Impact of substitution patterns on phonological learning by misarticulating children

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(Received 20 January 1995; accepted 5 July 1995)

Abstract

Learning and generalization of treated sounds to different word positions is a desired outcome of intervention in the phonologically disordered child's system. Unfortunately, children do not always learn the sound that is treated; nor do they always demonstrate across-word generalization. One possible explanation for differences in treatment outcome may relate to the pretreatment substitution patterns used by different disordered children. This *post-hoc* analysis of treatment data examines the effects on sound learning and generalization of consistent versus inconsistent substitutes. With a consistent substitute across-word position (CS), the same phone was used in initial, medial and final position for a phoneme that was not in the child's inventory. An inconsistent substitute was evidenced by a different phone for a target sound in each position of a word (InAP), or even within word position (InWP) for an error sound. Fourteen children with severe phonological disorders were treated on an obstruent in initial or final word position. Seven of these children had a consistent substitute for the treated obstruent, two children had variable substitutes across word position, and five children had variable substitutes within and across word position. The analysis revealed a tight relationship between pretreatment substitution patterns and learning. The seven children with a consistent substitute for an error sound learned the sound targeted in treatment and generalized this knowledge to other word positions. Children who had variable substitutes across word position learned the treated sound, but only in the treated word position. Four of the five children in the InWP group did not learn to produce the sound targeted in treatment in any word position. These results suggest that pretreatment substitution patterns may be a predictor of learning and generalization in phonologically disordered children.

Keywords: phonological disorders, substitution patterns, learning, speech acquisition.

Introduction

Numerous studies have shown that treatment can influence learning in children with phonological disorders, and that treated sounds can be generalized to different contexts (Elbert, Shelton and Arndt, 1967; Elbert and McReynolds, 1978; Weston

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and Irwin, 1971; Dinnsen, Chin and Elbert, 1992). These contexts include production of the treated sound in non-treated word positions (Powell and McReynolds, 1969; Elbert and McReynolds, 1975), in different phonetic environments than those treated (Elbert and McReynolds, 1978), and in more complex speech material than was treated (Elbert, Dinnsen, Swartzlander and Chin, 1990). Phonological learning and generalization also can follow linguistic principles in that phonologically disordered children may acquire sounds that are implicationally related to the sound that was treated (Dinnsen, 1984; Elbert, Dinnsen and Powell, 1984; Dinnsen *et al.*, 1992; Tyler and Figurski, 1994).

The conclusion of these reported results is that generalization occurs commonly through the course of phonological treatment and learning. Yet many children do not learn treated sounds, or do not expand the distribution of sounds within their inventories beyond the word position in which the sound was treated. For example, McLean (1970) found that articulation-impaired, mentally retarded, young adults did not generalize across word position. In this study, three of the four subjects were treated on a fricative or affricate (/s/ or /tʃ/) in word-initial position. A fourth subject was treated on /l/, also in word-initial position. None of these four subjects generalized production of the treated phonemes to medial or final position, though the subjects treated on obstruents did generalize to untreated words with the same initial phoneme as was targeted in treatment. The factors that limited across-word generalization in these subjects were not discussed by McLean, nor are these variables easy to infer from the data presented. Certainly, one factor could be the cognitive deficits, due to mental retardation, of the subjects in his study. Because the subjects in McLean's study were not typical of the population of phonologically disordered speakers, the data presented on generalization patterns may not be applicable to misarticulating children.

Examinations of phonologically disordered children indicate variation in learning of treated sounds and across-position generalization of these phones (Elbert and McReynolds, 1975; Powell and McReynolds, 1969; Ruscello, 1975; Rockman and Elbert, 1984; Olswang and Bain, 1985). For example, some children fail to learn treated sounds, but spontaneously learn untreated phones and generalize this learning across word position. Studies have shown that children can generalize a sound treated in any single position in a word to correct production in other positions (Elbert and McReynolds, 1975; Powell and McReynolds, 1969), whereas other studies demonstrated limited change of production of sounds in untreated positions (Ruscello, 1975; Rockman and Elbert, 1982). Differences in learning patterns may be explained by the presence or absence of related sounds in children's inventories, and by the complexity of the sounds omitted from the inventory (Dinnsen *et al.*, 1992; Elbert *et al.*, 1967). Similarly, Olswang and Bain (1985) suggest that differences in across-position generalization may be attributed, in part, to treatment targets. Large allophonic variation in different word positions (e.g. initial versus final /l/) will limit generalization to untreated positions. By contrast, sounds that are less influenced by context will generalize more easily.

Although phoneme complexity and allophonic variation are likely to inhibit learning and generalization from one word position to another, other factors must also be considered. Some children fail to generalize, or generalize incompletely, even when a treatment target has little across-position variation. For example, Olswang and Bain (1985) point to /s/ as a phoneme with little allophonic variation with word position. Yet Ruscello (1975) demonstrated that treatment of this phoneme in word-

initial position, only, limited acquisition of this sound in other word positions. Similarly, Rockman and Elbert (1984) reported on a child who was taught word-final /k/, and did not learn this sound either in treated or untreated position. Because production of /s/ and /k/ is thought to be relatively consistent in different positions of a word when all other contextual variables are held constant (Olswang and Bain, 1985), there must be factors other than allophonic variation influencing across-position generalization. Further, the complexity of the treated sound by Rockman and Elbert (1984), /k/, probably was not a major factor in learning, because the subject learned /s/ spontaneously. Because developmental norms show that /s/ appears rather late in children's inventories, it might be inferred that correct production of this fricative requires articulatory maturity.

The purpose of the present investigation is to explore one potential factor, consistency of substituted phone, influencing the success of learning of treated sounds and across-word generalization from a single treated position. Analysis of the error patterns of phonologically disordered children in any clinical setting reveals that some children use the same substitute for an erred phone across word position; other children use a different substitute in initial, medial and final positions; and some children use a variety of substitutes in each position of a word. What might these substitution patterns say about a child's understanding of the ambient phonology and his/her ability to learn and generalize correct production of treated sounds? Is the stability of the error a sign that the child is knowledgeable about the target phonology in that he/she understands that sounds have different realizations in different contexts? Or is this error pattern representative of a fixed mode of production, indicative of lack of knowledge of the variability in the sounds of the language in different contexts, such that different phonemes occupy different word positions? If a consistent substitute within- and across-word position is indicative of the inability to respond to variability in the production of phones, then one might predict that a child with this substitution pattern might have more difficulty in generalization. A child with a variable substitute for an erred phoneme in different word positions may be demonstrating an understanding of the natural variation of phones associated with contextual changes. The variation of the errors may indicate greater flexibility in this child's repertoire, which may lead to faster and more complete integration of a sound into the child's system.

Borrowing from the child-development literature, it is obvious that both invariance and flexibility are critical to the acquisition of new skills (Thelen and Smith, 1994). Stable performance may be reflective of well-learned, accurate and efficient use of a skill, such as articulation. If this is true, then a consistent substitution for a sound produced in error may indicate that a child recognizes the similarity of realization within a phoneme class. This recognition may aid in learning and across-word generalization in that the child understands the invariant component of the sound that is in error. The child may lack the ability to produce the sound, either because of representational or motoric limitations, but he/she understands the common features of the sound in different contexts and positions of a word. In this example of consistent substitution within and across word positions, one would hypothesize that treatment of a sound in word-initial position is likely to be learned and generalized to all positions.

Alternatively, a target sound that is substituted with a different phone in different contexts and/or positions may indicate that the child is experimenting with new ways to produce the sound to approximate the adult model. In this sense the child

may be moving away from a limited phonetic repertoire by trying different articulatory assemblages that may approximate correct production. This type of reorganization and variability of skill performance is common during motor development (e.g. walking). As skills develop, they are characterized by increases in variability in known skills, as well as inconsistency in the implementation of the behaviour being acquired. In speech acquisition, variability of a sound in different contexts or word positions may also indicate that the child has knowledge of the variation of sounds. If a phone cannot be produced correctly, normal allophonic variation may be represented by different substitutes. If this is the case, the child may learn the new sound quickly and implement this acquired phone in its various positions and contexts.

In the present investigation a *post-hoc* analysis was conducted of the effects of consistent versus inconsistent substitutes within and across word position on learning and generalization of a treated sound to untreated positions in a word. Consistent substitute (CS) was defined as the same phone used in all word positions and vowel contexts for a target phoneme that was not in the child's inventory. Inconsistent substitutes took two forms. Inconsistency across word position (InAP) meant that a child used a different phone for a target sound when that sound occurred in different positions in a word, whereas an inconsistent substitute within word position (InWP) was evidenced when a child used different phones both within and across word positions. The data in this report are from a subset of children who participated in a larger investigation of phonological knowledge and learning (Dinnsen, Chin, Elbert and Powell, 1990; Dinnsen *et al.*, 1992; Dinnsen and Chin, 1992). All children in the present investigation were treated on one to three phonemes that were missing from their inventories. To be considered for inclusion in a child's inventory, a phone had to be produced at least twice, even if the phone was not used phonemically. The focus of this study was on whether learning of treated sounds and across-position generalization were influenced by the consistency (i.e. stability or invariance) or inconsistency (i.e. flexibility or variability) of the substitute in different contexts and word positions. Although it is known that many factors such as stimulability (Powell, Elbert and Dinnsen, 1991), acoustic differentiation (Forrest, Weismer, Hodge, Dinnsen and Elbert, 1990; Tyler, Figurski and Langsdale, 1993), and phonological knowledge (Gierut, Elbert and Dinnsen, 1987) impact generalization and learning, the current analysis focuses on substitution patterns and their impact on phonological acquisition.

Methods

Subjects and procedures

Fourteen phonologically disordered children (nine boys and five girls) between the ages of 3;6 and 5;9 were included in this *post-hoc* analysis. The subjects of this investigation were chosen from 40 children who participated in a large-scale study of treatment protocols on phonological learning between 1985 and 1989 (see Dinnsen *et al.*, 1990, 1992; Dinnsen and Chin, 1992; Elbert *et al.*, 1990; Elbert, Powell and Swartzlander, 1991; Powell *et al.*, 1991). All children had at least six errors in three manner categories as determined by results of the *Goldman-Fristoe Test of Articulation* (Goldman and Fristoe, 1986), had normal hearing sensitivity at all octave frequencies between 250 and 8000 Hz (re: ANSI, 1989) and were within

normal limits on tests of receptive language (i.e. conversational sample and the *Peabody Picture Vocabulary Test-Revised* (Dunn and Dunn, 1981)).

Prior to the onset of treatment, children's phonetic inventories were determined from a 306-item probe list (adapted from Gierut, 1985) that tested all phonemes in all word positions in which they occur in American English. Probe responses were elicited from presentations of pictures. These responses were transcribed using the International Phonetic Alphabet, including diacritics, by the child's clinician and a second observer. Clinicians and observers were graduate students in speech-language pathology and/or certified speech-language pathologists. All transcribed consonants from the 306-item probe were compared for agreement of consonants across observers. Inter-judge reliability exceeded 80% for all children. Any disagreements (usually related to diacritics) were resolved by re-examination and consensus. Items for which transcription agreement could not be reached were eliminated from the phonological analysis so that all data in this report had 100% inter-judge agreement. The analysis of the children's inventories was repeated at the end of treatment and again, three months after treatment terminated. Following Dyson (1988) and Stoel-Gammon (1987), a child was credited with knowledge of a sound in a particular word position if it was produced correctly on at least two items on the 306-item probe. Tables 1-3 present summaries of the subjects' phonologies, including sounds targeted in therapy, at the start of treatment.

In addition to other errors, children in this study had at least two obstruents excluded from their inventories. Phones used as substitutes for the target phoneme also are listed in Tables 1-3. Although a variety of substitutions exist for target phonemes, seven of the 14 children used the same substitute in all word positions and contexts. Seven children used a different phone for the target as the sound varied as a function of vowel context or its position in a word. Of these seven children, two were consistent in the substitute used within position but used varied substitutes across word position (InAP). The remaining five children had inconsistent substitutes both within and across word position (InWP).

All children received conventional, minimal-pair treatment on one to three sounds¹ (see Elbert *et al.*, 1990 for a complete description of procedure). If a child received treatment on more than one sound, only the data from the first sound treated are presented in this study. Briefly, treatment included two therapy sessions per week with each session lasting 30 minutes. Children continued in treatment until they completed 20 therapy sessions, or until they had scored at least 50% correct on a generalization probe, whichever criterion was reached first. The generalization probe was composed of 30 words in which the treated sound occurred in initial, medial and final position. Words on the generalization probe were not used during the therapy sessions. Further, performance on the generalization probe was used only to determine treatment termination.

Of interest in the present study is the relation between learning of a treated sound and pre-treatment error pattern. Learning was defined as the appropriate use

¹ It was intended that all children receive treatment on three sounds. However, the experimental design of the main investigation (Elbert *et al.*, 1990, 1991; Dinnsen *et al.*, 1990) required that some children serve as control subjects, thereby delaying the start of their treatment until another subject reached criterion for treatment termination. During the interval from initial testing to onset of treatment, some children learned some of the sounds that had been targeted for therapy. These learned sounds, therefore, were not treated.

Table 1. *Subjects in consistent substitutes within word position (CS) group. Subject's age, sex, percentile on the Goldman-Firstoe Test of Articulation (GFTA), score on the Peabody Picture Vocabulary Test (PPVT), the sounds excluded from child's inventory, treatment targets and sound used as substitute for the treated phoneme*

Subject number	Age (years;months)	Sex	GFTA	PPVT	Sounds excluded from inventory	Treatment targets	Substitutes		
							I	M	F
5	3;8	F	3	102	θ, ʃ	θ/#	f	f	f
7	3;8	F	<1	53	f, v, θ, ð, s, z, ʃ, ʧ, l, r	s/#	t	t	t
11	3;10	M	<1	114	k, g, f, v, θ, ð, s, z, ʃ, l, h	f/#	t	t	t
12	3;11	F	6	102	θ, s, z, ʃ	ʃ/#	t	t	t
25	4;10	M	<1	87	k, g, θ, ʃ, ʧ, l	g/#	d	d	d
31	5;1	M	<1	122	θ, ð, r	θ/#	f	f	f
33	5;4	M	<1	100	k, g, s, z, ʃ, ʧ, ð	k/#	t	t	t

I = Initial position; M = medial position; F = final position.

Table 2. *Subjects in inconsistent substitute across word position (InAP) group. Subject's age, sex, percentile on the Goldman-Fristoe Test of Articulation (GFTA), score on the Peabody Picture Vocabulary Test (PPVT), the sounds excluded from child's inventory, treatment targets and sounds used as substitutes for the treated phoneme*

Subject number	Age (years;months)	Sex	GFTA	PPVT	Sounds excluded from inventory	Treatment targets	Substitutes		
							I	M	F
2	3;6	M	3	109	θ, ð, r, l	θ/#	f	ʃ	s
30	5;0	M	4	97	θ, ð, z, l, r	θ/#	ʃ	f	f

I = Initial position; M = medial position; F = final position.

of a sound in the child's inventory after treatment, as determined by at least two occurrences in a particular word-position (Dyson, 1988; Stoel-Gammon, 1987) on the 306-item probe. If a treated sound was learned, interest focused on the generalization of the learned sound from a single, treated position in a word to other non-treated positions. Across-word generalization also was determined from the 306-item probe administered to the children before treatment began (pretreatment probe) and after treatment was terminated (post-treatment probe). For example, a sound treated in word-initial position was 'learned' if it was produced at least twice in word-initial position on the 306-item post-treatment probe. Across-word generalization was defined by at least two target-appropriate occurrences of the sound in word-medial and word-final positions on the 306-item probe. The number of opportunities to produce a target phoneme varied with the sound and its position in a word. For the seven obstruents discussed in the current report there was an average of 13 word-initial targets, six word-medial targets, and seven word-final target words per sound.

Results

As indicated in Table 4, all of the seven children with a consistent substitute across word position (CS) for a phone that was omitted from his/her inventory learned the sound in the treated position and generalized this knowledge to other word positions. The determination of learning and generalization was made on the basis of performance on the 306-item probe that was administered at the completion of treatment. The two children who had inconsistent substitutes across word position (InAP) also learned the treated sound in the treated position. However, neither of these children generalized production of this sound to untreated word positions. The five subjects in the final group (InWP) used various substitutes, both within and across word positions prior to treatment, for target sounds omitted from their inventories. Four of these subjects did not learn the treated sound in either treated or untreated positions. The fifth subject in this group (Subject 36) learned the treated sound and generalized it to other word positions.

Attempts were made to determine factors other than consistency of substitute that may have influenced children's learning patterns. Recall that three phonemes were targeted for treatment for each subject. The analysis probes that serve as the data for this report were administered before treatment was initiated, and at the termination of treatment on all treated sounds. It is possible, therefore, that learning of the phonemes in this study was influenced by phonemes treated later in the therapy programme. For example, Dinnsen *et al.* (1992) showed that more complex

Table 3. Subjects in inconsistent substitute within word position (*InWP*) group. Subject's age, sex, percentile on the Goldman-Fristoe Test of Articulation (*GFTA*), score on the Peabody Picture Vocabulary Test (*PPVT*), the sounds excluded from child's inventory, treatment targets and sounds used as substitutes for the treated phoneme

Subject number	Age (years;months)	Sex	GFTA	PPVT	Sounds excluded from inventory	Treatment targets	Substitutes		
							I	M	F
4	4;7	M	<1	108	p, t, k, g, f, v, θ, δ, s, z, j, ʃ, ʧ, l, r	s/#	h, t, d k, n, m	h, d p, ø	ø, f
13	4;1	M	<1	95	f, θ, δ, s, z, j, ʃ, ʧ, l, r	s/#	p	ʔ, h	ø
20	4;4	F	<1	104	v, s, z, j, ʃ, ʧ	s/#	h, t, w θ, f, p	ø, t	ø
28	4;11	F	<1	91	f, v, θ, s, z, j, ʃ, ʧ, l, r	v/#	b, n,	d, ø	ø
36	5;9	M	<1	88	g, f, v, θ, δ, ʃ, ʧ, l	f/#	k, s	j, r, w s	s

I = Initial position; M = medial position; F = final position.

Table 4. Further description of subjects in each group, including stimulability, percentage correct consonants (PCC), percentage of syllables that were closed in the child's system, learning of treated sound and generalization to other word positions

Subject number	Phoneme treated	Subject group	Stimulability (%)	PCC	Percentage of syllables closed	Learning	Generalization across position
5	θ/#	CS	10	73	86	Yes	Yes
7	s/#	CS	0	47	100	Yes	Yes
11	f/#	CS	10	41	100	Yes	Yes
12	ʃ/#	CS	10	76	94	Yes	Yes
25	g/#	CS	0	62	88	Yes	Yes
31	θ/#	CS	0	70	94	Yes	Yes
33	k/#	CS	10	51	93	Yes	Yes
2	θ/#	InAP	*	64	100	Yes	No
30	θ/#	InAP	0	73	89	Yes	No
4	s/#	InWP	0	21	75	No	No
13	s/#	InWP	*	40	69	No	No
20	s/#	InWP	*	59	94	No	No
28	v/#	InWP	0	25	42	No	No
36	f/#	InWP	10	27	50	Yes	Yes

CS = Consistent substitutes across word positions. InAP = Inconsistent substitutes across word positions. In WP = Inconsistent substitute both within and across word positions. * Indicates that no stimulability data were collected for that subject.

sounds (e.g. strident fricatives) influence the learning of sound classes that are less complex (e.g. stops). For the present subjects, complexity of sounds treated late in the therapy sequence may have facilitated learning of earlier-treated phonemes. This does not appear to be the case; the order of treatment on targeted sounds was not systematically different for children in different subject groups. For example, Subject 36, who had an inconsistent substitute both within and across positions, and who was treated on the most complex sound first, learned what was treated, and generalized this knowledge across word positions. Subject 2, who had an inconsistent substitute across position, also was treated on the most complex sound first and, although he learned the sound in the treated position, he did not generalize to other word positions. In the present investigation, as in studies directed specifically towards investigation of implicational relations (Dinnsen *et al.*, 1992), there were no effects of treatment order on across-word generalization.

Other factors that could be suggested to influence learning and generalization did not differ in any systematic way as a function of substitution pattern or generalization. As shown in Tables 1–3, when a target sound was excluded from a child's inventory, the cognate was rarely present. Only one subject (Subject 5) had a cognate of a treated sound. It is evident from Table 4 that there is an overlap in percentage of correct consonants (PCC) between subjects in all three groups. Although, in general, the children in the InWP group had the lowest PCC, one subject in the CS group was comparable in this metric (Subject 11). Further, PCC did not seem to be a factor in generalization, in that children in the InAP group had relatively high PCC and did not generalize, and Subject 36 in the InWP had a lower PCC and did generalize his knowledge to untreated word positions. Similarly, performance on the Carter–Buck test of stimulability (Carter and Buck, 1958) did not predict learning in this study. As shown in Table 4, none of the children in this study were stimuable for the consonant that was treated.

Tables 1–3 may give the impression that the children in the InWP group did not close syllables, whereas children in the other groups were more likely to use word-final consonants. Recall, however, that the list of substitutes in Tables 1–3 is for the sound targeted in treatment for each child. Table 4 indicates that all children closed syllables for more than 40% of the phones in their inventories. Further, Subject 36, who had among the lowest percentage of closed syllables, did learn the treated sound, and generalized this knowledge to other word-positions. By contrast, Subject 2 produced syllable-final consonants for all sounds in his inventory, but still did not generalize from the sound in the treated position to other word positions.

In summary, all children in the CS group showed generalization of the learned sound to untreated positions. Both children in the InAP group learned the treated sound in the treated word position. However, neither of these children generalized this knowledge to untreated word positions. Four of the five children in the InWP group did not learn the targeted sound in the treated word position, nor did they evidence knowledge of that sound in other word positions. The last subject in that group did learn the targeted sound in both treated and untreated word positions. We have been unable to determine the factors that may have differentiated this subject from the others in the InWP group. This analysis, as well as other analyses, demonstrate that this subject performed differently from other subjects on many tasks that have been investigated (Barlow, in press).

Discussion

The results of this study indicate that, as in most cognitive and motor tasks, the formation of categories is an essential component of development. As stated by Thelen and Smith (1994), 'Critical to understanding how a fluid, dynamic assembly of neurons can make sense of the world is the ability of the mind to form *categories*, that is, to recognize that events or objects that are not identical may have equivalent meaning' (p. 162). As the present study demonstrates, learning and generalization of speech sounds are dependent on this recognition of phonemic categories. Whereas most children can perceive phonemic distinctions produced by *other* speakers, many young children have sounds missing from their productive repertoires. The correspondence between articulatory movements and their perceptual consequences is essential to the development of contextual generalization and expansion of a productive phonology. That is, specific output/input relations must be garnered so that the developing child learns the limits of productive variation that will result in perceptually correct phones despite variations in context. In normal speech development it is hypothesized that these production–perception interactions are the essence of categorical, phonemic representations. Although flexibility has a role in speech motor development (Forrest, Weismer, Dinnsen and Elbert, 1994), development of phonemic categories is a more basic prerequisite for speech acquisition. Once categories are established at the level of speech production, variability in the implementation of the phone may mark the generalization of the sound to new environments (Forrest *et al.*, 1994) or the expansion of the phonetic inventory to include new sounds.

The present data show that children who had a consistent substitute across position learned the sound targeted in treatment, in both treated and non-treated word positions. The presence of a consistent substitute across word position suggests that these children had a categorical representation of the phoneme, even though the production of that sound was incorrect. By contrast, the two children who used

a different substitute across word position (InAP) learned to produce the treated sound in the treated position *only*. The inference to be drawn is that these children did not have a categorical representation of the sound that was targeted for treatment. Rather, the representation of the sound varied with its position in the word. Treatment of the sound in a given word position had an effect on that position *only*. Perhaps because the sound was represented differently in other positions of the word, there was no generalization of production to untreated word positions.

The final group of children in this study, those children in the InWP group, seem to have the weakest representation of phonemic categories. For the children in this group, the representation of a phoneme does not appear categorical, nor are there systematic variations in the production of the targeted sound for most of these children. Four of the children in this group vary the substitute for a target phone somewhat randomly. One subject in this group (Subject 36) had some pattern to his errors, in that the sound used as a substitute was influenced by other consonants in the word (e.g. /fɪ/ → [ʃɪ], /fes/ → [ses]) or the tongue-position of the neighbouring vowel (e.g. /f/ + back vowel → /k/ + back vowel). Within this InWP group, only Subject 36 learned the treated sound and generalized it to other word positions. It is possible that before treatment this subject had some recognition of categories, even though the features of his category were incorrect. Perhaps, instead of using the features of place and manner as category determinants, Subject 36 distinguished categories on the basis of harmony between sounds in a word. As he learned the correct determinants of the labiodental-fricative category during treatment, he was able to replace the incorrect representation with the correct model in all word positions.

Investigation of other factors that may be predictors of learning and generalization in the present study was not revealing. For example, stimulability for the treated sounds was low for all subjects in all groups. Children in the InWP group did not produce very many consonants correctly, as evidenced by their low PCC, in their spontaneous speech. However, subjects in other groups (e.g. Subject 11 in the CS group) also demonstrated low PCC, and not only learned the sound treated, but generalized this learning to other word positions. More importantly, children in the InAP group had relatively high PCC and were not able to generalize the treated sound to other word positions. In sum, the major factor that predicted success in treatment was the child's substitution pattern for the error sound that was treated.

This effect may have some serious implications for treatment, that we are investigating currently. Specifically, it appears that children with a consistent substitute across word position can benefit from treating the error sound in a single position of a word. These types of children have a categorical representation of the error sound, although the representation is incorrect. When correct production of the sound is developed through treatment, these children are capable of applying this new representation to other contexts. If these predictions hold, then we have a way to streamline our treatment procedures for a subset of phonologically disordered children.

Children who produce a different substitute for a target sound as it appears in different positions of a word may need to receive treatment for the sound in initial, medial and final positions, as previous research suggests (Ruscello, 1975; Olswang and Bain, 1985). Children with this type of substitution pattern (InAP) may not have formed the category for the error sound so that, as context varies, so does the representation of the sound. Minimal-pair treatment in a single word position may

not generalize learning to other positions because the way the sound is represented differs with position. Although the child can learn to replace the error sound with correct production in the treated position, there may be no correspondence between the error in initial position, for example, and other word positions. Minimal-pair treatment may need to focus on prevocalic and postvocalic positions with different treatment pairs; that is, the substitute that is used in each position should be paired with the target sound. Alternatively, it may be more beneficial to treat the target sound without pairing it to the error. Either targeting the error sound as a unique entity without any pair, or using maximal opposition treatment (Gierut, 1990), may provide the child with a clearer sense of the unique categorical features of the treatment target.

Similar arguments can be made for the children in the InWP group. Minimal-pair treatment, in the present analysis, was not effective in teaching correct production of the target sound in any position of a word. Again, this suggests that the category of the sound is not formed for these children, and minimal-pair learning is targeting only a single type of error. For these children, treatment may need to focus on developing an understanding of phonemes, in general, before individual sounds are targeted. In the present study these children fared very poorly in treatment. If the problem was only that treatment did not target all possible substitutes for the error sound, one would predict that these children would have some correct productions of the targeted sound after treatment. Each treatment sound was paired with the sound used most often as its substitute, as required by the treatment protocol. Subject 20 had three different sounds that represented /s/ in word-initial position (see Table 3). This subject received minimal pair treatment in which /s/ was contrasted with its most frequent substitute, /θ/, in word-initial position *only*. If this was the only source of difficulty for learning and generalization, it would be expected that Subject 20 would replace incorrect /θ/ with /s/. Unfortunately, this did not occur, and /s/ did not appear in Subject 20's inventory after treatment terminated.

It appears, then, that children with multiple substitutes for an omitted phoneme need to have some concept of the similarity of a sound as it appears in different contexts. As with other motor and cognitive behaviours the development of categories is a prerequisite to phonological learning. Category development may proceed at different speeds or levels, such that some children recognize similarity within, but not across, word position, whereas other children do not have categorical representations even within the same position of a word. It appears that the greatest prediction of treatment success can be made for those children who have a firm, even if incorrect, categorical representation, as was seen in the children in the CS group.

Acknowledgement

This work was supported in part by NIDCD grant DC000260.

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