J. Child Lang. **25** (1998), 61–94. Printed in the United Kingdom
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On the characterization of a chain shift in normal and delayed phonological acquisition*

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(*Received* 23 *July* 1996. *Revised* 3 *June* 1997)

ABSTRACT

Several theoretical and descriptive challenges are presented by children's phonological substitution errors which interact to yield the effect of a chain shift. Drawing on an archival study of the sound systems of five children (ages 3;5 to 4;0) with normal development and 47 children (ages 3;4 to 6;8) with phonological delay, one such chain shift, namely the replacement of target /θ/ by [f] and the replacement of /s/ by [θ], was identified in the speech of six children from the two subgroups. Different derivational and constraint-based accounts of the chain shift were formulated and evaluated against the facts of change and the children's presumed perceptual abilities. An adequate account in either framework was found to require the postulation of underspecified and, in some instances, nonadult-like underlying representations. Such representations were able to reconcile within a single-lexicon model the presumed production/perception dilemma commonly associated with acquisition. Continuity was also preserved by limiting underlying change to just those lexical items which exhibited a change phonetically.

INTRODUCTION

In the course of acquisition (normal and disordered), children make many pronunciation errors that appear to be the result of substitution processes. These processes replace a target sound with some other sound that is

[*] We are especially grateful to Stuart Davis, Judith Gierut, Greg Iverson and three anonymous reviewers for comments on an earlier draft of this paper. Some aspects of this work were presented at the Hopkins Optimality Theory Workshop held in Baltimore, May, 1997. This work was supported in part by grants from the National Institutes of Health, DC00260 and DC01694. Address for correspondence: Daniel A. Dinnsen, Department of Linguistics, Indiana University, Memorial Hall 332, Bloomington, Indiana 47405, USA. e-mail: dinnsen@indiana.edu.

https://doi.org/10.1017/S0305000997003322 Published online by Cambridge University Press

presumed to be simpler in some sense. The replacement process generally results in the superficial merger of a target contrast. For example, one very common substitution pattern in normal development (ages 2;0–9;0) replaces target /θ/ with [f] (Hodson & Paden, 1981; Smit, 1993). This same substitution pattern is also evidenced by many older children with phonological disorders (Stoel-Gammon & Dunn, 1985). Thus, *thin* and *fin* would both be pronounced as [fɪn]. The basis for this and many other error patterns is often thought to reside in children's immature articulatory systems and/or perceptual difficulties (e.g. Donegan & Stampe, 1979; Locke, 1983; Kent, 1992; Hale & Reiss, in press). The troublesome segment /θ/ is certainly among the late-acquired sounds in normal development (Smit, Hand, Freilinger, Bernthal & Bird, 1990) and is (even for adult listeners) perceptually confusable with /f/ (Miller & Nicely, 1955). Many of the assumptions behind an account of such errors are, however, challenged by another relatively common and potentially interacting error pattern, namely the replacement of target /s/ by [θ], evident in normal development (ages 3;0–9;0) (Smit, 1993) and in phonological disorders (Grunwell, 1982). That is, *sin* is realized as [θɪn]. While these processes can occur independently in different children's systems, they can, as will be seen below, also co-occur in a given child's system. In those cases where the two processes co-occur, they can interact to yield the effect of a chain shift. That is, one process yields as an output the very sound that is an input to and that is replaced by the other process. Importantly, however, the output of the one process is not permitted to serve as the input to the other. The result in the case of this particular chain shift is that /s/ is not replaced by [f], but rather by [θ]. This chain shift can be schematized as in (1).

(1) Schematization of chain shift
/θ/ → [f]
/s/ → [θ]

While the target distinction between /f/ and /θ/ is merged in favour of [f] in the child's system, a distinction is also introduced between these sounds with the production of [θ] for target /s/. Any account of the replacement of /θ/ must therefore be reconciled against the concomitant selection of that sound as the substitute for some other sound. Chain shifts thus represent a special class of interacting substitution errors in that a target sound that is replaced is also the preferred substitute for some other sound, suggesting that something more than immature articulatory systems is involved.

Interactions of this sort are a prominent characteristic of many different linguistic domains and have far reaching theoretical implications. For example, various other phenomena in the sound systems of young children with normal or disordered phonological development constitute instances of a chain shift, although not always described in such terms (e.g. Applegate,

https://doi.org/10.1017/S0305000997003322 Published online by Cambridge University Press

1961; Pollack & Rees, 1972; Smith, 1973; Dinnsen, 1993, 1998; Dinnsen, Barlow & Morrisette, 1997). One of the more influential cases of a chain shift from normal development was reported by Smith (1973) for his son, Amahl (age 2;2–3;0), who replaced /d/ with [g] but also used [d] as the substitute for /z/. This chain shift was argued to motivate fully specified adult-like underlying representations and extrinsic rule ordering. A re-examination of the facts of that chain shift revealed, however, that the assumptions about the child's underlying representations were not warranted for many words (Macken, 1980). Chain shifts have also been observed as synchronic phenomena in fully developed languages, posing descriptive challenges for recent nonderivational constraint-based frameworks (e.g. Reiss, 1995; Kirchner, 1996). Many historical sound changes have also been attributed to chain shifts, raising questions about mechanisms of change (e.g. King, 1969). Chain shifts in second language acquisition are also similar and raise many of the same questions from first language acquisition. For example, English learners of Italian flap medial /t/ but produce [t] as the substitute for a medial geminate (Gregory Iverson, personal communication).

The descriptive and theoretical problem presented by chain shifts in acquisition is how to achieve these effects. An adequate account of these effects should also constitute an important measure of support for the linguistic principles and structures which underline the account. For example, within the standard derivational theory of generative phonology, which has dominated acquisition research for many years, certain assumptions would need to be made about the degree and substance of feature specification in children's underlying representations and their rules and rule orderings. These assumptions in turn would have consequences for models of the lexicon, abstractness of representations, the characterization of change, and the necessity of extrinsic rule ordering. Chain shifts also take on added significance in other more recent nonderivational constraint-based theories such as OPTIMALITY THEORY (Prince & Smolensky, 1993; McCarthy & Prince, 1995). In such a framework, there are no rules and thus no rule ordering relationships. Derivational effects are instead achieved by a ranked set of universal constraints which evaluate all possible output candidates in parallel. The particular challenge presented by chain shifts is accounting for a given sound being both favoured and disfavoured as an output at the same time. In such a framework, then, it is necessary to identify the relevant constraints and constraint rankings that will achieve these opacity effects. While optimality theory is largely a theory of constraints and constraint rankings, representational issues continue to be a concern, especially as regards constraints which require a correspondence between input and output representations. Surprisingly, these descriptive and theoretical challenges have received little attention with regard to chain shifts in acquisition. This paper thus has three related purposes: (a) to develop an account of this

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chain shift within the two very different derivational and constraint-based theoretical frameworks, (b) to evaluate the accounts against the facts of change and children's presumed perceptual abilities, and (c) to determine the degree of feature specification required for children's underlying (input) representations of the affected sounds.

As noted above (and elsewhere in the acquisition literature), there are many parallels between normal development and phonological disorders, especially where there is not apparent organic basis for the disorder. Many of the children's substitution patterns, the order in which their sounds are acquired, their phonotactic constraints, and the principles which otherwise govern their sound systems would seem to be the same (e.g. Ingram, 1989; Dinnsen, Chin, Elbert & Powell, 1990; Dinnsen, 1992; Chin & Dinnsen, 1992; Gierut, in press *a*). One of the more notable differences for the children with phonological disorders is that the early acquisition effects persist through somewhat older ages. To the extent that there is no discernible organic basis for the disorder and these delays do not otherwise differ substantively from normal development, it is expected that investigations focusing on either or both populations could yield compatible, mutually reinforcing results. It is in this vein that we will consider evidence from both populations. The paper is organised as follows: first, details of the chain shift schematized in (1) are presented from several case studies of children with normal development and others with phonological delays (or disorders). To assess issues of change, data are considered from two points in time. Some alternative derivational accounts of the facts are put forward in the following section and are evaluated against several factors, including the facts of change and the children's presumed perceptual abilities. The alternatives that are considered differ in the degree and substance of feature specifications in the children's underlying representations. The same assumptions are then adopted and evaluated in the following section within an optimality theoretic framework. It is argued that both frameworks are capable of accounting for the relevant facts only if the children's underlying representations are assumed to be (under)specified for certain features, resulting, in some instances, in representations that may differ from those of the target system. The paper concludes with a brief summary and suggestions for future research.

CASE STUDIES

Subjects and methods

In an attempt to document the prevalence of the chain shift in (1), an archival study on phonological development was consulted which included 47 children with functional (nonorganic) speech disorders between the ages 3;4

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and 6;8 and 5 other normally developing control subjects between the ages 3;5 and 4;0. Various aspects of the disordered systems have been described elsewhere (e.g. Dinnsen *et al.*, 1990; Chin & Dinnsen, 1992; Chin, 1993). The children with phonological disorders were highly unintelligible; all of them scored below the 35th percentile on the Goldman Fristoe Test of Articulation (Goldman & Fristoe, 1986), with the vast majority scoring at or below the 5th percentile relative to age-matched peers. It is important to note that the children were normal in all other respects, suggesting that the disorder more properly reflected a phonological delay. As part of an independent experimental study, the children with phonological disorders also received conventional minimal pair contrast treatment on one to three sounds with the intent of inducing change in their systems. This form of treatment contrasted particular target sounds that the child had merged. The amount of time each subject was in treatment varied from four to twelve months and was dependent on the child's meeting certain performance criteria as established by the original experimental design. The normally developing subjects evidenced many fewer errors and thus did not warrant clinical intervention. All scored above the 57th percentile on the GFTA (mean score 79%). Comprehensive speech samples were collected on all subjects at various points in time for purposes of phonological analysis and to assess changes in each child's system. The speech samples were elicited in a spontaneous (nonimitative) picture-naming task utilizing a 306-item probe adapted from Gierut (1985). The probe sampled all English consonant phonemes in a variety of contexts with special attention to the potential for alternations in morphologically related forms.

Speech sample 1

An examination of the children's data from the first speech sample revealed that six of the children evidenced the specific chain shift in (1), i.e. slightly more than 10% of the children with a phonological disorder and 20% of the normally developing children. For these children, target /f/ was produced appropriately; but target /θ/ was replaced by [f], and target /s/ was replaced by [θ]. Some of these children at various points in time did include a few occurrences of target appropriate realizations of /s/ and/or /θ/ (the relevance of which is taken up later). Some general characteristics (e.g. age, GFTA score, and treatment targets (if any)) of the six children evidencing this chain shift are given in Table 1. The children with phonological disorders are identified by number, and the child with normal development is identified by arbitrarily assigned initials. Each child's phonetic inventory is presented in Appendix A.

Since all of these subjects were administered the same elicitation probe and shared the same error pattern, their responses were largely the same, at least

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TABLE 1. *Subject profiles*[a]

Subject	Age	GFTA %	Treatment targets
14	4;1	5	dʒ v s
15	4;2	4	l v k
33	5;4	< 1	k θ r
45	4;7	5	st- tr-
46	5;2	1	st- tr-
RH[b]	3;7	95	—

[a] For each subject, the (pretreatment) age, percentile score on the Goldman Fristoe Test of Articulation (GFTA; Goldman & Fristoe, 1986), and treatment targets, if any, are provided.

[b] RH refers to the one subject with normal development.

with respect to the consonants in question. For this reason, we will focus our attention on just one of the children, but include comparable tokens for the other five children in Table 3 in Appendix B. Of the six children, we have chosen for discussion Subject 33, who exhibited a phonological disorder and received treatment on target /θ/, one of the sounds involved in the chain shift. One reason for focusing on this child is that, while the experimental treatment study was conceived independently of any issue of chain shifts, it might be conjectured that treatment on some sound might enhance its prospects for change in conformity with the target system. In other words, this child (and others treated on some aspect of the chain shift) might be expected to have the best chance of changing by undoing the error pattern.

The data in (2) are from Subject 33's first speech sample prior to any clinical intervention.

(2) Subject 33 (age 5;4)

a. [f] for target /f/

[faɪjəˠ]	'fire'	[faɪv]	'five'
[tafɪn]	'coughing'	[buɾəfʊ]	'beautiful'
[naɪf]	'knife'	[jif]	'leaf'

b. [f] for target /θ/

[fʌm]	'thumb'	[form]	'thorn'
[tifi]	'teeth (dimin.)'	[maʊfi]	'mouth (dimin.)'
[bæf]	'bath'	[tuf]	'tooth'

c. [θ] for target /s/

[θiʔ]	'sink'	[θʌn]	'sun'
[dɛθi]	'dress (dimin.)'	[aɪθi]	'icy'
[veɪθ]	'vase'	[duθ]	'juice'

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These data are entirely representative of the highly systematic character of the chain shift for this child (with the exception of the word [wʳiθ] 'wreath'). Some of the other children may have evidenced a few more target-appropriate realizations in contradiction of the chain shift; however, the error pattern was clearly dominant.

Speech sample 2

Changes in the pronunciation of words over time can provide important evidence in support of claims about children's underlying representations. Along these lines, then, a second speech sample for each subject was analysed to determine what, if any, aspects of the chain shift had changed. For the children with a phonological disorder, this second speech sample was elicited immediately post-treatment. For the normally developing children, the speech sample was elicited three months after the first sample. Relevant data are reported below for Subject 33 and in Table 3 (Appendix B) for the other children.

An examination of Subject 33's second speech sample (one year after the first sample but immediately following the conclusion of clinical treatment) revealed little change in the chain shift. That is, the chain shift persisted (3a–c), and the improvements that did occur diffused only gradually through the lexicon (3d–e). This is in striking contrast to the observed improvements in many of this child's other treated and untreated sounds (see Appendix A).

(3) Subject 33, posttreatment

a. [f] for target /f/

[faɪɚ]	'fire'	[fæɾɪ]	'fatty'
[lifɪ]	'leaf (dimin.)'	[læfɪŋ]	'laughing'
[roʊf]	'roof'	[kaf]	'cough'

b. [f] for target /θ/

[fʌm]	'thumb'	[froʊ]	'throw'
[bæfi]	'bath (dimin.)'	[tufi]	'tooth (dimin.)'
[rif]	'wreath'	[maʊf]	'mouth'

c. [θ] for target /s/

[θɪŋk]	'sink'	[θoʊ]	'sew'
[maʊθɪ]	'mouse (dimin.)'	[græθhapɚ]	'grasshopper'
[jɛθ]	'yes'	[aɪθ]	'ice'

d. [θ] for target /θ/

[θʌndɚd]	'thunder'	[θoʊrn]	'thorn'
[θɚθti]	'thirsty'		

e. [s] for target /s/

[dʒus]	'juice'	[dʒusɪ]	'juicy'
[spun]	'spoon'		

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The chain shift similarly persisted in the second speech sample for the other children with only a few lexical items being realized target-appropriately (see Appendix B).

In the following sections, we attempt to account for these and other facts within two competing theoretical frameworks with the intent of evaluating their adequacy and elucidating assumptions about the nature of representations.

DERIVATIONAL ACCOUNTS OF THE CHAIN SHIFT

This section considers two fundamentally different assumptions about the nature of underlying representations within a derivational framework as it would account for the chain shift in these developing systems. First, we consider an account founded on the widely held assumption that children's underlying representations are fully specified and adult-like. It is argued that such an account fails in several crucial respects. We then entertain an alternate set of derivational accounts appealing to underspecified representations which may differ in particular ways from target representations.

Fully specified adult-like representations

Within a standard derivational rule-based framework (such as generative phonology), the substitution patterns associated with this chain shift would be accounted for by two extrinsically ordered context-free feature-changing rules operating on fully specified adult-like underlying representations as illustrated in (4).[1] One rule would be formulated to change all target /θ/'s to [f]'s (Rule 1). The other rule would be formulated to change all target /s/'s to [θ]'s (Rule 2). As the derivations in (4) illustrate, Rule 2 would have to be extrinsically ordered after Rule 1 in a counterfeeding relation. This ordering is crucial in the child's realization of target words such as *sin*. That is, rule 1 is prevented from applying to /sin/ because its structural description is not satisfied at that point in the derivation. While Rule 2 can apply, the particular ordering relation prevents Rule 1 from operating on the output of Rule 2 (see (4c)). The opposite ordering relation would yield a phonotactically permissible but empirically incorrect result, namely [f] as the correspondent of target /s/ (see (4d)).

[1] The points considered here hold in a derivational theory independent of the particular model of the lexicon that is adopted. That is, rules mediate between levels of representation, and underlying representations are assumed to be adult-like at some level of representation.

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(4) Derivational account assuming fully-specified adult-like underlying representations

A. Rules

Rule 1: /θ/ → [f]
Rule 2: /s/ → [θ]

B. Derivations

	a. /fɪn/ 'fin'	b. /θɪn/ 'thin'	c. /sɪn/ 'sin'
Rule 1	—	fɪn	—
Rule 2	—	—	θɪn
	[fɪn]	[fɪn]	[θɪn]

	d. /sɪn/ 'sin'
Rule 2	θɪn
Rule 1	fɪn
	*[fɪn] Incorrect feeding order

An important element of this and most other accounts of acquisition is the assumption that the child's underlying representations are adult-like. Such an assumption would appear to be central to any account that attempts to specify a correspondence between the adult system and the child's system. We return to this point below and in a later section with some alternatives. In general, however, four empirical factors have been identified in the literature in support of claims about children's underlying representations, i.e. the nature of change over time, the systematic character of the substitution pattern, the differential behaviour of merged sounds, and the children's perceptual abilities. Each of these factors is considered below. In terms of change over time, it has been argued most notably by Smith (1973) for normal development that adult-like underlying representations correlate with the across the board elimination of many production errors. The rationale is that, if the rule responsible for the error pattern were somehow suppressed, those adult-like underlying representations would be free to surface target appropriately. If the children in this study had indeed internalized adult-like underlying representations for the sounds involved in the chain shift, we might have expected at least some part of the chain shift to be eliminated in an across the board fashion. Interestingly, however, in every one of the cases cited above, the children had difficulty eliminating the error pattern. Even those children with phonological disorders who received treatment on the affected sounds improved very little on those sounds. That is, the chain shift persisted even after the completion of treatment, and the improvements that did occur diffused only gradually through the lexicon.

The persistence of the chain shift for the other children did not appear to be attributable to the lack of treatment on the affected sounds. The fact is that other treated and untreated sounds did improve (see Appendix A). At the very least, then, the persistence of the chain shift and the gradual diffusion

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of the target sound in these cases were not consistent with the assumption of adult-like underlying representations.

Additionally, the gradual diffusion of target-appropriate realizations has the further consequence of obscuring any presumed systematic relationship between the child's productions and the target system. That is, the assumption of adult-like representations here in light of the nonsystematic substitution patterns (especially in, but not limited to, the second speech sample) would necessitate the rather unsatisfying claim that the applicability of one of the rules changed from obligatory to optional. To say that a substitution error is optional is to say that it is not predictable. The mergers that resulted from this chain shift also failed on other grounds to support underlying distinctions corresponding to the target distinctions. That is, if adult-like representations had been internalized by these children, we might have expected to find merged sounds acting differently in accord with the target distinctions. The fact is, however, that there was no evidence of differential behaviour such that [f]'s corresponding to target /θ/'s acted differently from target /f/ productions, nor did correct realizations of target /θ/'s act differently from [θ]'s corresponding to target /s/'s.[2] Independent of these considerations, the postulation of underlying /s/'s in the case of this chain shift (especially in the early stage) would be highly abstract. That is, the general nonoccurrence of [s]'s makes it difficult to support the claim that these children represented the occurring [θ]'s specifically as /s/ as opposed to some other sound. In sum, the facts of change, the nonsystematic character of the substitution patterns, the lack of any evidence of differential behaviour among merged sounds, and abstractness considerations argue against the assumption that these children's underlying representations for this chain shift were fully specified and adult-like. While these facts fail to support the assumption of adult-like underlying representations for these children, they do not in any way negate the appropriateness of the assumption for other children or other phenomena. They do, however, underscore the need to motivate the assumption on a case by case basis. Also, as we will see below, when some evidence of a target distinction is observed, it is equally important to establish on empirical grounds the substance of that distinction in the child's system, especially where other alternatives may be available.

In what follows, we consider some alternative derivational accounts which avoid the problems noted above but which make somewhat different assumptions about the substance of these children's underlying representations. These assumptions are founded in a particular version of underspecification theory which maintains that certain features need not be

[2] Target /s/'s and /θ/'s did behave differently in terms of their substitution patterns, motivating an underlying distinction in any framework. This is dealt with explicitly in our underspecification account below.

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specified underlyingly (e.g. Archangeli, 1988). These underspecified representations in turn are shown to have implications for another often cited piece of evidence bearing on the nature of children's underlying representations, namely their presumed perceptual abilities. In this regard, two different scenarios are considered, i.e. one where the child's production and perception appear to coincide and another where the child's perception appears to be in advance of production. We first begin with a brief sketch of the essentials of underspecification theory.

Underspecification theory

The essential claim of underspecification theory is that some features can and must be eliminated from underlying representations. Those excluded, or more precisely UNDERSPECIFIED features are ultimately filled in by rule as default features late in the derivation after application of relevant phonological rules. Debate continues over exactly how much featural information must be (under)specified underlyingly. For example, contrastive specification theory (e.g. Steriade, 1987) maintains that all and only contrastive features are specified underlyingly. All noncontrastive (redundant) features would be eliminated from underlying representations, i.e. they would be underspecified. As an illustration, the manner feature [continuant] is constrastive in obstruents in many languages. In those languages, then, both values of the feature would be claimed to be specified underlyingly to distinguish stops from fricatives. On the other hand, the feature [continuant] is nonconstrastive for nasals. Nasals would therefore be underspecified for that feature. The default [−continuant] value of the feature for nasals would ultimately be filled in late in the derivation. An alternate underspecification framework, namely radical underspecification theory (e.g. Archangeli, 1988; Archangeli & Pulleyblank, 1994), allows even less featural information to be specified underlyingly. In such a framework, then, only some contrastive features are specified. The result is that other contrastive features and all noncontrastive features are underspecified. The contrastive features that are specified underlyingly are usually (but not always) marked features. In terms of our illustration for the feature [continuant], it would likely be the marked [+continuant] value for fricatives that would be specified underlyingly for obstruents. The unmarked [−continuant] value of stops would be supplied to the underspecified obstruents (and nasals) late in the derivation by default.

By extending these considerations to acquisition phenomena, the correspondence between the target system and children's production facts can be expressed directly. That is, children's substitution patterns can be seen as coming about from their underspecifying underlyingly two or more sounds that are contrastive in the target system with that feature being filled in by default. A merger would obtain without resort to a feature-changing rule or

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the postulation of segment-types that do not otherwise occur phonetically in the child's system. Consider, for example, the common production error pattern in early phonological development (normal or disordered) whereby fricatives are replaced by stops. If, for such children, stops and fricatives were represented without an underlying feature specification for manner, the unmarked feature value [−continuant] would be supplied by default, resulting in a phonetic merger. Such an account would represent fricatives and stops in the child's system in the same way, i.e. as underspecified for manner. No features would be changed in derivations from underlying to phonetic representations and no phonetically nonoccurring fricatives would be posited underlyingly. For similar accounts of other substitution patterns in terms of underspecification theory, see Ingram (1992) and Dinnsen (1993, 1996*b*).

Underspecification accounts of children's substitution patterns make substantive claims about how children represent phonological information underlyingly. Those underlying representations might also be expected to have implications for the characterization of children's perceptual judgments of words from the target system. As presented thus far, the phonetic mergers associated with children's substitution patterns would appear to come about from the lack of an underlying distinction where there is a distinction in the target system. If some target distinction were underspecified in the child's system, we might expect that child to perceptually confuse target words which differ along that dimension. Aside from anecdotal reports, there are surprisingly few experimental studies of the perceptual abilities of children in this age range (cf. Barton, 1980; Gierut & Pisoni, 1989). Perceptual deficits have, however, been observed in some children (e.g. Kronvall & Diehl, 1954; Graham & House, 1971; Locke, 1980), and in other cases, children have been found to weight acoustic cues differently from adults (e.g. Nittrouer & Studdert-Kennedy, 1987). It is thus possible, as this conception of underspecification theory would claim, that some children may have a perceptual problem or a different weighting of acoustic cues where it would be appropriate to effect by means of underspecified representations a merger underlyingly and phonetically. The more widely held assumption is, however, that children's perceptual abilities are generally in advance of their production. Because both situations find support in the literature, and because no conclusive information is available on the perceptual abilities of the children in this study, we must entertain both scenarios below in formulating an underspecification account of the chain shift in (1).

Scenario 1: Perception and production coincide. To account for this chain shift in underspecification terms under one scenario, it is necessary to isolate the features that are merged in each component of the larger substitution pattern. The substition of [f] for target /θ/ involves a merger of a target place distinction within fricatives, suggesting that the child may represent these

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two target sounds as the same underlyingly, i.e. without a specification for place. Given the marked character of fricatives relative to stops, it might be assumed further that these fricatives are at least specified underlyingly for manner as [+continuant]. We represent these placeless fricatives as an archiphonemic fricative /F/ in (5Aa and b). Because the result of the merger is a labial fricative rather than some other place of articulation, it would seem that the default place feature for fricatives to be supplied by rule is [labial], at least for these children. While [coronal] is generally assumed to be the default feature for place in fully developed systems (e.g. Paradis & Prunet, 1991), there is some motivation for fricatives being handled differently for at least some children. That is, many children with normal or disordered phonological development may limit their fricative productions to a single place of articulation, either labial or coronal. For those who limit fricatives to a labial place of articulation, the place feature [labial] would be entirely predictable and thus would be underspecified. This independently motivated fill-in rule is formulated in (5) as Rule 1′ and can readily be attributed to the children evidencing the chain shift. This fill-in rule achieves the equivalent of Rule 1 above in accounting for one part of the correspondence. As a possible explanation for the emergence of this chain shift, it might be speculated that these children at an earlier stage of development allowed labials as their only frivatives. No definitive information is available on this point, but it is at least suggestive of one possible factor which might contribute to a predisposition for a chain shift of this sort.

To account for the other part of the chain shift, namely the replacement of target /s/ by [θ], the distinguishing stridency feature must be assumed to be underspecified. That is, it is assumed that target /s/'s were represented underlyingly by the children without any specification for stridency. Because the target /s/'s behaved differently from target /θ/'s, they had to be distinguished underlyingly from target /θ/'s. It is thus assumed that these target /s/'s were specified for place as [coronal] and for manner as [+continuant] as in (5Ac). We designate these segments as an archiphonemic coronal fricative (/S/), being underspecified for stridency. Coronal fricatives in these children's systems were predictably [−strident], allowing that feature to be filled in by default. This fill-in rule is formulated in (5B) as Rule 2′ and would achieve essentially the same effect as Rule 2 above. The two fill-in rules need not be ordered with respect to one another.

(5) Underspecification account
  A. Representations
    a. Target /f/ = /F/ [+continuant]
    b. Target /θ/ = /F/ [+continuant]
    c. Target /s/ = /S/ [+continuant, coronal]

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B. Fill-in rules

Rule 1′: $[\,] \rightarrow [\text{labial}] / \left[\frac{\quad}{+\text{continuant}} \right]$

A fricative underspecified for place is labial.

Rule 2′: $[\,] \rightarrow [-\text{strident}] / \left[\begin{array}{c} \frac{\quad}{\text{coronal}} \\ +\text{continuant} \end{array} \right]$

A coronal fricative underspecified for stridency is [−strident].

C. Derivations

	a. /Fɪn/ 'fin'	b. /Fɪn/ 'thin'	c. /Sɪn/ 'sin'
Rule 1′	fɪn	fɪn	—
Rule 2′	—	—	θɪn
	[fɪn]	[fɪn]	[θɪn]

By this account, target /s/ is kept distinct from target /f/ and /θ/, but /f/ and /θ/ are not distinct from one another. A two-way place distinction obtains between labial and coronal fricatives. The postulation of such representations has implications for claims about the children's presumed perceptual judgements. The claim would be that when presented with /f/'s and /θ/'s, these children would fail to identify reliably which is which. On the other hand, when presented with /s/ and /θ/ (or /f/), these children would correctly identify the target /s/ tokens as distinct from target /θ/ (and /f/), but would continue to confuse target /θ/ and /f/. Because no information is available on how these children might in fact have judged these items perceptually, we (like many others) can only speculate about what their perceptual abilities might have been. Nevertheless, it is possible under one scenario that the children of this study had a perceptual problem or different weighting of acoustic cues that would have yielded these effects. To the extent, then, that these children might have merged the target distinction in both perception and production, this account makes the correct claim.

This account also seems plausible in terms of what is known about speech acoustics and perception generally. For example, in terms of acoustics, /f/ and /θ/ are typically (but not exclusively) characterized by low intensity spectra, whereas /s/ has a high intensity spectrum (e.g. Harris, 1958). Labials and coronals obviously differ in other respects as well, for example, in terms of the tilt of their spectra (Stevens & Blumstein, 1978). These children under this scenario might be expected to ignore spectral tilt among fricatives as linguistically irrelevant or noncontrastive (cf. Levitt, Jusczyk, Murray & Carden, 1988). The intensity of the spectra alone would be

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sufficient for these children to identify target /s/ as distinct from the other two target fricatives. In other words, when presented with /s/, these children could have taken note of the high intensity spectrum and could equate this with their representation of a coronal fricative as in (5Ac). When presented with /f/ or /θ/, these children could have taken note of the low intensity spectra and could equate this with their distinct representation of other fricatives underspecified for place (5Aa and 5b), i.e. a labial fricative. Under this scenario, then, these children might take spectral intensity as a predictable correlate of place for fricatives.

While scenario 1 is certainly possible, the more widely held assumption is that children's perceptual abilities are generally in advance of their production. If this were true in the case of any of the children in this study, they would have been expected to have comprehended the target distinctions even though they failed to produce all of them. This may well have been the case; we thus entertain this possibility in the formulation of the underspecification account of a second scenario.

Scenario 2: Perception in advance of production. Mismatches between perception and production represent a long-standing dilemma in acquistion and have motivated various different theoretical proposals, including adult-like underlying representations within a single-lexicon model (e.g. Smith, 1973) and/or a dual-lexicon model, where representations for production may differ from perceptual representations which are posited as adult-like (e.g. Menn, 1976). We saw earlier, however, that the other standard empirical factors that are typically adduced in support of adult-like underlying representations were not borne out in the case of this chain shift. Also, a dual-lexicon model (i.e. one lexicon for production and the other for perception) has the unfortunate drawback of introducing extensive duplication. An alternative single-lexicon account under this scenario is available within underspecification theory as sketched in (6), achieving these effects without the associated problems. The representation of target /f/ and /s/ would remain (under)specified as postulated in scenario 1. The fill-in rules would also remain the same. The only difference relates to the underlying representation of target /θ/. Since target /θ/ was realized as [f], abstractness considerations and compatibility with the children's production facts suggest that it be represented as it appears phonetically. The problem is how to distinguish underlyingly the substitute from the phonetically identical target /f/. Since target /f/ is assumed to be underspecified for place, the substitute would be rendered distinct if it were specified underlyingly for some place feature. One possible nondiacritic (phonetically interpretable) place specification that is available and also consistent with the children's production facts is the feature [labial].

Target /θ/ could thus be represented underlyingly as in (6Ab), yielding a three-way place distinction at the underlying level among the target sounds

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of the chain shift.[3] These phonological distinctions result in a two-way place distinction at the phonetic level. The specification of a default feature such as [labial] (along with the underspecification of that feature for other segments) has been termed SHADOW-SPECIFICATION and has been motivated by other phenomena in developing systems (e.g. Dinnsen, 1993, 1998; Dinnsen *et al.*, 1997), as well as by phenomena in fully developed systems (e.g. Archangeli & Pulleyblank, 1994: 73–83, 98–101).

(6) Alternative underspecification account

A. Representations

a. Target /f/ = /F/ [+continuant]
b. Target /θ/ = /f/ [+continuant, labial]
c. Target /s/ = /S/ [+continuant, coronal]

B. Derivations

	a. /Fɪn/ 'fin'	b. /fɪn/ 'thin'	c. /Sɪn/ 'sin'
Rule 1′	fɪn	—	—
Rule 2′	—	—	θɪn
	[fɪn]	[fɪn]	[θɪn]

This account posits some representations which are not entirely adult-like but which do conform to a single-lexicon (as opposed to a dual-lexicon) model. It also remains plausible both in terms of the acoustic facts and the presumed perceptual abilities of these children. That is, when presented with /s/, these children might have taken note of the high intensity spectrum (and possibly also its rising tilt) and could have equated this with their representation of a coronal fricative (6Ac) which is underspecified for stridency. When presented with /θ/, they might have taken note of the low intensity spectrum along with its rising tilt and could have mapped those properties onto a distinct representation (6Ab) which is specified for place as [labial]. When presented with /f/, they might have taken note of the low intensity and relatively flat cline of the spectrum and could have mapped these properties to a distinct representation (6Aa) which is not specified for place. By this account, the tilt of the acoustic spectrum becomes perceptually relevant, especially in conjunction with the intensity of the spectrum. While adults

[3] The choice of which segment is to be specified for the default place feature is relatively arbitrary in this case. However, in other cases involving assimilatory phenomena (e.g. Dinnsen, 1998; Dinnsen *et al.*, 1997), a nonarbitrary choice can be made. In the case of this chain shift, the relative stability over time of target /f/ realizations is suggestive of their being underspecified with the appropriate place feature supplied by default. Also, by specifying target /θ/'s for place, correct realizations can potentially be achieved through an innovative sound change which uniquely targets those segments by shifting the underlying place specification of fricatives from [labial] to [coronal]. Fricatives that are underspecified for place would not meet the conditions required by the sound change and would thus not be subject to change.

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generally correlate a rising spectrum with coronal (and not labial) place, these children would at least be taking note of properties that do occur in the acoustic signal. The mismatch with the target system arises only in the children's label (or featural correlate) for that acoustic property.

This and the other underspecification account also provide a natural basis for the changes that occurred by lexical diffusion. Consider, for example, the posttreatment emergence of target-appropriate [θ] in the few lexical items in (3d) for Subject 33. Under the first scenario, the underlying representation of the affected segments in just those lexical items would have changed from being underspecified for place (5Ab) to being specified as [coronal] (5Ac). This change in underlying specification would have the further automatic consequence of yielding a [θ]. That is, as a result of the fill-in rule (Rule 2′), the feature [-strident] would be supplied to coronal fricatives by default. These few target-appropriate realizations would be largely fortuitous since the representation does not quite coincide with the target representation. The many other lexical items that continued to be produced in error (3b) would have remained unchanged at the underlying level and thus would have been subject to the fill-in rule (Rule 1′), supplying the feature [labial] by default. Even under the second scenario, the few phonetic changes that did occur were limited to underlying change. That is, the underlying [labial] specification for those labial fricatives corresponding to target /θ/ would have changed to [coronal] in a fashion similar to a historical sound change. Where no such underlying change occurred, all other aspects of the account would have remained unchanged. Under either scenario, in the case of those children where /s/ began to emerge, a change in underlying representation is also called for. That is, the affected segment in just those lexical items would have changed from a coronal fricative underspecified for stridency (5Ac) to being specified underlyingly as [+strident]. The fill-in rules would not be applicable to such a representation, resulting in a target-appropriate realization of [s]. The persistence of the error pattern relating to target /s/ (3c) would follow from no change in the underlying representation to those items and default feature realizations (Rule 2′). These accounts entail very little change in the grammar, providing for a high degree of continuity across stages of development. What changes at first is the specification of certain segments in a few lexical items. As time goes on, more and more lexical items are affected. The persistence of the error pattern continues to be attributable to underspecified representations and the fill-in rules. For a similar underspecification account of the acquisition of other phonemic contrasts, see Dinnsen (1996*a*, *b*, 1998).

In sum, whatever the perceptual judgements might have been for these children, both the production and perception facts can be accounted for within underspecification theory without resort to a dual-lexicon model or the empirically unsupported assumption that the children's underlying

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representations are fully specified and perfectly adult-like. Additionally, this account is compatible with the facts of change and affords a high degree of continuity.

The appeal to underspecification theory in the above accounts has been cast entirely within a derivational framework. It is not at all obvious whether such representations are relevant to accounts of the same facts within the nonderivational constraint-based framework of optimality theory (e.g. Prince & Smolensky, 1993; McCarthy & Prince, 1995). There are several reasons for this. First, optimality accounts of acquisition phenomena are only just beginning to emerge, and no such account has been offered for the rather special class of interacting substitution errors involving a chain shift as an acquisition phenomenon. Secondly, optimality accounts of phenomena in fully developed systems tend to eschew underspecification. In the following, we formulate and evaluate different optimality accounts of this chain shift, adopting different assumptions about the nature of these children's underlying representations.

OPTIMALITY THEORETIC ACCOUNTS

Background

Optimality theory as developed most notably by Prince & Smolensky (1993) and McCarthy & Prince (1995) differs from conventional derivational theories in several important respects. First of all, there are no phonological rules or derivations. Instead, a ranked set of universal constraints selects an optimal output for any given input representation from among all possible output candidates. Output candidates are evaluated in parallel by the constraints for potential violations. While the constraints are violable, some violations are more serious than others, as reflected by the language-specific ranking of the constraints. Those output candidates which violate high ranked constraints are eliminated from consideration; an output candidate which may only violate a lower ranked constraint survives as the actual output. The optimal output candidate is the one that is the most harmonic or incurs the fewest violations of high ranked constraints. The constraints are of two general types: faithfulness constraints and well-formedness (or markedness) constraints. The faithfulness constraints serve to eliminate disparities between an input (underlying) representation and an output representation. Different faithfulness constraints militate against the insertion or deletion of segments or features. The many well-formedness constraints often have the opposite effect by favouring unmarked outputs. The tension between these constraints is resolved by language-specific rankings. If faithfulness constraints dominate well-formedness constraints, then the optimal output will closely correspond to the input. If, on the other hand, the well-formedness constraints outrank the faithfulness constraints, the optimal output may

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differ substantially from the input and will reflect phonological unmarkedness. Within this theory, the only elements of grammar that are free to vary are the input representations and the constraint rankings.

The few available optimality accounts of acquisition phenomena have largely assumed adult-like underlying representations (e.g. Demuth, 1996; Gnanadesikan, 1996; Goad, 1996; Pater & Paradis, 1996; Smolensky, 1996; Stemberger, 1996). The fact that children's outputs often differ from their adult-like underlying representations has been accounted for by ranking relevant well-formedness constraints more highly than faithfulness constraints, at least in early stages of development. For example, then, the common error pattern which replaces fricatives with stops might be attributed to a highly ranked well-formedness constraint militating against the relatively marked feature [+continuant] in obstruent output candidates. Thus, even though a fricative might be posited in the input representation, the undominated character of the well-formedness constraint prevents a fricative from occurring in an actual output. While a stop substitute constitutes a violation of an antagonistic faithfulness constraint demanding that underlying input features be parsed in outputs, the lower ranking of such faithfulness constraints allows an unfaithful output to win. The acquisition process and the elimination of error patterns are seen as involving a reranking of constraints, resulting in the eventual promotion of faithfulness constraints over well-formedness constraints. If faithfulness constraints come to outrank well-formedness constraints and if input representations are adult-like, then target appropriate outputs that are faithful to those inputs should be guaranteed.

The particular facts surrounding chain shifts in acquisition have not been considered in this framework. The counterfeeding effect (in derivational terms) of chain shifts is especially interesting in a theory void of derivations where constraints are formulated in terms of outputs. The particular challenge is accounting for both the favoured and the disfavoured status of [θ] as an output. This section thus attempts to adopt various assumptions about these children's input representations in an optimality theoretic account of the chain shift with the intent, in part, of evaluating the adequacy of the framework and hopefully offering some insight into acquisition.

Fully specified adult-like underlying representations

An account of the substitution patterns of this chain shift, assuming adult-like input representations, would seem to require certain well-formedness constraints to outrank certain other faithfulness constraints. The constraints and constraint rankings in (7) are offered as likely possibilities.

(7) Constraints and rankings
*StridCor: Avoid strident coronals.

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DistFaith:	The output cannot differ from the corresponding input by more than a value of 1 on the scale /f/ = 1, /θ/ = 2, /s/ = 3.
*Cor:	Avoid coronal fricatives.
Max[Feature]:	Preserve underlying features in the corresponding output segment.
Rankings:	*StridCor, DistFaith >> *Cor >> Max-[Feature]

For each target sound involved in the chain shift, the constraints must evaluate different potential output candidates to determine which is optimal. For our purposes, we will consider just those candidates with different possible fricatives which might reasonably compete. Since [s] generally did not occur, a highly ranked well-formedness constraint must eliminate [s] as an output candidate for any input. The strident character of this fricative would seem to be the offending feature, leading to a fatal violation of a well-formedness constraint, *StridCor, which militates against the secondary enhancement feature [+strident] in a coronal fricative. Such a constraint reflects the relatively marked and late-acquired character of /s/ and would have to be ranked above a general faithfulness constraint which attempts to preserve underlying stridency (among other features). This antagonistic faithfulness constraint is formulated as Max[Feature]. The ranking of this faithfulness constraint relative to the well-formedness constraint claims that it is more important to avoid stridency in an output than it is to parse input stridency specifications. Since stridency is only contrastive among coronals in English, the role of these constraints is limited to those segments where a distinction might be posited in the input representations. The presumably strident nature of labials is not relevant to the well-formedness constraint as it is formulated. Another part of the chain shift that must be accounted for is the occurrence of [f] – especially as a correspondent of target /f/. A highly ranked faithfulness constraint which preserves underlying place features would appear to be responsible for this, as well as for the preservation of coronal place in the substitution of [θ] for /s/. The problem is that coronal place is not preserved in the substitution of [f] for /θ/. In this instance, the place feature [labial] appears to be more highly valued in an output, even at the expense of faithfulness. A constraint (or set of constraints) is thus needed that preserves place under certain circumstances but also tolerates a degree of unfaithfulness under certain other circumstances. Following from a proposal of Kirchner (1995) to account for synchronic chain shifts in fully developed systems, the segments involved in the chain shift might be grouped together and assigned a particular value along some dimension, e.g. /f/ = 1, /θ/ = 2, /s/ = 3. We purposely avoid for the moment the important issue of the correlates of this putative dimension and the reasons for the

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assigned values. A constraint of DISTANTIAL FAITHFULNESS, DISTFAITH, can then be formulated which requires that an output segment cannot differ from the input by a value of more than 1 on this scale. This has the consequence that no violations would be incurred by perfectly faithful outputs or by outputs that differ from their input by a value of 1. For example, then, no violations of this constraint would be incurred by a perfectly faithful output [s] or an output [θ] as correspondents for input /s/, nor would violations be incurred by a perfectly faithful output [θ] or an output [f] as correspondents for input /θ/. A fatal violation of this constraint would, however, be incurred by [f] as an output correspondent for /s/ since if differs by a value of 2 on this scale. Two additional constraints are required to select the optimal output for target /θ/. Any output candidate that included [s] would be eliminated by the previously mentioned and highly ranked well-formedness constraint *STRIDCOR. The other constraints considered thus far, however, fail to decide between [f] and the perfectly faithful [θ] as the optimal output for /θ/. Another well-formedness constraint (possibly an instance of a more general family of constraints disfavouring coronal fricatives) must militate against [θ]. A well-formedness constraint *COR would disfavour any coronal fricative in an output candidate. This constraint reflects the late-acquired character of coronal fricatives generally and /θ/ in particular, especially relative to /f/. A violation of this well-formedness constraint would thus be incurred by [θ], but not by [f] since the latter is not a coronal fricative. Furthermore, the well-formedness constraint *COR must dominate the faithfulness constraint MAX[FEATURE], since the optimal output [f] violates the faithfulness constraint by failing to parse the input stridency and place specifications. The optimal output for target /θ/ would then be [f], even though it would incur violations of the (lower ranked) faithfulness constraint MAX[FEATURE], which requires the preservation of stridency and place features. In such a system, then, the substitution of [f] for /θ/ obtains because it is more important to comply with the well-formedness constraint *COR disfavouring [θ] than it is to comply with the constraint favouring a faithful parse of stridency and place features. Our discussion of the well-formedness constraint *COR might reasonably raise questions about how the chain shift could yield the nonstrident coronal fricative [θ] as the optimal substitute for /s/. While [θ] violates *COR, the other competing candidates are eliminated by higher ranked constraints. More specifically, the perfectly faithful output candidate [s] fatally violates undominated *STRIDCOR, and the candidate output [f] fatally violates the undominated faithfulness constraint DISTFAITH. Thus, even though the winning candidate [θ] violates the well-formedness constraint, the lower ranking of that constraint renders [θ] as the most harmonic output. This effect is achieved by a now conventional property of optimality theory which allows a family of constraints to be exploded with other constraints interwoven in the overall ranking. In this case, a family of well-

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formedness constraints militating against coronal fricatives and their secondary enhancement properties, such as stridency specifications, is exploded to separate *StridCor from the lower ranked *Cor. The internal ranking of these two well-formedness constraints relative to the faithfulness constraint DistFaith allows [θ] to win out as an optimal output under certain circumstances. We have seen that DistFaith must outrank *Cor to account for the actual correspondent of an input /s/.

The ranking notation can be interpreted as follows: a comma between two constraints (e.g. between *StridCor and DistFaith) indicates that the two constraints are not crucially ranked with respect to one another. Double angled brackets between constraints indicate that the constraints are crucially ranked. Thus, DistFaith is crucially ranked higher than *Cor. In accord with the above discussion, the effect of these constraints and their rankings are detailed in Tableau 1. For all tableaux, input underlying representations

TABLEAU 1. *StridCor, DistFaith >> *Cor >> Max[Feature]

	*StridCor	DistFaith	*Cor	Max[Feature]
(1) /fɪn/ 'fin'				
☞ a. [fɪn]				
b. [θɪn]			*!	*
c. [sɪn]	*!	*	*	*
(2) /θɪn/ 'thin'				
☞ a. [fɪn]				*
b. [θɪn]			*!	
c. [sɪn]	*!		*	*
(3) /sɪn/ 'sin'				
a. [fɪn]		*!		*
☞ b. [θɪn]			*	*
c. [sɪn]	*!		*	

are given in the upper left corner along with relevant candidate output surface representations down the left side. The constraints are given across the top in ranked order. A solid vertical line between constraints indicates the constraints are crucially ranked with respect to one another, while a dashed

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vertical line indicates that the constraints are unranked. Violations of the various constraints by the different possible output forms are indicated by an asterisk '*', and fatal violations are indicated by an asterisk followed by an exclamation point '*!', which eliminates a candidate from being an occurring output. Finally, the symbol ' ' marks the winning or optimal candidate. A winning candidate is the candidate which best satisfies (or incurs fewer violations of highly ranked) constraints with respect to all other candidate forms.

This account largely accords with the facts of the chain shift (at least for the first speech sample for Subject 33) and the general characterization of acquisition which ranks well-formedness constraints above faithfulness constraints. The account does, however, entail the rather questionable appeal to distantial faithfulness and to an undefined dimension that assigns particular values to the sounds of the chain shift. Even if some other means were found to deal with these opacity effects (e.g. Kirchner, 1996; McCarthy, to appear), there are more serious empirical problems with the account when the facts of change are considered. Recall from the previous section that target-appropriate realizations of [θ] and [s] did not occur for any of the children in an across the board fashion in the second speech sample. Instead, these target-appropriate realizations diffused only gradually through the lexicon. If the children's underlying representations had been adult-like, we might have expected a reranking of the constraints (faithfulness >> well-formedness) to result in across the board change. The fact that the error pattern persisted while only a few lexical items evidenced target-appropriate realizations is suggestive of a ranking paradox. More specifically, to account for the posttreatment persistence of the substitution of [f] for target /θ/ in (3b) for Subject 33, the well-formedness constraint *Cor must outrank the faithfulness constraint Max[Feature] (as shown in Tableau 1). The emergence of target appropriate [θ] in (3d) would require the opposite ranking of these constraints. Similarly, the persistence of the error pattern for target /s/ as in (3c) requires *StridCor to outrank Max[Feature]; the emergence of the few target–appropriate realizations in (3e) requires just the opposite ranking. It thus appears that the constraints cannot be ranked if adult-like underlying representations are assumed in an account of a stage of development evidencing lexical diffusion. While the ranking paradox might be avoided if it were assumed that constraint rankings are specific to particular lexical items or that competing grammars with different constraint rankings can coexist for a period of time, falsifiability considerations render such proposals less desirable. Because of the problems associated with the assumption of adult-like underlying representations in these cases, we consider below some optimality theoretic alternatives which make somewhat different claims about the nature of these children's underlying representations.

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Alternative underspecification accounts within optimality theory

Most optimality accounts of phenomena in fully developed systems eschew underspecification. Lexicon optimization and learnability considerations have, however, been argued to motivate underspecified representations (e.g. Itô, Mester & Padgett, 1995). Acquisition phenomena of this sort may thus provide a window on this issue.

An alternative optimality account of the chain shift at both stages of development is available if children's underlying representations are assumed to be underspecified as presented earlier in (5) and (6). Those representations relating to the first scenario (which considered the possibility that target /f/ and /θ/ were perceptually confused) are repeated in (8).

(8) Underlying representations for Scenario 1
   a. Target /f/ = /F/ [+continuant]
   b. Target /θ/ = /F/ [+continuant]
   c. Target /s/ = /S/ [+continuant, coronal]

For purposes of evaluating potential output candidates, there will be a substantial lack of correspondence between these underspecified inputs and the more fully specified outputs. Faithfulness constraints are thus at issue and are given in (9) along with the required rankings. The effects of these constraints and rankings are detailed in Tableau 2. One relevant class of faithfulness constraints incurs violations if the output candidate does not include a feature from the corresponding input segment (MAX[FEATURE]). The other relevant class of faithfulness constraints incurs dependence (DEP[FEATURE]) violations if an output segment includes a feature that is not in the corresponding input segment. Many different features could in principle appear in the outputs of these underspecified representations in (8) to yield different output candidates, each of which would incur a DEP-[FEATURE] violation for each feature that does not also occur in the input. Some DEP[FEATURE] violations are, however, more serious than others, allowing some candidates to be eliminated and others to survive. For example, to account for the failure of [s] to survive as an output correspondent of any underspecified input, a highly ranked faithfulness constraint DEP-[+strid], is needed to disfavour the occurrence of the feature [+strident] in any output candidate corresponding with an input that is specified as a coronal fricative (8c). The occurrence of the feature [−strident] in an output would also incur a violation of another faithfulness constraint, DEP[−strid], but the lower ranking of this constraint makes it a less serious violation, resulting in [θ] as an optimal output for (8c). The highly ranked constraint MAX[FEATURE] plays a role here too by requiring that the underlyingly specified place feature [coronal] for target /s/ be parsed in the output. This eliminates any candidate that does not preserve the underlying input feature

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TABLEAU 2. DEP[+strid], MAX[FEATURE] >> DEP[−strid], DEP[coronal] >> DEP[labial]

	DEP[+strid]	MAX[FEATURE]	DEP[−strid]	DEP[coronal]	DEP[labial]
(1) /fɪn/ 'fin'					
☞ a. [fɪn]					*
b. [θɪn]			*!	*	
c. [sɪn]	*!			*	
(2) /fɪn/ 'thin'					
☞ a. [fɪn]					*
b. [θɪn]			*!	*	
c. [sɪn]	*!			*	
(3) /sɪn/ 'sin'					
a. [fɪn]		*!			*
☞ b. [θɪn]			*		
c. [sɪn]	*!				

[coronal]. Different place features could potentially occur in output candidates corresponding to the underspecified representations in (8a) and (8b), and would incur DEP violations. For example, the occurrence of the feature [coronal] in an output would violate another constraint, DEP[coronal], if that feature were not present in the input. This is different from the failure to parse the underlying feature [coronal] as required by MAX[FEATURE]. By ranking DEP[coronal] above DEP[labial], [s] and [θ] can both be eliminated as output candidates for target /f/ and /θ/ in favour of the optimal substitute [f]. This ranking accounts for the default character of labial place for fricatives by maintaining that it is worse for a placeless fricative to include the feature [coronal] than it is to include the feature [labial].

(9) Constraints and rankings

MAX[FEATURE]: Every feature in the input segment must occur in the corresponding output segment.

DEP[+strid]: The presence of [+strident] in the output of coronal fricatives must correspond to the presence of [+strident] in the input.

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DEP[−strid]:	The presence of [−strident] in the output must correspond to the presence of [−strident] in the input.
DEP[coronal]:	The presence of [coronal] in the output must correspond to the presence of [coronal] in the input.
DEP[labial]:	The presence of [labial] in the output must correspond to the presence of [labial] in the input.
Rankings:	DEP[+strid], MAX[FEATURE] >> DEP[−strid], DEP[coronal] >> DEP[labial]

Because target /f/ and /θ/ are represented as nondistinct underlyingly by this scenario, the evaluation of their output candidates is the same. While all the candidates we are considering faithfully parse all features of the input, they also include features not in the input. That is, candidate (c) fatally violates the undominated constraint DEP[+strid] (as well as the lower ranked DEP[coronal]), and candidate (b) violates both DEP[−strid] and DEP[coronal] (either one of which is fatal). While candidate (a) violates DEP[labial], the lower ranking of this constraint allows the candidate to win out. The input representation of target /s/ crucially includes the feature [coronal]. Output candidate (a) fails to parse that input feature, fatally violating the undominated constraint MAX[FEATURE] (as well as lower ranked DEP[labial]). Output candidate (c) faithfully parses all input features but fatally violates the undominated constraint DEP[+strid]. While candidate (b) violates DEP-[−strid], the lower ranking of that constraint allows the candidate to survive as optimal.

This account leads naturally to an account of the subsequent stage of development, which evidenced the emergence of some target-appropriate realizations of sounds involved in the chain shift along with the persistence of the chain shift. Recall, for example, the post-treatment facts for Subject 33 in (3). To account for the few target-appropriate realizations of [θ] in (3d), it would be claimed that the underlying specification of the affected segments in just those words changed from being underspecified for place to being specified underlyingly for place as [coronal]. This means that an underlying structure such as (8b) for some lexical items would have changed to a structure such as (8c) and would have been realized in the same way as other instances of (8c), namely as [θ]. The other input representations that did not change would be subject to all the same constraints and rankings as before. For those cases where the target-appropriate realization of [s] occurred in a few lexical items, the claim would be that the underlying representation of (8c) changed in just those words by specifying underlyingly the feature [+strident]. The highly ranked faithfulness constraint MAX[FEATURE] would require that all input features be parsed, including the feature [strident], and

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would thus eliminate all candidates which failed to include those specified input features. Again, inputs that did not change underlyingly would continue to be realised as before, accounting for the persistence of the error pattern.

These same constraints and rankings also account for the facts under the alternate second scenario, which considered the possibility that these children might have perceptually distinguished target /f/ and /θ/. Since, by this account, target /θ/ was assumed to be shadow-specified as [labial], the highly ranked faithfulness constraint MAX[FEATURE] would eliminate all output candidates that failed to parse the input feature [labial]. Thus, [f] is guaranteed to be the substitute for target /θ/ under this scenario. All other aspects of the account are the same as above for the first scenario. There is some question whether the facts of change would be predicted to be the same under this scenario. That is, it is possible that the shadow-specification of these segments could uniquely identify them for purposes of an across the board change brought about by a change in phonetic implementation or in constraint ranking. However, change by lexical diffusion also remains possible if not all target /θ/'s were shadow-specified. The facts of both production and perception are thus accounted for in a conventional single-lexicon model, resolving the presumed production/perception dilemma in acquisition (cf. Smolensky, 1996).

This account with its associated assumptions about children's underlying representations preserves a high degree of continuity in the grammars of these children through the various stages of development. What changes is not the rankings of constraints, but rather the underlying specification of just those words exhibiting a sound change. The proposed faithfulness constraints remain highly ranked across stages of development. This is not to say that changes in constraint rankings do not occur in other cases; the facts of change in these cases simply do not warrant changes in constraint rankings. This conception of change is entirely consistent with those accounts of other acquisition phenomena where children's underlying representations are assumed to be relatively impoverished in early stages and become more elaborated over time (e.g. Rice & Avery, 1995; Dinnsen, 1996*a*, *b*).

CONCLUSION

The particular chain shift considered here represented a conjunction of two common and independently occurring error patterns in phonological development (normal and disordered) and did itself occur with some prevalence in these systems. A number of other error patterns in other children's early phonological development have also been observed to interact with similar effects (e.g. Applegate, 1961; Smith, 1973; Dinnsen, 1993, 1998; Dinnsen *et al.*, 1997). A formal characterization of these other error patterns may be amenable to many of the same considerations presented in this paper.

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Because these chain shifts result in opaque (and sometimes nonsystematic) substitution patterns, something more than children's immature motor systems would appear to be involved. Interacting error patterns of this sort are thus a prominent and revealing property of developing systems and warrant further theoretical attention. On the basis of the considerations presented here, both derivational and constraint-based theories were found to be capable of accounting for the critical facts of this chain shift in acquisition, i.e. including the facts relating to production, perception and change over time. Importantly, however, no matter which theoretical framework was adopted, what emerged as a common result of any adequate account was that the children's underlying representations could not be assumed to be fully specified. More specifically, the particular facts supported the postulation of underlying (or input) representations that are radically underspecified (and possibly also shadow-specified) for certain features that are contrastive in the adult system. Such representations were able to reconcile the presumed production/perception dilemma commonly associated with acquisition within a single-lexicon model without appeal to segment-types that did not occur in the children's productions. They also allowed the facts of change to be accounted for by changes in the underlying specification of affected lexical items in a way that largely preserved continuity in the descriptions of the different stages of development. Another important aspect of this investigation is its appeal to converging evidence. Perhaps not surprisingly, many different assumptions and accounts of a phenomenon are possible when only a single point in time is considered. When the empirical domain is broadened to include in addition the transition from one point in time to another, the available set of assumptions and accounts is properly narrowed. These phenomena from acquisition and their characterization thus provide crucial additional support for theoretical proposals about the nature of phonological representations.

Several questions are raised by these accounts, including how this particular chain shift came into being, and why it was so resistant to change, even when directly targeted for clinical treatment. On the first of these questions, an insight from underspecification theory allowed us to speculate in our discussion that these children's first fricative might have been a labial. The reasoning behind such speculation was that labial place would then have been a predictable (or default) property of fricatives, accounting for the labial substitution pattern. After that point in time as other more marked fricatives might have been added, labial place would already have been established as the default place. The default character of labial place was ultimately a crucial component of the underspecification account of the substitution of [f] for /θ/ in the chain shift. Along these same lines, it might be speculated further that this chain shift might never emerge in other children's systems where their first and only fricative were a coronal. In such cases, coronal

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place would be entirely predictable and thus be the default place. Fricatives underspecified for place would then be expected to be realized as coronals rather than labials. If labial fricatives were to subsequently come into the system, they would be more marked and would have to be specified underlyingly for place. We thus might expect /f/ and /θ/ to act differently in such systems. Consequently, the particular fricative that is first acquired by a child may have implications for which place features are the default for that child and may predict whether that child is predisposed to the emergence of this chain shift.

On the other question regarding the resistance of this chain shift to change, target-appropriate realizations of /θ/ might have been expected to emerge more readily, especially given that the children were able to produce [θ]. Across the clinical literature, no one sound or even class of sounds is uniformly resistant to change as we have seen here. It thus seems that at the heart of the issue here is the interaction of the errors or possibly how that interaction comes about. The optimality account presented here may offer a partial answer. That is, the relevant faithfulness constraints are already highly ranked at an early stage of development. In other words, an optimal ranking has already been achieved with no further motivation for constraint rerankings. This is, however, not sufficient to achieve full conformity with the target system. The only other relevant property of the grammar that would be available to change is the input representations. It may be that the task of restructuring input representations is more difficult for children than to rerank constraints. This difficulty might then be manifested in the word by word restructuring of phonemic representations consistent with lexical diffusion as observed in these cases. Children with a phonological delay along these lines offer a unique window on these issues because of their compelling need for clinical intervention, which can then be experimentally directed at undoing the chain shift. It should be possible to determine from such treatment studies whether chain shifts generally are resistant to remediation, or alternatively whether the problem is with the interaction of these two specific error patterns. Also, different forms of treatment may be more or less effective with different error patterns. Recall that the children with phonological disorders in this study received conventional minimal pair contrast treatment which contrasted the substitute sound with the target sound. It may be desirable to entertain some other form of treatment in the case of a chain shift (e.g. Gierut, in press *b*). It also may be possible to experimentally induce (or preclude) this chain shift by the choice of a labial or coronal fricative as the first fricative to be taught to a child who otherwise excludes fricatives.

As more examples of this and other chain shifts are subjected to these various considerations, it should be possible to approach answers to these questions and to further evaluate the claims of our analyses.

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APPENDIX A

TABLE 2. *Phonetic inventories for each subject at each speech sample*[a]

Subject number	Speech sample 1							Speech sample 2						
14	pb			td		kg	ʔ	pb			td		kg	
		fv	θð	(s)					fv	θ(ð)	(sz)	ʃ		
			t͡θd͡ð									t͡ʃd͡ʒ		
	m			n		ŋ		m			n		ŋ	
				l							l	ɾ		
	w				j		h	w				j		h
15	pb			td		(kg)	ʔ	pb			td		kg	
		fv	θð	(sz)	ʃ				fv	θð	s(z)	ʃ		
					t͡ʃd͡ʒ							t͡ʃd͡ʒ		
	m			n		(ŋ)		m			n		ŋ	
				l							l			
	w				j		h	w				j		h
33	pb			td			ʔ	pb			td		kg	ʔ
		fv	θð						fv	θð	sz	ʃ		
			t͡θd͡ð									t͡ʃd͡ʒ		
	m			n		(ŋ)		m			n		(ŋ)	
				(l)							l	ɾ		
	w				j		h	w				j		h
45	pb			td		kg		pb			td		kg	
		fv	θð	(sz)					fv	θð	s̪			
	m			n				m			n		ŋ	
											(l)			
	w				j		h	w				j		h
46	pb			td		kg		pb			td		kg	
		fv	θð						fv	θð	(s)	ʃ		
					t͡ʃd͡ʒ							t͡ʃd͡ʒ		
	m			n		ŋ		m			n		ŋ	
					(r)									
	w				j		h	w				j		h
RH	pb			td		kg	ʔ	pb			td		kg	
		fv	θð	s̪z̪	ʃ				fv	θð	s̪(sz)	ʃ		
					t͡ʃd͡ʒ							t͡ʃd͡ʒ		
	m			n		ŋ		m			n		ŋ	
				l	ɾ						l	ɾ		
	w				j		h	w				j		h

[a] Symbols listed in parentheses indicate that the sound was emerging. The inventories collapse across contexts and do not necessarily correspond with target productions.

https://doi.org/10.1017/S0305000997003322 Published online by Cambridge University Press

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APPENDIX B

TABLE 3. *Sample tokens relating to the chain shift for each subject for both speech samples*

	Subject 14		Subject 15		Subject 45		Subject 46		Subject RH	
Gloss	1	2	1	2	1	2	1	2	1	2
fire	faɪju	faɪəˠ	faɪə	faɪʊ	faɪu	faɪo	faɪo	faɪʊ	faɪəˠ	faɪəˠ
five	faɪv	faɪv	faɪv	faɪv	faɪv	faɪv	faɪv	faɪv	faɪf	faɪv
beautiful	budɪfʊ	bjurəfo	budifʊl	bjurɪfʊl	budəfʊ	bjurəfʊl	bjutɪfo	bjɪrfʊ	bjudəfəl	bjurəfʊl
coughing	gɔfɪŋ	kɔfiŋ	tɔfɪŋ	kɔfɪŋ	kɔfɪn	kɔfɪŋ	kɔfɪŋ	kɔfɪŋ	kɔfɪŋ	kɔfɪŋ
knife	naɪf	naɪf	naɪf	naɪf	naɪf	naɪf	naɪf	naɪf	naɪf	naɪf
leaf	liv	lif	lif	lif	wiv	wif	wif	wif	lif	lif
thorn	foən	fom	foʊn	fɔn	foʊn	fʷon	fθon	θoən	fɔrn	θorn
thumb	fʌm	fʌm	fʌm	fʌm	fʌm	fwum	fʌm	fʌm	fʌm	θʌm
bath-y	bæfdi	bæfi	bæfi	bæfi	bæfi	bæfi	bæfi	bæfɪ	bæfi	bæfi
mouth-y	maʊfi	maʊfi	maʊfi	maʊfi	maʊfi	maʊfi	maʊfi	maʊfɪ	maʊfi	maʊfi
tooth	tut	tuθs	tuf	tuf	tuf	tuf	tuf	tuf	tuf	tuf
wreath	wɪf	wifi	wif	wif	wif	wif	wiθ	wʲif	rif	rif
sew	θo	θo	θo	θo	θoʊ	θoʊ	θo	soʊ	θoʊ	θoʊ
sink	θiŋk	θiŋk	θɪŋk	θɪŋk	θɪŋk	θɪk	θɪŋk	sɪŋk	θɪŋk	θɪŋk
bus-y	bʌθdi	bʌθi	bʌθti	bʌθi	bʌθi	bʌθi	bʌθi	bʌθɪ	bʌθi	bʌθi
ice-y	aɪθdi	aɪθi	aɪθi	aɪθi	aɪʂi	aɪθi	aɪθi	aɪtsɪ	aɪθi	aɪθi
juice	duθ	dʒuθ	dʒuθ	dʒuθ	d̪uθ	d̪uθ	dʒuθ	dʒuθ	dʒuʂ	dʒus
vase	beɪθ	veɪθ	beɪθ	veɪθ	veɪθ	weɪθ	veɪθ	veɪθ	veɪθ	veɪθ

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