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Interacting error patterns and their resistance to treatment

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Abstract

Interacting error patterns involving chain shifts have been purported to be highly resistant to change with clinical treatment. In this paper we examine a common chain shift involving the substitutions of [f] for /f/, [f] for /θ/, but [θ] for /s/. Two boys who exhibited this error pattern were enrolled in a single-subject experiment that targeted production of /s/ in treatment. The hypothesis was that introduction of the last element of the chain would facilitate its interruption. Results of treatment showed that both children evidenced gains in production accuracy of certain fricatives, but that the chain shift pattern still remained post-treatment. These observations are discussed relative to issues of treatment efficacy, particularly the selection of treatment targets and the methods of intervention.

Keywords: phonological disorders, phonological treatment, chain shifts, substitution patterns.

Introduction

There is substantial archival evidence from normal and delayed phonological development to support the occurrence of interacting error patterns in acquisition (Leopold 1947, Applegate 1961, Pollack and Rees 1972, Smith 1973, Macken 1980, Stemberger 1992, Dinnsen 1993, 1998, Gerken 1994, Dinnsen, Barlow and Morrisette 1997, Dinnsen and Barlow, 1998). One such pattern involves a *chain shift*. This is a case where a given sound is produced target-appropriately, but also serves as the substitute for a second target sound. Further, this second target is used as the substitute for a third sound. Interacting substitutions thus emerge in a chained relationship which can be schematized as C1→C2→C3, where C denotes a consonant. One of the most common chain shift patterns reported in the literature involves children's production of [f] for target /f/, [f] for target /θ/, but [θ] for target /s/ (Smit 1993).

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Chain shifts have received attention largely because of their prevalence in phonological acquisition. It is estimated that 20% of children exhibit interacting substitutions of this type in normal development (Dinnsen and Barlow 1998). For the most part, reports of chain shifts have emphasized documentation of the pattern, with proposed explanatory accounts. For example, Ferguson and Garnica (1975), citing data from Hildegard (Leopold 1947), attributed chain shifts in acquisition to perception–production discrepancies associated with children's less sensitive self-monitoring abilities. Smith (1973), in the classic 'puzzle–puddle–pickle' case of his son, Amahl, appealed to a formal derivational account of the substitution pattern that involved extrinsically ordered phonological rules. Macken (1980) countered this by suggesting that, in chain shift cases, a child's underlying representations may not be adult-like in structure. Most recently, Dinnsen and Barlow (1998) presented a comprehensive review and evaluation of the full range of chain shift accounts that have been put forth in the developmental literature. Their review re-examined the relationship between perception and production, the role of adult-like versus non-adult-like underlying representations, and further, representations that were fully specified versus underspecified in featural composition. Moreover, the adequacy of each of these accounts was considered from both derivational and optimality theoretic perspectives. Importantly, regardless of the formal details of the various competing accounts, the ultimate conclusion that emerged from Dinnsen and Barlow's review was two-fold. First, children who exhibit chain shifts must maintain two, not three, distinct phonological categories. Second, these two categories must be underspecified and non-ambient for features that are contrastive in the adult phonology. To illustrate with specific reference to the common chain of f→θ→s, the categories available to a child are labial and coronal place of articulation in fricatives. Labial is the unmarked and underspecified place category given its broad use and stable substitutions, whereas coronal is marked and specified. This is just the opposite from fully developed systems, where coronal is claimed to be the underspecified (or default) place of articulation (Paradis and Prunet 1991; see Rice and Avery 1995, Bernhardt and Stoel-Gammon 1996, Yavas 1997 for further discussion and implications of child-specific default properties).

Curiously, and of most interest to the present study, is the fact that there have been *no* accounts that have attributed chain shift patterns in acquisition to articulatory motor factors. Unlike other error patterns, a child with a chain shift is able to precisely articulate a given target sound as evidenced by its use as a substitute. Yet, at the very same time, a child does not use this sound target-appropriately. In the f→θ→s chain, [θ] is used for /s/, but *not* [θ] for /θ/. Despite a child's apparent articulatory capabilities, chain shifts are reportedly highly resistant to change (Dinnsen and Barlow 1998). This presents an unusual paradox that is especially relevant for children experiencing phonological delays. On the one hand, children appear to have the requisite ability to interrupt a chain, but on the other hand, the chain withstands interruption. To illustrate, Dinnsen and Barlow (1998) reported the case of a child who was treated on minimal pairs involving the target distinction between /f/ and /θ/. After a full year of intervention, this child failed to change the chain shift pattern of f→θ→s. It should be noted that, in this case, the goals of intervention derived from a clinical experiment on the relationship between phonological knowledge and learning, and treatment was not directed at the chain shift error pattern *per se*. Moreover, treatment of the /f θ/ contrast may not have been

the most efficacious target since this child already had these segments in his productive repertoire. Consequently, the success of treatment and the ease or difficulty of overcoming a chain shift error pattern remains undetermined.

The purpose of this paper is to provide a first direct look at the effects of clinical treatment on chain shift error patterns in two children with phonological delays. Both children exhibited the f→θ→s chain, and both received treatment on the single target segment /s/. We hypothesized that by introducing only one, and the last element of the chained sequence, children would add the new and treated phonological category, thereby shifting their existing categories accordingly. The end result would be an interruption of the chain.

Participants and their phonological systems

Two male children participated, having been recruited through public announcement to area schools and day-care facilities. The children are referred to herein as Subjects 74 (CA 4;0) and 90 (CA 4;8), with identifiers assigned in accord with a more general research programme on the development of phonological categories. Both children had normal hearing (ASHA 1985), receptive and expressive language (Dunn and Dunn 1981, Hresko, Reid and Hammill 1981, Newcomer and Hammill 1988), non-verbal intelligence (Levine 1986), and oral motor structure and function (Robbins and Klee 1987). Performance on the *Goldman–Fristoe Test of Articulation* (Goldman and Fristoe 1986) placed these children below the second percentile relative to age- and gender-matched peers, having produced at least seven ambient singletons in error across contexts. The children resided in monolingual English-speaking homes and were preliterate, as determined from parent report.

These two children were specifically selected for study because they exhibited the particular chain shift phenomenon involving f→θ→s. The chain shift pattern was identified through extensive speech sampling that included spontaneous connected speech, as well as elicited probe measures. The probes sampled all target English consonants and onset and coda clusters in each relevant word position in a minimum of five different exemplars (Gierut 1985, 1998a, 1999).

Probe items were elicited through spontaneous picture naming, with the items being common familiar words to children. The speech samples were audiorecorded and phonetically transcribed using narrow notation of the IPA. Two trained listeners independently transcribed the audiotapes for purposes of establishing inter-judge consonant agreement. Transcription reliability was computed on 20% of each child's sample and was determined to be 96% mean agreement, with 650 consonants transcribed.

Transcriptions were then submitted to phonological analyses that included, as one component, establishing the children's phonetic and phonemic inventories. Following conventional procedures (Dinnsen, Chin, Elbert and Powell 1990, Gierut, Simmerman and Neumann 1994), the phonetic inventory was based on a two-time occurrence of phones regardless if correct relative to the adult system; whereas the phonemic inventory was based on the occurrence of two unique sets of minimal pairs, regardless if correct relative to the adult system. Subject 74's phonemic repertoire of fricatives included /f v θ ð/, and Subject 90's, /f v θ ð ʃ/. Notice that both children used /f θ/, but not /s/, phonemically. Despite the fact that /θ/ was phonemic, neither child used this segment target-appropriately; instead, [f] was the consistent

substitute for target /θ/ across contexts. The descriptive data in table 1 exemplify this chain shift pattern for each child.

Experimental treatment

A single-subject staggered multiple-baseline design was employed, with each child receiving a baseline period of no-treatment followed by treatment (McReynolds and Kearns 1983). The number of baselines increased by one with each child enrolled, such that Subject 74 received two baselines and Subject 90 three baselines over a period of 4 weeks. The baseline measures and elicitation procedures corresponded to those described above for the singleton and onset/coda cluster probes.

For both children, treatment targeted production of the segment /s/ in the initial position of eight picturable real-world stimuli. Children's baseline production of target /s/ was 0% accurate. World-initial position was selected as the treatment context for consistency with general procedures of the research programme on phonological categories. Also, this context is more marked for continuants (Dinnsen 1996) and perceptually most salient (Walley, Smith and Jusczyk 1986), factors that could potentially enhance learnability. Stimulus words were selected from *Picture Gallery* (Psychological Corporation 1995), and were presented as digital displays during treatment. Treatment consisted of two phases: imitative and spontaneous production. Imitation required a child to repeat the stimulus items following a clinician's model. This phase continued until a child achieved 75% accurate production of target /s/ in the treated words over two consecutive sessions, or until seven sessions were completed, whichever occurred first. Treatment then shifted to the spontaneous phase, whereby a child produced the stimulus items without a preceding verbal model. This phase continued until a child achieved 90% accuracy of /s/ over three consecutive sessions, or until 12 sessions were completed, whichever occurred first. During treatment, a child was given 1:1 feedback as to the accuracy of responding. Treatment was scheduled three times weekly for 1-hour sessions. Both children followed the performance-based criterion for advancement through the treatment phases, receiving approximately 7 weeks of intervention.

The dependent measure was generalization of accurate production of the sounds /f θ s/ across contexts. Generalization was sampled longitudinally at five points in time, using the three probe measures cited above. Probes were administered at baseline, phase shifts of treatment from imitation to spontaneous responding, immediately post-treatment, 2 weeks and 2 months post-treatment. Potential additive effects of repeated probe administrations were controlled in two ways. First, the entire probe measures consisting of 543 items were administered even though only three segments, /f θ s/, were of research interest. This provided a sufficient set of foils so as to obtain the most representative sample of a child's productions by not inadvertently drawing attention to particular sounds. Second, with each probe administration, a different set of randomized picture stimuli was presented, although the probe words remained constant throughout. This ensured that a child's responses would not become bound to the pictorial stimuli. At each sampling point in time, a child's probe responses were audiorecorded and phonetically transcribed, with percentages of accurate production of target /f θ s/ computed from these data.

Results and discussion

The results are considered from both qualitative and quantitative perspectives to best capture the phonological changes that took place following treatment for both children. Modifications in the substitution patterns of each child's chain shift are detailed in table 1, with a general summary in table 2. Figure 1 displays the generalization learning curves for each child, with the plots reflecting percentage of accuracy in production of /f θ s/ on untreated probe items over time. The data are evaluated relative to the primary question of the effects of treatment on chain shift patterns.

Prior to treatment, the children maintained a two-way place distinction among

Table 1. *Sample chain shift data for each child over time*

				Post-treatment		
Subject	Target	Gloss	Pre-treatment	Immediately	2 weeks	2 months
74	/f/	'face'	feɪθ	feɪs	feɪs	feɪs
		'fire'	faɪjʊ	faɪjʊ	faɪjʊ	faɪjʊ
		'laugh' (dim.)	wæf ~ wæfɪŋ	wæf ~ wæfi	wæf ~ wæfɪŋ	wæf ~ wæfɪŋ
		'leaf' (dim.)	lif ~ wifi	wif ~ wifi	wif ~ wifi	wif ~ wifi
		'cough'	kɔf	kɔf	kɔf	kɔf
	/θ/	'thunder'	fʌndʊ	fʌndʊ	fʌndʊ	fʌndʊ
		'thief'	fif	fif	θiθ	θiθ
		'thirsty'	fʊθi	fʊsti	fʊsi	sfʊsi
		'tooth' (dim.)	θif ~ θufi	suf ~ sufi	fus ~ sufi	sif ~ sufi
		'bath' (dim.)	bæf ~ bæfi	bæf ~ bæθi	bæθ ~ bæfi	bæf ~ bæfi
		'wreath'	wif	wif	wif	riθ
	/s/	'sun'	θʌn	sʌn	sʌn	sʌn
		'sock'	θɔk	sɔk	sɔks	sɔk
		'soap'	θoʊp	soʊp	soʊp	soʊp
		'juice' (dim.)	duθ ~ duθi	djus ~ ǰusi	dus ~ dusi	dus ~ dusi
		'ice' (dim.)	aɪθ ~ aɪθi	aɪsː ~ aɪsi	aɪs ~ aɪsi	aɪs ~ aɪsi
		'dress'	dwɛθ	drɛs	dwɛs	dwɛs
90	/f/	'face'	feɪs	feɪs	feɪθ	feɪs
		'fire'	faɪjʊr	faɪjʊr	faɪjʊr	faɪjʊr
		'laugh' (dim.)	wæf ~ wæfɪn	wæːf ~ wæfɪn	wæːf ~ wæfɪŋ	wæf ~ wæfin
		'leaf' (dim.)	wif ~ wifi	wif ~ wivi	wif ~ wivi	wif ~ wifi
		'cough'	kɔf	kɔf	kɔf	kɔf
	/θ/	'thunder'	fʌndʊr	fʌndʊr	fwʌnʊr	fʌnʊr
		'thief'	fif	θif	fif	čif
		'thirsty'	fʊrsi	fʊrši	fʊrsi	θʊrši
		'wreath' (dim.)	wif ~ wifi	wif ~ wifi	wif ~ wifi	wif ~ wifi
		'bath' (dim.)	bæ ~ bæːi	bæθ ~ bæwi	bæθ ~ bæθi	bæθ ~ bæθi
		'mouth'	maʊf	maʊ θ	maʊ θ	maʊ θ
	/s/	'sun'	θʌn	θʌn	θʌn	θʌn
		'sock'	θɔk	θɔk	θɔk	θɔk
		'soap'	θoʊp	θoʊp	θoʊp	θoʊp
		'juice' (dim.)	ǰuθ ~ ǰuθi	ǰuθ ~ ǰuθi	ǰuθ ~ ǰuθi	ǰuθ ~ ǰuθi
		'ice' (dim.)	aɪθ ~ aɪθi	ʔaɪθː ~ ʔaɪθi	aɪs ~ aɪθi	aɪs ~ aɪsi
		'mouse'	maʊːθ	maʊ θ	maʊ θ	maʊs

Table 2. *Changes in the chain shift pattern for each child*

Subject	Probe sample	Chain shift pattern	Place distinction	Phonemic contrast	Phonetic accuracy
74	Pre-treatment	/f/→[f] /θ/→[f] /s/→[θ]	labial–coronal	/f/–/θ/	[f]
	2 months post-treatment	/f/→[f] /θ/→[f] /s/→[s]	labial–coronal	/f/–/s/	[f s]
90	Pre-treatment	/f/→[f] /θ/→[f] /s/→[θ]	labial–coronal	/f/–/θ/	[f]
	2 months post-treatment	/f/→[f] /θ/→[θ] /s/→[θ]	labial–coronal	/f/–/θ/	[f θ]

fricatives, namely, labial versus coronal.[1] This is evident from the forms in table 1 showing the collapse of the target contrast between /f θ/, having been merged in production as labial [f]. Target /s/ remained distinct, surfacing as the coronal (albeit *non*-ambient) [θ]. Quantitative learning data further support this because the children exhibited near 100% accuracy of target /f/ in comparison to near 0% accuracy of /θ s/ on baseline samples.

Following treatment, these children maintained exactly the same two-way place distinction among fricatives. As in tables 1 and 2, Subject 74 contrasted labial /f/ with coronal /s/; whereas Subject 90 contrasted labial /f/ with coronal /θ/. Treatment did not alter either the number or the nature of phonological categories that the children used distinctively. On descriptive phonological grounds it appeared that these children did not evidence any positive gains pre- to post-treatment. Quantitative changes did occur, however, because the children's two-way place distinction was more in line with the ambient phonological system following treatment. The learning curve in figure 1 illustrates that Subject 74 produced /s/ with 94% accuracy at the final probe sample. Similarly, Subject 90 exhibited target-appropriate productions of /θ/, achieving 73% accuracy at the final sampling point. Thus, both children experienced gains in production accuracy pre- to post-treatment relative to the ambient system, but they did not alter their pre-existing knowledge of the phonological categories involved in the chain shift.

Despite these consistencies across subjects, there were seeming individual differences in learning. In particular, Subject 74 evidenced post-treatment improvements in production of treated /s/ in comparison to Subject 90's gains in untreated /θ/. These differences emerged even though both children received identical treatment of target /s/. At first glance the findings may give an impression that the treatment

[1] Subject 74 maintained a labial–coronal place distinction in differentiation of /f θ ʃ/, the three voiceless fricatives that were present in the child's phonemic repertoire. To further distinguish among the coronals /θ ʃ/ required the feature anterior, with /θ/ being anterior and /ʃ/, non-anterior. The additional non-anterior coronal segment did not appear to factor into the chain shift pattern or learning during treatment.

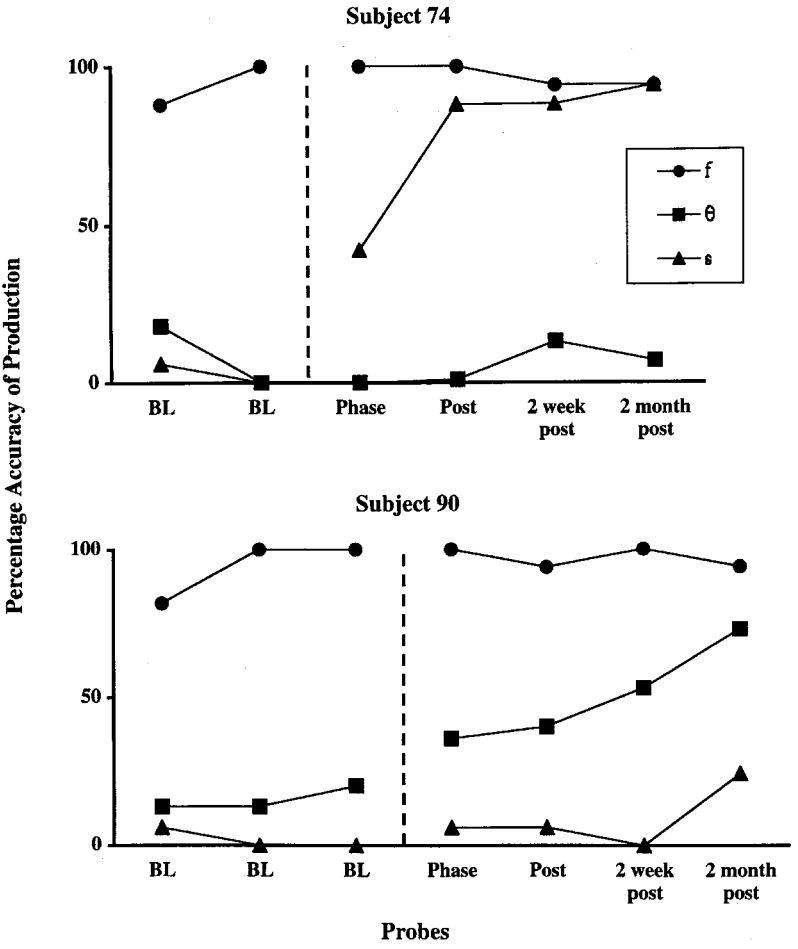

Figure 1. *Generalization learning curves for Subjects 74 and 90 as sampled on probes at baseline, phase shift between imitation and spontaneous production, post-treatment, 2 weeks and 2 months post-treatment.*

programme was 'successful' for Subject 74, but not for Subject 90. Subject 74 acquired the sound that was treated, whereas Subject 90 did not. However, upon closer inspection of tables 1 and 2 this premise does not hold. Notice that Subject 74 simply made a superficial switch in his phonetic implementation of coronal fricatives (for a similar case, see Gierut 1998b). Prior to treatment, /θ/ was in the child's phonemic repertoire; whereas following treatment, /θ/ was dropped from the system in lieu of phonemic /s/. While there was always a coronal fricative in this child's inventory, it happened to be /θ/ before treatment, and /s/ after treatment. Additional support for this swap in the implementation of coronals comes from Subject 74's over-generalizations. Prior to treatment, [θ] was the substitute for the palatal fricative /ʃ/ and affricate /ʧ/. With the exchange of /s/ for /θ/ post-treatment, the over-generalizations changed accordingly, such that [s] was now the consistent substitute for /ʃ/ and /ʧ/. This underscores our view that the underlying phonologies of these children were not enhanced by the treatment programme despite observed quantitative changes. A question that remains for future study and replication is why children

who are exposed to the same treatment programme may learn superficially different sounds following treatment directed at chain shift patterns.

From an applied perspective, the most critical finding was that treatment did not break the chain shift pattern for either child. The introduction of the last element of the chain in treatment of /s/ had no impact on the number or the nature of distinctive place categories, as we had originally hypothesized. Additionally, there were still residuals of the chain following treatment (table 2). For Subject 74, although /f/ and /s/ were distinct and ambient-like post-treatment, there was a remaining collapse of /f/ with /θ/. This is perplexing because the child demonstrated use of all three sounds of the interacting error pattern at one point in time or another, but he was still unable to alter the chained relationship between f→θ→s. The same was true in part for Subject 90, who maintained a residual merger of /s/ with /θ/ post-treatment. In this case, although /s/ was not learned immediately following treatment, /s/ did begin to emerge with 24% accuracy at the final sampling point 2 months post-treatment. (It must be acknowledged that these improvements cannot be causally attributed to the treatment programme given the general nature of A–B experimental designs like the staggered multiple-baseline (see McReynolds and Kearns 1983, for discussion).) This notwithstanding, both children still evidenced a partial chain shift at 2 months post-treatment, suggesting the resilience of this error pattern.

The potential resistance of chain shifts to treatment raises clinical questions about the appropriateness of certain treatment targets and the suitability of different teaching methods. Regarding treatment targets, one implication that emerges from this study is that interruption of a chain shift may require direct, explicit treatment of each sound involved. For the f→θ→s chain shift, all three sounds may need to be taught, even though a child probably has productive use of two of the three targets in an interacting pattern. Additional support for this recommendation comes from another type of merger that has been observed in delayed phonological systems; namely the case of phonemic splits (Gierut 1986). Phonemic splits differ from chain shifts in that the merger is between allophones of a single phoneme, with the allophones being in complementary distribution and therefore non-contrastive. As in the chain shift pattern, a child evidencing complementary distribution has the requisite articulatory ability to produce sounds, but does not do so in relevant contrastive contexts. In a treatment study of phonemic splits, Gierut (1986) demonstrated that it was not sufficient to teach just one segment of an allophonic relationship. Instead, both segments had to be taught in their relevant, but gapped, contexts before true phonemic change in the phonological system was observed. To illustrate more specifically, [f] and [s] were in complementary distribution for A.J., the child of Gierut's study. [f] was used word-initially and [s] post-vocalically for target fricatives. Treatment began by contrasting /f/ with /s/ in post-vocalic positions, but this production practice did not completely resolve the allophonic relationship. Consequently, A.J. also required treatment of the /f s/ distinction in word-initial position. One interesting possibility is that phonological mergers of any type may constitute special and more resistant cases for treatment in general. Alternatively, there may be a special class of resistant mergers, namely those that specifically affect labial and coronal fricatives. In either case, such mergers may necessitate treatment of each and every sound and context that is implicated in the collapse of contrasts.

Regarding teaching methods, our results suggest that chain shift errors may also warrant something other than traditional treatment of single sounds. In the present

study this method of intervention did not have positive consequences for expansion of children's phonemic distinctions. A likelihood is that the contrasts themselves may need to be directly taught, as in a minimal-pair format (Ferrier and Davis 1973, Weiner 1981). Recall, however, Dinnsen and Barlow's (1998) observation that conventional minimal-pair treatment, involving the contrast of a target sound versus its substitute, did not lead to modifications in chain shift patterns for the child of their study. Perhaps alternative types of minimal pairings may be called for, with all segments of a chained relationship presented in comparison to each other. This would entail, for example, the treatment of minimal triplets in the f→θ→s chain shift. An appealing aspect of this approach is that it would also take into account the prior suggestion that every sound of a merger be introduced in treatment. In subsequent treatment studies it will be necessary to evaluate the efficacy of these proposals in successfully modifying chain shift patterns.

A final consideration in the potential resistance of chain shifts to treatment relates to children's metalinguistic knowledge of phonological categories. Recent psycholinguistic studies have shown that a child's metalinguistic knowledge of distinctive feature categories may precede productive use of those same categories (Gierut 1996, 1998b). As applied to the present study, it may be that children with chain shifts have target-appropriate metalinguistic knowledge of place distinctions among fricatives, which thereby keeps these phonemic categories distinct. Any treatment of the chain shift would thus be directed at aspects of the phonology that children already 'know'. Given this, children may not see any need to modify their productions. Similar hypotheses about the interference of a child's pre-existing knowledge with alterations of chain shift error patterns have been advanced by Ferguson and Garnica (1975) and Gerken (1994) on perceptual grounds, and by Dinnsen and Barlow (1998) on phonological grounds. Future research will want to explore these possibilities by bringing together converging evidence from perception, production, and metalinguistic tasks in the characterization and treatment of chain shifts (cf. Edwards, Fourakis, Beckman and Fox 1999, McGregor and Schwartz 1992).

In conclusion, this study of chain shifts adds to the archival documentation of interacting error patterns in acquisition. It also provides an initial demonstration that chain shifts appear to resist change with clinical treatment, although a child's productions may seem to improve relative to the ambient phonology. The resilience of chain shift patterns, especially for children with phonological delays, remains a challenge for treatment efficacy research and potentially serves to motivate the development of alternative treatment options.

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