Phonological Treatment Efficacy and Developmental Norms

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A key aim of phonological intervention is to induce or facilitate change in a child's sound system. Phonological change through treatment is intended to bring a child's errored sound system more in line with the ambient phonology. Phonological change may be incurred at the level of the treated target phoneme or it

ABSTRACT: The efficacy of teaching sounds in developmental sequence as defined by age norms was evaluated in two independent investigations. Study I was a within-subject evaluation using an alternating treatments design, with three children each receiving treatment on one early-acquired and one later-acquired phoneme relative to chronological age. Study II was an across-subject evaluation involving six children in a staggered multiple baseline paradigm, whereby three subjects were each taught one early-acquired sound and three other subjects were taught one later-acquired sound relative to chronological age. Phonological change was measured on probes of sounds excluded from each child's phonemic inventory.

General results indicated that: (a) quantitatively, change in treated phonemes and manner classes was equivocal following treatment of early-acquired and later-acquired phonemes; (b) qualitatively, the onset of change was immediate following treatment of later-acquired phonemes, but delayed following treatment of early-acquired phonemes; and (c) treatment of later-acquired phonemes led to system-wide changes in untreated sound classes, whereas treatment of early-acquired phonemes did not. These findings were considered relative to clinical intervention and theories of phonological acquisition.

KEY WORDS: phonological disorders, phonological treatment, treatment efficacy, developmental norms

may be more widespread, affecting the overall structure and composition of a child's sound system.

From both clinical and research perspectives, the occurrence of phonological change—particularly broad system-wide improvements—has been taken as evidence of treatment efficacy (Olswang, 1990). In planning intervention then, it is important to consider those factors that may facilitate phonological change not only in treated sounds, but perhaps more importantly, in untreated (errored) aspects of the child's phonology.

The selection of target phonemes for treatment is one aspect of intervention that can be programmed specifically to facilitate broad change in children's sound systems. A variety of factors have been cited as relevant to the selection process, including, for example, the age of the child, age-appropriateness of the error relative to normative reports of sound mastery, consistency of the pattern of production, and intelligibility (see Powell, 1991 for review).

Recently, renewed concerns regarding treatment efficacy have motivated the experimental evaluation of these factors in inducing sound change (American Speech-Language-Hearing Foundation and the National Institute on Deafness and Other Communication Disorders, 1992). To date, seven factors have been assessed experimentally: stimulability, phonetic complexity, acoustic phonetic differentiation, markedness, phonological knowledge, homonymy, and phonemic complexity.

It is noteworthy that the efficiency of treatment associated with these factors has only been examined systematically from the perspective of improvements in performance, but not in terms of the time needed to complete treatment. Nonetheless, as a first step, this line of efficacy research has made it possible to identify conditions that will likely ensure extensive phonological change in a given child's sound system. Although preliminary, the research is of

clinical importance for structuring optimal intervention programs, and empirically validates the role certain factors play in the selection of target phonemes for treatment.

The goal of the present studies is to continue the experimental evaluation of treatment efficacy associated with the selection of target phonemes. In particular, developmental age norms as a metric for target phoneme selection were assessed. The recommendation that phonological treatment proceed in a manner consistent with normative reports of sound mastery was tested.

By way of introduction, a review of the general efficacy findings associated with the selection of target phonemes for treatment is first presented; this is followed by consideration and discussion of the age norm hypothesis being directly tested. At first glance, the studies may appear to be unrelated, but it will be shown that a common theme seems to emerge in the selection of target phonemes for treatment.

TARGET SELECTION: PHONETIC FACTORS[1]

With regard to the phonetic level of production, stimulability, phonetic complexity, and acoustic phonetic differentiation have all received attention. Specifically, one long-standing recommendation has been to teach stimulable rather than nonstimulable sounds (Hodson & Paden, 1991; Winitz, 1975). This is intuitively appealing because presumably, if a child is able to approximate phonetic placement and quality of a target sound, learning may be enhanced. Until most recently, however, this recommendation had not been tested.

Does treatment of a stimulable phoneme result in the greatest phonological change? In consideration of this question, Powell, Elbert, and Dinnsen (1991) demonstrated that the reverse was true. Treatment of a nonstimulable phoneme prompted change in that treated target as well as other untreated stimulable sounds. In contrast, treatment of a stimulable phoneme did not lead to changes in untreated stimulable or nonstimulable sounds. From the results of this initial study, nonstimulable phonemes may be preferred

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[1] Throughout this report, the terms *phonetic* and *phonemic* will be used consistent with conventional linguistic definitions that have been established in the literature (Kenstowicz, 1994). These definitions have also been applied to the study of the sound systems of children with phonological disorders (Dinnsen, 1984). In particular, the phonetic inventory refers to the sounds a child produces regardless if correct relative to the ambient language. The phonetic inventory is determined from a two time occurrence of phones (Stoel-Gammon, 1985). That is, any sound that occurs twice in a sample is considered part of the phonetic repertoire.

The phonemic inventory refers to those sounds that are used to signal meaning differences among morphemes. The phonemic inventory is determined from the occurrence of minimal pairs, also requiring a two time occurrence (Gierut, Simmerman, & Neumann, 1994). Minimal pairs are based on the child's contrastive use of sounds, as in [b u] "boot" and [k u] "cool" where /b/ and /k/ function to signal meaning differences among these morphemes. Like the phonetic inventory, the phonemic inventory may not be identical to the ambient language. It is often the case that the phonemic inventory consists of fewer segments than the phonetic inventory, and thus provides the more conservative estimate of a child's phonological system. For this reason, the phonemic inventory will be the focus of the present experimental studies.

sounds for treatment because they seem to facilitate greater phonological change overall.

Another consideration in the selection of target phonemes relates to ease of production. Here, the recommendation has been to teach target phonemes that are phonetically (or alternatively, motorically) less complex in order to enhance learning because it is possible that certain simpler skills may be required for mastery of more complex skills (Bernthal & Bankson, 1993; Hodson & Paden, 1991; Winitz, 1969; see, however, Kent, 1992 for difficulties in establishing complexity). In evaluation of this, Tyler and Figurski (1994) found that greater phonological change did not occur in this condition; rather, more extensive change was observed when treatment focused on more complex phonetic distinctions (cf. Dinnsen, Chin, Elbert, & Powell, 1990). Treatment of phonetically complex distinctions prompted change in these and other less complex distinctions, but the reverse was not observed in this study.

A related finding has emerged from examinations of the role of acoustic phonetic distinctions in phonological learning. Namely, some research has shown that if a child does not produce an auditorily perceptible contrast among phonemes, and further does not mark an acoustic distinction among these sounds, then treatment of the distinction is necessarily required to induce phonological change (Tyler, Edwards, & Saxman, 1990). However, if an acoustic (but not auditorily perceptible) contrast is maintained, then treatment may be either unnecessary (Forrest, Weismer, Hodge, Dinnsen, & Elbert, 1990) or mastery in conjunction with treatment may be quite rapid (Tyler, Figurski, & Langsdale, 1993). From these few available studies, acoustic distinctions appear to be predictors of imminent change and require no or minimal treatment. Instead, distinctions that are not marked auditorily or acoustically seem to warrant clinical consideration.

Taken together, these initial results of efficacy research aimed at the phonetic level of production appear to support the selection of sounds for treatment that are nonstimulable, phonetically complex, and acoustically and auditorily undifferentiated.

TARGET SELECTION: PHONEMIC FACTORS

From a phonemic perspective, four additional factors often considered in the selection of sounds for treatment have been assessed experimentally. With regard to a first factor, markedness, several studies have shown that treatment of more marked aspects of the phonological system facilitates the acquisition of unmarked properties, but not vice versa. This finding has been reported in the acquisition of: (a) voiced as opposed to voiceless obstruents (McReynolds & Jetzke, 1986), (b) voicing of stops in word-final as opposed to word-initial position (Rockman, 1983), (c) fricatives as opposed to stops (Dinnsen & Elbert, 1984), (d) clusters as opposed to singletons (Elbert & McReynolds, 1978; Gallagher & Shriner, 1975), and (e) marked clusters as opposed to unmarked clusters (Elbert,

Dinnsen, & Powell, 1984). The markedness factor may have broader applicability in that it apparently holds for learners with hearing impairments and those acquiring a second language (Eckman, 1977, 1985; Gass, 1979; Hawkins, 1987; Hyltenstam, 1984; McReynolds & Jetzke, 1986).

In terms of a second factor, productive phonological knowledge, a preliminary finding has been that treatment of phonemes of which a child has least knowledge results in extensive phonological change (Gierut, Elbert, & Dinnsen, 1987). Operationally, this translates to treatment of sounds that are excluded phonetically and phonemically from a child's system as defined by inventory constraints. Treatment aimed at constraints on the inventory in an attempt to increase the number and type of segments and distinctions produced by a child induced broad system-wide phonological changes. This was in comparison to the treatment of sounds affected by phonological rules, whereby limited changes in the overall sound system occurred.

A third phonemic factor is associated with the reduction of homonymy in a child's output. One recommendation has been that an explicit focus on homonymy through the presentation of minimal pairs will assist a child in disambiguating a phonemic contrast that has been collapsed (Ingram, 1989b; Leonard, 1985; Weiner, 1981). Contrary to this suggestion, others have proposed that homonymy in a child's system may be eliminated more readily if the distinctions in question are not explicitly paired (Johnston & Smith, 1989; Kornfeld & Goehl, 1974; Locke, 1979; Priestly, 1980; Weiner & Ostrowski, 1979). Two available treatment studies lend support to this latter proposal (Gierut, 1991; Gierut & Neumann, 1992): Greater phonological change resulted from the introduction of two new target phonemes in comparison to each other, rather than through the pairing of a new phoneme and its associated error substitution.

A final factor considered in the selection of sounds for treatment relates to phonemic complexity. Efficacy research specific to the minimal pair paradigm of intervention has demonstrated that treatment of phonemes that differ by major class distinctions (i.e., [consonantal], [sonorant], [syllabic]) induced more extensive change in a child's phonology (Gierut, 1990, 1992). Also, treatment of phonemes differing by maximal distinctive features facilitated greater change than pairs differing by few distinctive featural properties (Gierut, 1989, 1990). These results highlighted two additional considerations in the selection of target phonemes for treatment, namely, major class distinctions and maximal feature differences.

Collectively, the available findings suggest that, to induce the greatest phonological change at a phonemic level, consideration might be given to marked phonemes excluded from a child's inventory that differ by major class and maximal features in order to introduce new distinctions in the system. These phonemic considerations, in combination with phonetic factors described previously, will likely result in the broadest phonological change. Given this, these factors appear to be among those relevant to the selection of target phonemes for treatment.

TARGET SELECTION: DEVELOPMENTAL AGE NORMS

An additional recommendation has been that a target phoneme selected for treatment should be generally consistent with its expected emergence in normal phonological development (e.g., Ingram, 1989b; Khan & Lewis, 1990; Shriberg & Kwiatkowski, 1980; Smit, Hand, Freilinger, Bernthal, & Bird, 1990; VanRiper & Irwin, 1958). That is, a phoneme may be considered a potential candidate for treatment if it is typically mastered by younger children but has yet to be learned by a given older child with a phonological problem.

Although this recommendation is a logical extension of maturational accounts of learning (e.g., Brown, 1973; deVilliers & deVilliers, 1978; Prutting, 1979), it relies on certain inherent assumptions. First, it is implicit in this approach to target phoneme selection that children with phonological disorders mirror a normal pattern of sound learning (Dinnsen, 1992; Dinnsen et al., 1990; Ingram, 1989b; Leonard, 1992). That is, children who are normally developing or phonologically disordered constitute one and the same population, with the child who is phonologically disordered being "delayed" in phonemic acquisition.

Second, this approach broadly conforms to the underlying premises of developmental stage models, namely, continuity, complexity, and necessity (Ingram 1989a; Winitz, 1969). Specifically, the acquisition of phonemes is presumed to follow a sequence, such that sounds will be learned in a particular order. This order of acquisition becomes increasingly more complex, with early-acquired phonemes considered easiest to learn and later-acquired phonemes more difficult. Also, mastery of a given phoneme is taken to be a prerequisite for the acquisition of other phonemes.

Several investigators have questioned the validity of these assumptions (Ingram, 1988; Ingram, Christensen, Veach, & Webster, 1980; Leonard & Brown, 1984; Macken, 1980; Vihman, Ferguson, & Elbert, 1986). Others have cautioned against the appropriateness of relying on developmental norms in the selection of target phonemes for treatment (Bernthal & Bankson, 1984, 1993; Edwards & Shriberg, 1983; Ingram, 1989a; Winitz, 1969).

Despite these concerns, there has been no experimental demonstration of the efficacy of treatment programs that directly parallel age norms of sound mastery (cf. Dyer, Santarcangelo, & Luce, 1987). That is, it has not yet been established whether greater phonological change results when a child is taught presumably early-acquired phonemes relative to chronological age. The question thus remains: Will greater phonological change occur in a given sound system following treatment of an early-acquired versus a later-acquired phoneme?

This article reports two independent studies of treatment efficacy associated with the recommendation that target phoneme selection follow a developmental sequence. Study I was a within-subject evaluation of relative treatment efficacy, with three children each receiving treatment on one early-acquired and one later-acquired phoneme as determined from developmental norms relative to chronological age. In

complement, Study II was an across-subject evaluation of absolute treatment effects, whereby three children were each taught one early-acquired phoneme and three others were taught one later-acquired phoneme relative to chronological age. Phonological change was measured on probes administered during and following treatment.

On the one hand, if results show relatively greater phonological change following treatment consistent with normative reports of sound mastery, then this would be supported empirically as the more efficacious teaching condition. On the other hand, if the reverse occurs and greater phonological change follows the treatment of later-acquired sounds, then the validity of a developmental approach to target phoneme selection may be called into question. In either case, the results to emerge have consequences for the structure of clinical intervention and implications for models of phonological acquisition.

GENERAL METHODS

Subjects

Nine children with phonological disorders served as subjects in the two studies. Three girls, ages 3:7 to 5:6 (years:months), participated in Study I; 5 boys and 1 girl, ages 3:5 to 5:6, participated in Study II. All children met the following entry criteria:

- a minimum of 28 errors on the Goldman-Fristoe Test of Articulation (Goldman & Fristoe, 1986), with a corresponding percentile score not to exceed 5%;

- exclusion of a minimum of five target English sounds from the phonemic inventory as established by a standard generative phonological analysis;

- normal hearing as determined by a standard audiometric screening (ASHA, 1985);

- normal oral and speech motor abilities as determined by performance on the protocol developed by Robbins and Klee (1987);

- normal intelligence as assessed on the Leiter International Performance Scale (Arthur Adaptation, Levine, 1986);

- no prior clinical intervention; and

- residency in a monolingual English-speaking home.

General language abilities were also sampled using either the Test of Language Development–2 Primary (for subjects age 4 and older; Newcomer & Hammill, 1988) or the Test of Early Language Development (for those younger than 4 years; Hresko, Reid, & Hammill, 1981). Although these test results were not used to determine eligibility for participation, children's performance was within normal limits on these measures.

Phonological Descriptions

In each of the two studies, standard generative phonological descriptions were developed for each child before treatment based on extended samples of spontaneous connected speech and the 198-item Phonological Knowledge Protocol (PKP; Gierut, 1985). Generative descriptions provide an independent (as compared to a relational) analysis of a child's sound system. Such descriptions include a characterization of phonetic and phonemic inventories, allophonic and/or neutralization rules, and positional and inventory constraints on the distribution and occurrence of sounds, respectively. (For a detailed discussion of generative phonological analyses, see Dinnsen [1984], Gierut [1986], and Kenstowicz [1994].)

In these studies, children's phonemic inventories were of central importance because they provide a conservative estimate of the functional units of a sound system.[1] Further, only those target phonemes excluded by inventory constraints were examined in treatment. Inventory constraints correspond to the category "least phonological knowledge" (Gierut et al., 1987), and are formalized as redundancy statements that capture generalities about the classes of sounds excluded from an inventory (Gierut, 1992).

Inventory constraints have been operationalized qualitatively and quantitatively as follows. Qualitatively, these are phonemes of the ambient language that are never produced or used contrastively by the child in any word positions or in any morphemes. That is, these target phonemes do not function phonemically to distinguish meaning as evidenced by the lack of occurrence of minimal pairs (cf. criteria outlined by Gierut, Simmerman, & Neumann, 1994). Quantitatively, target phonemes excluded from the inventory are produced with 0% baseline accuracy in all non-imitative contexts.

Target phonemes excluded from each child's pretreatment inventory are displayed in Tables 1 and 2. From these, general observations can be made concerning the classes of sounds that posed the greatest difficulty for all children across both studies. In particular, all children excluded liquids and fricatives from the phonemic inventory. For liquids, some children excluded /l/, some /r/, and others both /l r/. For fricatives, even though there were gaps in the inventories, all children did produce at least one fricative pair. Approximately half the subjects had further restrictions on the occurrence of affricates and/or velar stops (both oral and nasal).

Stimulability of phonemes excluded from the inventory was not directly or formally assessed because it is not standard to the development of generative descriptions. However, there was some indication that the particular phonemes selected for treatment for each child were stimulable because, during the initial phases of treatment, all children were capable of imitating the treated phonemes following the clinician's model (see "Treatment Procedures," following). Based on this observation, it might be tentatively said that all children received treatment on stimulable phonemes. The stimulability status of all other phonemes excluded from the inventories was not known.

Relational analyses of substitution patterns were also not part of the development of generative descriptions. However, it can be said that the children of these two studies were highly variable in their substitutions. On average, a child produced four different substitutes for any given

Table 1. Study I subjects, phonemes excluded from the inventory, and phonemes treated. Phonemes excluded are listed beginning with the sound presumed to be first acquired according to Prather et al.[a] or Templin normative data:[b] parenthetical ages reflect the reported 75% criterion of mastery.

Subject	Sex	Age (y:m)	GFTA errors	percentile	Phonemes excluded	Phonemes treated early acquired	later acquired
EL1	F	3:7	47	1%	η (2:0)[a] l r (3:4) š č (3:8) ð (4:0) v θ ǰ (4:0+)	l	v
EL2	F	3:7	48	1-%	η (2:0)[a] k (2:4) g (3:0) l r (3:4) š č (3:8) ð (4:0) θ z ǰ (4:0+)	k	ǰ
EL3	F	5:6	28	4%	r (4:0)[b] š (4:6) θ l (6:0) ð (7:0)	r	ð

Table 2. Study II subjects, phonemes excluded from the inventory, and phoneme treated. Phonemes excluded are listed beginning with that sound presumed to be first acquired according to the Smit et al. normative data: parenthetical ages reflect the reported 90% criterion of mastery by sex.

Subject	Sex	Age (y:m)	GFTA errors	percentile	Phonemes excluded	Phoneme treated
E1	M	4:11	55	1-%	k f (3:6) g (4:0) v (5:6) ð š č ǰ (7:0) θ r (8:0)	k
E2	M	5:6	42	1-%	k (3:6) g (4:0) l (6:0) ð (7:0) θ (8:0) η s z (7:0–9:0)	g
E3	M	4:8	32	5%	f (3:6) v (5:6) ð (7:0) θ r (8:0)	f
L1	F	3:5	45	1%	f (3:6) ð (4:6) v (5:6) θ š č ǰ (6:0) r (8:0)	r
L2	M	5:0	32	4%	l (6:0) ð š č ǰ (7:0) θ r (8:0)	θ
L3	M	4:10	47	1-%	l (6:0) ð š (7:0) θ (8:0) s z (7:0–9:0)	s

target phoneme, with the upper limit being eight substitutes per target.[2] These could not be captured in any cohesive way as an error "pattern" because they cross cut place, manner, and voicing of production.

For instance, Subject E1 substituted [t ʔ s z ts l w] and null for target /š/. This child's substitutes were not specific to context and varied uniquely by lexical item, as has been observed in other studies of phonological acquisition (Leonard, Newhoff, & Mesalam, 1980). In general, then, the nonsystematic correspondences observed for the children of these studies attested to the overall severity of their phonological disorders and contributed to the extreme unintelligibility of their speech.

Treatment Procedures

In both studies, treatment was delivered in two phases: imitation and spontaneous production. No direct treatment was provided for the perception or discrimination of phonemes. During the imitative phase, the child repeated the clinician's verbal model until achieving either a preestablished performance- or time-based criterion, whichever occurred first. Specifically, treatment in imitation continued until the child maintained 75% accurate production of the treated phoneme over two consecutive sessions (i.e., performance-based criterion), or until seven consecutive sessions were completed (i.e., time-based criterion), whichever

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[2] The lower limit was one substitute per target but only in isolated cases: Subject EL2 produced [n] for /ŋ/, EL3 produced [d] for /ð/ and [s] for /š/, and E3 produced [z] for /ð/. These were the only cases of 1:1 correspondences between substitutes and targets in the entire phonological database. Moreover, these very same subjects produced multiple substitutes for all other errored target phonemes.

occurred first. Treatment then shifted to the spontaneous phase, with the child producing the treated phoneme without a model. This phase continued until the child maintained either a performance-based criterion of 90% accurate production of the treated phoneme over three consecutive sessions, or a time-based criterion of 12 consecutive sessions, whichever occurred first. The number of trials in a given session was held constant for all children.

In both phases of treatment, a response was judged correct if the treated phoneme was produced as in the ambient language. The child was verbally praised for each correct response. When a response was judged incorrect, the child was instructed that target sound production was inaccurate. Then, the clinician provided one subsequent model for imitation, but no new feedback was given.

The treated phoneme was always presented in the word-initial position of nonsense words (NSWs), with the phonetic composition of these words being consistent with English phonotactics. Following procedures described previously (Gierut, 1990, 1991, 1992; Gierut & Neumann, 1992), NSWs were assigned lexical meaning within the context of stories. Briefly, on the first day of each treatment week, NSW

stories were read, and then a child was presented with NSW pictures from the stories for either imitative or spontaneous naming (as above).

A variety of conceptually based teaching activities was used, including segment matching games, worksheets, coloring books, and audiocassettes of the NSW stories. These materials were made available to a child for informal practice outside of the treatment sessions. However, no formal or structured home program was required, described, or encouraged; production of the NSWs was left strictly to the discretion of the child and family. Typically, children simply colored the worksheets or coloring books, and then returned them to the clinician for display on the bulletin board.

During treatment, NSW stimuli were never differentiated from real words. Observation and parental report also indicated that all children readily accepted and subsequently used the NSWs in their everyday vocabulary. For example, some children taught their siblings the NSWs, others created repetitive singsong rhymes using the NSWs, and still others assigned pets or toys NSW names following from characters in the stories. These creative extensions are highly consistent with observed patterns in language development and with previous investigations of children's use of novel forms (Bryan & Howard, 1992; Carey, 1978).

Treatment was provided three times weekly in 1-hour sessions. Five clinicians were assigned to children across the two studies. Because these studies were part of a larger research program on the learnability of sound systems, clinicians had participated in extensive training to ensure consistency in the administration of the experimental protocol, and in previous treatment efficacy studies of this type. A given child worked with one and only one clinician for the entire duration of an experiment. As will be seen, children exhibited similar learning patterns despite being assigned different clinicians, thereby suggesting generalizability of results across clinicians.

STUDY I

The purpose of Study I was to establish the *relative* efficacy of treatment in developmental sequence as defined by age norms. It involved a *within-subject* comparison of differential phonological change in *treated* phonemes, with three children participating (Table 1).

Experimental Design

An alternating treatments design (ATD) was used in combination with a staggered multiple baseline (MBL) across subjects following experimental procedures and controls for multiple treatment interference that have been reported previously (Gierut, 1990, 1991, 1992; Gierut & Neumann, 1992). Briefly, each of the children was exposed to two separate "teaching conditions" in the remediation of target phonemes excluded from the pretreatment inventory. One teaching condition was consistent with a developmental sequence of sound mastery and the other was not, such

that each child was taught both a presumably early-acquired and a later-acquired phoneme as identified from developmental norms relative to chronological age (hence Subjects Early-Late1, EL2, EL3).

Both conditions and therefore both phonemes were presented in all teaching sessions. Because both conditions were introduced within each session, order of treatment was randomly varied. In each session, the phoneme associated with one teaching condition was first introduced, followed by a 10-min nonspeech-related activity, and then the phoneme associated with the second condition was presented. Through use of this design, it was possible to examine *differential* phonological change by a *given* child being exposed to *different* experimental teaching conditions.

Dependent variable: Measure of phonological change. Probes were administered to evaluate changes in a child's phonemic inventory that occurred as a result of treatment. All sounds excluded from a given child's pretreatment inventory were sampled using a subset of items from the PKP. Each phoneme was sampled in five different exemplars in each of three word positions (initial, intervocalic, final) and in both mono- and polymorphemic forms. Probe responses were obtained through a picture-naming task that elicited spontaneous productions. Responses were audiorecorded and phonetically transcribed by a trained listener. As in treatment, phonemes were judged correct if produced accurately as in the ambient language. No feedback was provided for probe responses.

Probes were administered during the baseline period, at phase shifts of treatment (imitation → spontaneous production), and at 2 weeks and 2 months posttreatment. In addition, probes were presented on average every other treatment session (i.e., variable ratio schedule of 2). Probes administered on-line during treatment were scheduled independently for each teaching condition, and were presented immediately following that condition.

For example, if a session began with treatment of an early-acquired phoneme, and a probe of this condition was scheduled, then immediately after treatment of that early-acquired phoneme (i.e., at the halfway point in the treatment session), its corresponding probe was administered. The second half of the session then continued, with the later-acquired phoneme being treated. Thus, in any given treatment session, it was possible that no probes were administered, one probe was administered as affiliated with either the early-acquired or later-acquired teaching condition, or two probes were administered corresponding to each of the teaching conditions.

Consistent with the ATD, probes administered during treatment are necessary to establish differential responding to two treatment conditions as a way of comparing the relative (and not absolute) effectiveness of teaching. Different degrees of generalization to each treated phoneme first establish that there is a genuine difference between the two teaching conditions and second, identify which teaching condition prompts greater change. It is this measure of change associated directly with the *treated phonemes* that unequivocally establishes relative treatment efficacy in the ATD (Barlow & Hayes, 1979; Kazdin &

Hartmann, 1978). For this reason, only change in the treated phonemes is reported for Study I.

Independent variable: Phonemes for treatment based on age norms. The normative databases of Prather, Hedrick, and Kern (1975) and of Templin (1957) were consulted in the selection of phonemes for treatment in Study I. The acquisition sequences relative to the 75% criterion of mastery were cited. Treated phonemes for Subjects EL1 and EL2 were determined from the Prather et al. norms; treated phonemes for Subject EL3 were identified from the Templin norms. Because this was a *within-subject* comparison, use of the Prather et al. norms for Subjects EL1 and EL2 provided the necessary replication, and use of the Templin norms for Subject EL3 served as an extension of treatment effects. In this way then, the relative impact of teaching early-acquired versus later-acquired phonemes on a given sound system could be established independent of a specific set of normative data.

In selecting phonemes for treatment, only those target sounds excluded from a child's pretreatment inventory were considered as possible candidates. In order to avoid a possibility that treatment effects would emerge as segment- or manner-specific, different phonemes were selected for treatment for each child. Treated phonemes were to be phonotactically permissible in the teaching context of word-initial position in the ambient system. Two target phonemes were identified for treatment for each child, one early-acquired and one later-acquired.

The extremes of the age norms were considered relative to each child's chronological age. That is, from the phonemes in error for a given child, the earliest and the latest sound projected to have emerged relative to the normative report and to the child's chronological age were identified for treatment. Specifically, a phoneme was operationally defined as "early-acquired" if, according to developmental norms, the reported age of mastery was below the child's chronological age and, further, if it would have presumably been learned first as compared to all other errored phonemes in the child's system. Similarly, a phoneme was considered "later-acquired" if the reported age of mastery exceeded a child's chronological age, and it would have been the latest acquired of errored phonemes. Phonemes selected for treatment are shown in Table 1.

Given these operational definitions, potential candidates as early-acquired phonemes for Subject EL1 were /l r/ (/ŋ/ was set aside because it is phonotactically impermissible in the word-initial teaching context). For Subjects EL2 and EL3, /k/ and /r/, respectively, were the only possible selections as early-acquired phonemes. Because each child was to receive treatment on different sounds, Subject EL1 was taught /l/, with Subjects EL2 and EL3 being taught /k/ and /r/, respectively.

Potential candidates as later-acquired phonemes for Subject EL1 were /v θ ʝ/ and, for Subject EL2, /z θ ʝ/. The only possible later-acquired phoneme that met the operational definition for selection for Subject EL3 was /ð/, and this became the obvious choice for treatment. Setting aside interdental fricatives, phoneme selection for the two other children was somewhat arbitrary, with the later-acquired phoneme selected for Subject EL1 being /v/ and, for Subject EL2, /ʝ/.

Reliability

Interjudge transcription reliability was calculated on 19% of the total number of probes administered across children. Whole word responses on randomly selected probes were transcribed by independent trained judges. Consonant transcriptions were compared point-to-point, with a total of 733 consonants transcribed. Interjudge transcription agreement was within an acceptable range as cited by Shriberg and Lof (1991), with a mean of 88% and a range of 83% to 95% agreement.

Results

The relative efficacy of teaching early-acquired as opposed to later-acquired phonemes was evaluated by considering changes in treated phonemes during the course of treatment and longitudinally posttreatment. Relative change was reflected in percentages of accuracy of the treated phonemes as measured on real word probes and plotted in Figure 1.

Phonological change during treatment. Visual inspection of the learning curves in Figure 1 revealed that differential change in treated phonemes occurred under the two teaching conditions. In particular, the probe data obtained during treatment showed that relatively greater production accuracy occurred in conjunction with the treatment of a later-acquired phoneme (closed circle plots). In comparison, minimal to no improvements were observed during treatment of an early-acquired phoneme (open circle plots).

Figure 1. Learning curves of subjects of Study I who each received treatment of early-acquired and later-acquired phonemes. Probes were administered on-line during treatment and longitudinally at three points: immediately following treatment, 2 weeks posttreatment, and 2 months posttreatment.
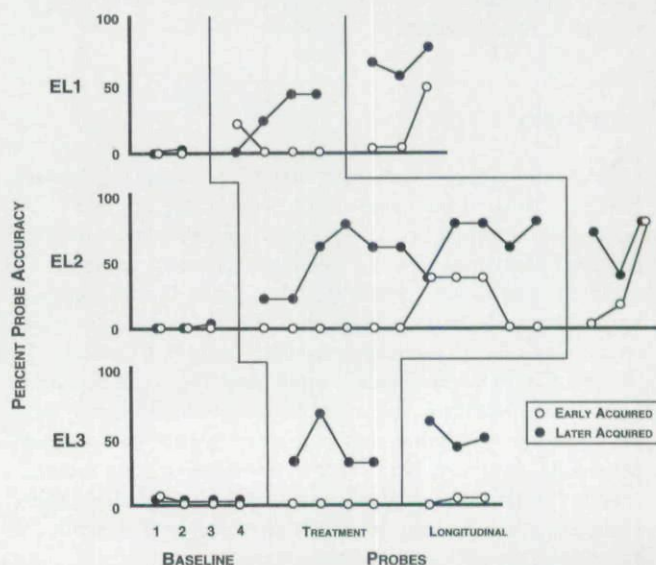
These different patterns of learning were consistent across the three children of this study, and were not specific to particular manners or places of production. The effects also appeared to be independent of a particular set of age norms, given that the Prather et al. norms were consulted in phoneme selection for Subjects EL1 and EL2, and Templin norms for Subject EL3. Thus, it seemed that when a given child was presented with both a later-acquired and an early-acquired phoneme in treatment, differential learning was observed such that change in the later-acquired phoneme exceeded that observed in the early-acquired phoneme.

Longitudinal phonological change. Longitudinal changes on probes administered following treatment also highlighted different improvements in early-acquired versus later-acquired treated phonemes (Figure 1). In particular, later-acquired phonemes continued to show improvements posttreatment, with the extent of change observed immediately posttreatment being approximately equivalent to that observed 2 months posttreatment. However, at 2 weeks posttreatment, a temporary decline in accuracy of the later-acquired treated phoneme was noted for all subjects, resulting in what might be characterized as U-shaped change. In contrast, longitudinal change in the early-acquired treated phonemes presented a different course. Immediately posttreatment, early-acquired phonemes were still produced with near 0% accuracy. This was consistent with the general pattern of responding observed during treatment, whereby virtually no change took place.

The first occurrence of improvement in early-acquired treated phonemes took place at 2 weeks posttreatment. Yet, even then, for two of the subjects (i.e., EL1 and EL3), this change was minimal. Finally, at 2 months posttreatment, gains in performance were observed, with the accuracy of early-acquired treated phonemes approaching that of later-acquired phonemes for Subjects EL1 and EL2. Subject EL3 still evidenced little change in production of the early-acquired phoneme, even at the 2 month posttreatment sample. Although longitudinal change did occur in early-acquired treated phonemes for two of the three subjects, these improvements were not readily apparent until 2 months posttreatment.

Summary

Results of Study I indicated that relative and differential change in treated phonemes took place under the two teaching conditions involving early-acquired versus later-acquired phonemes. During treatment, accuracy of later-acquired sounds was generally greater than that of early-acquired sounds. However, at some extended point in time, production of early-acquired and later-acquired treated phonemes was approximately equivalent for some children. This notwithstanding, the onset of longitudinal change in the early-acquired phonemes was considerably delayed relative to treatment, and relative to observed longitudinal changes in later-acquired phonemes. By comparison, later-acquired phonemes improved not only during treatment, but gains in accuracy continued over time.

STUDY II

The purpose of Study II was to evaluate the efficacy of treatment in developmental sequence by examining *absolute* treatment effects using an *across-subject* comparison of phonological change in both *treated* and *untreated* aspects of the sound system. Six children participated (Table 2). The experimental manipulations of Study II were independent of, but complementary to, Study I.

Experimental Design

The second experiment used a staggered MBL across subjects design. The experimental sequence consisted of a pretreatment baseline period followed by a treatment period for each child, with the number of baselines increasing by one as successive children entered the sequence. In addition, children were randomly assigned to one of two experimental treatment groups. One group of three children each received treatment on one phoneme reported to be early-acquired on age norms relative to chronological age (Subjects *E*arly1, E2, E3), whereas the other group of three each received treatment on a phoneme considered later-acquired (Subjects *L*ate1, L2, L3). Through use of this design, it was possible to examine the *similarity* of phonological change across *different* children being exposed to the *same* teaching condition.

Dependent variable: Measure of phonological change. As in Study I, probes were administered to measure change in a child's phonemic inventory as a consequence of treatment. The composition and scoring of probes was identical to that described for Study I, with all target sounds excluded from a given child's pretreatment inventory being sampled in a picture-naming task. The schedule of probe administration was consistent with MBL paradigms, whereby samples were obtained during baseline, at phase shifts of treatment (imitation → spontaneous production), and at 2 weeks and 2 months posttreatment. Longitudinal changes in both treated and untreated sounds were considered in the evaluation of treatment effects.

Independent variable: Phonemes for treatment based on age norms. In the MBL manipulation, the age norms reported by Smit and colleagues (1990: 795) were used, following the more stringent 90% criterion of mastery by sex. This particular normative database was consulted because it is the most comprehensive and contemporary report available, and, more importantly, specific clinical treatment recommendations have been advanced with regard to its use.

One target sound was selected for treatment for each child, consistent with the experimental group assignments. As in Study I, candidates for treatment were only those sounds excluded from a child's inventory that were also phonotactically permissible in word-initial position of the ambient system.

Following the specific treatment guidelines outlined by Smit et al. (1990), a phoneme selected for treatment was operationally defined as "early-acquired" if the reported age of mastery was minimally 1 year below a child's

chronological age. A phoneme selected for treatment was operationally defined as "later-acquired" if the reported age of mastery was minimally 1 year beyond a child's chronological age. Based on these operational definitions, phonemes selected for treatment are shown in Table 2.

For subjects taught early-acquired sounds, a limited set of phonemes was available for selection. In particular, the only potential treatment phonemes for Subject E1 were /k f/; for Subject E2, /k g/ (with /ŋ/ set aside because it is not phonotactically permissible in the word-initial teaching context); and for Subject E3, /f/. Again, because each child in an experimental group was to be taught a different sound, phoneme selection was such that Subject E1 was taught /k/, Subject E2, /g/, and Subject E3, /f/. For those children taught later-acquired sounds, there were many more potential phonemes for treatment, a possible reason being the stringency of sound mastery (i.e., 90%). In these cases, provided that the operational definition of the later-acquired phoneme and the general guidelines for target phoneme selection were met, the specific sound for treatment for a given child was rather arbitrarily assigned, with Subject L1 taught /r/, Subject L2, /θ/, and Subject L3, /s/.

Reliability

Interjudge transcription reliability was calculated on 15% of all probes administered. Mean point-to-point consonant agreement on whole word transcriptions of randomly selected probes was 91% (range = 87% to 94% agreement), with 2,989 consonants transcribed.

Results

The effects of teaching early-acquired as opposed to later-acquired phonemes were determined from examinations of longitudinal change in both treated and untreated aspects of children's sound systems. Change was reported in terms of percentages of phoneme accuracy on real word probes administered at phase shift of treatment, immediately following treatment, 2 weeks posttreatment, and 2 months posttreatment. The relevant comparisons were between groups of children taught early-acquired phonemes versus later-acquired phonemes. For each group, changes in treated aspects of the sound system are shown in Figures 2 and 3, and untreated aspects in Figures 4 and 5.

Longitudinal change in treated properties. The effects of treatment following developmental sequence were examined in two ways: (1) improvements in the treated phoneme itself, and (2) changes in untreated (errored) phonemes of the treated manner class. The latter comparison specifically examines *within-class generalization*. Within-class generalization was relevant to documenting the broader impact of treatment on a child's sound system. Specifically, when a fricative was treated (as for Subjects E3, L2, L3), did change extend to other untreated errored fricatives? Or, when a stop was treated (as for Subjects E1, E2), did untreated errored stops also improve?

First, with regard to the treated phoneme itself, similarities and differences among the experimental groups

emerged. Quantitatively, there were essentially no differences in the accuracy of production of early-acquired as opposed to later-acquired treated phonemes. This can be seen in reference to the closed circle learning curves in Figures 2 and 3. In particular, moderate improvements in production of the treated phoneme were observed for four subjects spanning the two experimental groups (i.e., E1, E2, L1, L2), with 25% to 60% accuracy noted at 2 months posttreatment.

One child receiving treatment of a later-acquired phoneme (i.e., L3) evidenced declines in performance over time to baseline levels; whereas another child learning an early-acquired phoneme (i.e., E3) achieved ceiling effects with 100% accuracy of the treated phoneme. In essence, the effects of treating early-acquired and later-acquired phonemes were equivocal. There were, however, qualitative differences in learning the treated phoneme that emerged among the groups. In particular, children who were taught an early-acquired phoneme exhibited a monotonic pattern of learning, with linear increases in the slope of the curve over time (Figure 2). In comparison, the learning curves of children taught a later-acquired phoneme were non-monotonic (Figure 3), with fluctuations in performance as detected by rising and falling slopes. Greater variability

Figure 2. Learning curves of subjects of Study II who received treatment of early-acquired phonemes. Percentage of probe accuracy of the treated phoneme (closed circle) and manner class (open circle) is plotted longitudinally at phase shifts of treatment (imitation → spontaneous production), immediately following treatment, 2 weeks posttreatment, and 2 months posttreatment.
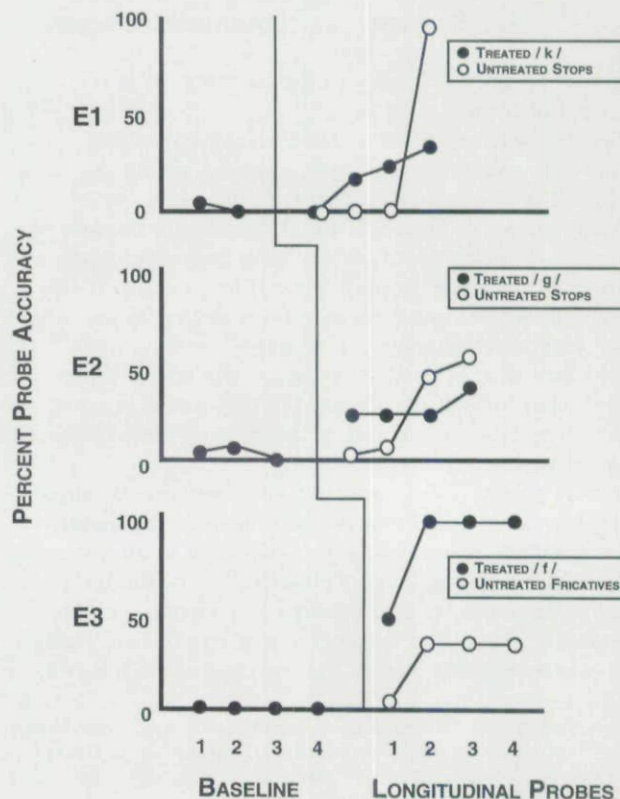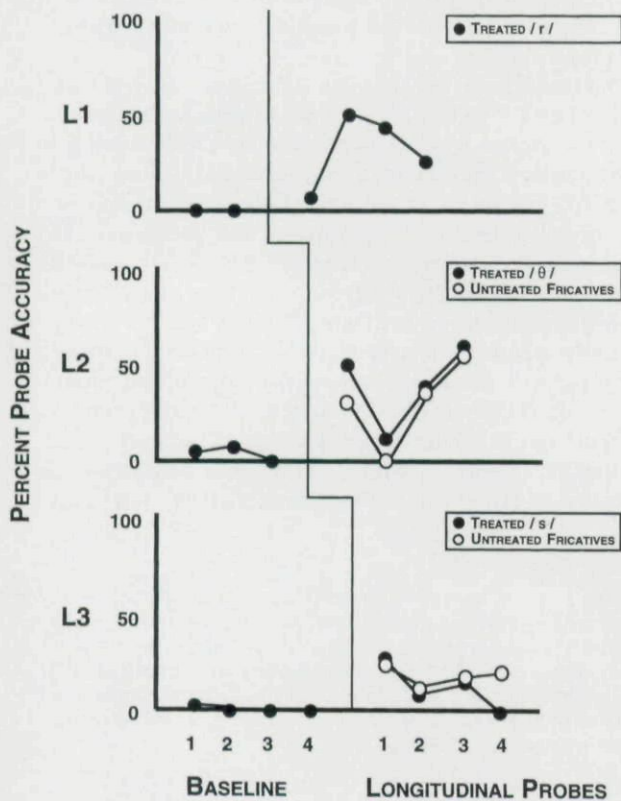
Figure 3. Learning curves of subjects of Study II who received treatment of later-acquired phonemes. Percentage of probe accuracy of the treated phoneme (closed circle) and manner class (open circle) is plotted longitudinally at phase shifts of treatment (imitation → spontaneous production), immediately following treatment, 2 weeks posttreatment, and 2 months posttreatment.

E2). Similarly, when a fricative was treated, change extended to errored untreated fricatives (i.e., E3, L2, L3).

Although there did not appear to be obvious quantitative distinctions in within-class generalization associated with experimental assignments, differences were noted in the onset of such change. When early-acquired phonemes were treated, gains in untreated sounds of the same manner class were somewhat delayed relative to treatment (Figure 2). Consider that Subject E3 first evidenced change in untreated fricatives posttreatment, and Subjects E2 and E1 improved production of untreated stops at 2 weeks and 2 months posttreatment, respectively. In comparison, children taught later-acquired phonemes demonstrated within-class generalization throughout the course of treatment (Figure 3). Moreover, for each child of the later-acquired treatment group, the longitudinal course of within-class change seemed to mirror the learning curve of the treated phoneme itself, with plots of within-class generalization and of the treated phoneme overlaying each other to some extent.

Longitudinal change in untreated properties. The effects of treatment following developmental sequence were also evaluated by considering *across-class generalization*. Across-class generalization was measured in untreated (errored) sounds of different manner classes than the treated phoneme. Across-class generalization explores whether treatment of one sound class facilitates learning of other sound classes, and thus provides insight into the global system-wide changes that treatment may promote (cf. Gierut et al., 1987). To illustrate, does treatment of a liquid (as for Subject L1) positively impact the production of errored untreated fricatives and affricates in the system?

Differences emerged among the groups in terms of across-class change. For children taught an early-acquired phoneme, the general finding was that system-wide phonemic changes were minimal. For the most part, untreated manner classes remained unchanged over time for this group (Figure 4). The learning curves were generally flat, with the accuracy of untreated sounds hovering at 10% across time.

By comparison, children who were taught later-acquired phonemes seemed to exhibit broader system-wide gains in untreated phonemes. For this group, the learning curves showed steady gains across time (Figure 5), with untreated phonemic classes being produced with 30% to 50% accuracy at the 2 month posttreatment sample. These positive gains were not limited to single segments, but extended to all errored sounds of untreated classes. The ultimate effect was that all untreated phonemes previously excluded from the inventory were now part of a child's repertoire. In addition, the onset of across-class change for these children was much like that of within-class change. System-wide improvements were first initiated during treatment and continued following the completion of treatment.

Summary

The results of Study II identified differences in the treated phoneme, within-, and across-class generalization for the groups of children who were taught early-acquired

appeared to be associated with the treatment of later-acquired phonemes.

Second, with regard to within-class generalization, similarities and differences again emerged among the groups. The observations follow from the open circle learning curves in Figures 2 and 3, which plot changes in untreated (errored) sounds of the same manner category as the treated phoneme for each subject. Specifically, it was noted that all children evidenced some degree of within-class generalization regardless of experimental assignment—treatment of early-acquired or later-acquired phonemes. (For Subject L1, /r/ was the only liquid in error; hence there was no opportunity to observe within-class changes in this sound system).

Across groups, the accuracy of untreated sounds ranged from 20% to 94% at 2 months posttreatment. Moreover, observed changes occurred across-the-board to all untreated sounds of the treated manner class. This was true for all children regardless of experimental assignment, with only minor exception.[3] That is, when a stop was treated, change was evident in other errored but untreated stops (i.e., E1,

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[3] Across both groups, the only phonemes that showed no within-class change were /θ/ for Subject E3 and /ʃ/ for Subject L3. Despite a lack of change in these specific phonemes, Subjects E3 and L3 *did* evidence change in other fricatives /v ð/ and /θ ð z/, respectively.

Figure 4. Percentage of probe accuracy across untreated manner classes for subjects of Study II who received treatment of early-acquired phonemes. Data are plotted longitudinally at phase shifts of treatment (imitation → spontaneous), immediately following treatment, 2 weeks posttreatment, and 2 months posttreatment.
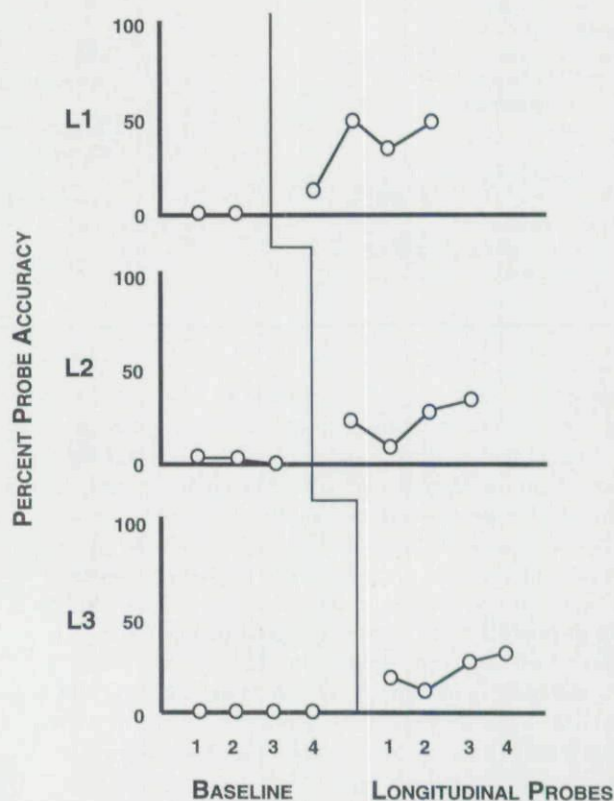
Figure 5. Percentage of probe accuracy across untreated manner classes for subjects of Study II who received treatment of later-acquired phonemes. Data are plotted longitudinally at phase shifts of treatment (imitation → spontaneous), immediately following treatment, 2 weeks posttreatment, and 2 months posttreatment.
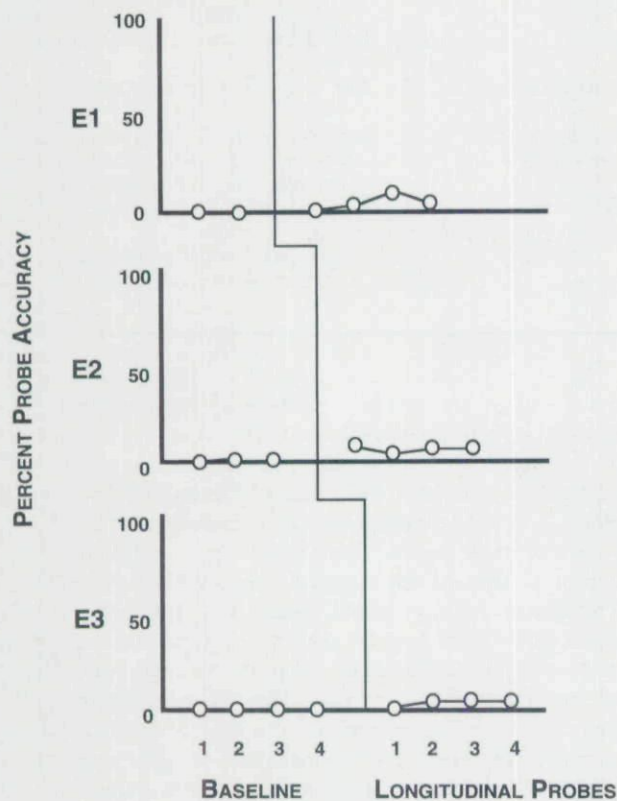
versus later-acquired phonemes. Qualitatively, later-acquired treated phonemes appeared more variable than early-acquired phonemes; quantitatively, there seemed to be no obvious differences in production accuracy. Similarly, the onset of within-class change distinguished among the experimental groups, despite no notable quantitative differences. Here, treatment of later-acquired phonemes facilitated immediate changes in untreated members of the treated manner class, whereas treatment of early-acquired phonemes resulted in within-class generalization that was somewhat more delayed. Finally, treatment of later-acquired phonemes had the effect of promoting widespread changes in the sound system because across-class generalization was observed. Treatment of early-acquired phonemes did not seem to have a comparable system-wide effect.

GENERAL DISCUSSION

The question of phonological treatment efficacy was examined in two independent but complementary experimental studies that involved the clinical treatment of early-acquired as opposed to later-acquired phonemes. The general aim of both studies was the same: to establish the

role of developmental age norms in the selection of target sounds for treatment. There were key differences across the studies, however, that motivated separate evaluations of results and precluded direct subject-by-subject comparisons of learning patterns. The differences included:

- basic assumptions of the experimental designs—within- versus across-subject manipulations;

- analyses of phonological change—relative versus absolute treatment effects;

- dependent variables—treated phonemes alone versus treated and untreated properties of the sound system;

- normative databases—Prather et al. and Templin versus Smit et al.; and

- criteria of mastery in the selection of treatment targets—75% versus 90%.

Despite these differences, when taken together, the outcomes of these two studies bear certain resemblance, as summarized in Table 3. Importantly, the similarity of the findings may have implications for the structure of clinical intervention, the direction of continued efficacy research, and theories of phonological acquisition.

In general, the collective findings suggest that phonological treatment may not need to mirror a developmental

Table 3. Summary of results of two studies evaluating the treatment efficacy of teaching in developmental sequence as defined by age norms.

	Study I	Study II
Subjects	$n = 3$	$n = 6$
Experimental design	ATD	MBL
Dependent variable	Treated phonemes only	Treated and untreated phonemes
Quantitative phonological change:		
% Accuracy	Late-acquired ≥ Early-acquired	Late-acquired = Early-acquired
Qualitative phonological change:		
Onset	Early-acquired: Delayed change Late-acquired: Immediate change	Early-acquired: Delayed change Late-acquired: Immediate change
Course		Early-acquired: Monotonic
	Late-acquired: U-shaped learning	Late-acquired: Nonmonotonic
System-wide change:		
Within-class generalization		Late-acquired = Early-acquired
Across-class generalization		Late-acquired only

sequence of sound learning as defined by age norms in order to be effective. This proposal derives from both quantitative and qualitative aspects of learning that were observed following treatment of early-acquired versus later-acquired phonemes in the two studies (Table 3).

For the most part, production accuracy following treatment of early-acquired and later-acquired phonemes was equivocal. It seemed to be just as easy for a child to learn to produce early-acquired treated phonemes as it is to produce later-acquired treated phonemes, as has been documented in other reports (Gierut et al., 1987; Gierut & Neumann, 1992; Powell, 1991; Rockman & Elbert, 1984). In the present studies, bear in mind that both early- and later-acquired treated phonemes were thought to be stimulable.

Furthermore, treatment of early-acquired and later-acquired phonemes both prompted within-class generalization. That is, following either treatment approach, change in untreated aspects of the system was observed. Yet, qualitatively, the onset of such change was a factor that differentiated phonological learning. In particular, the initiation of phono-logical change was immediate following the treatment of later-acquired phonemes, whereas change was delayed with the treatment of early-acquired phonemes. Moreover, treatment of later-acquired phonemes was the only condition that resulted in further and immediate system-wide improvements as characterized by across-class generalization. Thus, at a local level relating to change in treated phonemes or sound classes, teaching an early-acquired or a later-acquired phoneme seemed to yield similar quantitative results. At a global level involving system-wide change, treatment of later-acquired phonemes appeared to be central to inducing rapid gains in untreated sounds spanning both treated and untreated manner categories. Note, however, that the effects of stimulability on within-class and across-class generalization were not experimentally manipulated in these studies, and thus remain a concern for future investigations.

It is noteworthy that the observed behavioral differences were replicated directly and systematically across the two studies. The consistency of the findings may indicate that a distinction between early-acquired and later-acquired

phonemes is psychologically real because comparable behavioral effects were noted across the teaching conditions in both studies. This would also suggest that age norms are not as arbitrary as some have hinted (Sander, 1972). Further, it would seem to imply that, despite differences among normative reports, there are relevant uniformities that bear directly on phonological learning (Smit, 1986).

The general findings would appear to be relevant for clinical intervention because they may present alternatives to conventional recommendations in the selection of phonemes for treatment. In particular, the selection of target phonemes may or may not follow a developmental sequence as outlined by age norms. But, if age norms are consulted, then there are at least three possible scenarios for phonological learning that follow from the collective results of these two studies.

On the one hand, if the desired consequence of treatment is to effect quantitative change in the treated phoneme and manner class, then either an early-acquired or a later-acquired phoneme would seem to be an appropriate selection. If, however, the goal is to effect such change rapidly, then it may be preferable to select from among later-acquired phonemes. On the other hand, if the aim is to induce change in treated and untreated sounds and manner classes, and further, to initiate change immediately, then it may be more suitable to teach later-acquired sounds.

It must be cautioned that these suggestions for target phoneme selection may be restricted to sounds excluded from a child's phonological system by inventory constraints because this was the experimental focus of study. The role a developmental approach to phonological treatment plays in the remediation of phonological rules or positional constraints has yet to be established. Moreover, these recommendations may be limited to the use of developmental norms relative to chronological age. In these studies, each child's chronological age was uniquely considered in defining whether a sound was early-acquired or later-acquired. It remains to be determined whether similar results would be obtained if sound selection was based on absolute developmental sequences (cf. Shriberg, 1993), or if different operational definitions of early-acquired and later-acquired

phonemes were used. Finally, predictions of change associated with target sound selection relate specifically to lexical change as monitored in citation form probes. The transfer of accurate sound production to connected speech is another possible research extension, although some have reported that changes in the production of sounds in single words will also be reflected in connected speech (Elbert, Dinnsen, Swartzlander, & Chin, 1990).

The present studies add to the few available empirical validations of those factors that might be considered in target phoneme selection. By incorporating these findings with other available considerations, one or more of the following variables might be taken into account in planning intervention to effect or facilitate phonological change: (a) nonstimulable sounds, (b) phonetically more complex distinctions, (c) acoustically and auditorily undifferentiated contrasts, (d) phonologically marked properties, (e) least phonological knowledge as characterized by inventory constraints, (f) nonhomonymous sound pairs involving two new sounds, (g) major class and maximal distinctive feature differences, and (h) later-acquired sounds. Although these factors provide some preliminary directions in the selection of target phonemes for treatment, it is not yet known if there is a precedence relationship among the variables such that some will emerge as more important concerns than others. This deserves experimental attention.

Generally, treatment efficacy studies of sound selection have manipulated a single independent variable (e.g., age norms, or stimulability, or markedness) in order to identify a functional relationship between phonological change and treatment. Future research will also need to consider these findings in light of other functional considerations in target phoneme selection, such as the frequency of sound occurrence in the language or visual cues available in sound production (see Powell, 1991 for a more complete listing). It will be imperative to continue to systematically and experimentally evaluate the full range of factors considered in the selection of target phonemes, and further, to establish potential interactions among these factors.

It is interesting that across these few factors that have been experimentally evaluated, a common theme seems to emerge. Namely, treatment of seemingly more difficult aspects of the phonology may induce relatively greater sound change. Stated another way, treatment of superordinate properties may facilitate mastery of subordinate properties of phonological systems.

It is noteworthy that this pattern observed in the phonological domain has also received support in cognitive and educational psychology (Carey, 1985; Gagné, 1968, 1977; Keil, 1989; Markman, 1989). Perhaps what is being revealed from current efficacy studies of phonological learning in particular is a higher-order principle characteristic of the strategies of human learning in general. If true, this will likely impact the type of theories we may want to consider in accounting for phonological acquisition.

To parallel the course of theory formation in developmental cognitive psychology, we too may find that developmental stage models, as illustrated by normative reports of sound acquisition, may be inadequate (cf. Fischer, 1980; Gelman & Baillargeon, 1983; Wexler, 1982). Consequently,

alternative principle, implicational, dynamic, or cognitive models may need to be considered to a greater extent (e.g., Dinnsen, 1992; Gierut, 1994; Ingram 1990; Jusczyk, 1992; Mohanan, 1992; Thelen & Smith, 1994).

In conclusion, these studies provide a first test of the efficacy of teaching in accord with developmental age norms as a means of facilitating phonological change. The preliminary outcome was that a nondevelopmental approach may be more efficacious in promoting the most widespread and immediate phonological change. It remains to be determined how this sequence of teaching may integrate with other factors associated with the selection of target phonemes for treatment, how a nondevelopmental treatment approach may impact other components of the phonological system, and how these data may be reconciled in a more general theory of language acquisition and learning.

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