ABSTRACT: Purpose: The purpose of this study was to determine whether nonlinear phonology could be applied to assessment and treatment in a public school setting. It was hypothesized that the nonlinear phonology approach to target selection would result in more rapid improvement in specific treatment targets, more generalization to other structures or segments, and greater improvement in overall speech intelligibility than had occurred with previous treatment.

Method: Nonlinear phonology postulates a hierarchical organization of the sound system such that a word is composed of progressively smaller units, each with its own representational tier/level (i.e., words, syllables, segments, features). Targets chosen using this approach are typically derived from varying levels of the hierarchy (e.g., syllable structures and segments) to promote systemwide change. A nonlinear phonology approach to target selection was implemented with 1 child, age 6, who exhibited a moderate phonological disorder and had previously demonstrated slow progress in therapy. Treatment was administered using an ABAB single-subject experimental design.

Results: Single-word production improved for the treated segment (phoneme) and for nontreated phonemes. Overall conversational speech intelligibility also improved.

Conclusion: Target selection according to the principles of nonlinear phonology resulted in faster and more comprehensive changes in this child’s speech sound system than had been obtained in previous therapy. More research with more participants is needed, but this first application of nonlinear principles by researchers and clinicians not associated with the development of the method suggests that it can be used effectively in routine clinical settings.

KEY WORDS: nonlinear phonology, single-subject design, treatment efficacy, target selection, phonological disorders.
and with no expectation for generalization from one sound to another. This approach is helpful when evaluating and remediating an articulation disorder, but it has been shown to be less efficient than other approaches when it is applied to treating children with phonological disorders (Fey, 1992).

Pattern-based approaches, in contrast, identify systematic error patterns in a child’s speech (Fey, 1985). The clinician then chooses one phoneme, or a few phonemes, that represents the pattern exhibited by the child and works to change the error pattern rather than a single speech sound. To continue the same example, a child who does not produce /s/ and /ʃ/ correctly might be described under a pattern-based approach as exhibiting a systematic pattern of stopping or producing fricatives as stops. Therapy would start with targeting a small number of fricatives (e.g., /s/ and /ʃ/), and correct production would be expected to generalize to all fricatives. This therapy approach has been shown to be more efficient than traditional or sound-by-sound approaches (Fey, 1992). It also has the practical advantage that the clinician does not need to target all phonemes affected by the phonological process. By choosing one phoneme (or a few phonemes) that represents a class of sounds affected by a process, generalization to the other phonemes in that sound class is expected.

According to Bernhardt and Stoel-Gammon (1994), the phonological pattern approach has some weaknesses as a theoretical approach to children’s speech sound disorders because it only describes error patterns occurring in a child’s speech; additional analyses, such as phonemic and syllable inventories, need to be performed in order to provide a full description of a child’s phonological system. These additional analyses provide a more comprehensive picture of the child’s speech sound system because they identify a child’s phonotactic constraints, syllable structures, and stress patterns in addition to segmental (phoneme) and feature inventories. Furthermore, whereas there is some consensus among researchers regarding which phonological processes are exhibited by typically developing children, there is less of a consensus regarding the characterization of processes and which process to target during assessment and remediation. In other words, general phonological pattern-based approaches to assessment and remediation vary among researchers (Gierut, 1989; Hodson, 1992; Shriberg & Kwiatkowski, 1980).

The Nonlinear Phonology Approach

Nonlinear phonology differs from other pattern-based approaches in that it does not limit analysis to descriptive rules or processes to capture sound errors that are produced by children. Nonlinear phonological analysis not only describes phonological patterns but also explains these patterns. When using this approach in assessment, the focus is on what the child can do and what is missing from the child’s system that needs to be there (Bernhardt & Stemberger, 2000). The nonlinear phonology approach, as described by Bernhardt and colleagues, uses concepts from a variety of approaches, such as metrical phonology, feature geometry, and radical underspecification (for a review of these approaches, see Ball & Kent, 1997).

Unlike process-based or rule-based approaches, nonlinear theory does not consider words to be sequential arrangements of sounds in linear strings. Rather, a word is viewed as being composed of a number of smaller units, each with its own representational tier or level (Bernhardt, 1992b; Bernhardt & Gilbert, 1992; Bernhardt & Stoel-Gammon, 1994). This concept of hierarchical organization was originally proposed by Goldsmith (1979).

Figure 1 provides a visual representation of the hierarchical organization from the word level to the segmental level for the word monkey (Bernhardt & Stoel-Gammon, 1994). The highest level in the hierarchy is the word, which is composed of feer that reflect the stress patterns of the word. A root is defined as a unit that includes one strongly stressed syllable and zero, one, or two weakly stressed syllables (Velleman, 1998). To use the example above, the word monkey has one foot with one strong (mon-) and one weak (key) syllable, whereas the word banana also has one foot but with one strongly stressed (-na-) and two weakly stressed syllables (ba- and -na). Syllables are further subdivided into onsets (i.e., the consonant sounds that precede the vowel or nucleus of the syllable) and rimes (i.e., the nucleus of the syllable and any consonant

Figure 1. Hierarchical tree (word to segmental tier).

<table>
<thead>
<tr>
<th>Word tier</th>
<th>FOOT (CVC.CV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot tier</td>
<td></td>
</tr>
<tr>
<td>Syllable tier</td>
<td>(Strong) o</td>
</tr>
<tr>
<td>Onset-Rime tier</td>
<td>O  R  O  R</td>
</tr>
<tr>
<td>Skeletal tier</td>
<td>C  V  C  C  V</td>
</tr>
<tr>
<td>Segmental tier</td>
<td>Root node and other features</td>
</tr>
</tbody>
</table>

monkey /m /ŋ /k /i/

KEY: F = Foot. This is composed of a strong and weak syllable.
O = Syllable
R = Onset. This includes all prevocalic consonants (C) in a syllable.
O = Rhyme/Rime. This includes the vowel (V) and postvocalic consonants in a syllable.

sounds that come after it). For the syllable *mon* in monkey, /m/ would be the onset and /o/ would be the rime; for *key/, /k/ would be the onset and /i/ the rime. The skeletal or consonant-vowel (CV) tier relates the syllabic to the segmental/featural tier. In the skeletal tier, the CV structure of the syllable is specified without referencing the segmental identities or features of the consonants and vowels. For the syllable *mon* in monkey, the CV tier would be C-V-C and for *ki*, the CV tier would be C-V.

The segmental/featural tier includes segments (i.e., phonemes) and features (i.e., manner, laryngeal, and place) that comprise these segments. In turn, features are considered to have a hierarchical organization, with manner (or root node) features viewed as “higher” than laryngeal and place features/nodes (see Figure 2). The features of the phonemes of American English, according to nonlinear phonology, are provided in Bernhardt and Stoel-Gammon (1994). For example, the phoneme /m/ in *monkey* has root node features of [+consonantal, +nasal] and a place node feature of [+Labial]. The laryngeal node is unspecified (see explanation below) because all nasals are voiced and [+voice] feature of [+Labial]. (Archangeli & Pulleybank, 1994; Chomsky & Halle, 1968). Other features of the sound system are marked, or specified, and have to be learned as part of learning a specific language. For example, the universal default syllable structure is assumed to be an open syllable (e.g., *da, ba*). Because English uses both open and closed syllables, a child who is learning English learns to produce marked closed syllables (i.e., syllables that end with a consonant). The goal of therapy using a nonlinear approach is to establish specified features of the adult sound system that are marginal or absent in the system of a child with a phonological disorder. It should be noted that unmarked features, according to the nonlinear phonology approach, can vary somewhat among languages and even across individual children depending on the frequency of use of those features in the language and the child’s sound system. For example, a child who substitutes fricatives for both stops and fricatives may have a default of [+continuant] rather than the universal default of [–continuant]. In this case, considerable reorganization of the child’s sound system would be needed in order to match the adult’s phonological system.

Targets for intervention using a nonlinear phonology approach are typically chosen from maximally different levels of the hierarchy, such as segmental and syllabic targets (e.g., Bernhardt & Stoel-Gammon, 1994; Bernhardt, Stemberger, & Major, 2006). For example, assessment may reveal that a child has difficulty producing unstressed syllables and is unable to produce certain consonant clusters. Targets selected for treatment would include improving the production of unstressed syllables (i.e., syllable tier) in multisyllabic words and improving the production of consonant clusters (i.e., segment tier) with different place, manner, and voice. It is assumed that targeting structures at different levels of the hierarchy will result in greater systemwide change than will targeting structures at one level alone. In addition, development, according to a nonlinear phonology approach, is assumed to be top down rather than bottom up (a principle that also applies in other approaches to phonological disorders; e.g., Gierut, 2001). Therefore, structures at higher levels of the hierarchy are targeted before lower level structures (e.g., prosodic tier before segmental tier). Typically, new features are targeted using already established syllable shapes and vice versa; these principles are similar to those advocated by Slobin (1973) for language structures. According to Bernhardt and Stemberger (2000), this approach is most beneficial for children who exhibit a moderate to severe phonological disorder.

In summary, nonlinear approaches appear to provide greater explanatory power about the complexities of...
children’s phonological systems than do traditional and pattern-based approaches, which tend to be more descriptive in nature. Nonlinear approaches to assessment and treatment are also believed to be more efficacious, more efficient, and more likely to result in generalization of treatment gains, as compared with conventional approaches to speech sound remediation, because they attempt to capture the underlying basis for children’s errors.

Research Studies Using the Nonlinear Approach

Despite the appeal of the theories, relatively few studies have tested nonlinear intervention approaches in the remediation of speech sound disorders, and all of them have come from one research group (Bernhardt, 1992a; Bernhardt & Major, 2005; Major & Bernhardt, 1998). Bernhardt (1992a) applied the nonlinear approach to the planning and treatment of 1 child (age 5;10 years;months– 6;3) who exhibited a moderate to severe phonological disorder. In this multiple baseline and alternating treatments single-subject design, treatment focused on improving the prosodic and segmental levels of the child’s speech sound system. It was hypothesized that trained targets would show the greatest improvement and that those phonological elements similar to the trained targets would show the most improvement through generalization. Results showed improvement with trained and untrained segmental and prosodic targets. For the trained targets, the overall proportional gain was greater for the prosodic tier. Results also indicated that targeting separate syllabic and segmental tier goals in an alternating format was a successful intervention strategy, and that faster rate of change was noted for the targets at the syllabic level as compared with the segmental level.

Major and Bernhardt (1998) later used the nonlinear approach to phonological intervention to explore the relationships between phonological and metathophonological skills in children with moderate to severe phonological disorders and to study short-term outcomes in metathophonological development after nonlinear phonological intervention and after the combination of nonlinear phonological plus metathophonological intervention. Participants were 19 preschool children with moderate to severe phonological disorders. Intervention included 48 therapy sessions (3 per week) over three treatment blocks, with assessment at the end of each treatment block. Blocks 1 and 2 consisted of nonlinear phonological intervention only. Block 3 included metathophonological training (i.e., rhyming, alliteration) along with nonlinear phonological intervention. Nine of the 19 children improved their metathophonological skills following nonlinear phonological intervention alone, but the remaining 10 children did not show increases in their metathophonological skills until after the final (nonlinear phonological plus metathophonological) intervention block. These results suggest that nonlinear phonological intervention was as effective as more conventional approaches for improving metathophonological skills for some children (Hesketh, Adams, Nightingale, & Hall, 2000).

Bernhardt and Major (2005) conducted a follow-up study 3 years later of 12 children (age 6;1–8;5) who had participated in Major and Bernhardt’s 1998 investigation. The objectives of the follow-up study were to document the children’s current speech, language, and literacy skills; to determine if any of the children continued to exhibit residual speech disorders; and to observe if any of them were having difficulty acquiring literacy skills. Five of the 12 children continued to exhibit phonological impairment; 2 of these 5 children also showed below-average reading ability (i.e., decoding and comprehension). Five of the 12 children (including 2 of the 5 with a phonological disorder) scored below average in spelling performance. When comparing the outcomes from both studies, the researchers concluded that the strongest predictor of literacy development was the children’s performance on metathophonological skills at the end of the earlier intervention study, and the strongest predictor for ongoing speech disorder was their phonological skills also at the end of the earlier study.

In summary, there is very limited empirical evidence available to support the theoretical arguments in favor of a nonlinear approach to the assessment and treatment of speech sound disorders. Bernhardt (1992a) reported successful results; however, later reports showed that metathophonological skills were improved for only half of a group of 19 children using a nonlinear approach (Major & Bernhardt, 1998), and that many of those children continued to have problems several years later (Bernhardt & Major, 2005). These reports serve primarily to demonstrate the need for further research in this area. In addition, much of the remaining literature on this topic is theoretical, discussion based, or based on hypothetical examples (e.g., Baker & Bernhardt, 2004; Bernhardt & Gilbert, 1992; Bernhardt & Holdgrafer, 2001a, 2001b; Bernhardt & Stoel-Gammon, 1994; Bernhardt et al., 2006), making the true efficacy and efficiency of this approach essentially unknown.

Purpose of the Present Study

Interventions that purport to promote faster or greater change, or greater generalization, in any client’s speech or language abilities are very appealing to clinicians for many reasons. When they are theoretically well grounded and represent well-supported extensions of current practice, as is the case for nonlinear phonology, they deserve careful study by multiple research groups. Given the theoretical and empirical information and questions reviewed above, the purpose of the present study was to determine if the nonlinear approach to phonological intervention could be applied in a public school setting with 1 child who exhibited a moderate to severe phonological disorder. It was hypothesized that the child’s speech sound system would show rapid improvement when a nonlinear phonology target-selection approach was used. More specifically, this research evaluated whether the nonlinear phonology approach to target selection using a single-subject experimental design would result in (a) improvement in the specific treatment targets, (b) generalization to other structures or segments that were not targeted in treatment, and (c) improvement in overall speech intelligibility.
METHOD

Participant

A monolingual English-speaking girl age 6;4, who exhibited a moderate phonological impairment, participated in this study. She had been diagnosed with a severe phonological disorder at age 4;2 by a public school preschool speech-language pathologist (SLP) and had received phonological intervention in the public school setting for approximately 2 years. For approximately the first 18 months of intervention, therapy focused on reducing or eliminating the phonological processes of stopping, cluster reduction, and voicing. According to available clinical records, the child produced all of her target sounds in single words but demonstrated no generalization to conversational speech.

When the child entered kindergarten at age 5;11, the primary researcher in this study (KOS) became her SLP. Therapy for 4 months before the current study focused on imitation of single words containing /l, s, l, p, k/ in all positions. The goals addressed during these 4 months were designed to reduce or eliminate the phonological processes of stopping and cluster reduction. By the end of the 4 months, at age 6;3, the child was able to reduce stopping and cluster reduction with approximately 70%–80% accuracy in single words, and her conversational speech intelligibility with a trained listener when the context was known ranged from 78%–82%, as documented by informal clinical records. However, she was still reported to be very difficult to understand by others (i.e., teachers, peers, family members). Therefore, she continued to be classified as exhibiting a moderate phonological disorder and demonstrating very limited carryover of treatment targets to spontaneous conversational speech.

Testing Procedures and Materials

Parent permission for the child to participate in this study was obtained. The child passed a hearing screening at age 5;10 (6 months before the beginning of this study). Her receptive and expressive language skills, evaluated at age 4;2, were within normal limits. There were no additional language concerns reported at the time of the study, and she was performing at kindergarten grade level. A 100-word conversational speech sample was used to evaluate her speech intelligibility. Her conversational speech intelligibility, defined as percentage of words understood by a listener, was 83% with a trained, familiar SLP (the primary researcher, Judge 1, or J1) and was 73% with a trained, unfamiliar SLP (Judge 2, or J2). Percentage of consonants correct (PCC) was calculated using the same 100-word conversational speech sample. PCC as calculated by J1 was 71.7% (mild-moderate severity rating); PCC as calculated by J2 was 64.5% (moderate-severe).

To assess the child’s phonological skills using nonlinear analysis, the Computerized Articulation and Phonology Evaluation System software (CAPES; Masterson & Bernhardt, 2001) was administered. As recommended by CAPES, the child’s speech sound productions were recorded on the computer using a headset with a microphone. Single-word responses were elicited through a computerized picture-naming task. CAPES automatically generated a transcription of the child’s single-word productions. To elicit a connected speech sample, the child watched a video stimulus on the CAPES program. After watching the video, her narrative about the video was recorded on the computer. Her connected speech sample was typed into the CAPES program in orthographic form by J1. Once this was completed, the CAPES program converted the orthographic text into adult target phonetic transcription. The child’s narrative was transcribed using a combination of the automatic transcription software provided by CAPES and the researcher’s typed transcription of words that could not be transcribed by the software.

The CAPES program provides multiple reports and analyses. For this study, a phonemic profile summary and a comparison between the client’s productions and target forms were generated. The phonemic profile summary was chosen because it includes the client’s complete results for speech sound production, including the number of both correct and incorrect responses. The comparison between the client’s productions and target forms includes a series of reports based on a relational analysis of the child’s productions; it also addresses word length, stress patterns, word shapes, consonant inventories (with traditional and nonlinear features), and vowel inventories (with traditional and nonlinear features). These reports compare the child’s productions to the target productions. The treatment suggestions report, also provided by the CAPES software, indicated that the participant in the present study had difficulty with CVCC and CVCCVC word shapes and with the individual segments /θ/, /ʃ/, /tʃ/, /dʒ/, /l/, /ɾ/.

Target Selection

In accordance with nonlinear principles, treatment targets were selected to represent multiple levels of the hierarchy, including the highest level at which the child’s errors could be noted. A CVCC word shape target was selected first because this was the highest level error that the child produced. Segments that she could already produce accurately were used while targeting the CVCC word shape, as per the recommendations of the nonlinear phonology approach.

Because the nonlinear phonology approach advocates targeting various levels of the hierarchy to promote systemwide change, a segmental target was also selected. Of the six possible segmental targets for treatment (/θ/, /ʃ/, /tʃ/, /dʒ/, /l/, /ɾ/), two were eliminated as possibilities because the child produced them relatively accurately (100% correct for /l/ in initial and medial positions; 50% correct for /ɾ/ in initial position). The segment /θ/ was produced with only 33% accuracy in the initial position, but its cognate /ð/ was produced with 100% accuracy in the initial position; nonlinear analyses did not support the selection of /θ/ as a treatment target because of the expectation of generalization from /ð/ to /θ/. Although /ɾ/ was difficult for the child, this segment was not targeted because of her age; normative data indicate that this sound can be acquired by
typically developing children until as late as 7 years of age (Bauman-Waengler, 2007).

Both of the remaining phonemes in error (/f/ and /d3/) were produced with 33% accuracy in the initial position and 0% accuracy in medial and final positions. The segment /d3/ was chosen as the segmental target instead of /f/ in accordance with nonlinear principles because it contained more specified features that were marginal or absent in the child’s system. The affricate /d3/ requires production of the branching feature of continuants (i.e., [+continuant] [–continuant]), the voicing feature [+voice], and the place feature, coronal [–anterior], whereas /f/ does not require either the branching feature of continuants or voicing.

**Research Design and Session Description**

This study used a single-subject ABAB experimental design (A = baseline, B = treatment; Barlow & Hersen, 1984; Kazdin, 1982). Four 30-min sessions occurred each week, all as a traditional pullout service within a public school setting because of the child’s established school-based therapy schedule and according to the requirements of her individualized education plan (IEP). Two sessions per week were in a small group setting with 2 other children, and two were individual sessions, again as specified in the child’s existing IEP. During the group sessions, time was equally divided among the goals of the 3 children. All sessions were audiotape recorded for later analysis.

Progress was measured during the study by monitoring the (a) percentage of word shapes (i.e., CVCC, CVCCVC) produced correctly in a 10-word single-word production task that was completed at the end of each session in which word shapes had been targeted, (b) percentage of segments produced correctly in a second 10-word single-word production task that was completed at the end of each session during the experimental portion of the study, and (c) percentage of words understood by a trained listener during a 100-word conversational speech sample with known context that was completed as the last activity in every session during the experimental portion of the study and during an extended treatment and maintenance phase after the experiment was completed. The single-word production task for word shapes used segments that the child could already produce (e.g., /p, t/). The single-word production task for segments assessed their production in all positions of words (i.e., initial, medial, final) and used word shapes that the child was already producing (e.g., CVC, CV).

**Initial A phase: Baseline.** No treatment was administered during the initial A phase or baseline sessions. Group sessions during the A phase focused on the objectives of the other 2 children in the group. Individual baseline sessions focused on reading and discussing books from the child’s kindergarten classroom. During this phase, data were gathered for the word shape (CVCC) and segmental (/d3/) targets using the 10-word production tasks, and intelligibility data were gathered from the 100-word conversational speech samples. The initial A phase continued until stable data trends were obtained for both treatment targets, with stability defined as no more than 10% variation for both targets. Once the targets were stable, the treatment phase began.

**Initial B phase: Treatment.** The B phase was intended to introduce treatment for the word shape and segmental targets. Because the child’s performance on the word shape targets was 100% correct in Sessions 2–4, however, treatment was introduced only for the segmental target /d3/ (see Results). The first 5 min of each individual treatment session included setup and discussion about what was to be worked on during therapy. For the next 20 min of each session, the child was provided with multiple opportunities to produce the specified target correctly. The last 5 min of each treatment session included administering a 10-word posttest that included the target segment and collecting a 100-word spontaneous conversational speech sample.

Because nonlinear phonology specifies a method and rationale for target selection, rather than specifying treatment techniques, the treatment techniques used during the B phase were selected to be consistent with those that were previously used with this child (i.e., this study was intended to test the effects of target selection, so treatment techniques needed to be held constant). Placement and manner cues, along with minimal pair treatment, were provided to elicit the targets in a manner that was consistent with the child’s previous exposure to a hybrid treatment approach (i.e., phonetic approach combined with a phonemic approach).

The first B phase was terminated when noticeable changes in the trend and level of performance had occurred. Stability was not sought to avoid the problems of overlearned behavior failing to show a return to baseline.

**Second A phase: Return to baseline.** The second A phase was used to determine whether changes that had appeared to occur when treatment was introduced were affected by the withdrawal of treatment. Procedures for the second A phase were the same as those described for the initial A phase.

**Second B phase: Reinroduction of treatment.** After stable data trends were obtained for the target segment /d3/ during the second A phase, treatment was reintroduced to seek a replication of its effects. The final B phase was terminated when noticeable changes had begun to stabilize.

**Continuing treatment.** The child continued in treatment, beyond the duration of this study itself, using targets and procedures that had been identified as necessary and effective for her in assessment and in the experimental portion of the study. Generalization and maintenance data were also collected during this time.

**Description of the Generalization Test**

A generalization test was administered after the experimental portion of this study in Sessions 19, 27, and 35 to monitor the child’s production of /d3/ and of the four other segments that had been found to be in error during the initial assessment (/θ, j, tf, l/). Each sound was assessed in the initial position (two words), medial position (two words), and final position (one word) using word shapes that the child was able to produce correctly (e.g., CVC, CVCCV). Words in the generalization test were not used in treatment.
Measurement and Reliability

Word shape data. Accuracy of the CVCC word shape was defined as requiring production of a CVCC pattern regardless of the segments produced. CVCC productions were judged correct or incorrect by J1. J2 transcribed and calculated percentage correct data from every third session. There was 100% agreement between J1 and J2 as to the correct or incorrect production of CVCC word shapes in single words.

Segmental data. J1 transcribed the child’s productions of /dZ/ words from all single-word tests. Percentage of correct production of /dZ/ in single words was calculated. J2 transcribed and calculated percentage correct data from every third session. There was 100% agreement between J1 and J2 as to the correct or incorrect production of /dZ/ in single words.

Intelligibility data. J1 transcribed all 100-word conversational speech samples; J2 transcribed every third conversational speech sample. Mean percentage agreement between the two judges for the overall number of words understood in the 100-word conversational sample was 97.28% (range 94.30%–99%). Word-by-word agreement averaged 87.8% (range 71.02%–99%).

An untrained and unfamiliar listener (Judge 3 or J3) also listened to 20% of the 100-word conversational speech samples and calculated a percentage intelligibility rating (i.e., percentage of 100 words understood). This listener was used in order to provide an estimate of how much a layperson, such as the child’s teacher, understood the child’s speech. Mean percentage agreement between J1 and J3 for the overall number of words understood in the 100-word conversational sample was 95.18% (range 90%–99%). Word-by-word agreement was 88.7% (range 72.01%–99%). Both J2 and J3 were unaware of which phase of research the child was in.

J1’s intrajudge reliability was calculated for 33% of the 100-word conversational speech samples. Time between transcriptions was approximately 20 weeks. Mean intrajudge agreement for total number of words understood was 98.15% (range 93.2%–100%). Word-by-word intrajudge agreement was 91.8% (range of 75.03%–99.01%).

RESULTS

The planned ABAB single-subject design experiment was completed in a total of 18 sessions held over the course of approximately 2 months. Nonexperimental treatment and data collection also continued for another 18 sessions, over the course of another approximately 2 months, as explained below. Results are described in terms of the syllabic-level targets (word shape), the segmental-level targets (phonemes), and overall intelligibility in conversational speech.

Syllabic-Level Targets

Despite the CAPES and other assessment data indicating difficulties with CVCC and CVCCVC word shapes, the CVCC word shape was produced with 100% accuracy in Sessions 2–4 (first A phase). The other word shape in error at assessment, CVCCVC, was also produced with 100% accuracy in Session 8. Therefore, no intervention for syllabic-level targets was provided.

Segmental-Level Targets

Recall that /dZ/ was chosen as a segmental target because it contained more features that were marginal or absent than the other error segments (Bernhardt & Stoel-Gammon, 1994). During the first B phase, the child’s production of /dZ/ in single words increased from 30% to 50% and stabilized at this level (Sessions 5–9, Figure 3). Performance returned to baseline levels when treatment was withdrawn (second A phase, Sessions 10–13, Figure 3), suggesting that treatment rather than maturation was responsible for the changes that were seen during the first B phase. This treatment effect was replicated and extended in the second B phase; production accuracy increased from approximately 30% in the second A phase sessions to 70% at the end of the second B phase (Session 18, Figure 3).

Given the rapid progress with /dZ/, consideration was given after Session 18 to treating another segmental-level target. Nonlinear principles suggested the possibility of treating /l/ and /0/ because they differ from each other and from the child’s other error segments (i.e., /f, t/f/) (Bernhardt & Stoel-Gammon, 1994). However, /l/ was produced with 100% accuracy in all word positions during the generalization test in Session 19 (see Figure 4). Baseline data for /0/ were collected in Sessions 20–23 (not shown), but it became evident that this sound too was produced with a high degree of accuracy (100% in the generalization test conducted at Session 27; Figure 4). The segment /f/ was then considered as the next treatment target and was measured beginning in Session 24 (see Figure 5). Stable data were never obtained for /f/; furthermore, the child’s percentage accuracy for /f/ was also high, fluctuating between 70% and 80%. Segmental productions in single-word tasks continued to improve or remained high, as shown by the data from the third (Session 27) and fourth (Session 35) administrations of the generalization test (Figure 4). Additional segmental targets were, therefore, not treated.

Intelligibility Data

The overall results of this experiment on the child’s intelligibility in conversational speech, over Sessions 1–36, are shown in Figure 6. Intelligibility was judged to be 96% in Session 1, but with this point as an exception, intelligibility remained between approximately 80% and 90% through the first three (ABA) phases. During the second B phase, intelligibility began to show a steady increase to 97%, and it remained high throughout the remainder of the study.

DISCUSSION

The general purpose of the present study was to determine whether a nonlinear approach to target selection could be
Figure 3. Percentage accuracy of the segment /dZ/ in single words during baseline (A phases) and treatment (B phases) sessions.

Figure 4. Percentage accuracy of the segments /θ/, /N/, /L/, and /s/ in single words at initial assessment, after treatment (Session 19), and at two maintenance points (Sessions 27 and 35).
Figure 5. Percentage accuracy of the segment /ʃ/ in single words during baseline sessions.

Figure 6. Intelligibility, measured as percentage of words understood from a 100-word conversational speech sample during baseline (A phases), treatment (B phases), and poststudy maintenance or continued therapy (Sessions 19–36) sessions, as determined by three judges.
applied in a public school setting by experimenters or clinicians who were not associated with the development of this approach. In this sense, the study was clearly a success. More specifically, it was hypothesized that the child’s speech sound system would show more rapid improvement when a nonlinear phonology target-selection approach was used. This hypothesis was also supported, as discussed in greater detail below, for syllabic structures, segmental structures, and overall intelligibility.

**Improvement in Syllabic Productions**

One proposal of nonlinear phonology is that faster changes occur at a higher tier (e.g., word shapes), and targeting a higher tier results in positive changes in lower tiers (e.g., segments; Bernhardt & Stoel-Gammon, 1994). This study tried to test that prediction by considering CVCC and CVCCVC as word shape targets for intervention based on assessment results. Baseline data obtained during the study, however, showed that the child was able to produce both word shapes with a high degree of accuracy. Therefore, the nonlinear hypothesis that rapid and positive changes occurring at a higher tier/level will cause positive changes in lower tiers/levels could not be directly assessed because word shapes were not problematic for the child at the start of the intervention.

This discrepancy between assessment data and the data obtained within the baseline sessions of this study raises several interesting issues. Because less than a month elapsed between assessment and the beginning of this study, spontaneous improvement or improvement due to extraneous influences specifically occurring during that month is not likely. One possible explanation is that the assessment data generated by the CAPES software might have been compromised by use of the computer, headphones, and microphone, which were all new to the child. Results from single-word testing on CAPES paralleled those obtained in previous assessments, however, in that the child had trouble producing clusters, fricatives, and liquids. This consistency suggests that the assessment results from the CAPES were probably valid and reliable. The most likely explanation for the difference between assessment data and baseline data, therefore, is probably generalized improvement or generalization from earlier treatment, perhaps influenced by the data collection tasks used for this study.

**Improvement in Segmental Productions**

With respect to segmental-level structures, the clearest result from this study is seen in Figure 3. The child’s single-word accuracy for /dz/ words improved when treatment was introduced, deteriorated when treatment was removed, and improved again when treatment was reinstated, ending at 70% correct. This pattern of results clearly suggests that treatment rather than time or some other extraneous factor was probably responsible for the improvement in the child’s production of /dz/ in single words.

The segment /dz/ was selected as a treatment target for several reasons, as explained above. In nonlinear phonology, the child with a speech sound disorder is viewed as needing to learn the marked or specified features of the target language. Once the specified features are learned, the default values and features will become available from redundancies in the phonological system (Bernhardt & Stoel-Gammon, 1994). This prediction was borne out in the present study because nontreated phonemes also improved during this study. Distinguishing between generalization, reorganization of the phonological system, carryover from previous treatment, and general maturation is, however, more difficult in the case of other segments than in the case of the clear ABAB pattern obtained for /dz/. When generalization tests were administered, other segments that had previously been in error were produced with a relatively high degree of accuracy. However, /b/ showed greater improvement than /tf/, which was surprising because /tf/ is so similar to the treated sound /dz/, whereas /b/ differs in manner and place from /dz/. One might therefore have expected greater improvement in /tf/ than in /b/ if the mechanism were generalization from /dz/. The improvement in /b/ was more likely due to generalization from the high accuracy in production of its voiced cognate /b/ before treatment. Similarly, the increase in production accuracy of /l/ might have also occurred because it was already being produced with a high degree of accuracy at the time of assessment.

It is also important to emphasize, of course, that this child had been in treatment for 2 years before the beginning of this study. Improvements might also be due to an increase in the time spent on her treatment targets, as compared to previous semesters. With respect to both possible explanations, however, it again should be noted that the ABAB pattern of improvement and deterioration with the introduction and withdrawal of treatment suggested quite clearly that the treatment was the functional element in the child’s production of the segmental target /dz/. Differentiating between clinically desirable generalization from treatment gains and experimentally undesirable lack of experimental control over nontreated behaviors is difficult (Ingham, 1990). Nevertheless, the generalized improvements shown by this child in many related and unrelated speech sounds are consistent with a generalized restructuring of her phonological system that might have been predicted, within nonlinear phonology, as a possible outcome of effective treatment for the complex speech sound /dz/.

**Improvement in Intelligibility**

Intelligibility, measured as the percentage of words that are understood by trained and untrained, familiar and unfamiliar, listeners in a 100-word sample, improved most noticeably during the second B phase of this study (Sessions 14–18, Figure 6) and remained high. This result is consistent with the possibility that the improvements shown during treatment generalized to improved overall intelligibility. Anecdotal evidence from the child’s family and teachers also indicated that they did not have as much difficulty understanding her at the end of the study as they did before the study. Indeed, after this study, the child’s speech therapy time in the public school was decreased from 2 hr per week to 1 hr per week due to her increased intelligibility.
CONCLUSION

In summary, the results of this study suggest that nonlinear phonology approaches to target selection can be realistically and effectively incorporated into routine assessment and treatment by public school clinicians. The participant in this study improved her single-word production for the chosen sound target, showed improved production of nontreated structures at the segmental level of the nonlinear hierarchy, and showed improved conversational speech intelligibility both in formal data collection and by anecdotal report from persons beyond the treatment setting. These results were obtained in a timely manner (i.e., 18 sessions over 2 months); a short time frame that admittedly might have been influenced by the child’s previous years in treatment but that also represents a noticeable contrast to her years in previous therapy with little progress outside of the therapy setting. Further study of these approaches with more participants and by other research groups will help to clarify the many remaining questions, but it does appear that treatment based on nonlinear target selection approaches generated faster and more positive changes in this child’s speech sound system than previous approaches had been able to accomplish.

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Contact author: Suneeti Nathani Iyer, Department of Communication Sciences and Special Education, 564 Aderhold Hall, The University of Georgia, Athens, GA 30602. E-mail: snathani@uga.edu.