Progressive Changes in Articulatory Patterns in Verbal Apraxia: A Longitudinal Case Study

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This research reports findings in a 10-year study of an apraxic adult, who was one of five subjects described by Shankweiler and Harris, (*Cortex, 2*, 277–292, 1966). Confusion matrices and feature analysis were used to compare 1965 and 1975 performances. Results indicate that over the 10-year period, errors of place, manner, and omission were markedly reduced. Voicing errors, however, while reduced in total number, still constituted a significant percentage of the patient's residual errors. Implications of these findings are discussed.

INTRODUCTION

The nature of the articulatory disturbance that often accompanies aphasia has long been the subject of interest and disagreement in the literature. Disparate nomenclature (Aten, Darley, Deal, & Johns, 1975; Martin, 1974) is but one example of the lack of consensus. The syndrome has been termed phonetic disintegration (Alajouanine, Ombredane, & Durand, 1939), cortical dysarthria (Bay, 1962), apraxic dysarthria (Nathan, 1947), verbal apraxia, apraxia of speech, and dysarthria; however, it is generally agreed that the disorder is one of articulation, secondary to cerebral dysfunction that often co-occurs with aphasia and frequently remains after all, or most, aphasic symptoms are resolved. The present study uses the term "verbal apraxia," defined as impairment of the integrative control of the speech production apparatus due to cortical dysfunction.

Phoneme productions are characterized by inconsistency, although certain phonemes may never be produced accurately. The oral output is generally slow, labored, and dysprosodic. As utilized herein, the term excludes disorders related to bilateral neuromuscular involvement of the speech mechanism.

Research and publication related to this disorder has focused on description and classification; that is, specification of articulatory characteristics of groups of subjects during a single time period (Alajouanine et al., 1939; Nathan, 1947; Critchley, 1952; Fry, 1959; Bay, 1962; Shankweiler & Harris, 1966; Johns & Darley, 1970; Deal & Darley, 1972; Martin & Rigrodsky, 1974) and input or sensory deficits (Aten, Johns, & Darley, 1971; Rosenbek, Wertz, & Darley, 1973). Little is known about the evolution of the disorder and the efficacy of using remedial techniques for its amelioration. It is significant that with the exception of Schuell, Jenkins, and Jimenez-Pabon (1964); Rosenbek, Lemme, Ahern, Harris, and Wertz (1973); Darley, Aronson, and Brown (1975); and Dabul and Bollier (1976), little has been written about specific therapeutic techniques for use with the apraxic patient. It has been the empirical observation of aphasiologists that verbal apraxia is a syndrome particularly amenable to treatment, provided that the treatment occurs over a considerable time period—years rather than months. The present study was undertaken to investigate this observation.

In 1966, Shankweiler and Harris published the results of an experimental procedure that they had devised to analyze and describe disorders of articulation in aphasia. Subjects of their study were five patients who had suffered cerebrovascular accidents (CVA). In each case the stroke was followed by right-sided involvement and expressive aphasia with minimal comprehension deficits. Within the early recovery period, most of the aphasic symptoms were resolved, and articulation problems were the major residual. Each patient was given a battery of tests, including a test of speech perception, audiometric evaluation, and an articulation assessment.

The articulatory assessment consisted of a test of 200 real-word monosyllables. The list contained most singleton consonants, a sample of the most frequently occurring consonant clusters, and those vowels that are not ordinarily characterized by glides in the regional dialect. A major difference between this and all other tests was that each consonant and consonant cluster occurred eight times in each position, while the eight vowels occurred 25 times each. In a disorder characterized by inconsistency, this was important in order to draw inferences about the relative difficulty of each phoneme. The patient's task was to repeat each word once. Responses were tape-recorded and later analyzed by a phonetically trained listener, using broad phonetic transcription. The transcribed utterances were tabulated as confusion matrices in order to illustrate the frequency with which each phoneme and each cluster was correctly produced or replaced by another phoneme or cluster.

Shankweiler and Harris concluded that for four of their five subjects, initial phonemes were more difficult to produce than terminal phonemes. The vocalic portions of the words were produced with greater accuracy
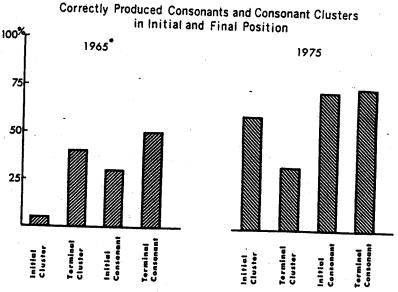
than the nonvocalic portions. Four of the five patients demonstrated accurate production of most vowels. Errors on consonants were classified in terms of whether the substituted sound differed from the target phoneme in (1) place of articulation, (2) manner of articulation, (3) both place and manner, or (4) whether the substituted phonemes were unrelated to the target or omitted completely. The results of the tabulations showed a similar incidence of errors of place and manner, with manner errors slightly predominating. The largest category of misarticulations, accounting for one-third of all errors, was the category of unrelated substitutions and omissions. Particularly common were substitutions of consonant clusters for single consonants, a phenomenon rarely observed in other disorders of speech production.

PROCEDURE AND RESULTS

One of the subjects of the Shankweiler–Harris study (J. P.) continued to seek and receive therapy during the 10-year period since the completion of the study. It therefore seemed worthwhile to replicate the testing procedure of the earlier study and thus derive comparative longitudinal data on this single patient.

J. P. suffered a CVA in 1964. He was a subject for the Shankweiler–Harris study during 1965, approximately 6 to 9 months postonset. He is now 56 years of age and has been healthy since the initial CVA. He continues to demonstrate right spastic hemiparesis and verbal apraxia as his major residual symptoms. He has received speech therapy, both group and individual, for 2–3 hr per week during the past 10 years. Therapy was conducted by a number of clinicians in two rehabilitation settings. In general, the therapeutic techniques followed traditional procedures emphasizing accuracy of articulation in imitation of the clinician. In the fall of 1975, a battery of tests for aphasia indicated only minimal residual deficits in language. Hearing was normal throughout the speech frequencies. On a test of auditory perceptual abilities, the Test of Differentiation of Phonemic Feature Contrasts (Mitchell, 1974), his perception of speech was within the normal range.

The articulatory assessment test devised by Shankweiler and Harris (1966) and previously described was administered. Figure 1 consists of two sets of bar graphs labeled 1965 and 1975. The 1965 graphs are extrapolated from Shankweiler and Harris (1966) as the results on J. P. The percentages shown are approximations rather than exact percentages since they were derived from a graph. Vowel production was not a significant problem for J. P. in 1965 or in 1975 and is therefore omitted from the presentation of results. The differences between 1965 and 1975 are readily apparent. J. P.'s production of initial clusters, initial consonants, and terminal consonants improved greatly. Production of terminal clusters was essentially un-

FIG. 1. Comparison of 1965 and 1975 data on correctly produced consonants and consonant clusters in initial and final position.

changed. Overall, in 1965, 51 initial phonemes, or 25% were correctly produced, while in 1975, 142 initial phonemes, or 71% were correctly produced.

These data are presented in greater detail in the confusion matrices of Figs. 2 and 3. In the matrices the target phonemes appear on the vertical axis, and the phonemes produced appear on the horizontal axis. Cells forming the diagonals indicate correct productions.

Some pattern shifts are recognizable on the matrices. For example, in 1965, /d/ was substituted 43 times and /b/ was substituted 30 times; together, /b/ and /d/ substitutions accounted for 49% of the 1965 errors. In 1975, /b/ and /d/ were each substituted four times, together constituting only 14% of the errors.

In 1965, 18 omissions were recorded, constituting 18% of the total errors. In 1975, no singleton consonants were omitted, indicating a marked pattern change.

In 1965, /s/ was substituted three times, constituting 2% of the errors, while /s/ substitution constituted 20% of the 1975 errors. In the 1975 matrix, 11 errors involved the addition of /s/ to a consonant or cluster. Errors involving /s/ (substituted or added) constituted 40% of the 1975 errors. It is clear that both the number and the nature of the errors changed dramatically during the 10-year period.
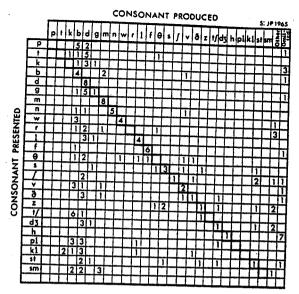
CONSONANT PRODUCED

S: JP 1965

	p	t	k	b	d	g	m	n	w	r	l	f	θ	s	ʃ	v	ð	z	tʃ	dʒ	h	pl	kl	st	sm	Other/Omit
p				5	2																					
t		1		1	5						1															1
k				1	3	1																				
b				4			2									1										3
d					8																					1
g				1	5	1																				
m							8																			1
n				1	1			5									1									
w				3					4																	
r				1	2		1						1									1				
l				3	1					4																3
f				1							6															
θ				1	2			1		1	1			1	1	1										1
s					1								1	3		1		1				1				
ʃ				2										1		1						2		1	1	
v				3	1		1								2											1
ð				3			1							1	1		1									1
z				1	2								1	2					1					2		
tʃ				6	1												1				1		1	2		
dʒ				3	1												1	1			1		1	2		
h				1	1																1					7
pl				3	3					1								1			1					
kl	2		1	3						1						1										
st				2	1						1				1		1				1					1
sm				2	2		3								1		1				1				1	

FIG. 2. Confusion matrix of 1965 phoneme errors.

Table 1 examines the nature of the errors through a feature analysis.[1] A single misproduced phoneme may differ from the target phoneme by one, two, or more features. Therefore, the error totals (Figs. 2 and 3) do not correspond to feature error totals. Shankweiler and Harris (1966) included "voicing" errors as a part of their "manner" category. The present study includes voicing and manner as separate categories. Since 10 of the 1965 errors were classified only as "other," these could not be analyzed by features; therefore, only 139 errors are included in the feature analysis for 1965. The omissions on the 1975 feature analysis are the result of omitting one element in a cluster and are listed as substitutions on the matrix. For example, /s/ was substituted for /st/ twice. Voicing, place, manner, and omission errors were all reduced in total number. The apparent increase in the number of errors of addition may result from our inability to analyze the 10 errors designated as "other" in the 1965 study.

[1] A simple, conventional feature analysis was used. Consonants (other than /h/) were considered to be labial, alveolar, palatal, or velar in place of production, and stop, fricative, continuant, or nasal in manner. Substitutions of /s/ for /θ/ were considered to be errors of place, while /r/–/l/ substitutions were considered as errors of manner only when these particular contrasts were made. Counting of errors of manner, place, and voicing for each phoneme in clusters increased the total number of errors in each category but did not alter the error pattern and was therefore omitted. With respect to clusters, omissions were scored if one or both members of the cluster were omitted. Errors of voicing, place, and manner were scored only for /st/ as noted by dashes in the table. The "additive" category would have been indicated in the 1965 analysis as "other;" phonemes for which these categories are scored are denoted by asterisks.

CONSONANT PRODUCED

S: JP 1975

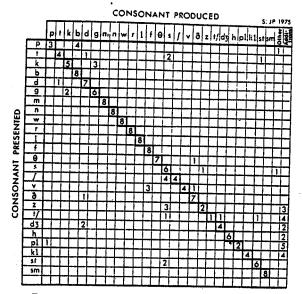| CONSONANT PRESENTED	p	t	k	b	d	g	m	n	w	r	l	f	θ	s	ʃ	v	ð	z	tʃ	dʒ	h	pl	kl	st	sm	Other/Addition
p	3			4																						1
t		4			1									2									1			1
k			5			3																				
b				8																						
d	1				7																					
g			2			6																				
m							8																			
n								8																		
w									8																	
r										8																
l											8															
f												8														
θ													7				1									
s														6	1			1								1
ʃ													4	4												
v												3				4	1									
ð					1												7									
z														3				2								3
tʃ														1	1				1	1			1			4
dʒ					2														4							2
h																			6							2
pl	1																			2						5
kl																							4			4
st														2										6		
sm																									8	

FIG. 3. Confusion matrix of 1975 phoneme errors.

Place and manner errors that were a factor in 31 percent and 37 percent of the 1965 errors were present in only 9% of the 1975 errors. At the same time, omission errors decreased from 18 to 5%. In contrast, voicing errors that were present in 37% of the 1965 errors were present in 34% of the 1975 errors. The addition errors that occurred in 34% of the 1975 errors were very consistent in nature. These errors all involved the addition of an initial voiceless fricative, usually perceived as /s/ by listeners.

In summary, between 1965 and 1975, errors of place, manner, and omission were markedly reduced, and voicing errors, while reduced in total number, still constituted a substantial percentage of J. P.'s residual errors.

DISCUSSION

On the basis of the analyses performed, it appears that therapy with J. P. had been effective in improving place and manner productions and in virtually eliminating omission errors. Therapy had apparently been less efficient in dealing with voicing and addition errors. In an attempt to understand the changes that had occurred, the results of the feature analyses were considered in terms of the dynamics of production.

As discussed by Lisker and Abramson (1964, 1967), the voicing contrast in stops is directly linked to the acoustic consequences of the time between the release of the stop occlusion and the initiation of vocal fold vibration. This temporal relationship is linked to the coordination of abductory and adductory forces at the larynx with upper articulator events (Hirose and Gay, 1972). From the feature analysis of J. P.'s errors, it was hypothesized

TABLE 1

COMPARATIVE FEATURE ANALYSIS OF ERRORS 1965 vs. 1975[a]

Phoneme	Voicing errors		Place errors		Manner errors		Omissions		Additions	
	1965	1975	1965	1975	1965	1975	1965	1975	1965	1975
p	7	4	2	0	0	0	1	0	0	1(s)
t	6	1	2	0	1	2	0	0	0	1(s)
k	5	3	4	0	0	0	3	0	0	0
b	0	0	0	0	3	0	1	0	0	0
d	0	1	0	0	0	0	0	0	0	0
g	0	2	6	0	0	0	1	0	0	0
n	0	0	2	0	3	0	0	0	0	0
w	0	0	0	0	3	0	0	0	*	0
r	1	0	2	0	5	0	0	0	*	0
l	0	0	1	0	4	0	0	0	0	0
f	1	0	0	0	1	0	1	0	0	0
θ	7	1	4	0	5	0	0	0	0	0
s	3	1	3	0	1	0	0	0	1	0
ʃ	3	0	5	4	2	0	1	0	*	0
v	0	3	2	1	5	0	1	0	0	0
ð	0	0	2	0	5	1	0	0	0	0
z	4	3	1	0	1	0	0	0	*	3(s)
tʃ	8	1	6	0	8	0	0	0	0	4(s)
dʒ	1	0	0	0	4	2	0	0	*	2(s)
h	0	0	0	0	0	0	7	0	0	0
pl	—	—	—	—	—	—	1	1	*	5(s)
kl	—	—	—	—	—	—	3	—	*	4(s)
st	5	0	1	0	0	0	2	2	*	0
sm	—	—	—	—	—	—	3	0	*	0
Totals	51	20	43	5	57	5	25	3	1	20
Percentages	37	34	31	9	37	9	18	5	.5	34

[a] Ten of the 1965 errors were recorded as "other" and could not be analyzed by features. Therefore, all percentages for 1965 are based on the 139 errors that could be analyzed.

that he was unable to control the initiation of voicing in relation to his stop release.

The addition of initial voiceless friction to a consonant or cluster occurs if airflow commences before the appropriate articulatory or phonatory constriction is achieved. In this paradigm, J. P.'s addition errors may be considered to result from poor temporal control of airflow, vocal fold adduction, and/or articulatory gesture.

The results of this analysis suggested that the voicing and addition errors arise from a common defect; that is, poor temporal coordination of airflow, phonation, and articulation. Most of J. P.'s residual errors would thus be considered errors of timing.

Three explanations for our subject's pattern of improvement appear possible. First, coordination of airflow, phonation, and articulation may be the most difficult task for the apraxic, or for J. P., and therefore this problem remains after the others have been resolved. Second, it is possible that therapeutic procedures that effectively stress and teach place and manner resulted in correction of these features, whereas therapy was less effective in attacking and correcting (or even recognizing) the effects of incoordination of airflow, phonation, and articulation. Finally, it appears possible that a combination of degree of difficulty and therapeutic emphasis resulted in this pattern of performance.

The results indicate that longitudinal studies of apraxic patients, using systems that allow comparison of consistency of articulation and permit an analysis of the error features, provide critical information about the nature of articulatory dysfunction secondary to cerebral vascular insults. Future studies should test the hypothesis that deficits in coordination underlie a significant portion of the phonemic errors that constitute verbal apraxia.

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