ENHANCEMENT OF LEARNING FOR CHILDREN WITH PHONOLOGICAL DISORDERS

Judith A. Gierut

Dept. of Speech and Hearing Sciences, Indiana University, Bloomington, IN, USA
gierut@indiana.edu

ABSTRACT
Children with functional phonological disorders warrant clinical treatment to accelerate their acquisition of the sound system. In this paper, I focus on the linguistic factors that converge to enhance phonological learning in treatment, with specific reference to segmental, featural and syllabic levels of structure. The primary finding to emerge is that treatment of more complex linguistic structures yields the greatest phonological gains for these children. Converging evidence from other populations further supports the relevance of linguistic complexity to learning.

CHILDREN WITH PHONOLOGICAL DISORDERS
Children with functional phonological disorders present a particular clinical and theoretical challenge. These children have highly unintelligible speech characterized by a reduced segmental inventory (Gierut, 1998 for review). They constitute approximately 10% of the preschool population (NIDCD, 1994), and are typically identified between 2 and 4 years of age. In terms of their sound system, children with phonological disorders produce, on average, 8 of the 24 consonants of target English. Their inventories might include nasals, stops and glides, but not at all places of articulation, and perhaps one fricative (Dinnsen et al., 1990). Some children also have reduced or errored vowel repertoires (Pollock & Keiser, 1990). Most notably, however, these restrictions on the sound system come in the absence of any other overt deficits. Children's prenatal and developmental histories are unremarkable; they have normal hearing and intelligence; other properties of the linguistic system are intact; and they do not generally appear to have perceptual, processing, or oral-motor limitations.

Despite their unintelligibility, if we were to use conventional descriptive linguistic techniques in examining the occurrence, distribution and contrastiveness of sounds, we would find that children with disorders have a highly systematic phonology, complete with phonetic and phonemic inventories, phonotactic constraints, and contextually governed sound changes (Dinnsen, 1984). In fact, disordered phonological systems bear striking resemblance to the sound systems of fully developed languages of the world. The critical question then is how did these children get this way? How could English as the input language lead to a grammar so very different from English? What's the cause? Although much effort has been devoted to such questions, there is no known cause of phonological disorders in children (Shriberg et al., 1986). Some have identified co-occurring, but not causal deficits (e.g., Throneburg et al., 1994). Preliminary and emerging evidence points to possible genetic bases for limited subsets of children (Shriberg, 1993). Still others have pinpointed risk factors that increase 7.7-fold the probability for developing the disorder as based on male gender, an affected sibling, and low maternal education (Campbell et al., 2003). Aside from these observations, little is else known about the underlying cause of phonological disorders.

An important point that is known, however, is that there is a critical period for speech sound normalization (Shriberg et al., 1994). The optimal window of time in which to bring a child's sound system into conformity with the target language is between the ages of 4 and 6. Moreover, beyond age 8.5, there are plateaus in learning, which limit the amount and degree of change in production. These, in turn, can further impact children's ability to read, write, and perform academically (Felsenfeld et al., 1992). Consequently, while there is no known cause, there is an urgent and early need for clinical treatment of phonological disorders. It is this arena that has benefited most from research guided by linguistic theory. Specifically, linguistic properties of sound systems can be used to enhance phonological learning in treatment. This observation draws interesting parallels with Ken Stevens' research on the universal correlates of distinctive features, which converge to augment the perceptual salience of phonological contrasts in languages of the world (e.g., Stevens & Keyser, 1989; Stevens, 2003). In this paper, we follow in the footsteps of Stevens' general approach in validation of the constructs of linguistic theory, but through the learning patterns of children with phonological disorders. Perhaps counter-intuitively, it will be demonstrated that complexity of the input triggers phonological learning in clinical treatment (Gierut, 2001, 2003 for review). That is, the more difficult the target of treatment, the greater the phonological gains.

Before turning to the data, a few words are in order about the course of clinical treatment. For insight to children's patterns of learning, a novel and perhaps unconventional approach to the experimental process has been adopted, such that clinical treatment serves as the independent variable (McReynolds & Kearns, 1983). Treatment is administered within the context of complex single-subject longitudinal designs, with power achieved through direct and systematic replications within and across children. Treatment consists of imitative then spontaneous phases of production practice that continue to predetermined time- and performance-based criteria. As implemented in our research, a child is taught to produce the treated sound (or sounds) in the initial position of phonotactically permissible nonwords; these are assigned meaning by being embedded in children's stories. During and following treatment, generalization to treated and untreated sounds is monitored as the dependent variable. Generalization is probed on a variable ratio schedule across phonetic contexts and lexical items. The ultimate goal is to induce change in the structure, function and accuracy of the child's errored pretreatment phonology. Based on the resulting patterns of generalization, the linguistic conditions that trigger system-wide gains in phonology following a minimum of intervention can then identified. Treatment can thus be viewed as an experimentally induced and accelerated version of sound change in progress.

SEGMENTAL COMPLEXITY

As noted, children with phonological disorders present with systematic, rule-governed grammars. An obvious question then is which aspect of the grammar should be treated to yield the greatest gains? On the one hand, treatment might begin with sounds that a child produces accurately, but only in certain well-defined contexts. Linguistically, this translates to sounds affected by phonological rules, either allophonic or neutralizing. On the other hand, another possibility is for treatment to begin with sounds that a child never produces or uses in any context. Linguistically, these targets would be phonotactic exclusions from the grammar. Of the two possibilities, it might be thought that sounds affected by rules are better targets, being easier to learn given that they are already being used in specific contexts. In tests of this hypothesis (Gierut et al., 1987), children were assigned to one of two groups. One group began

treatment with a focus on the elimination of nontarget phonological rules, whereas the other group received treatment aimed at the elimination of phonotactic constraints. For both groups, whether treated or not, change in rules and in phonotactics were monitored and reflected in the percentage accuracy of sounds. Representative learning curves from two children, one from each condition, are shown in Figure 1. In the left panel, it can be seen that when rules were the target of treatment, there were improvements in this property of the phonology, but other phonotactic constraints on the system remained unchanged. This contrasts with the effects of treating phonotactic constraints, as in the right panel. Treatment of phonotactics promoted gains in this aspect of the sound system, but also induced concomitant changes in the use of phonological rules. Thus, sounds excluded from children's inventories as the apparently more difficult target promoted greater gains across the phonological system, yielding the more efficacious teaching condition.
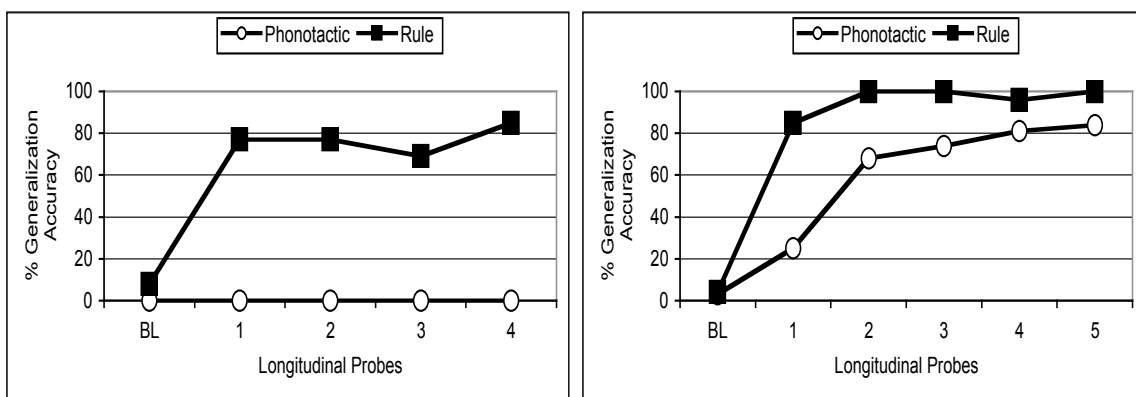

Figure 1. Generalization learning patterns following treatment aimed at the elimination of nontarget rules (left panel) versus phonotactic constraints (right panel) (Adapted from Gierut et al., 1987)

If sounds excluded from the inventory are optimal treatment targets, then a question that follows is whether certain types of sounds are better than others. In this regard, it might be expected that early, as opposed to later acquired sounds would be learned more readily because these are in keeping with observed stages of development. Earlier acquired sounds are first learned and by implication, easier and prerequisite for later acquired sounds. This proposal was put to experimental test, with just the reverse effects on phonological learning in treatment (Gierut et al., 1996). Later acquired sounds triggered greater learning, with generalization extending to treated sounds and untreated sounds from the same and different manner classes. Thus, treated, within, and across class generalization were observed. A further observation was that change was instated immediately in treatment of later acquired sounds. Thus, presumably more difficult later acquired sounds led to swift system-wide phonological gains.

FEATURAL COMPLEXITY

A common clinical teaching procedure invokes the use of minimal pairs. In the conventional use, a child's substitute is paired with the intended target in a minimally contrastive relationship (Weiner, 1981). For example, a child might substitute [t] for target /s/, with these differing only in continuancy. This way of setting up minimal pairs is consistent with Trubetzkoy's (1958/1969) notion of a proportional contrast, where a minimal feature distinction is repeatedly instantiated in

the phonology. As applied to clinical treatment, the assumption is that proportional contrasts will propagate throughout the sound system, such that a child learning the /t/–/s/ contrast is expected to generalize to other stop–fricative pairs. But what is the role of maximal (or isolated) contrasts? These are cases where a particular complex of features is not repeated in other phonemic pairs of the language, with maximal differences in place, voice and manner. For example, the complex of features that differentiates /m/ from /tʃ/ is unique to just that pair. Trubetzkoy claims that isolated contrasts are opaque and most difficult to analyze, but from a functional perspective, such contrasts might be more informative. Maximal contrasts may facilitate a child's discovery of the range of features that are relevant and how these are systematically implemented in the grammar. This alternative is in keeping with cognitive linguistic models of phonological acquisition (Macken & Ferguson, 1983).

A series of studies was designed to test these proposals in identifying the optimal structure of minimal pairs in clinical treatment (Gierut, 1989, 1990, 1991, 1992; Gierut & Neumann, 1992). An alternating treatments experimental design was used such that a given child was exposed to two different conditions that rapidly and randomly varied across treatment sessions. The premise of this design is the learner will differentiate between the two conditions, and respond with improved performance to the condition that is 'favored' (McReynolds & Kearns, 1983). In this particular manipulation (Gierut, 1990), children were treated on sounds excluded from the inventory in contrast to another sound. In one of the teaching conditions, the pairing sound was the substitute, differing from the target by only a single feature (i.e., proportional or minimal contrast). In the other condition, it was a known (nonerrored) sound of the child's repertoire that differed from the target in features of place, voice and manner (i.e., isolated or maximal contrast). Representative generalization learning patterns of a child taught /s/ versus /t/ in the proportional condition and /tʃ/ versus /m/ in the isolated condition are shown in Figure 2 (left panel). Within and across children, greater generalization was observed for maximal relative to minimal contrasts. This implied that maximal feature contrasts enhance phonological learning to a greater degree than minimal contrasts, even though the former are reportedly more difficult. An important consequence was that the optimal teaching condition that emerged was just the reverse of conventional clinical practice, thereby precipitating procedural modifications in treatment delivery.

A further assumption associated with the use of minimal pairs in treatment is that homonymy in a child's system will motivate phonological change. The premise is that a child will recognize that production mergers have negative consequences on communication. For example, if a child produced the minimal pair 'tip' and 'sip' as one and the same output [tɪp], listeners would be confused about the intended meaning. Presumably, the child would then aim to clarify the intent by altering his or her productions to disambiguate meaning. While plausible, it is the case that homonymy is perfectly legal in languages generally. Moreover, Labov (1987) has shown that homonymy plays little role in promoting sound change in progress. Given this, what function does homonymy play in phonological learning? To address this question, an alternating treatments design was again used, with a given child receiving treatment on two sets of minimal pairs (Gierut, 1991; Gierut & Neumann, 1992). One pair resulted in homonymy, being comprised of the child's substitute contrasted with its corresponding target. The other pair was not homonymous, being simply two sounds excluded from the child's inventory paired with each other. In the latter case, both sounds were in error, but one was not a substitute for the other. Of the two conditions, the nonhomonymous pairing may be viewed as more difficult because a

child would have to acquire two new sounds instead of one, or twice the learning. Representative results from one child are shown in Figure 2 (right panel). As can be seen, there was greater generalization associated with the nonhomonymous pairing of /s/–/ʃ/ than with the homonymous pairing of /ð/ and its substitute /d/. Across children, comparable differential effects supported that greater phonological learning followed from treatment of two new sounds excluded from the inventory, as the apparently more challenging condition.
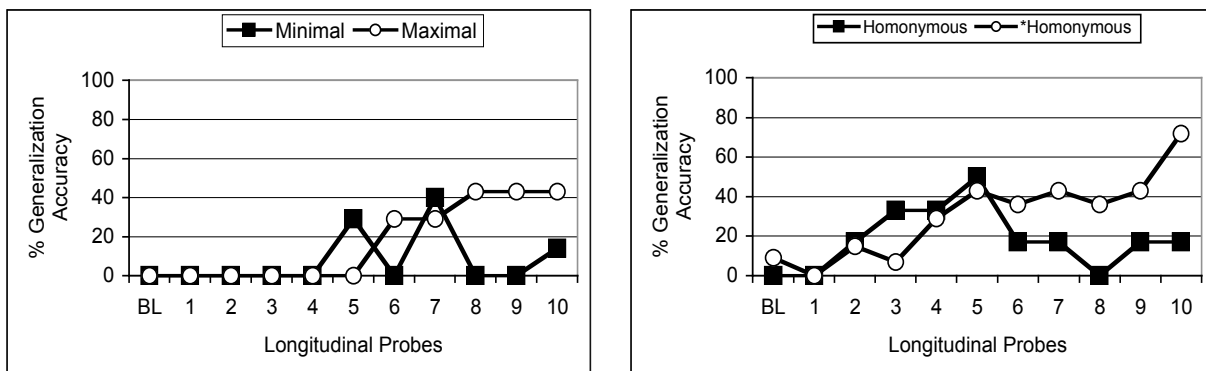

Figure 2. Generalization learning patterns following minimal pair treatment. The effects of teaching minimal versus maximal feature distinctions are shown on the left, and homonymous versus nonhomonymous sound pairs on the right. (Adapted from Gierut, 1990, 1991)

Another unanticipated effect on learning was observed across this series of minimal pair studies. Namely, when minimal pairs involved a major class distinction, as in contrasts of an obstruent and a sonorant, children evidenced greater generalization than when nonmajor class distinctions were involved (Gierut, 1992). Taken together, the collective set of studies on distinctive features yielded a continuum of treatment efficacy. The primary enhancement condition was treatment of two new sounds that differed in major class and maximal features. This was followed by two new sounds that differed in nonmajor and maximal features. Interestingly, the latter condition was equally effective as treatment of one new sound that differed from its comparison by major and maximal features for an apparent trade-off between number of sounds and type of distinction. Finally, the least effective contrast involved one new sound that differed from its comparison by nonmajor and maximal distinctions.

SYLLABIC COMPLEXITY
It is a well-documented fact that children, albeit typical or disordered, have difficulty acquiring onset clusters (Smit, 1993). In general, developmental studies have tended to view clusters as an undifferentiated category, distinct from singletons. Yet, from a linguistic perspective, within the category of clusters, there are varying degrees of cluster difficulty as associated with sonority. Sonority is a relative measure that is directly correlated with intensity and inversely correlated with intraoral air pressure (Parker, 2002). Sounds that are highly sonorous are produced with greater intensity and lower intraoral air pressure. Conversely, sounds that are low in sonority are produced with less intensity and greater intraoral air pressure. On a continuum, the least sonorous classes are stops and affricates, followed by fricatives, nasals, liquids, and glides, with vowels being most sonorous. The closer two classes are to each other on this

continuum, the smaller their sonority difference. With respect to clusters, a smaller sonority difference between consecutive segments in the sequence reflects increased complexity on cross-linguistic grounds. For example, in English, the cluster /fl-/ is more complex than /tw-/ because the sonority distance between a fricative and a liquid is smaller than the distance between a stop and a glide, following from the aforementioned continuum. Moreover, if a language allows clusters of a small sonority difference, it will also permit clusters of all greater differences. This has obvious implications for treatment of children with phonological disorders because it suggests that some clusters might be better targets than others in promoting broad generalization. By this, treatment of marked clusters involving small sonority differences will predictably induce greater generalization, even though they are structurally more complex.
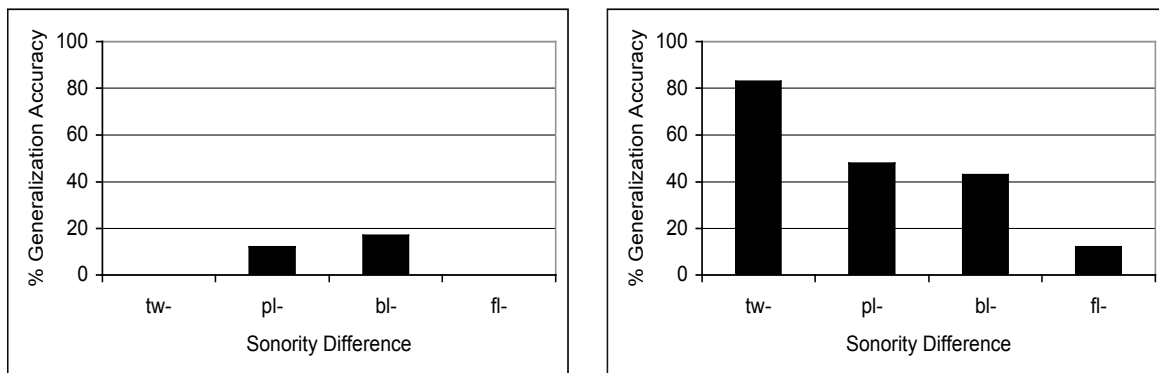

Figure 3. Generalization learning patterns following treatment of unmarked (left panel) versus marked (right panel) clusters. (Adapted from Gierut, 1999)

To test this hypothesis, children who did not produce any target English clusters were enrolled in a set of experimental studies (Gierut, 1999; Gierut & Champion, 2001). One subgroup was taught simpler (unmarked) clusters like /tw-/ and /kw-/, while another subgroup was taught complex (marked) clusters like /fr-/ or /fl-/. (s+stop sequences were considered in the published manuscript, but are set aside herein given their indeterminate markedness status in English.) Representative learning data from two children are shown in Figure 3. Complexity of target English clusters is ranked along the x-axis from least to most marked. The labeling of clusters is meant to be schematic of the general class, e.g., /bl-/ references the collective set of voiced stop+liquid sequences /bl-/, /br-/, /dr-/, /gl-/, and /gr-/. Notice, in the left panel, that the child who was treated on the unmarked sequence /pr-/ evidenced low levels of generalization, learning only voiceless and voiced stop+liquid sequences. Generalization did not, however, pattern as predicted from sonority because the voiceless stop+glide sequences were not also learned even though they are a simpler type. In comparison, in the right panel, the child who was treated on /fl-/ as a marked cluster showed a more comprehensive pattern of learning. More complex clusters were learned, and so were all of the other less complex sequences even though these were untreated. Further, there was a gradient pattern of accuracy in learning from simple to complex cluster types. In all, the results showed that treatment of more marked clusters promoted greater phonological learning in treatment, demonstrating positive and predictable effects of complexity as based on sonority.

COMPLEXITY AS AN ENHANCEMENT PRINCIPLE

The consistent finding that has emerged from the study of children with phonological disorders is that linguistic complexity enhances phonological learning in clinical treatment. The differential effects of complexity have been illustrated herein for three levels of phonological structure, but the end result has been instantiated more broadly for a whole host of phonological properties (Gierut, 2001, 2003 for review). Interestingly, similar learning patterns have obtained for other populations evidencing phonological errors, including children with hearing impairments, cleft palate, cognitive deficits, and developmental apraxia of speech. More interesting still, is that complexity appears to extend beyond phonology to other domains of language, as demonstrated by adults with aphasia relearning syntax and those with apraxia relearning semantics. Thus, the proposal that has been advanced is that linguistic complexity is an enhancement principle at the core of language learning (Gierut, 2001). While this is consistent with formal arguments about language learnability, these supporting data from clinical populations provide necessary behavioral instantiations of the role of complexity. For the future, the full extent of complexity remains to be defined, along with potential ceiling or floor effects and additive or precedence relationships among levels of structure. Linguistic complexity has potential to benefit a wide range of disordered populations by promoting efficacious clinical practice that is based on theoretically grounded principles.

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