Clinical Forum

Implicationally Related Error Patterns and the Selection of Treatment Targets

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Speech-language pathologists and acquisition researchers have long been interested in children's phonological error patterns. Until recently, the most widely held view concerning these patterns has been that they are the result of children simplifying rules or processes (e.g., Ingram, 1989; Smith, 1973). A further assumption has been that rules (and thus the error patterns they describe) are independent of one another. Thus, we should not expect that the occurrence of any one error pattern necessarily would imply or entail the occurrence of any other error pattern. Extending this claim to clinical treatment, we should not expect the elimination of one error pattern necessarily to impact any other error pattern. With the advent of optimality theory (McCarthy & Prince, 1995; Prince & Smolensky, 1993), however, there has been a shift away from rules. In fact, the claim with optimality theory is that there are no rules, forcing a rather different characterization of children's error patterns. This newer framework embodies many other differences as well, but the question that must be asked is whether those differences result in divergent claims with distinct empirical consequences for acquisition or clinical treatment. This paper attempts to offer an answer to this question by focusing on one important area of difference. Specifically, it will be argued that optimality theory can provide for previously unnoticed implicational relationships among certain error patterns. The idea is that some error patterns are related to one another in a very special way: If a child exhibits one particular type of error pattern, that same child necessarily will exhibit another specific type of error pattern. Error patterns with this special property are dubbed "implicationally related." In addition, it will be suggested that the discovery of implicationally related error patterns offers new perspectives on clinical treatment.

ABSTRACT: This paper compares some of the different claims that have been made concerning acquisition by traditional rule-based derivational theories and the more recent framework of optimality theory. Case studies of children with phonological delays are examined with special attention given to two seemingly independent error patterns, namely, place harmony and spirantization. Contrary to the expectations of derivational theories, these (and other) error patterns are argued to be implicationally related. Optimality theory is shown to offer a principled explanation for the facts with novel implications for clinical treatment.

KEY WORDS: place harmony, spirantization, optimality theory, phonology, treatment

The paper begins with a highlight of some of the claims of the more traditional rule-based derivational theories. Next, case studies of young children with phonological delays are presented in support of these claims, giving special attention to two seemingly independent error patterns. It is argued, however, that these error patterns are implicationally related, and that derivational theories fail to capture this relationship. After providing a brief overview of optimality theory, an account of the facts is formulated within this alternate framework. The implicational relationship between the two error patterns is shown to have a

0161–1461/01/3204–0257

principled explanation within optimality theory. Then, the consequences that implicationally related error patterns have for acquisition and clinical treatment are considered. The paper concludes with a brief summary.

RULE-BASED DERIVATIONAL THEORIES

For more than 40 years, phonological theory has been guided by approaches that are essentially rule-based and derivational. Generative phonology in its various forms has remained the most dominant example of this approach for the characterization of fully developed languages (e.g., Chomsky & Halle, 1968; Kenstowicz, 1994). This framework also has been applied with much success to the developing phonologies of young children with typical or atypical development (e.g., Dinnsen, 1984, 1999; Elbert & Gierut, 1986; Gierut, Elbert, & Dinnsen, 1987; Ingram, 1997; Smith, 1973).

Another variety of this same approach that may be more familiar to clinicians is natural phonology, as developed most notably by Donegan and Stampe (1979). What is common to these approaches and makes them derivational is that underlying representations (i.e., the internalized mental representations of words) are changed into phonetic representations by a series of rules (or processes) that apply one after the other in an ordered sequence. The most widely held assumption is that children's underlying representations are target-appropriate (e.g., Smith, 1973). Although not crucial, we will adopt this assumption throughout this paper. Rules take as their input an ill-formed sequence of segments and convert that sequence into a more acceptable (pronounceable) sequence. Thus, rules have two essential parts: the structural description and the structural change. The *structural description* is simply that part of the rule that sets out the conditions that are required in order for a rule to apply to some word. It specifies what is ill-formed about a particular sequence of segments. All words that match the structural description of a rule normally would be expected to undergo the rule. The *structural change* is that part of the rule that specifies how to repair the ill-formed sequence.

One example of a rule that is relevant to early stages of acquisition is consonant place harmony (e.g., Vihman, 1978). This rule describes the common error pattern whereby a consonant is replaced by another consonant that agrees in place of articulation with a (nonadjacent) consonant elsewhere in the word. An acknowledged but unexplained peculiarity of this phenomenon is that, although it is common in phonological development, it seems not to occur in fully developed languages. A particular instance of this error pattern is illustrated by the data in (1). These data are from a child aged 3:11 (years:months) with phonological delays, Child 126 from the Developmental Phonology Archives at Indiana University. The data in (1a) show that the child replaced the coronal stop /t/ in word-initial position with the velar [k] when a velar occurred later in the word, presumably as a result of assimilation. The data in (1b) show that /t/ did occur in this child's repertoire and was produced target-appropriately in postvocalic contexts. The data in (1c) show that other word-initial coronals, in particular, fricatives, resisted assimilation and were produced target-appropriately, even when a velar occurred elsewhere in the word.

(1) Child 126

a. /t/ replaced by [k] as a result of assimilation

[kaɪgoʊ]	*tiger*	[kɪkɪn]	*ticking*
[kɪkɪt]	*ticket*		

b. /t/ produced target-appropriately in post-vocalic contexts

[goʊt]	*goat*	[koʊt]	*coat*
[kæt]	*cat*	[peɪnt]	*paint*
[pʌpɪt]	*puppet*		

c. Coronal fricatives resist assimilation

[sɪk]	*sick*	[sʌkin]	*sucking*
[sɑk]	*sock*	[sɑki]	*sock* (dim.)
[muzɪk]	*music*	[sænkju]	*thank you*

In terms of formulating a rule for this error pattern, the ill-formed sequence that must be changed by the rule would be a word-initial coronal stop that is followed by a (nonadjacent) velar stop. The target of the rule (or the segment to be changed) would be the coronal stop /t/, and the trigger (or context) of the rule would be the following velar. The repair prescribed by the rule would be to change the coronal stop into a velar so that the consonants agree in place of articulation. There are a number of alternative formalisms available for the formulation of this rule, depending on one's concept of phonological representations (e.g., underspecified representations and/or feature geometry; cf. Dinnsen, 1998; Dinnsen, Barlow, & Morrisette, 1997; Goad, 1997). Putting aside the technical details and controversies associated with the formulation of this rule, it will suffice for our purposes to state the rule informally as follows:

(2) Place harmony rule

/t/ → [dorsal] / #__ V [+consonant, dorsal]
(The coronal stop /t/ in word-initial position is replaced by [k] when it is followed by a nonadjacent velar consonant.)

Rules are assumed to be independent of one another. A rule is either present in a grammar or not. If two or more rules co-occur in a child's grammar, the rules must be ordered. The order of rules can vary across children's grammars. Because of the independence of rules, there is no expectation for any one rule to co-occur with any other rule. This is an important claim of the theory for at least two reasons. First, it makes predictions concerning the range of individual differences that we might expect to observe during the course of acquisition. Second, it has implications for the clinical treatment of disorders. For example, clinical treatment aimed at eliminating a particular rule should have no necessary effect on any other rules.

Stated differently, eliminating one error pattern should have no necessary consequence for the persistence or loss of another error pattern that is governed by a different rule.

With these considerations in mind, we turn to another rule-governed error pattern that also occurred in this child's speech and affected word-initial /t/. The data in (3) show that word-initial /t/ was replaced by the fricative [s], a process called spirantization or assibilation. The substitution of fricatives for stops is a particular instance of a problem that many children have with the manner of articulation of a consonant. For example, some children replace affricates with stops (deaffrication), and others replace fricatives with stops (stopping). Spirantization is perhaps less common in early phonological development, especially compared with stopping, but Bernhardt and Stoel-Gammon (1996, p. 51) noted the occurrence of spirantization processes in 27% of the children with phonological disorders in their study. This spirantization process merged the distinction between /t/ and /s/ in favor of [s] in word-initial position (cf. the data in (1c)). It is important to observe that this spirantization error pattern affected just those word-initial /t/s that were not followed by a velar consonant.

(3) Word-initial /t/ replaced by [s]

[saɪ]	*tie*	[sɑp]	*top*
[seɪp]	*tape*	[soʊz]	*toes*
[sɛʊ]	*tail*	[sis]	*teeth*

The rule responsible for this spirantization error pattern can be distinguished from place harmony on several counts. First, whereas place harmony is an assimilatory rule, spirantization more likely is non-assimilatory and possibly is related to a strengthening process such as aspiration. Also, the two rules effect changes in different feature classes (i.e., a place feature in one case and a manner feature in the other). The contexts of the rules also are different. The spirantization rule can be formulated as in (4). There is no simple way to express in this rule the fact that it applies to all word-initial /t/s not affected by place harmony. However, formulating the rule in its most general form seems correct given that the spirantization process applies in a wider range of contexts as compared with place harmony. For example, whereas place harmony depends on the occurrence of a velar consonant later in the word, spirantization has no such limitation: It can apply whether or not there is another consonant in the word. It will be apparent shortly that this more general formulation of spirantization is supported by an ordering relation between these two rules.

(4) Spirantization rule

/t/ → [+continuant] / #__
(/t/ is replaced by [s] word-initially)

Because these two rules both affect word-initial /t/ with opposing results, they must be ordered. Notice in (5) that if the spirantization rule were to apply before place harmony, the wrong result would be obtained for this child. In fact, all word-initial /t/s would change to [s], preventing place harmony from ever applying to any word-initial /t/s. Recall the data in (1c) that showed that fricatives resisted place harmony.

(5) Incorrect ordering of rules

Underlying representation	/tɪkɪt/	*ticket*
Spirantization	sɪkɪt	
Place harmony	—	
Phonetic representation	*[sɪkɪt]	

Alternatively, if these two rules were applied in the reverse order, as in (6), with place harmony ordered before spirantization, we can account for the co-occurrence and interaction of these two error patterns in this child's speech. Notice in (6a) that the requirements of the place harmony rule are satisfied by /tɪkɪt/, resulting in the application of the rule to yield the intermediate representation [kɪkɪt]. Because spirantization only affects /t/s, the prior application of place harmony changes /t/ to [k], thereby preventing spirantization from applying and yielding the actual phonetic output [kɪkɪt]. In (6b), however, the requirements for place harmony are not met by /taɪ/, given that the word does not include a velar consonant. Thus, the rule is blocked from applying to that word. That word does meet the conditions set forth by the spirantization rule and thus undergoes the change to [saɪ].

(6) Correct ordering of rules

Underlying representation	a.	/tɪkɪt/	*ticket*	b.	/taɪ/	*tie*
Place harmony		kɪkɪt			—	
Spirantization		—			saɪ	
Phonetic representation		[kɪkɪt]			[saɪ]	

It might be argued that the required ordering of these two rules follows from the elsewhere principle (Kiparsky, 1973). This principle maintains that when two rules co-occur in a grammar and are moreover in a special/general relation, the more specific rule must be ordered before the more general rule. These two rules are indeed in a special/general relation because place harmony is formulated to operate on a subset of the representations to which spirantization could potentially apply. The incorrect derivation in (5) is thus precluded by the elsewhere principle.

The elsewhere principle can only be invoked if two such rules co-occur in the grammar. There is, however, no theoretical requirement that both of these rules must co-occur. In fact, it is predicted by rule-based derivational theories that a range of individual differences reasonably might be expected to occur with regard to these error patterns. The relevant predictions are summarized in Table 1, yielding a classification scheme or typology.

The two right-most columns in the table indicate how target words such as *ticket* and *tie* would be pronounced by different children with and without these two error patterns. The case study reported here is an instance of (a) in Table 1, where place harmony occurs with spirantization and the two rules are ordered in accord with the elsewhere principle. The situation depicted in (b) in Table 1 represents a different but highly common case where place harmony occurs without a spirantization rule. In such a case, word-initial /t/s are produced target-appropriately, except when

Table 1. Typological predictions of derivational theories.

	Child's production	
Error pattern	ticket	tie
a. Place harmony ordered before spirantization	[kɪkɪt]	[saɪ]
b. Place harmony but no spirantization	[kɪkɪt]	[taɪ]
c. No place harmony and no spirantization	[tɪkɪt]	[taɪ]
d. Spirantization but no place harmony	[sɪkɪt]	[saɪ]

followed by a velar consonant, which then triggers place harmony. The data in (7) for Child 132 (age 3:9) also are drawn from the Developmental Phonology Archives at Indiana University and serve as a particular instance of this prediction.

(7) Child 132

a. Coronals assimilate to velars (place harmony)

[gʌks]	*duck*	[gʌki]	*duckie*
[gɔg]	*dog*	[gɔgi]	*doggie*
[kaɪgoʊ]	*tiger*		

b. Coronals produced target-appropriately in other contexts (no spirantization)

[tʌb]	*tub*	[tʌbi]	*tub* (dim.)
[tʌn][1]	*tongue*	[dʌn]	*done*
[doʊ]	*door*	[tioʊ]	*tear*
[toʊᵊz]	*toes*	[taʊw]	*towel*
[tis]	*teeth*	[teɪoʊ]	*tail*
[dioʊ]	*dear*	[dwʳaɪzɪn]	*driving*
[dwʳɛsi]	*dressy*		

Yet another instance of the typology, namely that in (c) in Table 1, is exemplified by those many children (and adult speakers of English) for whom neither place harmony nor spirantization occurs. Finally, it is predicted that some children could exhibit spirantization without any evidence of place harmony, as illustrated in (d) in Table 1. In such a case, all word-initial /t/s would be replaced by [s], independent of the following sounds within a word. Notice that this is the same result that would have been obtained from the co-occurrence of both rules with spirantization ordered before place harmony, as was illustrated in the erroneous derivation in (5). Although the elsewhere principle would preclude that particular ordering relationship between the two rules, there is nothing in the theory to prevent spirantization from occurring in a grammar without the place harmony rule. The theory thus predicts that this instance of the typology should be possible. We are, however, unaware of any such case, and a review of the published reports has not shed much light on the issue. The problem is that until now, there has been no theoretical reason to expect any asymmetries in the occurrence of these or other error patterns. Thus, there has been no perceived need to validate or evaluate this prediction. Also, to address the issue properly would require detailed descriptions of individual children's phonologies; yet the bulk of the published studies typically report group results, which makes it difficult or impossible to discern which error patterns might (co-)occur in an individual child's phonology. Of course, this absence of evidence cannot by any means be taken as conclusive, but it does at least raise a question about whether spirantization can ever occur without place harmony. If it turns out that this absence of evidence is indeed systematic, it would seem then that the occurrence of spirantization errors depends on the occurrence of place harmony errors, but not vice versa.[2] This would mean that the place harmony and spirantization error patterns may be related implicationally, as expressed in (8).

(8) Implicational relationship

The occurrence of spirantization implies necessarily the occurrence of place harmony, but not vice versa.

Statements of this sort are reminiscent of other implicational (markedness) relationships that have been observed for certain classes of sounds in the languages of the world. For example, the occurrence of fricatives has been found to imply the occurrence of stops, but not vice versa (e.g., Jakobson, 1968). Thus, fricatives would be considered "marked" and stops "unmarked." The markedness of sounds relates in part to the tendency for the so-called marked sounds to be less frequent, later acquired, and/or articulatorily more complex. Other similar implicational relationships among feature classes have been identified with special reference to developing sound systems (e.g., Dinnsen, 1992). The discovery of implicational relationships among error patterns, especially place harmony and spirantization, is, however, novel and should come as a complete surprise within derivational theories.[3] It certainly is at odds with the claim that rules (and thus the error patterns they describe) are independent of one another. Although the relationship between these two rules might be stipulated (much the way other markedness

[1] Due to a general inventory constraint prohibiting velar nasals, this form does not undergo place harmony.

[2] It should be kept in mind that the spirantization process considered here is distinct from the spirantization process that is evident in languages such as Spanish. In those languages, the spirantization rule is formally and functionally quite different: It typically applies in postvocalic contexts, affects all places of articulation, is limited to voiced obstruents, and is allophonic. The fact, then, that languages like Spanish do not exhibit place harmony cannot be taken as a counterexample to the implicational relationship considered in this paper.

[3] A possible exception to this claim might be earlier attempts to relate certain rules in terms of their functional unity or "conspiracies" (e.g., Kisseberth, 1970). The idea here would be that these two rules would indeed be expected to co-occur because they both conspire toward the common goal of eliminating word-initial [t]s. However, even if conspiracies were incorporated into rule-based theories, the problem would remain to explain why it is that the rules do not always co-occur and why it is that it is place harmony that can occur without spirantization and not the reverse. Adopting a different theoretical perspective, Salus and Salus (1974) observed that some rules of early phonological development are implicationally related, but they offered no explanation for the purported relationships among the various rules.

relationships are expressed about feature classes), it must be acknowledged that the stipulation does not follow from anything in rule-based derivational theories. Consequently, any relationship among these two error patterns would be entirely unexpected. Although derivational theories do not expect implicational relationships to be obtained between rules, the discovery of such relationships suggests the need for an alternative theoretical approach that can capture the appropriate generalizations and that can take advantage of those generalizations in the clinical treatment of such error patterns. In the following sections, it will be demonstrated that optimality theory can account for the case studies and the larger typology reported here. In addition, the implicational relationship between the two error patterns will be shown to have a principled explanation within optimality theory. Finally, the new clinical insights that emerge from the discovery of implicationally related error patterns will be considered.

OPTIMALITY THEORY

Background Sketch

Before embarking on our optimality theoretic account, this section provides a brief sketch of some of the essential claims and terminology of optimality theory. The illustrations in the subsequent sections should help to demonstrate further how the theory works. Space limitations preclude the type of exposition that would be necessary to appreciate the intricacies of the theory fully. Nonetheless, it is expected that the remainder of the paper should be accessible even to those who are unfamiliar with optimality theory. For a tutorial introduction to optimality theory with special attention to acquisition issues, see Barlow and Gierut (1999) and Kager (1999).

Optimality theory differs from derivational theories in several important respects. The central hypotheses are that there are no rules and thus no rule-ordering relationships, no serial derivations, no intermediate levels of representation, and no language-specific restrictions on the set of available input representations (underlying representations). Instead, for any given input, a ranked set of universal constraints evaluates in parallel a potentially infinite set of output candidates (phonetic forms of words) 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. With the exception of those constraints that participate in a fixed universal ranking, the ranking of all other constraints can vary across languages. Constraints are of two fundamental and often antagonistic types, namely markedness constraints and faithfulness constraints. *Markedness constraints* sometimes are referred to as well-formedness constraints or structural constraints. In any case, they are formulated exclusively in terms of output properties and disprefer marked segment types, sequences, and structures. Markedness constraints resemble one part of rules, namely the structural description of a rule. Thus, markedness constraints and rules have in common that they identify and disfavor phonetic forms that are not allowed. They are, however, different from rules in that they do not specify how the output is to be repaired. The repair instead follows from the interaction of the constraints. *Faithfulness constraints* demand identity between corresponding elements in input and output representations. These constraints assign violation marks to output candidates that are different from an input representation. Faithfulness constraints are the antithesis of rules in that they disfavor change. Another important difference between constraints and rules is that the constraints are presumed to be universal (whereas rules are language-specific). Thus, the constraints are the same across languages and are present in all grammars. The conflict between constraints is resolved by 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 children's early stages of development have been characterized by an initial state or default ranking of the markedness constraints over the faithfulness constraints (e.g., Demuth, 1995; Gnanadesikan, 1996; Smolensky, 1996). By ranking markedness constraints over faithfulness constraints, target contrasts will be sacrificed in favor of simplified, unmarked outputs. 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).

An Optimality Theoretic Account

With this theoretical overview in mind, let us return to the case studies reported here and formulate an account. The constraints that are most relevant to these phenomena are displayed in (9).

(9) Relevant constraints

a. Markedness constraints

*t/k: Avoid word-initial [t] before a (nonadjacent) velar consonant in the same word
*#t: Avoid [t] word-initially
*DORSALS: Avoid velar consonants
*FRICATIVES: Avoid fricatives

b. Faithfulness constraints

MAX[dorsal]: Preserve input [dorsal] features
MAX[coronal]: Preserve input [coronal] features
ID[manner]: Input and output [manner] features (e.g., [continuant]) in corresponding segments must be identical

The first two markedness constraints are especially relevant to Child 126's problems with word-initial /t/s. Both constraints disfavor word-initial coronal stops under somewhat different circumstances. Although coronal stops often are considered unmarked (e.g., Paradis & Prunet, 1991), this should not be taken to mean that they are immune to replacement. In fact, it is that same unmarkedness that renders them vulnerable to assimilation to more marked sounds (e.g., Stoel-Gammon & Stemberger, 1994). The first markedness constraint is a particular instance of a more general constraint that disfavors different consonantal place gestures within a word when the consonants already agree in manner. For example, the target English word *take* would violate this constraint because it contains a coronal stop and a velar stop within the same word. Although this constraint would assign a violation mark to an output candidate that is identical to the input /teɪk/, the constraint does not tell us how to repair the form, nor does the violation mark necessarily eliminate the candidate from consideration. The seriousness of a violation mark depends on a constraint's relative ranking in the hierarchy. If *t/k is undominated, the faithful candidate will be eliminated. There also are at least two other potential output candidates that would fare better by virtue of complying with the constraint (e.g., [teɪt] and [keɪk]), both of which exhibit place harmony. Thus, these two candidates would compete, with the choice between the two being made by some other constraint.

The constraint *t/k does not disfavor word-initial coronal stops in all words, only those with a following velar consonant. We know, however, that Child 126 replaced all word-initial /t/s with one or another sound. This reveals the need for the second markedness constraint disfavoring word-initial coronal stops under all other circumstances. Again, this constraint does not specify the repair. In fact, there are several options available that would avoid violating the constraint. For example, /t/ could be replaced by [s] or [k], either of which would comply with the constraint and both of which have been documented in other case studies (e.g., Bernhardt & Stoel-Gammon, 1996). These two markedness constraints participate in a special/general relation similar to what was observed for the rules of place harmony and spirantization. As such, the ranking of these two constraints cannot vary and is universally fixed, with the more specific *t/k outranking the more general *#t.[4]

The relevance of the other two markedness constraints will become clearer when we consider the interaction of the various constraints. Briefly, however, *DORSALS and *FRICATIVES are context-free markedness constraints that disfavor velar consonants and fricatives, respectively, in all contexts. Given that velar consonants and fricatives occurred in the speech of the children considered here and, in some instances, were even the preferred substitutes for coronal consonants, both constraints must be ranked low enough to tolerate violations by any of those occurring forms with velars or fricatives.

All of the above markedness constraints militate against (or disfavor) certain place or manner features. Accordingly, the faithfulness constraints in (9b) are antagonistic to those markedness constraints in that they would assign violation marks to output candidates that fail to preserve input place or manner features. The first of these faithfulness constraints, MAX[dorsal], demands that the particular input place feature [dorsal] be preserved in the corresponding segment of an output candidate. For example, given the input /teɪk/ *take*, the output candidate [teɪt] would incur a violation of MAX[dorsal] because the final consonant fails to include the input feature [dorsal] for that same consonant. The fact that velar consonants served as the trigger for place harmony in these children's speech suggests that MAX[dorsal] was highly ranked. Such a ranking also would be consistent with the fact that target velar obstruents were never replaced by any other consonants. Another faithfulness constraint, MAX[coronal], assigns violation marks to those output candidates that fail to preserve the input place feature [coronal]. The output candidate [keɪk] for input /teɪk/ serves to illustrate a point regarding both of these faithfulness constraints. First, this output candidate would comply with MAX[dorsal] because it preserves the final consonant's place feature. However, that same output candidate would violate MAX[coronal] because the initial consonant fails to retain the input place feature [coronal]. Consequently, for place harmony to occur, this latter faithfulness constraint must be ranked low enough to tolerate a violation mark in the winning output candidate.

The final faithfulness constraint relevant to these phenomena, ID[manner], demands that input and output candidates be identical in terms of manner features such as the feature [continuant]. This constraint would be violated by, for example, words exhibiting the spirantization error pattern because an input stop is changed to a fricative.

The specific ranking of constraints required to account for the facts of Child 126 is displayed in (10). The use of a "," (comma) between constraints indicates that the ranking of the constraints is indeterminate. The symbol ">>" between two constraints indicates a crucial ranking such that the first constraint of the two outranks or dominates the second. The claim is that the ranking in (10) is the ranking of the constraints in the child's grammar. As analysts, it is possible to discover the child's constraint ranking by comparing the violation marks that the constraints assign to the competing output candidates. The idea is that some violations are more serious than others. The more serious violations are assigned by highly ranked constraints that have the effect of eliminating candidates from the competition. Less serious violations are assigned by lower ranked constraints. The winning candidate likely will violate some constraint, but the lower ranking of that constraint allows the candidate to survive as optimal.

(10) Constraint ranking for Child 126
*t/k >> *#t, MAX[dorsal] >> MAX[coronal], ID[manner] >> *DORSALS >> *FRICATIVES

With this ranking of constraints, we can now demonstrate how a particular candidate is selected as optimal given a specific input (or underlying representation). It is conventional to use a display known as a tableau for this purpose. In all tableaux, the input representation is displayed in the upper left corner. Competing output candidates are listed down the left side of the tableau. In this case, the candidate set will be limited to the most likely

[4] For a fuller discussion of universally fixed constraint rankings, see Dinnsen and O'Connor (in press) and references therein.

competitors, namely those that differ in their place and manner features. Constraints are provided along the top in accord with their ranking. Crucial rankings are indicated by a solid vertical line between affected constraints. Constraints whose ranking with respect to one another 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 "☞."

The tableau in Figure 1 considers a representative input such as /teɪk/ for *take,* which must be realized with the place harmony error pattern in the speech of Child 126. The faithful candidate (a) is eliminated because of its fatal violation of the undominated markedness constraint *t/k. Candidate (b) is somewhat better by virtue of complying with this undominated constraint. That is, the initial and final consonants are not produced with different (opposing) place features. The candidate does not survive, however, because it includes a word-initial [t], fatally violating the next lower ranked markedness constraint *#t. That candidate is suboptimal for other reasons as well, namely for its failure to preserve the final consonant's [dorsal] place feature as required by MAX[dorsal]. Candidates (c) and (d) are left to compete and are equally viable with respect to all but the lowest ranked constraint. Although candidate (c) violates ID[manner] because of the change of the initial consonant to [s], it does at least preserve the [coronal] place feature of the corresponding input segment. Candidate (d), on the other hand, preserves the manner of the input segments, but has changed the word-initial [coronal] to [dorsal]. These two candidates each violate different but equally ranked faithfulness constraints, resulting in a tie. The tie then must be passed down to the next lower ranked constraint, *DORSALS. Interestingly, both candidates also violate that constraint. The violation incurred by candidate (c) is obvious given the occurrence of the final velar consonant. Although candidate (d) includes two velar consonants, it violates *DORSALS only once because of the single [dorsal] feature that is multiply linked.[5] The tie, then, must be passed down further to *FRICATIVES. It is this constraint that eliminates candidate (c) with the initial fricative, yielding the place harmony error pattern of candidate (d) as optimal.

Let us now turn to another representative word from Child 126, where the spirantization error pattern occurred. Figure 2 assumes the same ranking of constraints and considers an input such as /taɪ/ for the target word *tie*. All three output candidates comply with *t/k because there is only one consonantal place feature in each candidate. The faithful candidate (a) is eliminated due to its fatal violation of *#t. The remaining two competitors each incur one violation of the next lower ranked constraints, resulting in a tie. The choice then must be passed down to the next lower ranked constraint, *DORSALS. Candidate (c), with the initial velar consonant, incurs a fatal violation of this constraint. Although candidate (b), with the initial spirant, violates *FRICATIVES, the lower ranking of that constraint renders the violation less serious, allowing candidate (b), with the spirantization error pattern, to be selected as optimal.

It has been shown that this ranking of the constraints accounts for the occurrence of both error patterns in Child 126's speech. To account for the facts of Child 132 with place harmony but no spirantization, it will be necessary to consider a different ranking of the same constraints. The crucial and most minimal difference for this case is that the markedness constraint *#t must be demoted below the faithfulness constraint ID[manner], which prevents a stop from changing to a fricative. The constraint ranking required for Child 132 is displayed in (11). It should be noted that this ranking retains the fixed universal ranking of *t/k over *#t, as dictated by the elsewhere principle.

(11) Ranking of constraints for Child 132

*t/k >> MAX[dorsal] >> MAX[coronal], ID[manner] >> *#t, *DORSALS >> *FRICATIVES

This ranking of the constraints does not change any of the results relative to place harmony; the account of place harmony for Child 132 is essentially the same as for Child 126 (cf. Figure 1). The crucial difference is illustrated by

[5] The candidate set also includes the phonetically identical (but structurally different) candidate [keɪk] with two independent dorsal features, each of which is linked singly to one of the velar consonants. However, this candidate is judged worse than its phonetically identical counterpart because it incurs an added violation of *DORSALS, the second of which is fatal.

Figure 1. Place harmony error pattern.

/teɪk/ *take*	*t/k	*#t	MAX [dorsal]	MAX [coronal]	ID [manner]	*DORS	*FRICS
a. [teɪk]	*!	*				*	
b. [teɪt]		*!	*				
c. [seɪk]					*	*	*!
☞ d. [keɪk]				*		*	

Note. ☞ = optimal output; * = constraint violation; *! = fatal violation; ¦ or , = equal ranking; | or >> = crucial ranking.

Figure 2. Spirantization error pattern.

/taɪ/ *tie*	*t/k	*#t	Max [dorsal]	Max [coronal]	ID [manner]	*Dors	*Frics
a. [taɪ]		*!					
☞ b. [saɪ]					*		*
c. [kaɪ]				*		*!	

reconsidering a target word such as "tie," as shown in Figure 3.

Once again, because there is only one consonant in the word, none of these candidates violates the undominated markedness constraint *t/k. Candidates (b) and (c) do, however, exhibit changes in either place or manner features, thus incurring fatal violations of Max[coronal] and ID[manner]. Although the faithful candidate (a) incurs a violation of *#t, the lower ranking of that constraint for this child allows that candidate to survive as optimal, blocking spirantization.

Continuing on with our typology, a slightly different ranking of these constraints would account for the typical case where neither place harmony nor spirantization occurs (e.g., adult English). That ranking is displayed in (12) and shows that the faithfulness constraints all outrank the markedness constraints. Any output candidates that differ from their corresponding input representations in terms of the place or manner features would be eliminated by those highly ranked faithfulness constraints, effectively precluding both place harmony and spirantization.

(12) Constraint ranking for adult English (no place harmony and no spirantization)

Max[dorsal], Max[coronal], ID[manner] >> *t/k, *Dorsals, *Fricatives >> *#t

Figures 4 and 5 for *take* and *tie,* respectively, show how the highly ranked faithfulness constraints eliminate all unfaithful competitors in favor of the target-appropriate candidates. The complete domination of the markedness constraints in this instance makes it difficult to discern whether the fixed ranking of *t/k over *#t is in fact being maintained. It would seem in this instance that it does not matter how the two constraints are ranked relative to one another. There is, however, no evidence that is contrary to a fixed ranking here or in any other instance of the typology. Consequently, in all three attested instances of the

Figure 3. Spirantization error pattern blocked.

/taɪ/ *tie*	*t/k	Max [dorsal]	Max [coronal]	ID [manner]	*#t	*Dors	*Frics
☞ a. [taɪ]					*		
b. [saɪ]				*!			*
c. [kaɪ]			*!			*	

Figure 4. Faithfulness over markedness: No place harmony.

/taɪ/ *tie*	Max [dorsal]	Max [coronal]	ID [manner]	*t/k	*Dors	*Frics	*#t
☞ a. [teɪk]				*	*		*
b. [teɪt]	*!						*
c. [seɪk]			*!		*	*	
d. [keɪk]		*!			*		

Figure 5. Faithfulness over markedness: No spirantization.

/taɪ/ *tie*	MAX [dorsal]	MAX [coronal]	ID [manner]	*t/k	*DORS	*FRICS	*#t
☞ a. [taɪ]							*
b. [saɪ]			*!			*	
c. [kaɪ]		*!			*		

typology, it is possible to maintain the fixed universal ranking of *t/k over *#t in accord with the elsewhere principle. Operating within the limits of this fixed ranking, we have seen that the occurrence, co-occurrence, and non-occurrence of these error patterns can be attributed to different rankings of these markedness constraints relative to the faithfulness constraints. The problem is, however, that this in itself is not sufficient to exclude the seemingly unattested case where spirantization would occur without place harmony. Aside from the fixed ranking of *t/k over *#t, the other constraints would in principle be free to vary in their rankings. In the absence, then, of any other considerations, the hypothetical constraint ranking in (13) would yield the unattested case where spirantization would occur without place harmony.

(13) Hypothetical ranking of constraints yielding spirantization without place harmony

MAX[dorsal], MAX[coronal] >> *t/k >> *#t, *DORSALS >> *FRICATIVES, ID[manner]

Figure 6 considers the target word "take" and illustrates how the hypothetical ranking in (13) would erroneously yield spirantization without place harmony. There are, however, several reasons for believing that the hypothetical ranking in (13) is disallowed on other grounds. First, Steriade (2001) identified other similar cases where some logically possible constraint rankings fail to be supported empirically, at least in fully developed languages. This suggests the need to impose further theoretical restrictions that would eliminate those possibilities. To rule out this particular hypothetical ranking, it would be necessary to prevent ID[manner] from being ranked below MAX[coronal]. Such a restriction could be achieved by imposing a fixed ranking among these two constraints such that ID[manner] universally outranks MAX[coronal]. The rationale for the fixed ranking of these two constraints does not appear to involve the elsewhere principle, but rather may find some basis in conceptions of feature organization that connect place features with manner features in a dependency relation (e.g., Padgett, 1994; Selkirk, 1990). This restriction also may be related to place feature hierarchies that give the lowest priority to coronal place (e.g., Kiparsky, 1994). That is, among the different place features, coronal place seems to be preserved as a last resort. The combined effect of these considerations is that place and manner features are not entirely independent of one another, and that the preservation of coronal place will never be more important than the preservation of manner. Also, on independent grounds, the hypothetical ranking in (13) would not appear to be learnable. That is, if learning requires positive evidence, and crucially, if an earlier stage of development exhibited both error patterns (cf. the ranking in (10)), a faithfulness constraint (ID[manner]) in the early stage would have to be demoted below a markedness constraint in the later stage. Such a reranking is judged implausible because it would require negative and counterfactual evidence. That is, a child would have to observe the absence of a manner contrast in the speech to which he or she is exposed, contrary to the facts of English. Whatever the theoretical or empirical reasons ultimately may be for disallowing the ranking in (13), the important point is that the desired results can be achieved within optimality theory but apparently not within rule-based derivational theories.

Table 2 summarizes our explanation of the typological facts relating to the occurrence of place harmony and

Figure 6. Spirantization without place harmony.

/teɪk/ *take*	MAX [dorsal]	MAX [coronal]	*t/k	*#t	*DORS	*FRICS	ID [manner]
a. [teɪk]			*!	*	*		
b. [teɪt]	*!			*			
☞ c. [seɪk]					*	*	*
d. [keɪk]		*!			*		

Table 2. Summary explanation of the optimality theoretic typology.

Error pattern	*Constraint ranking*	*Child's production*	
		ticket	tie
a. Place harmony and spirantization	*t/k >> *#t, MAX[dorsal] >> ID[manner] >> MAX[coronal] >> *DORSALS >> *FRICATIVES	[kɪkɪt]	[saɪ]
b. Place harmony but no spirantization	*t/k >> MAX[dorsal] >> ID[manner] >> MAX[coronal], *#t >> *DORSALS >> *FRICATIVES	[kɪkɪt]	[taɪ]
c. No place harmony and no spirantization	MAX[dorsal], ID[manner] >> MAX[coronal] >> *t/k, *DORSALS, *FRICATIVES >> *#t	[tɪkɪt]	[taɪ]
d. Spirantization but no place harmony	Impossible	[sɪkɪt]	[saɪ]

spirantization. The fixed rankings between *t/k and *#t and between ID[manner] and MAX[coronal], along with the permissible rerankings of the other constraints, explain the implicational relationship among these error patterns and provide for the exclusion of the presumably unattested situation where spirantization would occur without place harmony. In a comparison of different theoretical accounts, it is important to keep in mind that the constraints of optimality theory are universal and thus present in all grammars. Unlike rules in derivational theories, constraints cannot be added to or lost from a grammar; they can only be ranked or reranked as delimited by the principles of the theory.[6]

CLINICAL IMPLICATIONS

Our optimality theoretic explanation for these facts has direct and testable consequences for acquisition and clinical treatment. First, in terms of acquisition, the different instances of our typology can be arranged along a strict developmental continuum proceeding from an early stage to an end state. This progression is reflected in Table 2 and begins with case (a), where both place harmony and spirantization co-occur. The theoretical reason for placing this case at the early end of the continuum is that more of the markedness constraints outrank the faithfulness constraints. This is consistent with claims concerning the default ranking of constraints in the initial state (e.g., Demuth, 1995; Gnanadesikan, 1996; Smolensky, 1996). The next intermediate stage of development would find place harmony occurring without spirantization ((b) in Table 2). This would be obtained from the sustained dominance of *t/k and the minimal demotion of *#t below ID[manner]. The demotion of *#t would be motivated on the basis of positive evidence, namely the child's recognition that /t/ and /s/ contrast in word-initial position. The demotion of *#t can be effected without any impact on the ranking of *t/k. The only requirement (imposed by the elsewhere principle) is that *t/k must outrank *#t. That dominance relation is preserved in this intermediate stage of development. The next stage of development reflects the end state (or adult English, as in (c) in Table 2), where the place harmony error pattern (along with spirantization) has been lost as a result of the minimal demotion of *t/k below MAX[coronal]. Again, this reranking would be motivated on the basis of positive evidence alone, namely the child's recognition that /t/ and /k/ contrast in word-initial position even when a velar consonant follows later in the word. An important consequence of this account is that it absolutely rules out from the developmental progression the logically possible (but seemingly unattested) situation where spirantization might occur without place harmony ((d) in Table 2). The fixed ranking of *t/k over *#t makes it impossible to demote *t/k without also demoting *#t. As more longitudinal case studies come to the fore, it should be possible to evaluate the correctness of this hypothesis.

Several new and interesting predictions following from our account are relevant to clinical intervention. These predictions can be illustrated by considering some of the treatment options that are available for children (like Child 126) who present with both place harmony and spirantization error patterns. In particular, we would like to consider what might happen if treatment were focused on one or the other error pattern. That is, treatment might be aimed at eliminating the spirantization error pattern or, alternatively, the place harmony error pattern. The issue is whether there are any advantages afforded to the child as a result of targeting one error pattern for treatment versus the other. The novel suggestion that emerges from our account is that there is indeed an advantage afforded by one of these treatment plans.

To illustrate this point, we might adopt a conventional minimal pair treatment protocol where the child's errored production is contrasted with the corresponding correct form (Weiner, 1981).[7] First, if treatment were directed at the elimination of the spirantization error pattern, pairs of English words such as *tie* and *sigh* or *toe* and *sew* might be opposed for the child during treatment. The intent would be

[6] For an alternate perspective, namely that some constraints may be child-specific, see Pater (1997; cf. Rose, 2000).

[7] For references and a review of minimal pair treatment along with other possible treatment protocols, see Gierut (1998).

to teach the child that /t/ and /s/ contrast in word-initial position. If successful, the spirantization error pattern would be lost. In optimality theoretic terms, and assuming the ranking of constraints in (a) in Table 2 for Child 126, this means that the markedness constraint *#t must be demoted below ID[manner]. As we saw from our discussion of a developmental progression above, *#t can be demoted without any necessary consequence for the ranking of *t/k. This means that *t/k could remain undominated with the place harmony error pattern persisting. Thus, although focusing treatment on the spirantization error pattern might eliminate that error pattern, place harmony likely would persist and probably would require further treatment specific to that error pattern. Such treatment essentially would yield the ranking of constraints in (b) in Table 2, which was characteristic of Child 132.

The other option for children like Child 126 is to focus treatment instead on the elimination of the place harmony error pattern. Under this treatment plan, pairs of words such as *take* and *cake* might be opposed. The intent here would be to teach the child that /t/ and /k/ contrast word-initially even when they are followed by a velar consonant in that word. For these sounds to contrast in the child's speech, it would be necessary for *t/k to be demoted below MAX[coronal] (cf. the ranking of constraints in (a) in Table 2 with the desired ranking in (c)). Interestingly, because of the fixed ranking of *t/k over *#t, the demotion of *t/k requires the concomitant demotion of the subordinate constraint *#t. This would result necessarily in the dominance of ID[manner] over *#t. This latter point is based on the assumption that constraint rerankings are minimal and preserve as much as possible from the prior stage. The consequence here is that ID[manner] and MAX[coronal] would have retained their fixed ranking in the hierarchy. The resultant ranking would preclude the spirantization error pattern. Consequently, treatment aimed at eliminating the place harmony error pattern should result automatically in the loss of the spirantization error pattern without direct treatment on that error pattern. Given our discovery of the implicational relationship between these error patterns, it should not be surprising that the loss of place harmony would result in the loss of spirantization. The occurrence of the spirantization error pattern is dependent on the occurrence of place harmony. Stated another way, spirantization cannot exist without place harmony. The two different treatment options with their different predicted outcomes for children who present with both error patterns are summarized in Table 3.

The findings from this study do not appear to be isolated. Other error patterns also have been found to be implicationally related. For example, in another comparison of rule-based derivational theories and optimality theory, Dinnsen and O'Connor (in press) discovered two other common error patterns to participate in an implicational relationship. One of the error patterns, gliding, replaced the liquid consonant /r/ with the glide [w]. A word such as *ray* was realized as [weɪ]. The other error pattern, manner harmony, replaced the glide /w/ with a nasal consonant when a nasal consonant occurred later in the same word. A word such as *won* was realized as [nʌn]. This latter error pattern was similar to place harmony in that assimilation seemed to be involved with the trigger and target of assimilation separated by an intervening vowel. In any event, it was found based on cross-sectional and longitudinal evidence that the occurrence of the manner harmony error pattern implied necessarily the occurrence of the gliding error pattern, but not vice versa. This translated to the fact that gliding might or might not occur, but if manner harmony occurs, gliding must co-occur. The occurrence of manner harmony thus is dependent on the occurrence of gliding.

Rule-based derivational theories offer no way of capturing this generalization. The optimality theoretic explanation for the implicational relationship between the gliding and manner harmony error patterns again were cast in terms of a fixed universal ranking of constraints that followed from the elsewhere principle. The clinical implications also were similar. That is, it was suggested that for children presenting with both gliding and manner harmony, treatment that succeeds at eradicating the gliding error pattern automatically should result in the loss of manner harmony without direct treatment on that error pattern. On the other hand, treatment directed at manner harmony should have no necessary consequence for gliding, allowing gliding to persist.

This same approach might be extended profitably to the implicational relationships that have been observed to hold for phonetic inventories in the acquisition of different classes of sounds (e.g., Dinnsen, 1992). For example, it has been observed that fricatives are acquired before liquid consonants. Stated somewhat differently, the occurrence of liquid consonants necessarily implies the occurrence of fricatives, but not vice versa. This might be translated reasonably to two implicationally related error patterns, namely, stopping and gliding. The stopping error pattern would as a general process replace all fricatives with less marked stops, and the gliding error pattern would replace liquid consonants with less marked glides, as we saw earlier. Some children clearly exhibit both error patterns; other children exhibit gliding only, without the stopping error pattern. It appears, however, that no child would exhibit stopping as a general error pattern unless he or she also evidenced the gliding error pattern. The implicational relationship is that the occurrence

Table 3. Summary of treatment options and predicted outcomes.

Targeted error pattern	*Treatment words*	*Targeted constraint*	*Outcome*
Spirantization	*toe* vs. *sew*	Demote *#t below ID[manner]	Spirantization lost but place harmony persists
Place harmony	*take* vs. *cake*	Demote *t/k below MAX[coronal]	Place harmony and spirantization lost

of the stopping error pattern depends on or implies the co-occurrence of the gliding error pattern. For children presenting with both error patterns, the clinical recommendation would be to eliminate the gliding error pattern because that should result in the loss of the stopping error pattern without ever treating that specific error pattern.

Within optimality theory, the implicational relationship between gliding and stopping might follow naturally from a default ranking of two markedness constraints, one that disfavors liquid consonants (*LIQUIDS) and the other that disfavors fricatives (*FRICATIVES). It also is assumed that there is a generalized faithfulness constraint (which we abbreviate as FAITH) that is antagonistic to these markedness constraints and that demands that input and output representations be identical. Table 4 summarizes an optimality theoretic account of the facts related to these two error patterns.

First, it should be noted that the summary in Table 4 reflects a ranking of the two markedness constraints such that *LIQUIDS outranks *FRICATIVES in all cases. By ranking both of these markedness constraints above FAITH, as in (a) in Table 4, liquid consonants and fricatives would be banned from a child's phonetic inventory and presumably replaced by glides and stops, respectively. The situation characterized in (b) in Table 4 is a likely intermediate stage of development where gliding occurs without the stopping error pattern. This means that stops and fricatives could occur, but liquid consonants would continue to be replaced by glides. This would be arrived at by reranking *FRICATIVES below FAITH. Finally, adult English ((c) in Table 4) would develop from the demotion of *LIQUIDS below FAITH. The logically possible but unattested situation where stopping might occur without the gliding error pattern ((d) in Table 4) is ruled out because it would violate the fixed ranking relationship between the two markedness constraints. This is clinically relevant because if treatment were aimed at undoing the gliding error pattern (i.e., at demoting *LIQUIDS below FAITH), the stopping error pattern would be lost automatically (i.e., *FRICATIVES would necessarily be demoted below FAITH). This prediction is supported by results from Tyler and Figurski's (1994) experimental treatment study, which essentially addressed this question from a very different theoretical position.

The clinical perspective that we have entertained here is different from earlier approaches in some interesting ways. For example, an important insight of earlier approaches has been that treatment on one sound of an error pattern reasonably might extend or generalize to other sounds affected by the same error pattern (e.g., Ingram, 1989; Leonard & Brown, 1984; Weiner, 1981). We are suggesting here that this insight can be broadened to include sounds affected by other implicationally related error patterns. More specifically, the insight is that if two error patterns are found to participate in an implicational relationship, treatment that is aimed at eliminating one particular error pattern should be the more efficacious. That is, eradicating the implied error pattern (i.e., the one on which others are dependent) should result in the loss of the implying error pattern without direct treatment on the latter. Conversely, treatment aimed directly at eliminating the implying error pattern should have no necessary consequence for the implied error pattern. The theoretical basis for these predictions is grounded in the fixed universal ranking of certain constraints. In the case of such fixed constraint rankings, forcing the demotion of a dominating markedness constraint should result necessarily in the demotion of the related subordinate constraint and the loss of both error patterns. Forcing the demotion of the subordinate markedness constraint alone should result in the loss of one error pattern but not necessarily the other.

CONCLUSION

In the comparison of rule-based derivational theories and optimality theory, we have limited the focus to some of the different claims that each makes. There are, of course, also many claims that are common to these theories that could not be considered here but that are no less important. For example, one issue that is equally challenging for all theories is the fact that place harmony and spirantization (whether described by rules or by constraints) appear to be phenomena of early developing phonologies but not fully developed languages. None of these theories has a ready explanation for this asymmetry, and thus all theories are challenged equally on this point. However, at least within the realm of development, optimality theory seems to offer an explanation for the implicational relationship that holds between these (and other) error patterns.

It is at present unknown how common it might be for children to present with both place harmony and spirantization. This lack of information, however, should not be taken to mean that the co-occurrence of these two error patterns is rare, or that the issues they raise do not warrant attention. The fact is that the more traditional theories would not have led anyone even to look for implicationally related error patterns, possibly accounting for the paucity of

Table 4. Summary account of the implicational relationship between gliding and stopping.

Error pattern	*Constraint ranking*
a. Gliding and stopping	*LIQUIDS >> *FRICATIVES >> FAITH
b. Gliding without stopping	*LIQUIDS >> FAITH >> *FRICATIVES
c. Neither gliding nor stopping	FAITH >> *LIQUIDS >> *FRICATIVES
d. Stopping without gliding	Impossible

information on this point. Also, even though there are many cross-sectional group studies that document the incidence of occurrence of error patterns, including either place harmony or spirantization (e.g., Bernhardt & Stoel-Gammon, 1996; Smit, 1993; Stoel-Gammon & Stemberger, 1994; Vihman, 1978), it must be recognized that such studies do not report the co-occurrence of error patterns for a given child. To discern anything about the co-occurrence of error patterns and to evaluate the implicational relationship among these and other error patterns, it will be necessary to appeal to other detailed case studies of individual children. There also will be a need for more longitudinal case studies to document the actual course of development associated with error patterns that stand in this implicational relationship. It is predicted, based on our optimality theoretic account, that these two specific error patterns are most likely to co-occur (with some frequency) in early stages of development or in the speech of children with severe phonological delays. However, even if it were to turn out that the co-occurrence of these two error patterns is relatively rare, we still are obliged to account for the typological asymmetry that finds spirantization to occur only if place harmony occurs. It is, of course, possible that this asymmetry is nothing more than accidental, and that if we look long enough, we will find a case where spirantization occurs without place harmony. The discovery of other implicationally related error patterns suggests, however, that this asymmetry may be more systematic than accidental. In any event, these issues have now become equally relevant to the evaluation of the competing theories considered here.

In sum, some important differences have been identified in the claims that current phonological theories make concerning acquisition. On the one hand, the more traditional rule-based derivational theories have viewed children's error patterns as independent of one another (cf. Salus & Salus, 1974). As a result, no one error pattern is expected to co-occur with any other error pattern. Moreover, in terms of a developmental progression, no one error pattern is expected to be lost before any other error pattern. Finally, in terms of clinical intervention, no particular advantage should be afforded by treating one or the other error pattern. On the other hand, the fixed ranking of certain constraints within optimality theory predicts that some error patterns will be implicationally related. We have seen here that this prediction is borne out. In particular, we discovered that the spirantization error pattern appears to be dependent on the occurrence of the place harmony error pattern. It also was suggested that other error patterns are implicationally related (e.g., manner harmony is dependent on gliding, as is stopping). A further consequence of this optimality theoretic account is the strict developmental progression that it imposes on the loss of error patterns. The general claim is that for error patterns in an implicational relationship, it will be the implying error pattern that is lost first. Finally, and perhaps most importantly, the theories differ in their clinical implications. Optimality theory offers a principled basis for targeting one error pattern for treatment over the other when a child presents with two (or more) implicationally related error patterns. For the most efficacious results, the recommendation in such cases is to treat that error pattern on which other error patterns are dependent.

There has never been any question that these two theoretical frameworks are different in their formalisms. Such differences would be uninteresting if the theories made no different empirical claims. It is evident, however, that these two frameworks do make different claims, especially regarding the occurrence, treatment, and loss of implicationally related error patterns. Ultimately, the value of any theory rests in the (new) insights that it offers. The discovery of implicationally related error patterns afforded by optimality theory must be regarded as one positive development that sets out readily testable predictions and that holds promise for uncovering other new insights about acquisition.

ACKNOWLEDGMENTS

We are especially grateful to Judith Gierut and Laura McGarrity for their ongoing discussions with us regarding all aspects of this work. We also have benefited from the helpful comments of Ruth Bahr, Jessica Barlow, and two anonymous reviewers. This work was supported in part by a grant from the National Institutes of Health (DC01694) to Indiana University.

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Received April 6, 2001
Accepted July 6, 2001
DOI:10.1044/0161-1461 (2001/023)

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