The Relationship Between Stimulability and Phonological Acquisition in Children With Normally Developing and Disordered Phonologies

Adele W. Miccio
The Pennsylvania State University, University Park, PA

Mary Elbert
Karen Forrest
Indiana University, Bloomington, IN

The relationship between stimulability and phonological acquisition was investigated in eight children, four with phonological disorders who were aged 3;10 (years;months) to 5;7 and four with normally developing phonologies who were aged 3;6 to 4;1. Children with disordered phonologies received treatment on one nonstimulable fricative. A multiple baseline, across subjects, single-subject design was used for experimental control of the treatment aspect of this study. Children with normally developing phonologies were examined at the beginning of the study and upon termination of treatment for the children with disorders. These data were obtained to determine the relationship of stimulability to normal acquisition. In both cases stimulable sounds underwent the most change and stimulability was related to the learning patterns observed. This study supports the hypothesis that nonstimulable sounds are least likely to change without treatment. The results also suggest that stimulability for production of a sound may signal that it is being acquired naturally.

Key Words: stimulability, phonological acquisition, phonological disorders, treatment, generalization

Testing for stimulability—a child's ability to imitate a sound absent from his/her phonetic inventory immediately following an examiner's model—is a common procedure in the assessment of phonological disorders (Milisen, 1954). The relevance of the ability to imitate sounds to phonological acquisition, however, has not been directly known (Shelton & McReynolds, 1979). It is assumed that stimulability provides information about the child's potential readiness to learn a new sound (Bernthal & Bankson, 1998) and has been suggested as a possible indicator of normal development of speech sounds among school-age children (Carter & Buck, 1958; Diedrich, 1983).

Past research indicates that stimulability may be used to predict the potential for improvement in speech sound production with and without treatment (Carter & Buck, 1958; Diedrich, 1983; Farquhar, 1961; Irwin, West, & Trombetta, 1966; Snow & Milisen, 1954; Somers et al., 1967). Kindergarten, first and second grade children with poor stimulability skills benefit greatly from treatment (Carter & Buck, 1958; Somers et al., 1967). Of children in the first and second grades who do not receive treatment, those with high stimulability scores demonstrate significant improvement (Carter & Buck, 1958; Irwin et al., 1966; Snow & Milisen, 1954).

Authors of these earlier studies (e.g., Carter & Buck, 1958; Somers et al., 1967) operationally defined stimulability as a generalized measure of a child's ability to correct errors in an imitative context. A child, for example, who was not stimulable for several sounds in spontaneous speech but produced some of the sounds in an imitative task was described as 50% stimulable or 100% stimulable depending on the percentage of self-correction from spontaneous to imitative productions across phonemes. More recently, researchers have defined stimulability as a phoneme-specific measure. Using this approach, one refers to a child as stimulable for /k/ but not /l/ (for example) based on the child's ability to imitate a sound that is absent from the phonetic inventory (Powell & Miccio, 1996).

Pretreatment evidence of phoneme-specific stimulability has also been used to explain generalization patterns following intervention (Dinnsen & Elbert, 1984; Elbert & McReynolds, 1978; Miccio, 1995a; Powell & Elbert, 1984; Powell, Elbert, & Dinnsen, 1991; Rvachew, Rafaat, & Martin, 1999; Tyler, Edwards, & Saxman, 1987). Powell et al. (1991) designed an experimental investigation to study prospectively the relationship among phoneme-specific stimulability skills, the choice of treatment targets, and generalization of correct sound production in six children with phonological disorders. They found that children who were stimulable for production of particular sounds tended to improve production of those sounds regardless of treatment target. If stimulable sounds are acquired regardless of treatment target, they are more likely to develop through maturation than nonstimulable sounds. The structure and function of the articulatory mechanism are presumably intact and the required articulatory movements are produced in more supportive circumstances (Bain, 1994; Pollock & Rees, 1972; Shelton, Hahn, & Morris, 1968; Turton, 1973). A nonstimulable sound, on the other hand, is more likely to require direct treatment. Thus, stimulability may predict self-correction, generalization, or response to treatment.

If an individual is stimulable, the integrity of the sensory input, linguistic, and motor output system must be intact to some degree (Powell & Miccio, 1996). One must receive the input, perceive the unit presented, and execute the skilled motor movements necessary to produce it. Dinnsen and Elbert (1984) reasoned that stimulability necessitates some degree of linguistic knowledge at the phonological level. If the child imitates a sound that is not produced in the phonetic inventory, then it is conceptually distinct from the form used in error.

Kwiatkowski and Shriberg (1993) posit that stimulable children not only have the capability of comprehending and producing speech sounds, but also have the ability to focus on productions and are motivated to change. If stimulability indicates a child's comprehension of a sound and the ability to produce it, stimulable sounds may develop normally through maturation. Predicted changes in the use of stimulable sounds should be the same in children with normal phonologies and children with disordered phonologies.

Purpose of the Study

The purpose of this investigation was to examine the relationship between stimulability and phonological acquisition in eight children, four with normally developing phonologies and four with disordered phonologies. Because these children participated in a larger study of the acquisition of voiceless fricatives, at least two fricatives were required to be absent from their phonetic inventories at the beginning of the study. Children with phonological disorders received treatment on one nonstimulable voiceless fricative. Children with normally developing phonological systems were examined at the beginning of the study and again following termination of treatment for the children with disordered phonologies. The following questions were posed:

1. Will children with phonological disorders acquire stimulable sounds regardless of treatment target?
2. Will children with normally developing phonologies acquire stimulable sounds in a similar time frame?

Method

Participants

Two groups of children, a group with normally developing phonologies and a group with disordered phonologies, were identified as participants for this study. All participants were monolingual speakers of English who had normal hearing sensitivity as indicated by a pure-tone screening at 500, 1000, 2000, and 4000 Hz at 20 dB HL (ANSI, 1969) under earphones in a quiet room. All participants earned passing scores on the Oral Speech Mechanism Screening Examination–Revised (St. Louis & Ruscello, 1986). In addition, children scored within normal limits on the Peabody Picture Vocabulary Test–Revised, Form L (Dunn & Dunn, 1981) and the Test of Early Language Development–2 (Hresko, Reid, & Hammill, 1991). These general language tests were used for descriptive purposes only and were not a factor in determining eligibility for participation in the study. Results of screening tests for the eight participants are shown in Table 1.

Group assignment was determined on the basis of the number of sounds and sound classes in error on whole-word transcriptions from the Goldman-Fristoe Test of Articulation (GFTA; Goldman & Fristoe, 1986), percentile rank on the Sounds-in-Words Subtest of the GFTA, and comparison of error profiles to the Iowa-Nebraska Articulation Norms (Smit, Hand, Freilinger, Bernthal, & Bird, 1990). To be included in the treatment group, participants were required to meet four criteria. The first three criteria established the presence of a phonological disorder. Treatment group participants had (a) at least six sounds in error across three manner classes, (b) a score at or below the 5th percentile on the GFTA, and (c) at least four sounds in error that had been acquired by 75% of children of the same age (75% cutoff) or at least four atypical errors, that is, errors that were produced by less than 5% of children of a given age according to the Iowa-Nebraska Articulation Norms (Smit et al.). In addition, because of the purposes of the larger study, treatment participants were required to have a least two voiceless fricatives excluded from the phonetic inventory according to results of the Phonological System Analysis described below (PSA; Miccio, 1995b).

To establish that children in the normal control group were developing phonology within normal limits, they were required to score above the 10th percentile on the GFTA, have no errors on sounds that are acquired by 75% of children of the same age according to Smit et al. (1990), and have no consistent atypical singleton consonant errors; that is, errors that occur in less than 5% of their age group according to the phonologic error distributions for the

TABLE 1. Results of screening tests.

			PPVT-R	TELD-2	GFTA	Stimulability for Fricatives	
P	Gender	CA	SS	Language Quotient	%ile	Yes	No
T1	F	5;7	111	125	2	f v ð s z	θ ʃ
T2	F	3;10	95	130	<1	f v	θ ð s z ʃ
T3	M	3;11	94	100	5	ð	f v θ s z ʃ
T4	M	4;0	92	111	3	f θ ð	v s z ʃ
C1	M	3;6	113	114	39	f v θ ð s z ʃ	
C2	F	3;7	104	108	26	f v s z	θ ð ʃ
C3	F	4;0	99	110	50	f v s z ʃ	θ ð
C4	M	4;1	100	115	59	f v θ ð s z ʃ	

Note. P = participant; CA = chronological age; SS = standard score; PPVT-R = Peabody Picture Vocabulary Test–Revised, Form L standard score; TELD-2 = Test of Early Language Development, 2nd Ed.; GFTA = Goldman-Fristoe Test of Articulation percentile rank; T = Treatment group; C = Control Group.

Iowa-Nebraska Articulation Norms. To illustrate, 15–30% of children between the ages of 3;6 and 5;0 produce [f] for /θ/ (Smit, 1993) in the word-initial position; however, less than 3% of children within this group omit /θ/. Thus, the production of [f] for words beginning with /θ/ is a typical developmental substitution, whereas the omission of word-initial /θ/ is considered atypical.

Group With Normally Developing Phonologies (Control Group). Four children between the ages of 3;6 (years;months) and 4;1 were selected for this group. They had normal phonological development as judged by their percentile ranks in the average to high average range on the GFTA and comparison of their ages and errors to the Iowa-Nebraska Articulation Norms (Smit et al., 1990) and error distributions (Smit, 1993). None of the control group had acquired all fricatives at the beginning of the study (Table 2).

Table 2 shows that participant C1 had more than six sounds in error; however, these errors did not occur across three sound classes. In addition, C1 had no errors above the 75% cutoff on the Smit et al. (1990) norms nor did he have any atypical errors. This child also ranked in the 39th percentile on the GFTA.

Participant C2 also had more than six sound in error (Table 2); however, none of the errors were on sounds that had been acquired by 75% of children of her age (Smit et al., 1990). C2 had two atypical but inconsistent errors (Table 3); the substitution of [dz] for /dʒ/ sometimes occurred in the word-initial position. C2 sometimes substituted [d] for /dʒ/ in the initial position, a typical error for her age, and /dʒ/ was produced correctly in word-final position. Participant C2's second atypical error, the substitution of [s] for /tʃ/ in the word-final position, also occurred inconsistently. Target /tʃ/ was sometimes produced as [ts] in word-final position, a typical error according to Smit (1993). Target /tʃ/ was always produced correctly in word-initial position. Participant C2 also scored in the 26th percentile on the GFTA.

Participant C4 had one atypical error using the criteria of Smit (1993). He sometimes produced a voiced bilabial fricative [β] for word-final /v/. Otherwise, /v/ was produced as [b], a typical error. Productions of [β] were inconsistent and did not occur on a sound acquired by 75% of children of his age. In addition, C4 scored in the 59th percentile on the GFTA. Because none of the control group

TABLE 2. Consonant error profiles for the treatment and control groups.

	No. of Errors		Inventory Constraints		Errors Above 75% Level	
Participant	Sounds	Classes	Voiceless Fricatives	Other Consonants	Voiceless Fricatives	Other Consonants
T1	11	4	θ ʃ	l r	θ ʃ	k g v dʒ l r
T2	16	5	f θ s ʃ	k g v ð z tʃ dʒ l r	f s	k g tʃ dʒ w h l
T3	11	3	f θ s ʃ	v z tʃ dʒ	f s	tʃ dʒ
T4	13	4	f θ s ʃ	ð z tʃ dʒ	f s ʃ	d dʒ h l
C1	7	2	θ ʃ	ð	—	—
C2	7	3	θ ʃ	ð	—	—
C3	5	2	θ	v ð	—	—
C4	4	2	θ	v ð r	—	—

Note. Errors above 75% level = sounds in error above the age at which 75% of children have acquired the sound (Smit et al., 1990).

TABLE 3. Consonants for which participants produced atypical errors.

Participant	Initial Position: Voiceless Fricatives	Initial Position: Other Consonants	Final Position: Voiceless Fricatives	Final Position: Other Consonants	Total No. Sounds
T1	ʃ	k g v	f	dʒ	6
T2	f s ʃ	k z tʃ w h l r	f θ s ʃ	v z tʃ dʒ	14
T3	s ʃ	z tʃ	f s ʃ	z dʒ	6
T4	f s ʃ	k g z tʃ	f θ s ʃ	z tʃ dʒ	9
C1					0
C2		dʒ		tʃ	2
C3					0
C4				v	1

Note. Atypical = Errors produced by less than 5% of children on the Iowa-Nebraska Articulation Norms (Smit et al., 1990).

met the three criteria for disordered phonologies, they were considered to have normally developing phonologies.

Group With Phonological Disorders (Treatment Group). Four children between the ages of 3;10 and 5;7 received treatment. Comparison of the participants' performance to the Iowa-Nebraska Articulation Norms (Smit et al., 1990) is summarized in Table 2 along with performance of the normal control group for comparison of the groups. As illustrated in the table, all children in the treatment group produced several atypical errors using the criteria of Smit (1993) and met the operational definition for inclusion in the treatment group.

At the beginning of the study, Participant T1 produced /f s z/ correctly across word positions. Three positional constraints occurred: /v/ was produced correctly in the word-final and intervocalic positions but as [b] in the word-initial position. The voiced interdental /ð/ was produced correctly in the word-initial position but as [d] in the intervocalic position. The affricate /dʒ/ was produced correctly in the word-initial position but as an alveolar affricate [dz] in the intervocalic and word-final positions. The fricatives /θ/ and /ʃ/ were excluded from the phonetic inventory and were produced as [f] and [s], respectively. In addition to the problems with fricatives, T1 produced alveolar stops for velar stops in the word-initial position. The liquids /r/ and /l/ were both produced as [w] in the word-initial and intervocalic positions and as vowels at the ends of words.

Participant T2 did not produce any fricatives at the beginning of the study. All fricatives were produced as [d] in the word-initial position, [ʔ] in the intervocalic position, and were omitted word-finally. In addition, alveolar stops were substituted for velar stops and affricates across word positions. Glottal stops were substituted for the glides /w/ and /h/ and in the word-initial position. The liquids were produced as [w] in the intervocalic position and as vowels in the word-final position.

Participant T3 produced only one fricative, /ð/, and production was restricted to the intervocalic position. Otherwise, all fricatives and affricates were produced as stops. The liquids were produced correctly in the word-initial and intervocalic positions but were produced as vowels in the final position. Stops, nasals, and glides were used correctly relative to the adult target.

At the beginning of the study, T4 produced one fricative /v/ in the word-initial and word-final positions, but substituted [d] for /v/ in the intervocalic position. All other fricatives and affricates had the same substitutions, [d] in the word-initial and intervocalic positions and [t] in the final position. Labial and alveolar stops were produced correctly across positions. Alveolar stops were substituted for velar stops in the word-initial position. Glides /w j/ were produced correctly but /h/ was sometimes produced as [ʔ] in the word-initial position. Liquids were produced correctly in the word-initial position, but as the glide [w] in the intervocalic position. In the final position /r/ was produced correctly but /l/ was produced as a vowel.

Materials

Phonological System Analysis Probe (PSA). At the beginning of the study, a 100-item phonological system analysis probe (Miccio, 1995b) was administered to all participants to sample English consonants in word-initial, intervocalic, and word-final positions. This picture naming tasks provides the opportunity to produce each English phoneme at least 10 times. With the exception of glides and /ð/, each phoneme is elicited at least 5 times in the word-initial position, 3 times in the word-final position and twice in the intervocalic position. The glides and /ð/ are elicited a minimum of 5 times each in the word-initial and intervocalic positions. The probe was readministered to treatment participants from 2 to 5 days posttreatment, and again 2 months later (follow-up). Control participants received the PSA at the beginning and the end of the study. The children's responses were phonetically transcribed on-line by the first author and a graduate student in speech-language pathology with training in narrow phonetic transcription. Results of the probe were used to compile a phonetic inventory for each participant. A consonant was considered to be included in the participant's phonetic inventory if it was produced in at least two lexical items with different base morphemes (Stoel-Gammon, 1985).

Stimulability Probe. An adaptation of the Carter and Buck (1958) Nonsense Syllable Task was used to assess stimulability of singleton consonants in isolation and in consonant-vowel (CV) syllables during an imitation task. Each consonant was paired with two different vowels in the prevocalic, intervocalic, and postvocalic positions. A sound that was correctly imitated at least twice was classified as stimulable. The stimulability probe was administered to treatment subjects and control subjects at the beginning of the study and after treatment was terminated. Treatment participants returned for a follow-up stimulability probe 2 months later.

Treatment Generalization Probe. Once a treatment participant's phonetic inventory was compiled and a target fricative was chosen for treatment in the word-initial position, a probe was developed to measure generalization across word positions and to untrained words. The generalization probe included 65 items; 20 items were used to assess generalization of the treatment sound (8 word-initial, 8 word-final, and 4 intervocalic), and 45 more items were included to measure generalization to untrained fricatives and other phonemes of the sound system. The treatment generalization probe was administered to each treatment participant three times before treatment to establish baseline measures and at the beginning of every week of treatment to probe for generalization in response to treatment. The 20 participant-specific items used to assess generalization of the treatment sounds are listed in Appendix A and the remaining probe items appear in Appendix B.

Experimental Design

Treatment Procedures. The treatment component of this study used a multiple baseline, across subjects, single-subject design (McReynolds & Kearns, 1983). The four treatment participants were paired. T2 served as the experimental control for T1, and T4 served as the experimental control for T3. Both participants in each pair received at least three baseline probes before treatment. The second participant in each pair received a fourth baseline probe immediately before his/her treatment began. Treatment for the second participant in the pair started after the first participant reached a generalization score at least 20% above his/her mean baseline score or after 5 weeks had elapsed since the first member of the pair started treatment.

Experimental control was demonstrated at three points in the study. First, control was demonstrated during the baseline period in that productions of the treatment sound remained stable across the three or four probe administrations. Second, control was shown when correct production of the treatment sound occurred only after a child began treatment. Third, control was evidenced by the lack of phonological change in the second participant in a pair while in an extended baseline (Figures 1 and 2). These controls confirmed that change was the result of treatment and not due to repeated testing, maturation, or other extraneous variables (McReynolds & Kearns, 1983).

The treatment sound was one fricative missing from the child's inventory. Participant T1 was taught /ʃ/ and Participants T2, T3, and T4 were taught /s/. Treated sounds were targeted in the word-initial position and changes in the production of the treated fricative and other fricatives were monitored across word positions.

The pretreatment test battery, PSA, and stimulability probe were administered before beginning treatment. The treatment generalization probe was administered to treatment participants three or four times before treatment to establish baseline measures. Stable baselines of 0% correct were evidenced for all participants.

Once a stable baseline was determined, treatment began on one fricative absent from a participant's phonetic inventory and followed a hierarchy of treatment that included production of sounds in isolation and five minimally paired words contrasting the target sound with the child's customary error (Elbert, Rockman, & Saltzman, 1980). Participant T1 was taught the contrast between /ʃ/ and /s/. Participant T2 was taught the contrast between /s/ and /t/. Participants T3 and T4 were taught the contrast between /s/ and /θ/.

The treatment program consisted of two phases with two different steps in each of these phases. A child remained in a step until a criterion of 80% correct productions across two sets of 20 responses was met. During Phase A, reinforcement was continuous (CRF). In Phase A Step 1, the child imitated the target fricative in isolation during sound play activities and received continuous reinforcement for correct productions. Upon reaching criterion, the child advanced to Step 2 in which the child imitated the clinician's production of words with the target word-initial fricatives in a picture-naming task. If a participant could not produce the target sound in a word, a branching step was inserted in which the sound was taught in CV syllables. Pictures of silly space figures were given CV names, e.g., /si/, /sɑ/, to assist in elicitation of the target sound in a CV context. Upon reaching a criterion of 80% correct production across two sets of 20 items, the child returned to word production. During Phase A, a session was defined as 100 responses to a sound in isolation or a single word.

In Phase B Step 1, the words with the target fricative were paired with minimally contrasting words containing the child's substitution. The child imitated the clinician's production of the minimal pairs. In Phase B Step 2, the child spontaneously named pictures of randomly presented minimal pairs. During Phase B, a session was operationally defined as 100 responses to the minimal pairs and reinforcement was systematically decreased (variable ratio 3).

Participants were seen twice a week for 45 minutes each visit. Because a session was defined by the number of responses, the number of sessions completed within each 45-minute visit varied according to the length of time required for completion of 100 responses. During imitation of a sound in isolation, for example, a child may produce 200 responses in 45 minutes but during minimal pair activities, a child may produce only 100 responses in the same amount of time. A token reinforcement system was used whereby the child earned chips for correct responses. These chips were redeemed for small prizes at the end of each visit. When a participant generalized to 50% of the 20 untrained probe items targeting the treatment sound, treatment was discontinued. If generalization was less than 50%, treatment was discontinued after a maximum of 20 sessions.

Reliability

Interjudge agreement on phonetic transcriptions was calculated for the PSA and stimulability probes for all participants. In addition, interjudge agreement was calculated for the experimental and generalization probes for the four experimental participants. All phonological, experimental, generalization, and stimulability probes were phonetically transcribed independently by two judges, the first investigator and a graduate student in speech-language pathology. Because of the severity of the phonological impairments in the study participants, the intent was to compute reliability for all samples; however, the occasional absence of a reliability judge occurred, and the percentage of samples used for reliability computation is indicated below. After reliability was computed, all disagreements were resolved by consensus and the final transcript was used in the study. Interjudge agreement was calculated using the formula: Percent Interjudge Agreement = Agreement/(Agreements + Disagreements) × 100. Interjudge agreement for the control participants reached 100% on the phonological analysis and stimulability probes administered at Month 1 and Month 5.

Each treatment participant received three PSA probes. Point-to-point reliability was calculated based on each judge's transcription of each consonant. Reliability was calculated on 83% of the samples and mean interjudge agreement was 91% with a range of 83% to 99% agreement.

The number of treatment generalization probes varied according to the number of weeks that a subject remained in treatment. The number of these probes ranged from 5 to 17 across participants. Transcription reliability for untreated consonants was calculated for 92% of the probes and interjudge agreement reached 91% with a range of 70% to 100% agreement across repeated probes. Transcription reliability for the treatment sound was determined separately from the other consonants and reflects the degree to which judges agreed on the production of the treated fricatives. Reliability was calculated on 100% of the probes and the mean interjudge agreement was 99% with a range of 70 to 100% agreement across administrations.

The number of stimulability probes also ranged from 5 to 17 across participants. Stimulable/nonstimulable reliability was calculated for 94% of the samples. Interjudge agreement was 98% with a range of 89 to 100% agreement across repeated probes.

Results

This study focused on characteristics of fricative acquisition by children learning phonology normally as well as by children who acquired fricatives as a result of treatment. Transcriptions of all participants were analyzed to determine sounds established in the phonetic inventories and stimulability for correct production of sounds absent from the phonetic inventories.

Control Group

Data for the two analysis points, Month 1 and Month 6, are discussed. Participants C1–C3 were tested at the beginning of the study (before intervention for the treatment group) and again at the end of the study (termination of treatment). The original Participant C4 was lost from the study due to attrition. A new C4 was recruited and completed all Month 1 assessment procedures at the time of identification. He then returned 5 months later to complete Month 6 testing following the same timeline as the other control group participants.

Phonetic Inventories. At the beginning of the study, participants C1 and C2 produced all consonants except three fricatives: /θ ð ʃ/. Participant C3 produced all consonants except /θ ð v/ and Participant C4 produced all consonants except /θ ð v r/. When probed 5 months later, Participants C1 and C4 had complete English phonetic inventories and Participants C2 and C3 produced all sounds but the interdental fricatives. Changes in the phonetic inventories of the children in the control group are presented in Table 4.

Stimulability. At the beginning of the study, Participant C1 was stimulable for correct production of the three fricatives missing from his phonetic inventory; 5 months later these sounds, /θ ð ʃ/ were present in the inventory. Although Participant C2 had the same three fricatives absent from the phonetic inventory as C1, C2 was only

TABLE 4. Phonetic inventories of control group participants.

Participant	Month 1	Month 6
C1	p b t d k g f v☒☒s z ☒ tʃ dʒ m n ŋ w j h l r	p b t d k g f v θ ð s z ʃ tʃ dʒ m n ŋ w j h l r
C2	p b t d k g f v☐☐s z ☒ tʃ dʒ m n ŋ w j h l r	p b t d k g f v☒☒s z ʃ tʃ dʒ m n ŋ w j h l r
C3	p b t d k g f☒☐☐s z ʃ tʃ dʒ m n ŋ w j h l r	p b t d k g f v☒☒s z ʃ tʃ dʒ m n ŋ w j h l r
C4	p b t d k g f☒☒☒s z ʃ tʃ dʒ m n ŋ w j h l ☐	p b t d k g f v θ ð s z ʃ tʃ dʒ m n ŋ w j h l r

Note: "☒" = consonants missing from the inventory which were stimulable for production; "☐" = consonants missing from the inventory which were not stimulable for production.

stimulable for correct production of /ʃ/. Five months later, /ʃ/ was present in the inventory and /θ ð/ remained absent from the inventory but stimulable. Participant C3 had three fricatives /v θ ð/ missing from the phonetic inventory, with only /v/ stimulable for correct production at the beginning of the study. Five months later, /v/ had been acquired and although still restricted from the inventory, /θ ð/ were stimulable for correct production. Participant C4 had four consonants /θ ð v r/ missing from his phonetic inventory at the beginning of the study. The fricatives /θ ð v/ were stimulable but the /r/ was not. Five months later, all four sounds were in the phonetic inventory. As shown in Table 4, these four participants acquired any stimulable fricatives missing from their phonetic inventories by the time treatment terminated for children with disordered phonologies. In addition, those children who had not acquired the interdental fricative after 5 months had passed were stimulable for correct production of the interdentals. These changes are illustrated in Table 4.

Treatment Group

Participant T2 served as the control for T1 and Participant T4 served as the control for T3 as shown in Figures 1 and 2. Because of the differences in error profiles and learning patterns, each child in the treatment group will be discussed separately. Characteristics of treatment progress are noted. Phonetic inventories are described and results of stimulability testing are reported. By viewing each child's phonetic inventories longitudinally, a general trend emerges where stimulable sounds are those most likely to be acquired by the next analysis and those sounds that are phonetically related to the treatment sound, a fricative, are most likely to become stimulable.

Participant T1. At the beginning of the study, T1's phonetic inventory contained all stops, affricates, nasals, and glides, and the fricatives /f v ð s z/. Distributional constraints restricted occurrence of the sounds /k g v dʒ/. T1 never produced liquids and was not stimulable for correct production of any sounds excluded from the inventory. T1's pretreatment, posttreatment, and follow-up phonetic inventories are shown in Table 5.

T1 was taught to produce /ʃ/ in isolation, single words and minimal pair contrasts and met the generalization criterion during the second week of treatment (Figures 1 and 3). Treatment was discontinued and the PSA was readministered. The treated sound /ʃ/ was added to the posttreatment phonetic inventory and the non-English alveolar affricate was no longer produced. Although the sounds /θ l r/ remained restricted from the inventory, both /θ/ and /l/ became stimulable. At the follow-up probe administered 2 months later, T1's phonetic inventory included all English consonants except the liquids. Liquid

FIGURE 1. Performance of Participants T1 and T2 on untreated items containing /ʃ/ and /s/, respectively, during baseline and weekly generalization probes throughout treatment.

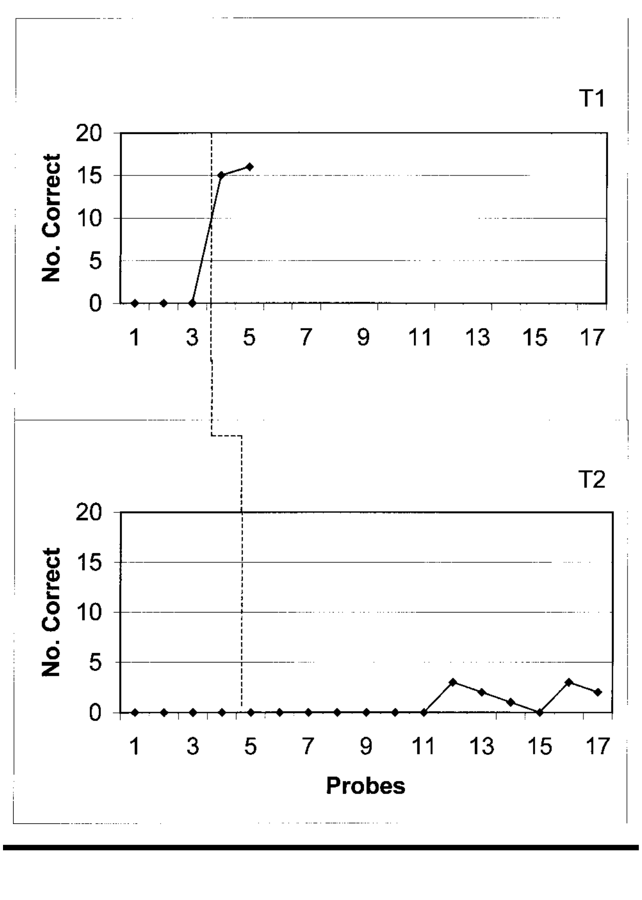


FIGURE 2. Performance of Participants T3 and T4 on untreated items containing /s/ during baseline and weekly generalization probes throughout the course of treatment.

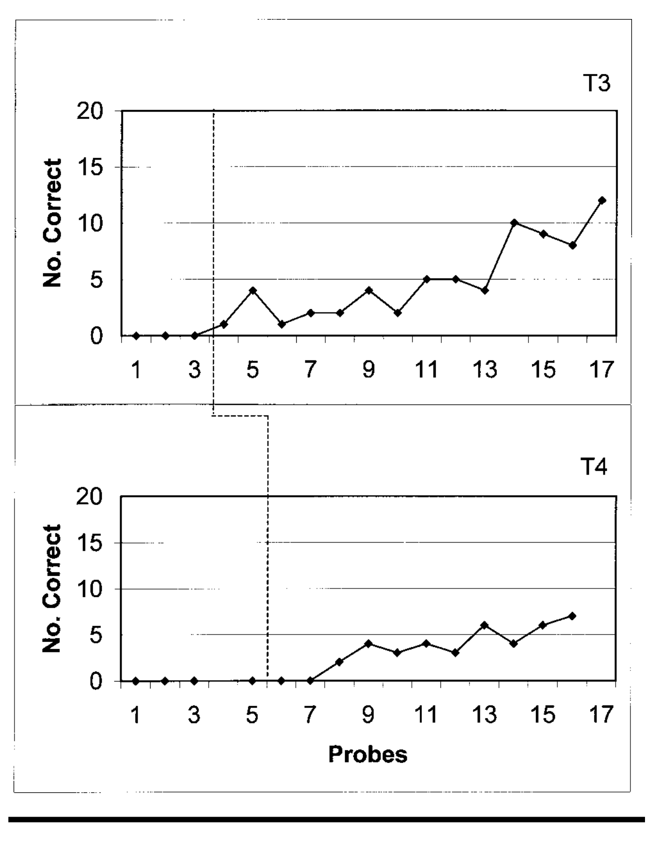


FIGURE 3. T1's production accuracy for /ʃ/ during Treatment Steps A1, A2, B1, and B2 (NT = no treatment).

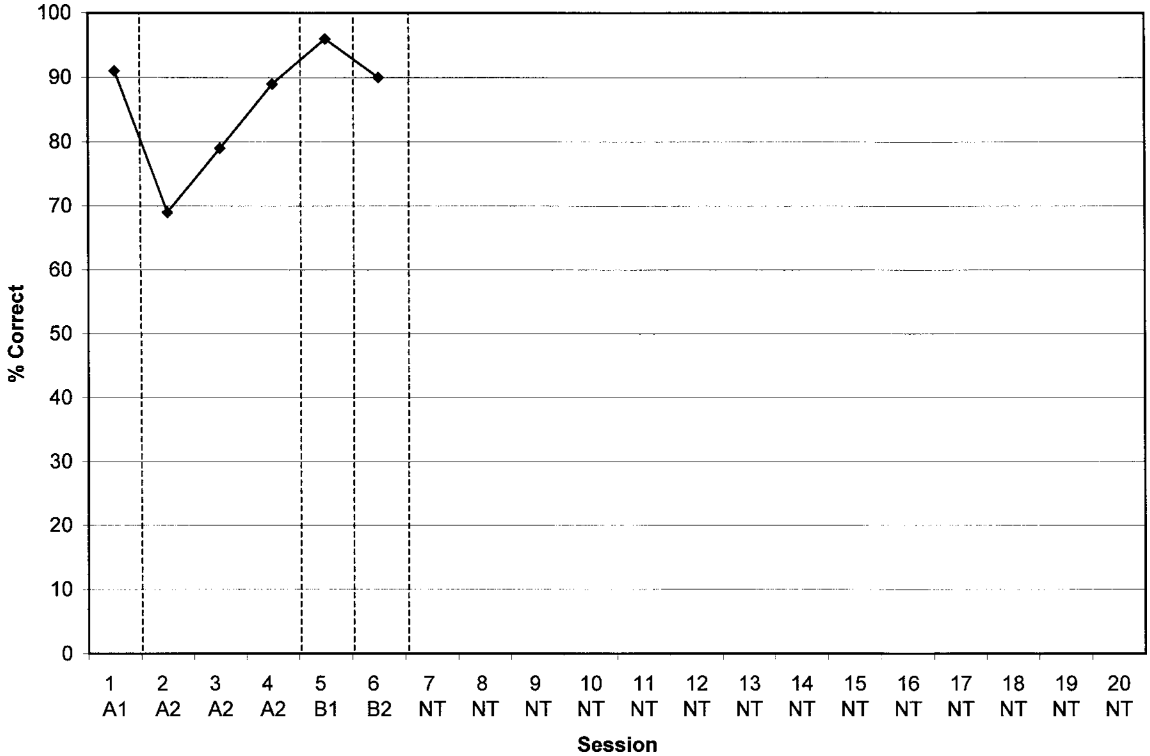


TABLE 5. Phonetic inventories of treatment participants.

Participant	Pretreatment	Posttreatment	Follow-Up
T1	p b t d k g f v ☐ ð s z ☐ dz tʃ dʒ m n ŋ w j h ☐ ☐	p b t d k g f v ☒ ð s z ʃ tʃ dʒ m n ŋ w j h ☒ ☐	p b t d k g f v θ ð s z ʃ tʃ dʒ m n ŋ w j h ☒ ☐
T2	p b t d ☐☐ ☒☒☐☐☐☐ ☒ ☒ m n ☐ w j h ☐ ☐	p b t d k g ☒ v ☐☐☐☐ ☒ ☒ dʒ m n ☐ w j h ☐ ☐	p b t d k g f v ☒☒☒☒☒ tʃ dʒ m n ŋ w j h ☐ ☐
T3	p b t d k g ☐☐☐ ð ☐☐☐ ☐ ☐ m n ŋ w j h l r	p b t d k g f v θ ð s ☒ ☐ ☐ ☐ m n ŋ w j h l r	p b t d k g f v θ ð s z ☒ ☒ ☐ m n ŋ w j h l r
T4	p b t d k g ☒ v ☒☒☐☐☐ ☐ ☐ m n ŋ w j h l r	p b t d k g f v θ ð s ☒☐ ☐ ☐ m n ŋ w j h l r	p b t d k g f v θ ð s z ☒ ☐ dʒ m n ŋ w j h l r

Note. "☒" = consonants missing from the inventory which were stimulable for production; "☐" = consonants missing from the inventory which were not stimulable for production.

/l/ was stimulable but /r/ was not. Changes in stimulability are illustrated in Table 5.

In this child's case, the sound that was taught was the only sound added to the phonetic inventory. This participant had knowledge of both continuancy (produced some fricatives and all stops) and stridency (produced /z/ and /ð/) at the beginning of treatment. T1 needed to learn the distinction between the two sibilants /s/ and /ʃ/, that is, that the alveolar fricative was [+anterior] and distinguished from the [–anterior] palatal fricative. Adding /ʃ/ resulted in acquisition of this feature distinction.

Sounds of which T1 had some knowledge at the beginning of the study continued to spread across word positions (e.g., /k/ and /g/). The liquids /r/ and /l/ remained absent from the phonetic inventory but /l/ was stimulable. Changes in production accuracy for sounds in error at the beginning of the study are illustrated in Figure 4.

Participant T2. At the beginning of the study, T2 produced only labial and coronal stops and nasals and glides. She was stimulable for /f v/ and [dʒ]. T2 was taught to produce /s/. Although this participant met the treatment criterion to move from production in isolation to words by the second session, she was unable to produce the sound at the word level. A branching step was used to teach production of /s/ in CV syllables. T2 then returned to Step A2. The criterion for advancement was met at Session 13 and minimal pairs were trained from that point on. Although T2 produced some minimal pairs, the performance criterion for termination of treatment was not met (Figure 5). Treatment was terminated after 20 sessions and the PSA was readministered.

Results of the PSA indicated that T2 had added the labiodental fricative /v/ and the affricate /dʒ/ to her phonetic inventory. She continued to be stimulable for correct production of /f/ and was stimulable for /ʃ/ and /tʃ/. At the follow-up probe administered 2 months later, T2 had added /f/ and /tʃ/ to the phonetic inventory and was stimulable for correct production of the remainder of the fricative class. The velar stops and liquids continued to be excluded from the inventory and nonstimulable (Table 5). Changes in production accuracy on untrained words are illustrated in Figure 6.

Following treatment of /s/, T2 acquired two sounds /v dʒ/ and three sounds /f ʃ tʃ/ were stimulable. By the follow-up probe, the stimulable sounds /f tʃ/ had been acquired and all remaining fricatives were stimulable. Two interesting findings are apparent relative to the research question. First, T2 did not add the fricative that was trained but did add a manner distinction among the obstruents by establishing the fricative class. Second, the sounds that were learned during treatment were stimulable before treatment and the sounds acquired between the posttreatment and follow-up probes were stimulable when treatment was terminated.

Participant T3. At the beginning of the study, T3's phonetic inventory included all stops, the voiced interdental fricative /ð/, and all English sonorants. T3 was not stimulable for correct production of any of the fricatives

FIGURE 4. Changes in T1's production accuracy on the pre- and posttreatment and follow-up administrations of the PSA. The treated sound is shown on the left followed by the other fricatives and other consonants produced in error. *Note.* Although T1 produced /l/ on the posttreatment and follow-up probes, the sound did not meet criteria for inclusion in the phonetic inventory.

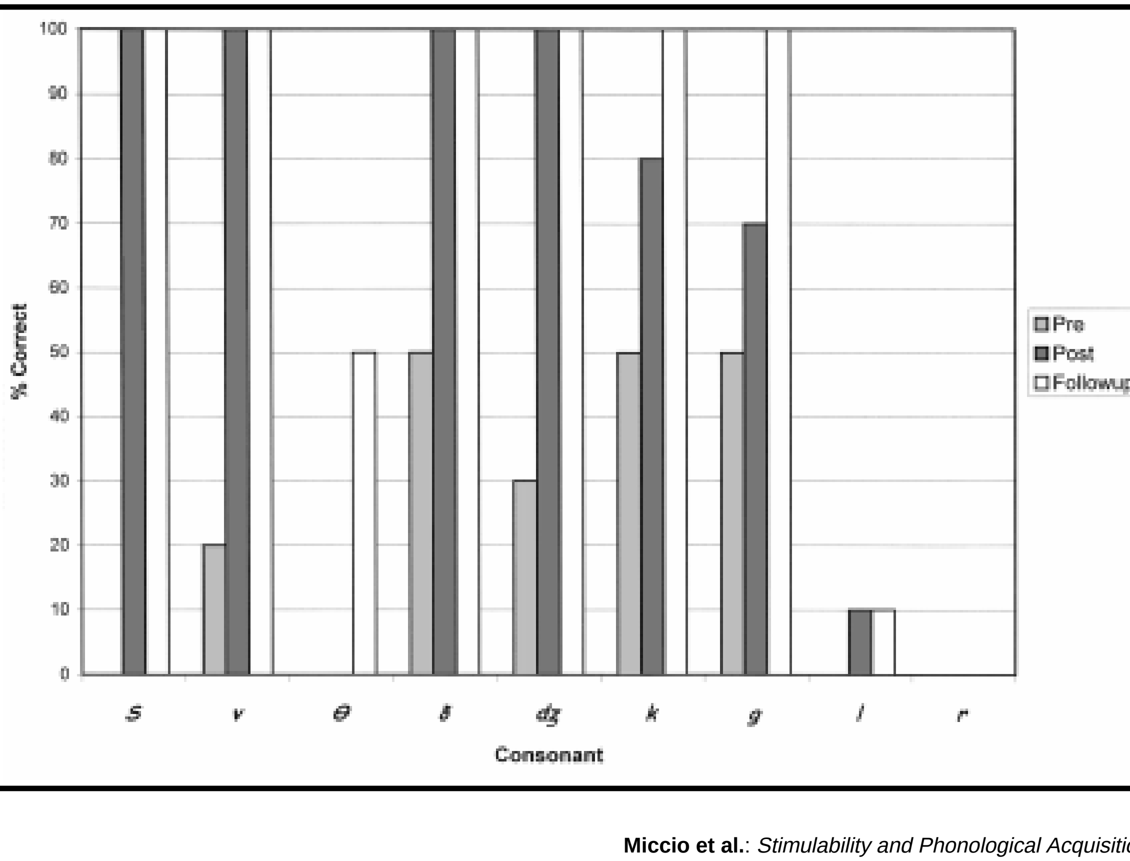


FIGURE 5. T2's production accuracy for /s/ during Treatment Steps A1, A2, a branching step to production in CV syllables (BR CV), the return to Step A2, and Steps B1 and B2.

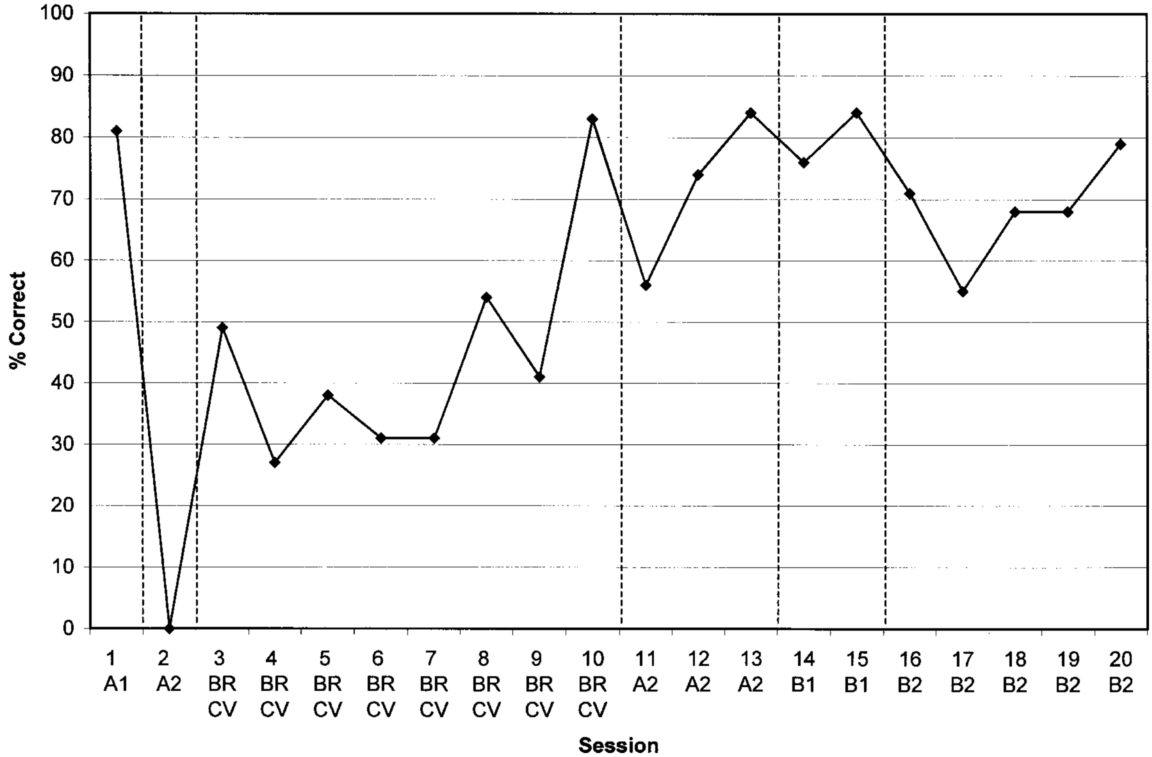
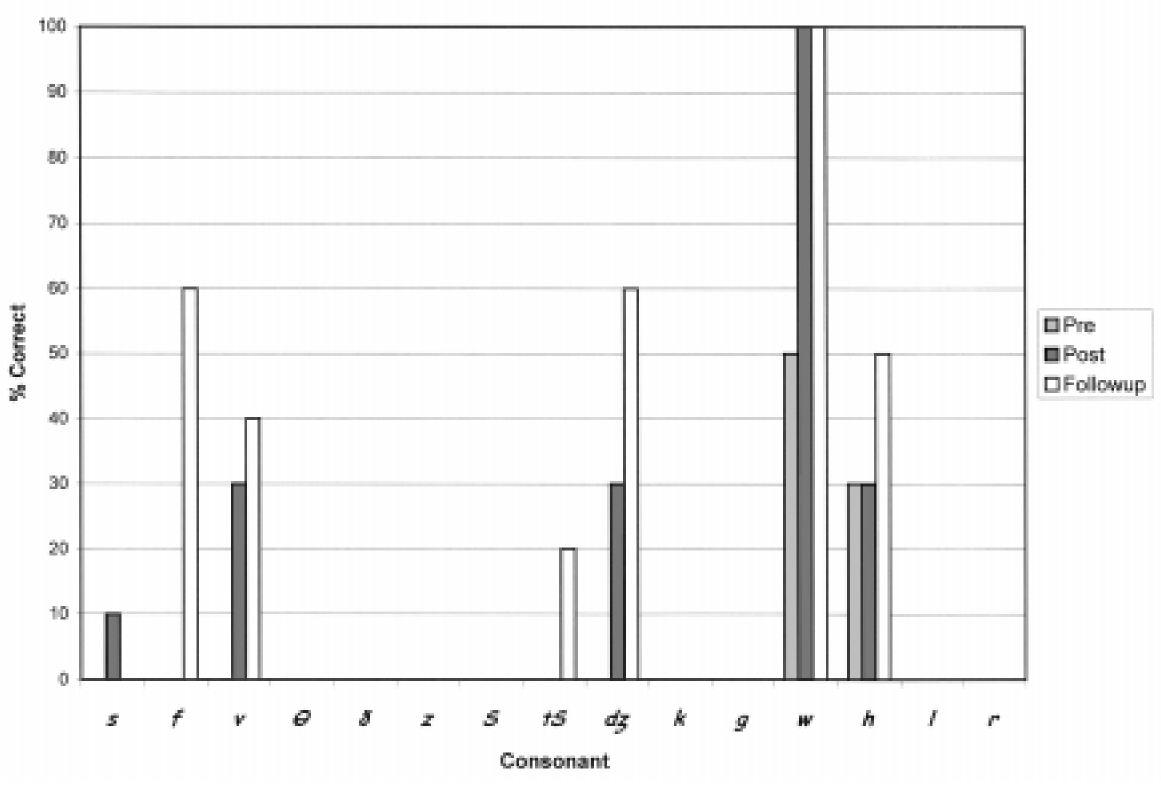


FIGURE 6. Changes in T2's production accuracy on the PSA. The treated sound is shown on the left followed by the other fricatives and other consonants produced in error.



that were missing from the phonetic inventory and was taught to produce /s/. He was unable to imitate /s/ during the first session. A branching step was introduced where a tongue depressor was used to obtain correct production of /s/. The tongue depressor was discontinued in Session 3 and /s/ was trained in isolation by imitation. Words were introduced at Session 7 but T3 was unable to produce /s/ in this context. A second branching step was introduced to teach /s/ in CV syllables. Single words were reintroduced at Session 14. Although T3 correctly produced some words with initial /s/, the performance criterion of 80% correct productions over two sets of 20 stimulus items was not met before Session 20 (Figure 7). At that time, treatment was discontinued and the PSA was readministered. Participant T3 had added /s f v θ s/ to his phonetic inventory and was stimulable for production of /z/. He was not stimulable for production of /ʃ tʃ dʒ/. When the PSA was readministered 2 months later, T3 produced all fricatives except /ʃ/, but was stimulable for production. He also was stimulable for /tʃ/ but not /dʒ/. Changes in stimulability and T3's phonetic inventories are displayed in Table 5.

For this participant, treatment resulted in acquisition of the treated sound and the nonsibilant fricatives. Although the palatals were not acquired, the voiceless /ʃ tʃ/ were stimulable. By the end of treatment correct production of /r/ generalized to the final position and by the follow-up probe, /l/ was also produced correctly in the final position. These changes in production accuracy are illustrated in Figure 8.

Participant T4. At the beginning of the study, T4 produced all stops and sonorants. He produced one fricative, /v/. The affricates were restricted from the phonetic inventory (Table 5). When tested for stimulability, T4 imitated production of /f θ ð/ but not the coronal fricatives. T4 was taught to produce /s/ and met the criterion to advance from imitation to words in the first session. T4 could not produce any contrasting minimal pairs and treatment continued using single words beginning with the target sound (Figure 9). Although T4 produced /s/ correctly in some exemplars at all sessions, the performance criterion was not met and the PSA was readministered after 20 sessions. T4 had added /f θ ð s/ to his phonetic inventory. The palatals /ʃ tʃ dʒ/ continued to be excluded from the inventory and were nonstimulable. Although restricted from the inventory, /z/ was stimulable. Two months later, T4 produced all fricatives except /ʃ/ but it was stimulable. The voiceless affricate /tʃ/ continued to be restricted from the inventory and nonstimulable, although the voiced cognate, /dʒ/, was in the inventory. The liquids were produced correctly across word positions and the velar stops continued to increase in production accuracy. Changes in production accuracy are shown in Figure 10.

Discussion

This study examined the hypothesis that stimulability is a predictor of phoneme-specific acquisition in children with normal and disordered phonologies. The discussion will address how the hypothesis was supported by results of this study.

Will children with phonological disorders acquire stimulable sounds regardless of treatment target?

In this study, each treatment participant was taught to produce one fricative that was excluded from the phonetic inventory. All participants in the treatment group added fricatives to their phonetic inventories by the posttreatment analysis. All participants added some stimulable sounds to their phonetic inventories and increased the number of stimulable sounds by the follow-up probe.

Children in the treatment group who were stimulable for sounds missing from their phonetic inventories at the pretreatment probe acquired those sounds without direct treatment. One of the children with a phonological disorder failed to acquire the sound that she was taught. This same child, however, acquired sounds that were stimulable at the beginning of the study and increased the number of stimulable sounds by the follow-up probe.

Will children with normally developing phonologies acquire stimulable sounds in a similar time frame?

At the beginning of the study all children in the control group had complete phonetic inventories with the exception of three fricatives and in the case of C4, the liquid /r/. All children in the control group produced /f/ and /s/ correctly and two participants had /ʃ/ in their phonetic inventories. At the end of the study, /ʃ/ was added to the phonetic inventories of the remaining participants. At the Month 6 analysis, the interdentals were the only fricatives not produced by all participants and these were stimulable.

Results of this study showed that children with normally developing phonologies acquired sounds that were stimulable for production within a few months. All children in the control group acquired sounds that were stimulable at Month 1 by Month 6. At Month 6, the few sounds excluded from the control group children's inventories were stimulable for production or already acquired.

Is acquisition of untreated stimulable sounds an indirect result of treatment on other sounds?

Powell et al. (1991) found that stimulable sounds were the most likely to evidence gains in production regardless of the specific sounds targeted for treatment. They acknowledged, however, that it is possible that treatment on any sound may focus a child's attention on speech sounds, in general, and may help a child "learn how to learn" speech sounds.

In the current study, stimulability for production was also probed in normally developing children who did not receive any treatment. The children acquired all stimulable sounds within 5 months of the initial probe. Taken together, these results indicate that stimulability influences change in children with normally developing phonologies and in those with disordered phonologies. Results of this study replicated those found by Powell et al. (1991) and support the hypothesis that stimulable sounds are most

FIGURE 7. T3's production accuracy for /s/ during Treatment Steps A1, a branching step using a tongue depressor (BR TD), the return to Step A1, Step A2, a branching step to production in CV syllables (BR CV), and the return to Step A2.

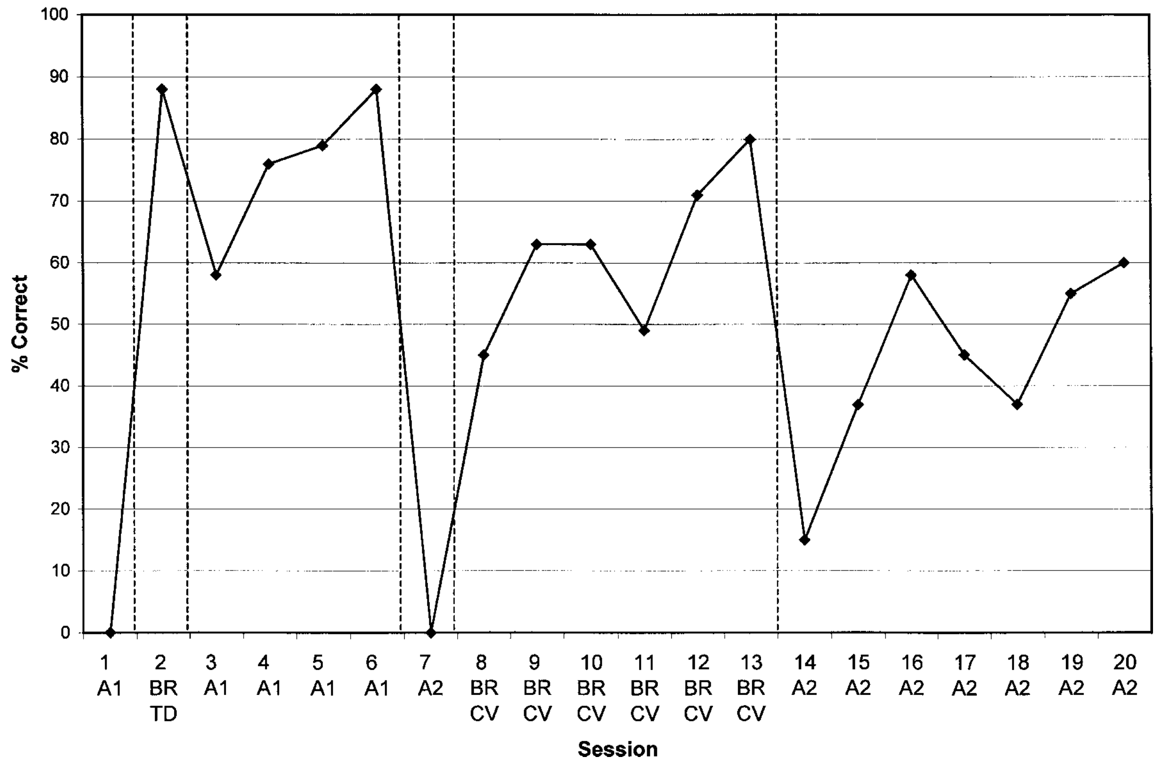


FIGURE 8. Changes in T3's production accuracy on the PSA. The treated sound is shown on the left followed by the other fricatives and other consonants produced in error. *Note.* Although /z/ was produced correctly on the PSA posttreatment, the criteria for inclusion in the phonetic inventory were not met until the follow-up probe.

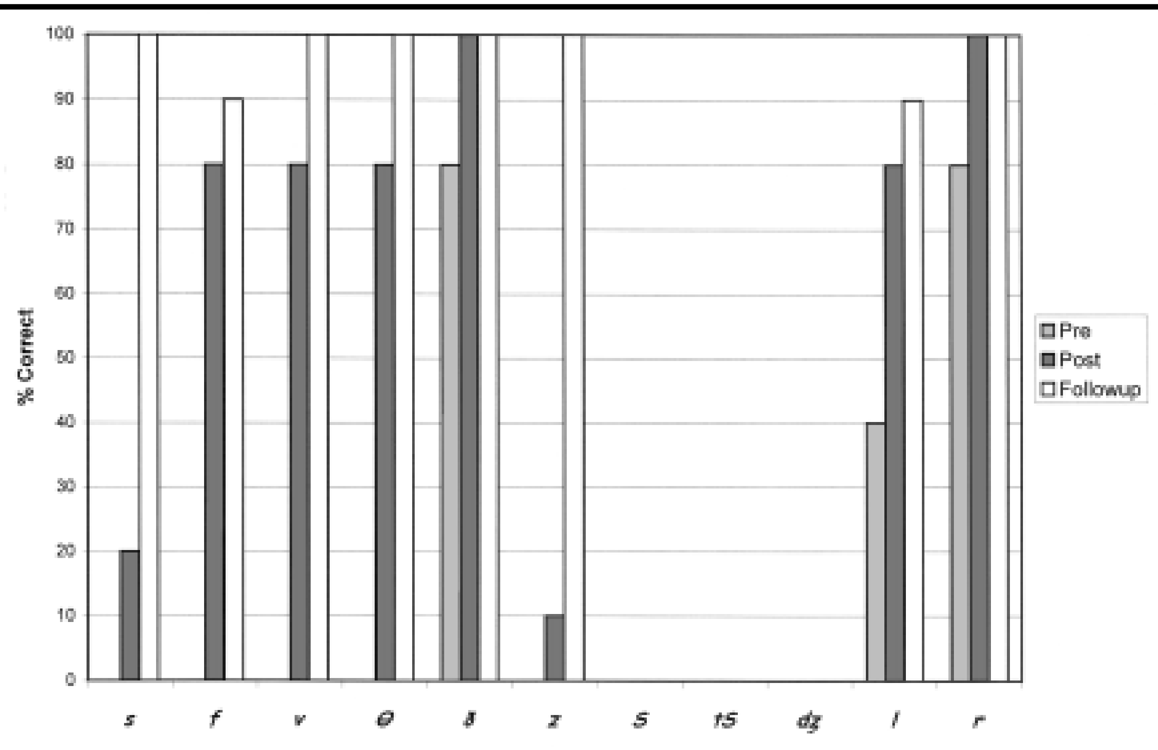


FIGURE 9. T4's production accuracy for /s/ during Treatment Step A1, A2, B1, a return to Step A2, a second attempt at Step B1, and a second return to Step A2.

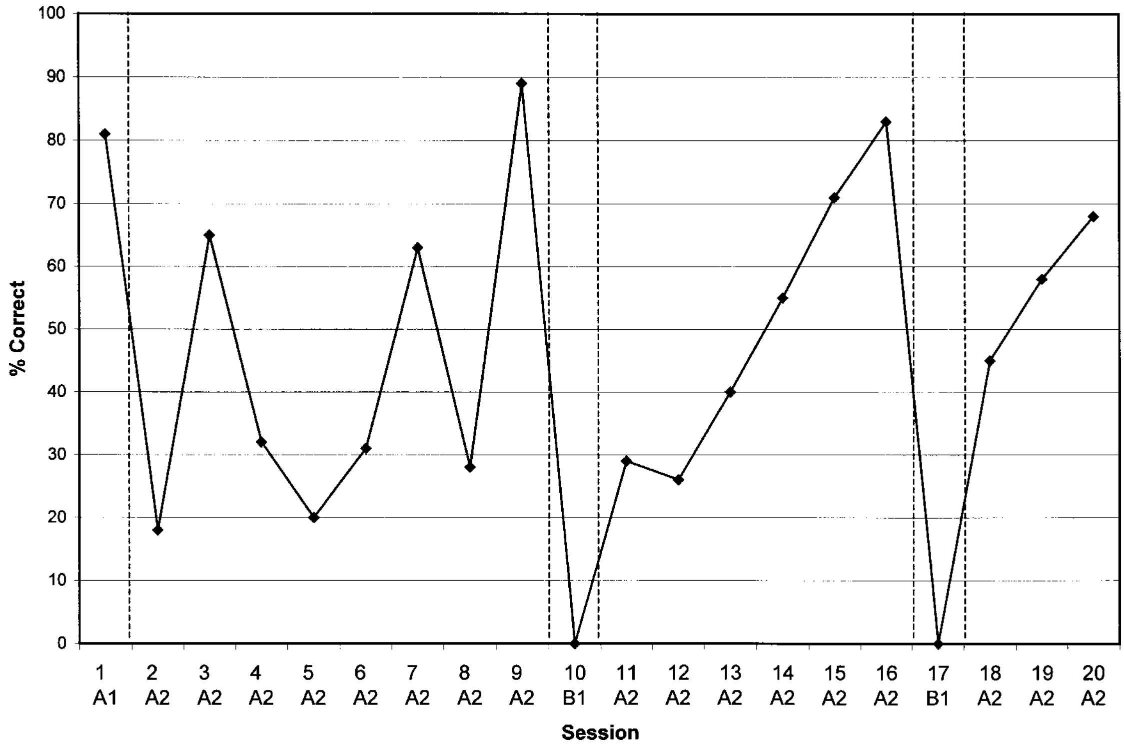
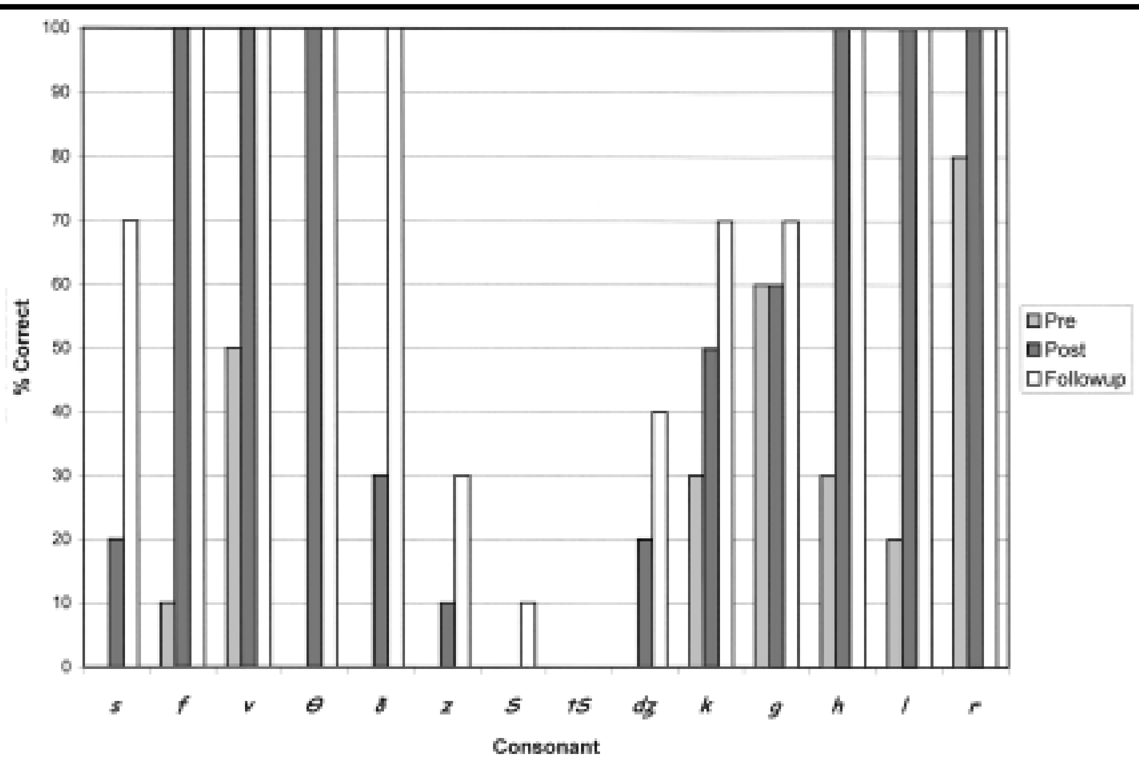


FIGURE 10. Changes in T4's production accuracy on the PSA. The treated sound is shown on the left followed by the other fricatives and other consonants produced in error. *Note.* Although the sounds /f/ and /z/ were produced on the pretreatment PSA, they did not meet criteria for inclusion in the phonetic inventory. Posttreatment /z/ was also produced minimally and /ʃ/ was produced in one exemplar during the follow-up probe.



likely to change without treatment. In addition, this study extended the findings to include children with normally developing phonologies who did not receive treatment.

Is phonological acquisition during treatment comparable to acquisition under normal developmental circumstances?

Determining whether children who receive direct treatment acquire sounds in the same way as children who acquire sounds under normal circumstances is difficult. Studies of normal phonological acquisition have revealed individual differences in acquisition among children who acquire sounds normally (e.g., Edwards, 1979). When the focus moves away from individual sounds to patterns of acquisition, however, consistencies have been identified across inventories (Stoel-Gammon, 1985).

The fricative sound class was of primary interest in this study. Moskowitz (1975) noted that some of her 8 subjects, examined longitudinally, produced a presumably later developing fricative, /θ/, at early ages and then discontinued the use of this sound until a much later time when it was reintroduced into the phonetic inventory. One of the children with a disordered phonology in this study also produced an interdental fricative in the absence of others at the beginning of the study. With regard to the children with normally developing phonologies, however, the interdental fricatives were the only remaining consonants absent from the inventories of two children in this group.

In the present study, fricative acquisition was studied in children who were acquiring the fricative sound class under normal circumstances and in children who were directly taught to produce a fricative. Children in the control group had already acquired /f/ and /s/ at the beginning of the study and added /ʃ/ to their inventories by the end of the study. In addition, two children also added /θ/. This pattern of fricative acquisition has been described by Ferguson (1978) and attested to in cross-sectional research (Smit et al., 1990).

With regard to the treatment group, Participant T1 produced /f/ and /s/ before treatment, was taught /ʃ/ and acquired this sound. By the follow-up probe, /θ/ had also been added to the phonetic inventory. This participant also followed the general order of fricative acquisition of participants who developed this sound class normally.

Participant T2 did not produce any fricatives at the beginning of the study, and the only voiceless fricative that was acquired by the follow-up probe was /f/. Participant T2, however, had acquired /v/ by the postreatment probe. The studies of normal acquisition reviewed earlier reported /v/ as one of the later developing fricatives. This suggests that acquisition may not follow the normal path in this child's case and more direct treatment may be needed before sounds missing from the phonetic inventory will be acquired. Acquisition of the normally later acquired /v/ cannot be explained by treatment because /s/ was the targeted fricative and expected to develop earlier than /v/.

At the beginning of the study, Participant T3 produced /ð/, a reportedly later developing fricative. As discussed earlier, Moskowitz (1975) reported having observed an interdental in early development. That interdental, /θ/, disappeared from the phonetic inventory and emerged again much later in development. Children in Moskowitz's study, however, did produce other early developing fricatives as well, whereas T3 did not. Participant T3 was taught /s/ and acquired this sound as well as /f θ ð z/. The palatal /ʃ/, however, was not acquired and would be expected to occur before the interdentals according to Ferguson (1978).

Pretreatment, T4's phonetic inventory appeared very similar to that of T3. It included only one fricative, /v/, a presumably later developing fricative. Following training of /s/, T4 added /f θ ð s/ to his inventory and was stimulable for production of /z/ but not /ʃ/. T4's fricative inventory did not include a palatal before acquiring the interdentals.

Thus, three of the treatment participants did not follow the most generally reported order of acquisition of voiceless fricatives, that is, /f/ and /s/ followed by /ʃ/ and finally /θ/. If their inventories are studied in a broader sense, all children except for participant T1 complied with the typological universals described by Dinnsen, Chin, Elbert, and Powell (1990). Inventories that contained fricatives also contained stops, nasals, and glides. If an inventory contained a stridency distinction among the fricatives, then the inventory also contained at least one liquid. The only exception was T1, whose phonetic inventory contained a stridency distinction among the fricatives but did not contain a liquid consonant. Although T1 was stimulable for production of /l/ posttreatment, the sound did not meet criteria for inclusion in the inventory. A larger speech sample may have revealed more productions of this sound.

Stimulability and Treatment Planning

Stimulability assists in the prioritization of sounds to target for treatment (Powell & Miccio, 1996). This study supported the rationale that nonstimulable sounds should be given high priority in treatment plans (Powell et al., 1991; Powell & Miccio, 1996) because sounds that are stimulable are most likely to be added to the phonetic inventory without direct intervention.

In this study, children were first taught to imitate sounds and then production was extended to words. McReynolds (1981) reviewed generalization in articulation learning and concluded "learning to imitate production of the target sound consistently is more important to generalization than contextual and other variables which have been studied." (p. 246). Results of treatment research also suggest that imitation may be a prerequisite to generalization (Powell, Elbert, Miccio, Strike-Roussos, & Brasseur, 1998; Saben & Ingham, 1991). If so, the clinician should address nonstimulable sounds early in the treatment sequence through direct imitation (Miccio & Elbert, 1996; Powell, 1996). Without treatment, nonstimulable sounds are highly unlikely to change (Powell et al., 1991).

In this study, some of the participants had difficulty producing the treatment targets in words and minimal pair contrasts. Despite these difficulties, posttreatment and follow-up probes showed that, with the exception of T2, treated sounds were acquired and correct production spread to untreated words containing these sounds. Thus, although some of the tasks appeared unusually difficult at the time of treatment, learning was taking place. The sounds became stimulable for production and were acquired as predicted.

Miccio and Elbert (1996) provided evidence of the success of a program designed to enhance stimulability for production of sounds absent from a child's phonetic inventory. In this program, children are provided with multiple opportunities to imitate the clinician's use of the missing sounds in isolation and single words through turn-taking and requesting activities. Although the children are not required to imitate the clinician, the nature of the treatment activities encourages production practice and indirectly provides multiple opportunities for imitation. This compromise provides the opportunity for in depth production practice in a more naturalistic format than drill. This approach may be especially helpful for younger children.

In this study, stimulable sounds were acquired as predicted. In addition, other members of the fricative class were often acquired. For the most part sounds that participants produced correctly in some contexts continued to generalize without direct treatment. Participant T1, for example, produced the velar stops in the final position and intervocalically before treatment. These sounds, however, were excluded from the word-initial position. Following treatment on /ʃ/, velar stops occurred across word positions. Participant T2, on the other hand, did not produce velar stops before treatment and these sounds continued to be excluded from the phonetic inventory and nonstimulable following treatment. Because these sounds continued to be resistant to change, it is likely they would require direct treatment. Stimulability should alert the clinician to look for subsequent changes in children's productions. Sounds that are produced in restricted word positions should gradually spread across word positions and error patterns should be eliminated. If stimulable sounds do not begin to emerge in real words, or if generalization does not spread across word positions in subsequent probes, acquisition may not be occurring as predicted. Sounds that are resistant to change are candidates for further direct treatment.

Does stimulability represent a phonetic skill or a phonological skill?

Although one can speculate that the stimulable sounds were developing normally, it is possible that the participants in this study learned because of indirect relationships between untreated and treated sounds. In the treatment study, all treated sounds were fricatives and the sounds most affected were also fricatives or affricates. T2 was missing velar stops at the beginning of the study and these sounds were nonstimulable at the end of the study. Affricates, on the other hand, were acquired. This suggests that the velar problem may be one of place of articulation and require direct treatment. All treatment participants with missing affricates either acquired them or were stimulable for production of an affricate by the end of the study suggesting that attention paid to the feature [continuant] during treatment may have assisted in acquisition of affricates with the features [–continuant] [+continuant] (Bernhardt & Stoel-Gammon, 1994). It appears that increased understanding of a feature leads to further acquisition of other sounds that share that feature (McReynolds & Bennett, 1972; Powell, Miccio, Elbert, Brasseur, & Strike-Roussos, 1999).

Little evidence of change in sonorants was noted among treatment participants. All had already acquired glides and most nasals at the beginning of the study. Liquids were little affected by treatment of fricatives. Participants T1 and T2 were missing this sound class at the beginning of the study. Although T1 was stimulable for [l] at the end of the study, liquids continued to be restricted from T2's inventory and nonstimulable. In this study, three of the children with normally developing phonologies had already acquired all English sonorant consonants at the beginning of the study. Although C4 had not acquired /r/ and was not stimulable for its production, it was fully acquired by the Month 6 analysis.

Locke (1983) argues that all things phonologic are phonetic. Attention to the physical aspects of sound production assists the organization of the sound system and treatment may assist the interaction among subsystems. In other words, the ideal model of phonological acquisition de-emphasizes the separation of phonetic and phonemic aspects of development (Ferguson & Farwell, 1975).

If stimulable sounds represent greater productive knowledge of the phonological system than nonstimulable sounds, then treatment of stimulable sounds should not affect production of unrelated stimulable sounds or nonstimulable sounds. Following treatment on a nonstimulable sound, however, one expects improvement in stimulable sounds that are known to some degree (Dinnsen & Elbert, 1984; Elbert, Dinnsen, & Powell, 1984; Fey & Stalker, 1986; Gierut, Elbert, & Dinnsen, 1987; Powell et al., 1991). Thus, it appears that stimulability does demonstrate some degree of phonological knowledge of the phoneme in question.

Participants in this study were presumed to have normal cognitive ability based on parent questionnaire and language testing. Thus, it cannot be assumed that the generalization to untrained consonants would necessarily occur in children with other identifiable contributing factors such as developmental delays in cognition. Research suggests that the error patterns of persons with cognitive impairments are similar to those of younger normally developing children (Bleile, 1982; Smith & Stoel-Gammon, 1983) and children with phonological delays (Shriberg & Widder, 1990). The amount and extent of generalization following treatment has received little attention. It is likely that more extended treatment and direct attention to generalization would be necessary for sounds to spread across the system. It is also likely that stimulable sounds would generalize more rapidly and nonstimulable sounds would require the most attention.

In this investigation, phonological change in children was studied both as a function of maturation and as a function of treatment. In both cases, stimulability was related to the learning patterns observed. Children with normally developing phonologies acquired stimulability sounds within a few months of their identification. Children with disordered phonologies acquired stimulable sounds regardless of the treatment targets. This study supports the hypothesis that treatment may be most efficient when priority is given to sounds that are unlikely to change without treatment. In addition, stimulability appears to signal that sounds are developing naturally.

Author Note

This work was supported in part by a grant from the National Institutes of Health (DC00260). Gratitude is extended to Julie Church, Michael Gettleman, Penny Huddleston, Kelly Klecka, Risa Kruphoff, Tina Leslie, Lauri Peter and Lynn Utterback for their assistance in data collection. We would especially like to thank two anonymous reviewers for their helpful comments on an earlier version of this manuscript.

References

American National Standards Institute (ANSI). (1969). *Specifications for audiometers* (ANSI S3.6-1969). New York: ANSI.

Bain, B. A. (1994). A framework for dynamic assessment in phonology: Stimulability revisited. *Clinics in Communication Disorders*, *4*, 12–22.

Bernhardt, B. H., & Stoel-Gammon, C. (1994). Nonlinear phonology: Introduction and clinical application. *Journal of Speech and Hearing Research*, *37*, 123–143.

Bernthal, J. E., & Bankson, N. E. (1998). *Articulation and phonological disorders* (4th ed.). Boston: Allyn & Bacon.

Bleile, K. (1982). Consonant ordering in Down's Syndrome. *Journal of Communicative Disorders*, *15*, 275–285.

Carter, E. T., & Buck, M. W. (1958). Prognostic testing for functional articulation disorders among children in the first grade. *Journal of Speech and Hearing Disorders*, *23*, 124–133.

Diedrich, W. (1983). Stimulability and articulation disorders. *Seminars in Speech and Language*, *4*, 297–311.

Dinnsen, D. A., Chin, S. B., Elbert, M., & Powell, T. W. (1990). Some constraints on functionally disordered phonologies: Phonetic inventories and phonotactics. *Journal of Speech and Hearing Research*, *34*, 1318–1328.

Dinnsen, D. A., & Elbert, M. (1984). On the relationship between phonology and learning. In M. Elbert, D. A. Dinnsen, & G. Weismer (Eds.), Phonological theory and the misarticulating child. (*ASHA Monographs*, *22*, pp. 59–68.)

Dunn, L. M., & Dunn, L. M. (1981). *Peabody Picture Vocabulary Test–Revised.* Circle Pines, MN: American Guidance Service.

Edwards, M. L. (1979). Word position in fricative acquisition. *Papers and Reports in Child Language Development*, *16*, 67–75.

Elbert, M., Dinnsen, D. A., & Powell, T. W. (1984). On the prediction of phonologic generalization learning patterns. *Journal of Speech and Hearing Disorders*, *49*, 309–317.

Elbert, M., & McReynolds, L. V. (1978). An experimental analysis of misarticulating children's generalization. *Journal of Speech and Hearing Research*, *34,* 81–87.

Elbert, M., Rockman, B. K., & Saltzman, D. (1980). *Contrasts: The use of minimal pairs in articulation training*. Austin, TX: Pro-Ed.

Farquhar, M. S. (1961). Prognostic value of imitative and auditory discrimination tests. *Journal of Speech and Hearing Disorders*, *26*, 342–347.

Ferguson, C. (1978). Fricatives in child language acquisition. In V. Honsa & M. N. Hardman-Bautista (Eds.), *Papers on linguistics and child language* (pp. 647–664). The Hague, Netherlands: Mouton.

Ferguson, C., & Farwell, C. (1975). Words and sounds in early language acquisition. *Language*, *51*, 419–439.

Fey, M. E., & Stalker, C. H. (1986). A hypothesis-testing approach to treatment of a child with an idiosyncratic (morpho)phonological system. *Journal of Speech and Hearing Disorders*, *41*, 324–335.

Gierut, J. A., Elbert, M., & Dinnsen, D. A. (1987). A functional analysis of phonological knowledge and generalization learning in misarticulating children. *Journal of Speech and Hearing Research*, *30*, 462–479.

Goldman, R., & Fristoe, M. (1986). *Goldman-Fristoe Test of Articulation*. Circle Pines, MN: American Guidance Service.

Hresko, W. P., Reid, D. K., & Hammill, D. D. (1991). *The Test of Early Language Development* (2nd ed.). Austin, TX: Pro-Ed.

Irwin, R. B., West, J. F., & Trombetta, M. A. (1966). Effectiveness of speech therapy for second grade children with misarticulations—Predictive factors. *Exceptional Children*, *32*, 471–479.

Kwiatkowski, J., & Shriberg, L. D. (1993). Speech normalization in developmental phonological disorders: A retrospective study of capability-focus theory. *Language, Speech, and Hearing Services in Schools*, *24*, 10–18.

Locke, J. L. (1983). Clinical phonology: The explanation and treatment of speech sound disorders. *Journal of Speech and Hearing Disorders*, *48*, 339–341.

McReynolds, L. V. (1981). Generalization in articulation training. *Analysis and Intervention in Developmental Disabilities*, *1*, 245–258.

McReynolds, L. V., & Bennett, S. (1972). Distinctive feature generalization in articulation training. *Journal of Speech and Hearing Disorders*, *37*, 462–470.

McReynolds, L. V., & Kearns, K. P. (1983). *Single-subject experimental designs in communicative disorders*. Austin, TX: Pro-Ed.

Miccio, A. W. (1995a). Metaphon: Factors contributing to treatment outcomes. *Clinical Linguistics and Phonetics*, *9*, 28–36.

Miccio, A. W. (1995b). *A spectral moments analysis of the acquisition of word-initial voiceless fricatives in children with normal and disordered phonologies.* Unpublished doctoral dissertation, Indiana University, Bloomington.

Miccio, A. W., & Elbert, M. (1996). Enhancing stimulability: A treatment program. *Journal of Communication Disorders, 29*, 335–352.

Milisen, R. (1954). The disorder of articulation: A systematic clinical and experimental approach. *Journal of Speech and Hearing Disorders, Monograph Supplement 4.*

Moskowitz, B. A. (1975). The acquisition of fricatives: A study in phonetics and phonology. *Language*, *46*, 426–441.

Pollock, E., & Rees, N. (1972). Disorders of articulation: Some clinical applications of distinctive feature theory. *Journal of Speech and Hearing Disorders*, *37*, 451–470.

Powell, T. W. (1996). Stimulability considerations in the phonological treatment of a child with a persistent disorder of speech-sound production. *Journal of Communication Disorders, 29*, 314–334.

Powell, T. W., & Elbert, M. (1984). Generalization following the remediation of early- and later-developing consonant clusters. *Journal of Speech and Hearing Disorders, 49*, 211–218.

Powell, T. W., Elbert, M., & Dinnsen, D. A. (1991). Stimulability as a factor in the phonological generalization of misarticulating preschool children. *Journal of Speech and Hearing Research*, *34*, 1318–1328.

Powell, T. W., Elbert, M., Miccio, A. W., Strike-Roussos, C., & Brasseur, J. (1998). Facilitating [s] production in young children: An experimental evaluation of motoric and conceptual treatment approaches. *Clinical Linguistics & Phonetics*, *12*, 127–146.

Powell, T. W., & Miccio, A. W. (1996). Stimulability: A useful clinical tool. *Journal of Communication Disorders*, *29*, 237–254.
Powell, T. W., Miccio, A. W., Elbert, M., Brasseur, J., & Strike-Roussos, C. (1999). Patterns of sound change in children with phonological disorders. *Clinical Linguistics & Phonetics*, *13*, 163–182.
Rvachew, S., Rafaat, S., & Martin, M. (1999). Stimulability, speech perception skills, and the treatment of phonological disorders. *American Journal of Speech-Language Pathology*, *8*, 33–43.
Saben, C. B., & Ingham, J. C. (1991). The effects of minimal pairs treatment on the speech-sound production of two children with phonologic disorders. *Journal of Speech and Hearing Research*, *34*, 1023–1040.
Shelton, R., Hahn, E., & Morris, H. L. (1968). Diagnosis and therapy. In D. Spriestersbach & D. Sherman (Eds.), *Cleft palate and communication* (pp. 225–248). New York: Academic Press.
Shelton, R. L., & McReynolds, L. V. (1979). Functional articulation disorders: Preliminaries to treatment. In N. J. Lass (Ed.), *Speech and language: Advances in basic research and practice* (Vol. 2, pp. 1–111). New York: Academic Press.
Shriberg, L. D., & Widder, C. (1990). Speech and prosody characteristics of adults with mental retardation. *Journal of Speech and Hearing Research*, *33*, 627–653.
Smit, A. B. (1993). Phonologic error distributions in the Iowa-Nebraska Articulation Norms Project: Consonant singletons. *Journal of Speech and Hearing Research*, *36*, 533–547.
Smit, A. B., Hand, L., Freilinger, J. J., Bernthal, J. E., & Bird, A. (1990). The Iowa Articulation Norms Project and its Nebraska replication. *Journal of Speech and Hearing Disorders*, *55*, 779–798.
Smith, B., & Stoel-Gammon, C. (1983). A longitudinal study of the development of stop consonant production in normal and Down's syndrome children. *Journal of Speech and Hearing Disorders*, *48*, 114–118.
Snow, K., & Milisen, R. (1954). The influence of oral versus pictorial presentation upon articulation testing results. *Journal of Speech and Hearing Disorders, Monograph Supplement*, *4*, 45–50.
Somers, R. K., Leiss, R. H., Delp, M., Gerber, A., Fundrella, D., Smith, R., Revucky, M., Ellis, D., & Haley, V. (1967). Factors related to the effectiveness of articulation therapy for kindergarten, first, and second grade children. *Journal of Speech and Hearing Research*, *13*, 428–437.
St. Louis, K., & Ruscello, D. (1986). *Oral Speech Mechanism Screening Examination–Revised*. Austin, TX: Pro-Ed.
Stoel-Gammon, C. (1985). Phonetic inventories, 15–24 months: A longitudinal study. *Journal of Speech and Hearing Research*, *28*, 505–512.
Turton, L. J. (1973). Diagnostic implications of articulation testing. In W. Wolfe & D. Goulding (Eds.), *Articulation and learning* (pp. 195–218). Springfield, IL: Charles C. Thomas.
Tyler, A. A., Edwards, M. L., & Saxman, J. H. (1987). Clinical application of two phonologically based treatment procedures. *Journal of Speech and Hearing Disorders*, *53*, 393–409.

Received January 4, 1999
Accepted June 30, 1999

Contact author: Adele W. Miccio, PhD, Department of Communication Disorders, The Pennsylvania State University, 110 Moore Bldg, University Park, PA 16802.
Email: awm4@psu.edu.

Appendix A

Treated Sound Probes

	Participant T1: Target [ʃ] (Substitution [s])	Participant T2: Target [s] (Substitution [t])	Participants T3 and T4: Target [s] (Substitution [θ])
1.	sheet	seal[a]	sack[a]
2.	sugar	sad[a]	sour[a]
3.	crash	ice	ice
4.	wash	goose	goose
5.	shop	sail	sail
6.	trash	mouse	mouse
7.	shirt	salt	salt
8.	shake	gas	gas
9.	leash	sub[a]	song[a]
10.	shape	soak	soak
11.	sharp	face	face
12.	splash	soft	soft
13.	shark	mess	mess
14.	bush	bus	bus
15.	smash	Sam	Sam
16.	brush	grass	grass
17.	washing	icing	icing
18.	splashing	grassy	grassy
19.	ocean	dinosaur	dinosaur
20.	brushing	messy	messy

[a]These probe items for Participant T2 differed from those of participants T3 and T4 because of the different substitutions for the target sounds. Words were used to form minimal pairs for treatment.

Appendix B

Treatment Generalization Probe

1. thimble	21. brother	41. fudge
2. thirsty	22. buzz	42. chess
3. teeth	23. food	43. jelly
4. teethy	24. zipper	44. garbage
5. bath	25. cave	45. teach
6. soak[a]	26. puzzle	46. ladder
7. sad[a]	27. valentine	47. Lab
8. ice[a]	28. Goofy	48. red
9. icing[a]	29. giraffe	49. doll
10. mouse[a]	30. oven	50. headphones
11. wash[b]	31. feather	
12. sheet[b]	32. give	
13. brush[b]	33. cheese	
14. brushing[b]	34. burger	
15. sharp[b]	35. ketchup	
16. knife	36. Mickey	
17. vine	37. rug	
18. zoom	38. magic	
19. they	39. dig	
20. that	40. watch	

[a]Included for Participant T1; [b]included for Participants T2–4.