Feature Analysis of Segmental Errors in Children With Phonological Disorders

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There has been a longstanding controversy about the existence, nature, and differentiation of developmental apraxia of speech (DAS), leading to numerous investigations of characteristics that define this articulatory disorder. An analysis of substitutions relative to target sounds led Thoonen, Maassen, Gabreëls, and Schreuder (1994) to conclude that children with DAS show a pattern of feature retention in their error productions that contrasted with that of children with normal articulation. This pattern, in which place of articulation was retained in the substituted sound less frequently than manner of production or voicing, was considered by Thoonen et al. to be of diagnostic significance. The current research re-examines this claim by comparing the retention patterns obtained by Thoonen et al. for children suspected of having DAS to patterns for children suspected of having a phonological disorder. An examination of substitutions used by 20 children who were diagnosed with and treated for phonological disorders demonstrated the same pattern of feature retention that was described for children with DAS. The results of this study showed that voicing is maintained most frequently; manner of production is the next most retained feature; and place of articulation is the feature that is retained least often when a substitute is used for a sound that isn't produced correctly. In a second analysis, this pattern of feature retention was compared to children's phonological knowledge as indexed by percent correct underlying representation (PCUR). Contrary to the findings of Thoonen et al., however, the present work found an inverse relationship between retention of place and phonological knowledge. Children with greater phonological knowledge retained place less often than children with more limited phonetic inventories. These patterns of feature retention may be representative of specific development sequences that occur during phonological acquisition.

KEY WORDS: features, phonological disorders, developmental apraxia of speech

Developmental apraxia of speech (DAS) has been described as "a label in search of a population" (Guyette & Diedrich, 1981, p. 39) because of the difficulty of identifying precise characteristics that define the disorder or differentiate it from other articulatory disorders of childhood. The primary rationale for differentially diagnosing DAS from phonologically based speech impairments is the need for different treatment protocols for the two groups of children; children with DAS are resistant to "traditional or conventional remediation techniques" (Hall, Jordan, & Robin, 1993). Speech characteristics of DAS include a high rate of consonant omissions and substitutions (Crary, 1984; Hall et al., 1993), problems in sequencing sounds (Hall et al., 1993), errors on motorically complex consonants such as fricatives, inconsistent articulatory errors, and vowel distortions (Robin, 1992; Yoss & Darley, 1974). Nonspeech oral movements are typified by movement awkwardness, slow diadochokinetic rates, and symptoms of effortful groping (Hall et al., 1993; Robin, 1992). However, many of these characteristics also are evident in children with severe phonological disorders (Powell, 1996). Because only the output from the speech mechanism can be observed, either perceptually or by instrumental evaluation, it is difficult to isolate linguistic from motoric contributions to articulation difficulties in children. The interaction between cognitive processes, motor activities, and learning (Thelen & Smith, 1994) further challenges our efforts to segregate motor from phonological influences in children's functional articulation disorders.

This challenge may be met by better diagnostic criteria that differentiate speech attributes of DAS from those of other developmental delays in articulation (Shriberg, Aram, & Kwiatkowski, 1997a, 1997b, 1997c; Thoonen, Maassen, Gabreëls, & Schreuder, 1994). Using detailed subject-selection criteria, Thoonen et al. analyzed consonant errors of children with DAS and normally developing children. To be classified in the "developmental verbal dyspraxia group," referred to as DAS in the current report, subjects went through a multistage screening process to ensure that they evidenced a deviant articulatory system, many assimilatory errors, highly variable articulatory substitutions, and groping behavior during attempted phone productions, that is, characteristics that often are associated with DAS (Thoonen et al., 1994; Hall, 1992). All children in this group were rated as having moderate to severe DAS. A group of children with normal articulation skills was enlisted for comparison purposes. All children in this group demonstrated age-appropriate cognitive, motor, and perceptual abilities, as determined by classroom teachers and speech-language pathologists.

Thoonen et al. (1994) conducted analyses of speech errors in multisyllabic real and nonsense words to determine whether diagnostically significant differences could be identified for the two subject groups. The analyses assessed the retention of phonetic features that included place, voicing, and manner distinctions, as well as the prevalence of contextually based errors. When errors were made by children in the DAS group, the substituted sound was most likely to vary from the target by the feature place of articulation. This pattern of retaining *place* of articulation for the substituted phone less often than the features of manner or voicing, was prevalent in the group of children with DAS. This was the only characteristic that distinguished the children with DAS from the children in the control group. The pattern was highly reliable and diagnostically significant. Not only did it distinguish the normally articulating from DAS children, but this place retention also correlated with the severity of speech disorder. Those children judged to be the most severely dyspraxic by the speech-language pathologists had the lowest percentage of place retention in their errors. Thoonen et al. concluded that the children's errors were related to phonological encoding as defined by Levelt (1989) and therefore indicative of DAS, rather than a problem of phonological representation that would connote a phonological disorder.

This conclusion seems premature based on theoretical and methodological grounds. Whereas theories of speech production may differentiate abstract concepts of coding from those of representation, only the output of the complex speech production system can be viewed or measured. Furthermore, recent theories of development emphasize the interactive nature of representation, action, and perception (Thelen & Smith, 1994) as opposed to a series of static processes. With these considerations in mind, it is unlikely that the underlying process of a functional articulation disorder can be defined exactly; rather, the dynamics of speech acquisition patterns must be considered. Even if the locus of impairment could be identified, Thoonen et al.'s claim should be questioned on the basis of methodological concerns. The control group used in their study was composed of children who were following normal paths toward phonological acquisition. Therefore, the only claim that can be made is that children with articulation disorders show patterns of feature retention that differ from normal. Conclusions about the diagnostic significance of feature retention patterns must include children with articulation impairments of different etiologies to determine if this pattern differentiates subgroups. Comparative data on children suspected of having phonological disorders would provide a stronger argument for the use of feature retention patterns in distinguishing children with DAS. The present research addresses these issues. Specifically, do children with articulatory deficits associated with phonological disorders demonstrate feature retention patterns in their segmental errors that differ from those of children diagnosed with DAS? If specific feature retention patterns do exist in children diagnosed with a phonological disorder, do these patterns relate to the amount and/or type of phonological knowledge that the children possess?

In the current post hoc analysis, comparisons are made between the features retained in the errors of children with phonological disorders and the feature profiles of DAS children described by Thoonen et al. (1994). Additionally, a correlational analysis of the relation between retention pattern and phonological knowledge, as measured by PCUR, was undertaken. PCUR was chosen as a means of assessing phonological knowledge because it provides insight into the "mental representation" of the contrastive elements of a language (Dinnsen

& Chin, 1995, p. 138) as opposed to the more commonly used metric, percent correct consonants (PCC; Shriberg & Kwiatkowski, 1982) which provides details about the surface representation, only. In this sense, then, knowledge is used to refer to contrastive distinctions within a child's inventory.

To determine the accuracy of the relation of phonological knowledge to feature retention, data from a second group of subjects were used in a cross-validation procedure. All data in this report are from a subset of children with phonological disorders who participated in studies of the effects of treatment protocols on phonological learning and generalization (Dinnsen, Chin, & Elbert, 1992; Dinnsen, Chin, Elbert, & Powell, 1990; Elbert, Dinnsen, Swartzlander, & Chin, 1990).

Methods

Participants

Two groups of ten children diagnosed with phonological disorders (PD children) served as the subjects of this post hoc investigation. Children were chosen randomly from a larger group of 40 subjects from southern Indiana who had served in a study of treatment efficacy in phonological disorders (Dinnsen et al., 1990; Dinnsen et al., 1992; Elbert et al., 1990). The PD children in the current study displayed a range of phonological knowledge (see Table 1), but all subjects had at least six sounds in error across three manners of production as determined by the Goldman-Fristoe Test of Articulation (Goldman & Fristoe, 1986). All subjects had normal auditory sensitivity at octave frequencies between 250 Hz and 8000 Hz (ANSI, 1989), as well as receptive language skills that were within normal limits on the Peabody Picture Vocabulary Test–Revised (Dunn & Dunn, 1981).

The exact criteria for distinguishing between children's phonologically based speech errors and those influenced by motoric deficits such as DAS are unclear. Furthermore, articulation disorders may not have pure etiologies, so that children with DAS may also demonstrate linguistic deficits (Velleman & Strand, 1994), and children with phonological disorders may exhibit motoric difficulties (Bernthal & Bankson, 1998). For these reasons, the existence of some motor influences on the speech disorders displayed by the children in this study cannot be dismissed. However, no children in this study displayed characteristics that are commonly associated with DAS (Hall et al., 1993; Rosenbek & Wertz, 1972; Stackhouse, 1992). For example, no children evidenced groping behavior, silent posturing, or obvious signs of oral-motor apraxia; children were not identified to have vowel errors; and all children responded favorably to traditional phonological treatment.

Table 1. Subject profiles.

Subject	Age	PCUR	PCC	GFTA	PPVT
		Group 1			
3	3;6	54	NA	5	101
13	4;1	40	43	<1	95
14	4;1	65	59	5	108
16	4;2	33	NA	<1	106
20	4;4	59	43	<1	104
26	4;11	21	19	<1	85
33	5;4	51	56	<1	100
34	5;5	73	65	<1	114
36	5;9	27	47	<1	88
38	5;11	57	77	6	103
M	4;9	48	51.1	2.3	100.4
SD	0;8	17.1	17.4	2.1	8.9
		Group 2			
4	3;7	21	27	<1	108
6	3;8	70	59	22	105
8	3;9	65	68	<1	86
11	3;10	41	40	<1	114
18	4;3	18	32	<1	86
25	4;10	62	56	<1	87
27	4;11	48	63	<1	100
28	4;11	25	NA	<1	91
30	5;0	73	71	4	97
40	6;8	53	60	<1	92
M	4;5	47.6	52.9	3.4	96.9
SD	0;7	20.6	15.9	6.6	9.9

Data from the first group of subjects were used to determine if a pattern of feature retention could be observed in PD children and, if so, whether the pattern related to the severity of phonological disorder. This group consisted of 6 boys and 4 girls ranging in age from 3;6 to 5;11 (*M* = 4;6). The second group of children provided data that were used to test the validity of any relation found in the first group of PD children. This second group of children was composed of 7 boys and 3 girls between the ages of 3;7 and 6;8 (*M* = 4;4). Table 1 presents a summary description of the subjects used in the analyses.

The data that are presented in this report are based on subjects' phonetic inventories that were calculated prior to the onset of treatment. Phonetic inventories were assessed by means of a 306-item probe list (adapted from Gierut, 1985) that sampled the production of all consonants in all the word positions in which they occur in American English. Items on the probe list were elicited by picture presentations, and each response was transcribed by two graduate-student clinicians using the International Phonetic Alphabet, including diacritic markings. Transcription reliability was calculated by comparing transcriptions on a consonant-by-consonant basis. The average reliability was 80% (range = 67%–

93%). Any disagreements between the clinicians, which were usually related to diacritics, were resolved by consensus. If consensus between the judges could not be reached, a third, independent judge with extensive experience in the transcription of disordered speech, resolved the disagreement (Elbert et al., 1990). A child was credited with knowledge of a sound if it was produced at least two times during the probe (Dyson, 1988; Stoel-Gammon, 1987), independent of the target sound (i.e., credit was given for all sounds produced, whether or not they were target appropriate). Measures of phonological knowledge were based on PCUR and PCC. PCC was used to compare the severity of articulation impairment of the present subjects to the DAS subjects described by Thoonen et al. (1994). In general, the subjects in the current investigation had more limited phonological systems (*M* PCC = 52.7, *SD* = 16.1) than those studied by Thoonen et al. (*M* PCC = 70.0, *SD* = 12.2). PCUR was used to relate phonological knowledge to feature retention, a relationship that might provide insight into phonological acquisition. PCUR was chosen as the index of phonological knowledge because it seemed to more closely approximate what a child "knows" about the system than PCC, which provides information about what a child "produces correctly" as noted by the surface representation. Although there may be significant differences between these measures (Dinnsen & Chin, 1995), PCC and PCUR were highly correlated in the current research ($r = 0.82$).

Procedures

Following the method outlined by Thoonen et al. (1994), the percentage of features retained was calculated. As an initial step in this calculation, a confusion matrix was constructed for each subject to determine the segments that were used as substitutes for target sounds that were omitted from the child's phonetic inventory. Consistent with the procedures outlined in Thoonen et al. (1994), only sounds that were omitted from the inventory were included in this analysis. Each substituted or omitted segment was compared to the target for consistency of place, manner, and voicing, and from this matrix, the total number of correct or incorrect place, voicing, and manner relative to the target sound was calculated. For example, Subject 13 had a phonetic inventory that excluded all liquids and fricatives, except /v/, and his substitutions for omitted phones were very variable. His substitutes for target /s/ were /t, h, d, ʔ, f, k/, or the segment was omitted, thereby leaving /ø/ in place of the target segment. Table 2 provides an example of how the types and number of features were retained for each target sound for Subject 13. For each subject, the substitutes were compared to the target segment to determine the type and number of features that were retained. If a segment was omitted, no features were retained. The percentage of features retained was calculated as the number of retained features relative to the number of target segments with that feature (Thoonen et al., 1994).

A final analysis was conducted to determine if children's phonological knowledge, as measured in percent correct underlying representation (Dinnsen & Chin, 1995), was related to the types and percentage of features retained. In the current research, PCUR evaluated a child's productive knowledge; no assessment was made of the children's perceptual representations. Detailed explanations of techniques used to define underlying representations can be found elsewhere (Dinnsen, 1984; Kenstowicz & Kesseberth, 1979). A brief description of the procedures used in the current research follows. A child was credited with correct productive underlying representation if the child produced the target segment correctly or there was evidence that correct and incorrect forms of the targeted segment alternated in a morphophonemic relation (Dinnsen & Chin, 1995). To calculate PCUR, 1 point was assigned to each consonant in each position in a word that a child produced on the 306-item probe list. For example, if a child produced a target-appropriate /t/ in initial, medial, and final positions

Table 2. Example of the calculation of place retention for subject.

Target	Substitute	Bilabial	Labiodental	Interdental	Alveolar	Palatal	Velar	Glottal	ø	Total
/s/										
	h							9		9
	ø								20	20
	t				14					14
	d				1					1
	ʔ							3		3
	f		1							1
	k						1			1
Total					15					49

Note. The shaded column represents the correct *place* for the target sound, /s/.

of a word, 3 points would have been assigned. Because each consonant appeared on the probe list in one to three word positions there was a maximum score of 63. The following formula was then applied:

$$\text{PCUR} = \frac{\text{Number of phones produced with correct underlying representation}}{63} \times 100$$

Statistical Analysis

Data from the first group of PD children were arcsine transformed according to the formula provided by Thornton and Raffin (1978). A one-way ANOVA was performed on these transformed values to compare the percentage retention of each feature (i.e., place, voicing, and manner) for the segments that were omitted from the children's inventories. Post hoc *t* tests were undertaken to determine the extent that differences existed in the percent retention of the different features. A per-experiment error rate of 0.05 was used for all comparisons. Similar transformations and comparisons were made for the second group of PD subjects to validate the findings.

To investigate if phonological knowledge and feature retention were related, correlation coefficients were calculated between percent correct underlying representation and the percent retention of each feature. These correlations were determined independently for each of the two groups of PD subjects so that the data from the second group of children could be used as a validation or refutation of results from the children in the first PD group.

Results

The results of this investigation of feature retention in phonologically disordered children replicated the effects seen in children with DAS by Thoonen et al. (1994); that is, place of articulation was the least retained feature in children with phonological disorders. Consistent with data on children with DAS, voicing was the feature that was retained most frequently when PD children in this study substituted one phone for another. Percentage retention of the feature *manner* fell between that for voicing and place. These differences in the percentage of feature retention were significant for both groups of PD subjects, $F(2, 27) = 74.65$ and $F(2, 27) = 58.36$, for Groups 1 and 2, respectively. Follow-up *t* tests indicated significant pairwise differences for each contrast (i.e., voicing vs. place, voicing vs. manner, place vs. manner, place vs. voicing). Table 3 presents a summary of the retention of each feature for each child.

Table 3. Summary of feature retention for each subject.

			Percent of features retained		
Subject	PCUR	PCC	Place	Manner	Voicing
Group 1					
3	54	NA	5	54	92
13	40	43	13	11	59
14	65	59	1	50	85
16	33	NA	14	62	47
20	59	43	8	70	93
26	21	19	16	5	41
33	51	56	0	90	98
34	73	65	0	100	86
36	27	47	13	23	60
38	57	77	4	62	84
M	48	51.1	7.4	49.0	74.8
SD	17.1	17.4	6.2	32.6	20.9
Group 2					
4	21	27	3	30	75
6	70	59	2	31	100
8	65	68	2	8	98
11	41	40	42	6	75
18	18	32	5	21	70
25	62	56	0	100	48
27	48	63	0	61	48
28	25	NA	12	28	40
30	73	71	0	17	98
40	53	60	7	17	97
M	47.6	52.9	7.3	31.9	77.3
SD	20.6	15.9	12.8	28.5	20.6

Note. Data are collapsed across error sounds and substitutes.

The strongest relationship was between voicing and PCUR with a mean correlation of .714 across the two groups. The relationship between percent place retention and PD children's phonological knowledge, as indexed by PCUR, was significant but negative for both subject groups [Mean $r = -.54$, $t(18) = -2.8$] and a significant positive relationship was found between percent manner retention and phonological knowledge [Mean $r = .46$, $t(18) = 2.60$]. These correlations suggest that PD children with greater phonological knowledge have less retention of place and greater retention of voicing and manner than is found in children with less phonological knowledge.

Discussion

There are numerous ways to differentiate children who are developing speech normally from those with articulation disorders (see Stackhouse, 1992, for a review). By contrast, the criteria that distinguish subgroups of misarticulating children remain elusive. In their extensive review of issues surrounding the differentiation of DAS and speech delay of unknown origins, Shriberg et al. (1997a, 1997b, 1997c) find only inappropriate stress production to be distinctive for a subset of children with DAS. The remaining 50% of children who were suspected of having DAS could not be distinguished from children with speech delays by any of the parameters that they investigated. However, although their analysis included some feature errors, patterns of phonetic feature retention were not assessed.

This investigation was undertaken to determine the strength of feature retention profiles in differentiating children assumed to have phonological disorders from children thought to have DAS (Thoonen et al., 1994). As the results indicate, patterns are similar for these groups of children in that the place feature was retained least by children with articulatory deficits. Furthermore, place retention in substituted segments was inversely related to a child's phonological knowledge: children with greater phonological knowledge retained the place feature less often than children with more limited knowledge. Although this pattern was evident for the group of children, there were some subjects who did not exhibit this pattern. For example, Subject 4 had a very low PCUR but did not retain place of articulation in his substituted segments. In contrast, Subject 11, with a higher PCUR, did show a high level of place retention. It is not clear why patterns for these children diverged from the group effects.

It could be argued that the children in the current study were incorrectly assumed to have phonological disorders when they actually had DAS. However, all children in this study received treatment that targeted phonological problems (Dinnsen et al., 1990; Dinnsen et al., 1992; Elbert et al., 1990; Gierut, 1985), and all children responded to this treatment in a way that was consistent with other children diagnosed with phonological disorders.

The results of this study can be viewed from two perspectives. It is possible, given the conflicting results of this study and that of Thoonen et al. (1994) that distinctions between children with DAS and those with phonological disorders are not identifiable at the segmental level (Shriberg et al., 1997b, 1997c). Alternatively, production of correct place and voicing may represent a relatively early stage in acquisition. As the child's phonological knowledge becomes more sophisticated, manner features become more strongly represented, and the place feature weakens, whereas the production of correct voicing remains constant throughout acquisition.

The acquisition of stops precedes that of more complex sounds such as fricatives and affricates (Smit, Hand, Freilinger, Bernthal, & Bird, 1990). A child who can only produce stop consonants correctly may mark relevant information about a target fricative by using the homorganic stop. In this sense, the children with low PCURs may be limited in what they have available to represent an incorrectly produced target; place of articulation may be their only available mode. Children with a more adult-like phonological system, as reflected in higher PCURs, may have great flexibility in the substitutions that they use. The question, then, is why do these children with greater phonological knowledge gravitate toward correct manner of production and voicing in their substitutes as opposed to correct place? It is possible that the answer to this question may give some insight into how children acquire and represent their sound systems.

There has been a longstanding debate about the way children recognize words and represent them in the mental lexicon (see Charles-Luce & Luce, 1990 and Dollaghan, 1994 for reviews). At the center of this controversy is whether children have the same representations as adults (Charles-Luce & Luce, 1990; Dollaghan, 1994; Logan, 1992; Nittrouer & Studdert-Kennedy, 1987). In an attempt to address this issue, Logan (1992) studied lexical neighborhoods of children between the ages of 1 and 5 years, using two representations of the CHILDES database. In the first representation, which Logan denoted as the *phonemic analysis*, lexical neighbors were defined as differing by a single segment, such that /kæt/, /sæt/, /fɔt/, and /fɪt/ would all be neighbors of /fæt/. The second representation, which Logan called the *nonphonemic analysis*, was applied to the CHILDES database to determine the similarity of words based on single-feature distinctions such as place and manner of production. In the manner classification system, words were considered neighbors if the addition, substitution, or deletion of the manner category for a single segment yielded a different word (e.g. /fɪt/, /bit/, and /fɪʃ/ are all neighbors). A similar definition of neighborhood was adopted for place of articulation such that /bɪd/ and /dɪd/ would be neighbors in this classification scheme.

Logan (1992) identified two effects of classification schemes on neighborhood density: first, there were fewer neighbors in the phonemic representation system than in the nonphonemic systems, and second, classification on the basis of manner of production yielded less dense neighborhoods than were determined from a place representation. This effect was most pronounced for children between the ages of 1 and 3 years, a period of rapid lexical acquisition. Recognizing a word from a dense neighborhood may be difficult because of the potential for confusion with other words or because of the need for greater perceptual ability to disambiguate neighbors (Charles-Luce & Luce, 1990). With this in mind, Logan proposed that manner might be a means by which young children represent lexical information, because neighborhoods formed on this basis are less dense than those based on place of articulation.

In the present research, the phonetic features of manner of articulation and voicing seemed to dominate in children with relatively high levels of phonological knowledge. This may represent a step in phonological acquisition that is characteristic of all developing systems, whether normal or disordered. This production pattern may develop to aid the listener; maintenance of manner of production may result in fewer ambiguous choices about the identity of a target sound or word. Both the listener and the speaker would benefit from a system that limited confusion, thereby maximizing information transfer. Because the present study was not longitudinal, these speculations cannot be verified. However, it is clear from this study that patterns of feature retention do not uniquely define children with DAS. Rather, there seem to be commonalities across children with articulation problems, independent of the etiology.

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