed to have input representations identical to any of the output candidates in these tableaux, and the same results would obtain. This is consistent with RICHNESS OF THE BASE, which maintains that underlying representations are universal, effectively prohibiting language-specific restrictions on input representations (Prince & Smolensky, 1993;

Tesar & Smolensky, 1998).[11] A derivational account of this case might handle the issue of underlying representations differently, that is, by excluding /r/'s from this child's phonemic inventory and lexical representations. No such language-specific restriction is available within optimality theory. Optimality theory must, therefore, allow for the possibility that the full range of contrasts is available for children's underlying representations, yielding the optimal output candidate from the constraint hierarchy alone. The conclusions about underlying representations would be slightly different in both frameworks if children's comprehension (generally assumed to be target-appropriate) were also considered. That is, both frameworks would converge on target-appropriate underlying representations for each word. This, too, is consistent with richness of the base given the greater range of available contrasts in the target system. For one possible account of the comprehension/production dilemma within optimality theory, see Smolensky (1996).

Harmony and gliding with a counterfeeding effect

To achieve the equivalent of the counterfeeding effect (as was observed for Subject 23 in (1)) a slightly different ranking of the same constraints would be required. The markedness constraints *R and ALIGN must outrank MAX[root] to account for the co-occurrence of the two error patterns. The primary difference lies in the ranking of MAX[manner] relative to LICENSE, as will be seen shortly for the realization of *run* in (14). First, in (13) for input /wʌn/, we see that the faithful (unassimilated) candidate (a) is eliminated for its failure to align the manner feature [nasal] to the left edge of the word. While the similar candidate (b) complies with ALIGN, it is eliminated due to its violation of LICENSE. ALIGN and LICENSE must therefore outrank MAX[root]. The only candidate that survives is the assimilated candidate (d). While candidate (d) violates MAX[root], that violation is less serious than the demand to comply with ALIGN.

[11] There are at least two related issues that might require further comment. First, it remains an open question whether the base must provide for inputs that are identical to both candidates (a) and (b). While these two candidates can contrast superficially in output representations (cf. tableaux 13–16), it is unclear whether any language requires the same distinction in input representations. If the distinction is not necessary in input representations, the base may be less rich (consistent with universal considerations) in much the same way that prosodic structure is generally assumed to be excluded from input representations. Second, if a choice must be made among alternative input representations, an auxiliary learning principle of optimality theory is available, namely lexicon optimization (Prince & Smolensky, 1993; Itô, et al., 1995). In this case, lexicon optimization would select an input representation that is identical to the assimilated candidate (d) as the most harmonic input representation for these two words. This will only be relevant when several possible inputs converge on a single output as a result of a given constraint hierarchy.

(13) Input /wʌn/realized as [nʌn]
*R, Max[manner], Align >> License >> Max[root]

/wʌn/ ‘won’ N	*R	Max[manner]	Align	License	Max[root]
a. wʌn N			*!		
b. wʌn A N				*!	
c. rʌn A N	*!				*
☞ d. nʌn N					*

The tableau in (14) considers how the input /rʌn/ would be realized given the same constraint ranking shown in (13). The faithful (but nonoptimal) candidate (c) complies with all constraints, except for *R. The undominated character of *R would render that violation fatal. The assimilated candidate (d) also complies with all constraints, except, in this case, Max[manner]. The violation is incurred for the failure to parse the manner feature [approximant] of the /r/. Max[manner] must, therefore, be undominated in order to eliminate the assimilated candidate (d). Candidate (a) suffers many more deficiencies, violating Align, Max[manner] and Max[root]. Even though candidate (b) violates two constraints, namely License (due to the [approximant] feature being associated with the glide) and Max[root], it survives as optimal since all other competitors have been eliminated.

(14) Input /rʌn/realized as [wʌn]
*R, Max[manner], Align >> License >> Max[root]

/rʌn/ 'run' A N	*R	Max[manner]	Align	License	Max[root]
a. wʌn N		*!	*		*
☞ b. wʌn A N				*	*
c. rʌn A N	*!				
d. nʌn N		*!			

The counterfeeding effect associated with this case (especially the tableau in (14)) results in a non-surface-true generalization or a type of phonological opacity. In derivational terms, the opacity obtains because it appears a rule (i.e. harmony) should have applied but did not. Such opacity effects generally have challenged optimality theory and have been argued to require either a special type of correspondence relation such as SYMPATHY (McCarthy, 1999) or LOCAL CONJUNCTION (Smolensky, 1995). Interestingly, the account developed here achieves the desired effects without resort to either. We will return to the significance of this point later when we consider how opacity effects might emerge in the course of development.

Gliding with no harmony

The next pair of tableaux illustrates the account of that instance of the typology where gliding occurs without harmony (as we saw for Subject 5 in (8)). Once again, the only difference for this child is the ranking of constraints. While *R must continue to outrank MAX[root] to yield gliding, the crucial difference here for this child is that MAX[root] must now dominate ALIGN. This is especially important for the tableau in (15) for input /wʌn/ where the assimilated candidate (d) is eliminated by the greater imperative to accurately parse root features over the need to comply with ALIGN. Assuming that it is the faithful candidate (a) that wins rather than candidate (b), LICENSE plays a role as well. Alternatively, if it is candidate (b) that wins, LICENSE would have to be lower ranked.

(15) Input /wʌn/realized as [wʌn]
*R, MAX[manner] >> LICENSE, MAX[root] >> ALIGN

/wʌn/ 'won' | N	*R	MAX[manner]	LICENSE	MAX[root]	ALIGN
☞ a. wʌn | N					*
b. wʌn | | A N			*!		
c. rʌn | | A N	*!			*	
d. nʌn \/ N				*!	

The tableau in (16) for the input /rʌn/ shows that it is more important to avoid /r/'s than it is to preserve root features. Of the two candidates with an initial glide, namely (a) and (b), candidate (a) is eliminated for its failure to parse the input /r/'s manner feature [approximant]. The assimilated candidate (d) is similarly ruled out by undominated MAX[manner]. Candidate (b) thus wins, even though it violates lower ranked LICENSE.

(16) Input /rʌn/realized as [wʌn]
*R, Max[manner] >> License, Max[root] >> Align

/rʌn/ 'run' | | A N	*R	Max[manner]	License	Max[root]	Align
a. wʌn | N		*!		*	*
☞ b. wʌn | | A N			*	*	
c. rʌn | | A N	*!				
d. nʌn \\/ N		*!			

One consequence of this account and our assumptions about feature specifications is the predicted (phonological/phonetic) difference between output candidates (a) and (b). That is, two different kinds of glides possibly occurred for this child. One type of glide would have corresponded with target glides and could have been represented phonetically without the feature [approximant] (candidate (a)). The other type of glide would have corresponded with a liquid consonant and could have been represented phonetically with the feature [approximant] (candidate (b)). It is unknown whether this phonological difference manifested itself in a phonetic difference for this child; however, subtle acoustic differentiation of seemingly merged contrasts have been documented for liquids and glides as well as for other sound classes (for a review, see Weismer, 1984).

No harmony and no gliding (adult English)

The tableaux in (17) and (18) reflect the case of adult English where neither gliding nor harmony occurs. The dominance of the faithfulness constraints over the markedness constraints ensures that root and manner features will be accurately parsed to yield the appropriate contrasts. For the input /wʌn/ in (17), a further ranking among the markedness constraints would be necessary if a choice were to be made between candidates (a) and (b). That is, License would have to be ranked above Align if the faithful candidate (a) were chosen as optimal.

(17) Input /wʌn/realized as [wʌn]
Max[manner], Max[root] >> *R, License >> Align

/wʌn/ 'won' | N	Max[manner]	Max[root]	*R	License	Align
☞ a. wʌn | N					*
b. wʌn | | A N				*!	
c. rʌn | | A N		*!	*		
d. nʌn \\/ N		*!			

(18) Input /rʌn/realized as [rʌn]
MAX[manner], MAX[root] >> *R, LICENSE >> ALIGN

/rʌn/ 'run' (A N)	MAX[manner]	MAX[root]	*R	LICENSE	ALIGN
a. wʌn (N)	*!	*			*
b. wʌn (A N)		*!		*	
☞ c. rʌn (A N)			*		
d. nʌn (N)	*!				

Explaining the implicational relationship

Let us now return to our observed implicational relationship between error patterns, which finds harmony to depend on the occurrence of gliding. If the ranking of all constraints were permitted to vary freely across the grammars of different children, it should be possible to generate the nonoccurring instance of the typology where harmony occurs without gliding (4e). Such a case would require ALIGN to outrank MAX[root] in order to provide for harmony. However, since liquid consonants would presumably be produced without error, *R would have to be low ranked. For illustration purposes, we entertain in (19) and (20) a ranking of constraints that is consistent with this hypothetical (but unattested) situation. The crucial ranking is ALIGN over both MAX[root] and *R.

Assuming that the assimilated candidate (d) in (19) would be the winner for input /wʌn/, Align must outrank Max[root] in order to eliminate the faithful candidate (a). Candidate (b) complies with Align but fatally violates License. Candidates (c) and (d) both violate Max[root], but candidate (c) also incurs a violation of *R (not incurred by candidate (d)).

(19) Input /wʌn/realized as [nʌn]
Align, License, Max[manner] >> Max[root], *R

/wʌn/ 'won' N	Align	License	Max[manner]	Max[root]	*R
a. wʌn N	*!				
b. wʌn A N		*!			
c. rʌn A N				*	*!
☞ d. nʌn N				*	

(20) Input /rʌn/realized as [rʌn]
Align, License, Max[manner] >> Max[root], *R

/rʌn/ 'run' (A N)	Align	License	Max[manner]	Max[root]	*R
a. wʌn (N)	*!		*	*	
b. wʌn (A N)		*!		*	
☞ c. rʌn (A N)					*
d. nʌn (N)			*!		

This same ranking of constraints would allow the faithful candidate (c) for input /rʌn/ in (20) to survive as optimal, even though it violates *R. More specifically, all of the other competitors would be eliminated by the higher ranked constraints.

Thus, if Align were permitted to outrank *R in this way, the unattested case of harmony without gliding would be predicted to occur. This empirically indefensible ranking can be excluded on principled grounds if *R and Align are recognized to participate in a fixed universal (or what is termed HARMONIC) ranking relation, such that *R universally outranks Align, as set forth in (21).

(21) Harmonic (fixed universal) ranking
*R universally outranks Align.

While the attested cases from our typology may not always reveal the need for a ranking relationship between these two constraints, there are at least some cases where the ranking is crucial, and *R must dominate Align, i.e. the case where gliding occurs to the exclusion of harmony (4c). This same ranking can be imposed on the other cases and still account for the facts of those cases. Importantly, there is no evidence that requires ALIGN to ever outrank *R.

A variety of harmonic ranking relationships have been identified for other constraints involving, for example, hierarchies for sonority, nasalization, and place of articulation features, for complex versus elementary constraints, and for context-sensitive versus context-free constraints (e.g. Prince & Smolensky, 1993; Kiparsky, 1994; Smolensky, 1995; Pulleyblank, 1997; Walker, 1999). While some of these hierarchies have been argued to be phonetically grounded, the explanation for the harmonic ranking at hand may more properly find some basis in the special/general relation that can be seen to hold between *R and ALIGN. A closer examination of the conditions on the gliding error pattern reveals contextual restrictions in the acquisition of /r/, which place the two constraints in an ELSEWHERE relation (Kiparsky, 1973). The Elsewhere Principle has the effect of imposing a precedence relation (ranking) between two generalizations where one is a more restricted or specific instance of the other. The more specific generalization is assumed to take precedence over the more general statement. Let us reconsider the formulation of *R. According to Smit (1993: 539), Gliding persists longer in syllable onsets than in other contexts. Syllable onsets are apparently a more marked context for /r/ and are thus more resistant to the appearance of /r/. This suggests that *R be reinterpreted as an abbreviation for two related markedness constraints, i.e. a contextual markedness constraint and a context-free constraint. The contextual markedness constraint would disfavor /r/ (the co-occurrence of [+consonantal] and [approximant]) in syllable onsets, and the context-free version of the constraint would disfavor /r/ elsewhere. Consistent with the Elsewhere Principle, these two constraints themselves would participate in a harmonic ranking with the more specific context-sensitive constraint dominating the context-free version of the constraint. If both instances of the constraint were ranked above Max[root], /r/ would be excluded in all contexts. The fixed ranking of the two versions of *R would also provide an account for the later acquisition of /r/ in the more marked environment of syllable onsets. That is, the lower ranking of the context-free version of *R would render it more vulnerable to demotion below MAX[root], allowing /r/ to surface first in the less marked post-vocalic contexts. The sustained dominance of the context-sensitive instance of *R over MAX[root] would prevent /r/ from occurring in syllable onsets. Keeping in mind these contextual restrictions on the acquisition of /r/, the context-sensitive instance of *R is arguably also more specific than ALIGN and should therefore outrank ALIGN. That is, the contextually restricted version of *R refers to an interplay between a specific root feature and a specific manner feature in the prosodic domain of a syllable onset, whereas ALIGN only requires reference to the general class of manner features (without regard to root features) in that same prosodic domain.

Admittedly, the connection between these two constraints is otherwise not obvious. That is, there seems to be no independent scale or hierarchy (similar to the sonority hierarchy) to which we might appeal to relate *R and ALIGN. Our explanation for this harmonic ranking relationship instead relies on Kiparsky's Elsewhere Principle and the substantive properties of the two constraints. Such an explanation might reasonably raise other questions about harmonic rankings generally. One issue is whether there are any necessary restrictions on the constraints that can participate in fixed rankings of this sort. For example, must the constraints belong to the same family of constraints? We have been assuming that *R and ALIGN both belong to the general family of markedness constraints, but some alignment constraints as formulated for other phenomena more closely resemble faithfulness constraints (cf. McCarthy & Prince, 1995). Even if our constraints were found to belong to different families, other constraints from distinct families have been related to account for other phenomena, for example, through the local conjunction of markedness and faithfulness constraints to account for DERIVED ENVIRONMENT EFFECTS (or the failure of a generalization to hold for tautomorphemic sequences; Lubowicz, 1998). Whether or not our explanation for the fixed ranking of these constraints is correct, on empirical grounds alone *R must outrank ALIGN to account for that instance of the typology where gliding occurs to the exclusion of harmony and to rule out that instance of the typology that does not occur. The empirical necessities here ultimately may differ little from those associated with other universal rankings or hierarchies. Few, if any, of the explanations for these other hierarchies are without question. There is, however, little doubt about their necessity. One difference may lie in the fact that the relation between harmony and gliding can be expressed within optimality theory by an independently necessary device, namely constraint ranking; no comparable device or restriction is available for the same purpose within derivational theories.

The fixed ranking of *R over ALIGN also begins to suggest why harmony of this sort may be so rare in fully developed languages. That is, the occurrence of /r/ in some language would, all other things being equal, require MAX[root] to dominate *R. If *R were so dominated, the fixed ranking between *R and ALIGN would necessitate that ALIGN also be dominated by MAX[root], precluding harmony. Even if /r/ were not to occur in some language as a result of *R being undominated, the required lower ranking of ALIGN would render it more vulnerable to demotion below MAX[root], making it less likely that harmony would occur.

The characterization of the typology that results from our optimality-theoretic account (with the harmonic ranking integrated) is summarized in (22). The predicted developmental progression is also reflected in this display.

(22) Optimality-theoretic account of typology and development

Error Pattern(s)	*Ranking*	*Empirical characteristics* 'won'	'run'
a. Gliding & harmony (feeding)	*R ≫ ALIGN, LICENSE ≫ MAX[root], MAX[manner]	[nʌn]	[nʌn]
b. Harmony & gliding (counterfeeding)	*R, MAX[manner] ≫ ALIGN, LICENSE ≫ MAX[root]	[nʌn]	[wʌn]
c. Gliding & no harmony	*R, MAX[manner] ≫ LICENSE, MAX[root] ≫ ALIGN	[wʌn]	[wʌn]
d. No harmony & no gliding (adult English)	MAX[manner], MAX[root] ≫ *R, LICENSE ≫ ALIGN	[wʌn]	[rʌn]
e. Harmony & no gliding	Impossible due to harmonic ranking	[nʌn]	[rʌn]

This typology and its account have been supported by descriptive studies of cross-sectional variation. Additional support should also be sought from other sources. In the remainder of this paper, we consider the available evidence from longitudinal development and suggest some promising experimental tests of our hypotheses.

FURTHER VALIDATING THE ACCOUNT

Longitudinal development

The cross-sectional variation associated with this account is suggestive of a developmental progression by which the markedness constraints are gradually demoted below the faithfulness constraints (e.g. Levelt & Van de Vijver, 1998). Beginning with a presumably early stage of development (22a) where gliding and harmony occur with a feeding effect (as we saw for Trevor in (6)), the markedness constraints outrank the faithfulness constraints. Unfortunately, no information is available about Trevor's earlier or subsequent development to establish with confidence that this stage is indeed the earliest in the overall progression. It is, however, noteworthy that it is the only case in which all of the relevant markedness constraints must outrank these specific faithfulness constraints, which is itself hypothesized to be one of the primary characteristics of early development. Subsequent stages of development for Trevor would be predicted to resemble the other stages given in (22). One of those subsequent stages (22b) would find harmony and gliding co-occurring with a counterfeeding effect (as we saw with Subjects 23 and 9 in (1) and (2)). This would obtain by the initial demotion of some of the markedness constraints (i.e. LICENSE and ALIGN) below MAX[manner] but not yet below MAX[root].

This counterfeeding effect would seem to represent a more advanced stage than the feeding effect on both empirical and theoretical grounds. Empirically, the counterfeeding case exhibits a contrast not evident in the feeding case. The realization of the contrast is not the same as in the target system, but it does at least correspond to that distinction. That is, the counterfeeding stage distinguishes between those glides corresponding with target glides and those corresponding with /r/'s. In the feeding case, however, all glides behave the same relative to harmony, no matter what they correspond to in the target system. On theoretical grounds, the counterfeeding case would also appear to be more advanced given the more prominent role of at least one of the faithfulness constraints, namely the undominated character of MAX[manner].

The further demotion of ALIGN below MAX[root] would yield the next stage of development (22c) where gliding occurs without harmony (as we saw with Subject 5 in (8)). Interestingly, this hypothesized progression is instantiated in the longitudinal records of both Subjects 23 and 9. Finally, the demotion of *R below MAX[root] would yield adult English (22d) with neither harmony nor gliding. Once again, this developmental progression was instantiated in the longitudinal records of another of the children discussed above, namely Subject 5. Important to our account is the harmonic ranking of *R over ALIGN. It is this ranking which excludes on principled grounds the empirically unattested case where harmony would occur without gliding (22e). It also explains why ALIGN would be demoted below MAX[root] before *R would. That is, the inherently lower ranking of ALIGN makes it more vulnerable to demotion.

This developmental progression is largely instantiated by the case studies reported here and follows uniquely from an optimality-theoretic account. The explanation for this particular developmental progression (as opposed to others) resides in the hypothesized default ranking of markedness constraints over faithfulness constraints and the unidirectional demotion of markedness constraints. An interesting consequence is the predicted emergence of opacity effects as an intermediate stage of development. That is, the co-occurrence of harmony and gliding with a counterfeeding effect (22b) constituted an opaque interaction and was argued to emerge from an earlier stage where harmony and gliding co-occurred with a transparent feeding effect (22a). This might seem surprising to some given the speculation that opacity effects are dispreferred or hard to learn (e.g. Walker, 1999). According to our account, however, opacity effects can emerge as a natural transition from a stage with a transparent interaction of two or more error patterns to a subsequent stage which has lost one of those error patterns and evidences more contrasts. Within derivational theories, this same developmental progression is certainly possible, but other courses of development are equally possible and cannot readily be excluded, at least given current conceptions of derivational theories. It is unclear how (or whether) derivational theories could be modified to capture the implicational relationship between harmony and gliding, especially given that the rules associated with these two error patterns must be permitted to apply in different orders. Nevertheless, derivational theories may find it fruitful to consider extending the concept of markedness as it has been applied to implicational relationships among classes of sounds to implicational relationships among rules. Future research may reveal other more promising considerations.

Some potential test implications

The predictions of this account are amenable to experimental tests, especially in clinical populations through single-subject designs of the sort employed in various treatment studies (e.g. Gierut, 1998). Children with phonological delays have been found to contribute to our understanding of acquisition through the slow-motion view that they often afford of the otherwise normal developmental process (e.g. Ingram, 1989; Dinnsen, 1999). Additionally, experimental treatment studies provide an opportunity to control variables and monitor learning. For children with phonological delays who present with both error patterns (whether in a feeding or counterfeeding relation), our account has direct clinical implications for the selection of treatment targets and the projection of learning. Some of these implications are summarized in (23). On the one hand, treatment could be directed toward eradicating the harmony error pattern. If this were the goal, conventional minimal pair treatment (Weiner, 1981) might oppose a pair such as *won* and *none*. The special relevance of these words is that the correct realization of the glide in *won* would require compliance with MAX[root], while also compelling a violation of ALIGN for its failure to associate the [nasal] manner feature with the left edge of the word. While [nʌn] would satisfy ALIGN, it would violate MAX[root] if it were the correspondent of input /wʌn/. Success at introducing a contrast between a glide and a nasal in this context essentially demands in optimality-theoretic terms that ALIGN be demoted below MAX[root]. The consequence of demoting ALIGN below MAX[root] should block (or eliminate) harmony, but it would have no necessary consequence for the gliding error pattern, namely the ranking of *R relative to MAX[root]. Thus, even if treatment were successful in eliminating harmony, the prediction is that gliding would likely persist.

Treatment might alternatively be directed toward the elimination of the gliding error pattern. In this case, a relevant minimal pair for treatment might be to oppose *way* and *ray*. Such a pair would isolate gliding from harmony since neither word includes a trigger for harmony. The word *ray* is relevant because its correct realization demands compliance with MAX[root] over the need to satisfy *R. The correct realization of the contrasting word *way* would comply with *R but would violate MAX[root] if it were the correspondent of input /reɪ/. Success at introducing the contrast between /r/ and /w/ demands that *R be demoted below MAX[root]. Interestingly, however, since *R is hypothesized to universally outrank ALIGN, the demotion of *R below MAX[root] would necessarily entail the demotion of ALIGN below MAX[root]. The prediction here is that success at undoing the gliding error pattern should result automatically in the loss of the harmony error pattern without direct treatment on the latter.

(23) Some clinical implications

Treated error pattern	*Treatment pair*	*OT analog*	*Result*
Harmony	'won' vs. 'none'	ALIGN demoted below MAX[root]	Harmony eliminated but gliding persists
Gliding	'ray' vs. 'way'	*R and ALIGN demoted below MAX[root]	Gliding and harmony both eliminated

Given the implicational relationship between these two error patterns and the harmonic ranking of *R over ALIGN, it might be speculated that it would be more difficult (in some sense) to eradicate the gliding error pattern than it would be to eliminate the harmony error pattern. The reason for this in optimality-theoretic terms would be that *R requires at least one more demotion argument than ALIGN in order to be dominated by MAX[root].

According to the developmental claims of our account, children who present with the co-occurrence of these error patterns represent either the early feeding stage or the subsequent counterfeeding stage. One consequence of this claim is that children from the different stages should in all likelihood respond differently to the same treatment. For example, children with the feeding interaction who are treated on the gliding error pattern might be expected to first pass through the counterfeeding stage before eliminating harmony (and gliding). On the other hand, children with the counterfeeding interaction who are treated on the gliding error pattern should find it easier (more direct) to eradicate harmony (and gliding).

These various predictions about treatment targets and learning that derive from our optimality account constitute promising empirical tests of the claims of optimality theory.

CONCLUSION

Our investigation and claims about harmony and gliding have been limited to a particular variety of manner harmony, namely that which restricts targets to glides. Other varieties of manner harmony have been documented elsewhere and reveal restrictions to other targets, e.g. obstruent stops can be replaced by nasals (Vihman, 1978; Dinnsen, 1998; Dinnsen & Barlow, 1998). Because these other cases of harmony do not effect changes in the [+consonantal] status of the targeted segment, they are not expected to interact with the gliding error pattern in the same way. It is thus possible that this latter variety of harmony could occur alongside correct productions of liquid consonants. This variety of harmony does, however, entail a change in the sonority of the targeted segment and might therefore be expected to interact with some other error pattern affecting the same feature, possibly participating in another harmonic ranking relationship with ALIGN. Our findings and this approach generally hold promise for revealing (implicational) relationships among other seemingly independent error patterns. The discovery of harmonic rankings is important because they restrict what is a possible grammar and what is a possible course of development.

It has been argued that optimality theory and derivational theories make different empirical predictions about the occurrence and co-occurrence of specific error patterns. Given the error patterns of harmony and gliding, we find that current conceptions of derivational theories fail to capture the connection between the two and thus predict a wider range of variation than can be attested. Optimality theory, on the other hand, first connects the two error patterns by their shared violations of the faithfulness constraint MAX[root]. The further discovery of a harmonic ranking relationship between *R and ALIGN has led to the principled exclusion of the unattested case where harmony would occur in the absence of gliding. These optimality-theoretic predictions about cross-sectional variation are also instantiated in the longitudinal development of many of the children cited here. Finally, optimality theory offers promising test implications for the course of development and the efficacy of clinical treatment.

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