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AN EXPERIMENTAL APPROACH TO THE PROBLEM OF ARTICULATION IN APHASIA[1]

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The purpose of this paper is to outline an experimental approach to an old problem: the nature of the articulatory disturbance which is often associated with so-called "motor" aphasia. It has long been known that in some cases of disturbance of expressive language, a breakdown of speech production occurs at the most molecular level; that is to say, the patient has major difficulties in producing the gestures words are made of. Patients who exhibit the syndrome Alajouanine has called "phonetic disintegration" articulate slowly, hesitantly, with extrinsic facial movements and with many substitutions of one phoneme for another. This condition, which is sometimes called "cortical dysarthria" (Bay, 1962) and "apraxic dysarthria" (Nathan, 1947), must be distinguished from dysarthric disorders arising from damage restricted to lower levels of the motor system. In the latter, articulatory movements are impaired in a more stereotyped and regular fashion; the neural mechanisms responsible for organization of the gestures which convey the phonological units of speech are not involved.

Phonetic disintegration can occur in combination with widespread disorders of expression or, less frequently, in remarkably "pure" form. In the latter case, in spite of the difficulties in emitting speech sounds, expressive abilities (e.g., as shown in writing) may be well preserved, indicating continued access to vocabulary and continued adherence to the rules of syntax. Thus, speech may be

[1] Some of the material on which this paper is based was presented at the annual meeting of the Academy of Aphasia, Niagara Falls, Canada, October 1965.
[2] Also at the Institute of Physical Medicine and Rehabilitation, New York University Medical Center.

selectively impaired at the phonetic level. Phonetic disintegration is most likely to occur as an isolated disturbance at a late stage in recovery from aphasia after remission of other expressive disabilities. It is easy to observe in these cases that the difficulties in articulation do not reflect a corresponding disturbance in speech recognition.

The phenomena of disordered articulation in aphasic patients have not received the study they deserve in view of the opportunities they provide to observe the breakdown of the processes of speech production. The reawakening of interest in the disorders of articulation associated with aphasia owes much to the work of Alajouanine and his colleagues. Alajouanine, Ombredane and Durand (1939) argue forcefully for the necessity of obtaining an adequate phonetic description of speech in cases with disturbed articulation, viewing this as an indispensable requirement for understanding the physiological bases of the syndrome of phonetic disintegration. Important suggestions are made about the ways speech production is linked to the various stages of recovery, ranging from the earliest stage in which only vowels can be produced to later ones in which virtually all segments of speech can be identified, though they are produced unreliably and in the wrong articulatory contexts. Unfortunately, the results of their phonetic studies are not presented in such a way that the reader can make his own evaluation of their findings. The work also suffers from failure to provide the necessary controls.

Fry (1958) has provided an illustration of a method for systematic analysis of the utterances of an aphasic patient with articulatory disorder. The problem was to develop an adequate test to enable an investigator to determine the relative difficulty of all the sounds of speech in their various articulatory contexts. Not only must the sample include all the words required for a complete survey, but it must include enough words of each type to provide adequate sampling. The problem was met by having the patient repeat a list of words chosen to meet these requirements. Phonetic analysis of the patient's tape-recorded utterances was carried out and a complete tabulation of all responses was made. This permitted a classification of all substituted phonemes according to place and manner of articulation. Fry's paper demonstrates the relevance to aphasia studies of a powerful method for discovering the dimensions of a phonological disturbance.

Mention must be made of another approach to the study of articulatory disorders. Lehiste (1965) has carried out meticulous spectrographic analyses of the utterances of a diverse group of patients suffering from a variety of neuromotor disorders, many of them due to damage to brain stem and cerebellar regions. We cannot compare her findings directly with our own because we did not use the technique of spectrographic analysis and because we confined our study to patients with presumably unilateral lesions of the left cerebral hemisphere.

The preliminary findings presented here are a part of a larger ongoing comparative study of articulatory function in cases of damage at different levels and sites in the sensorimotor system. In the present study we have tried to gain an accurate picture of the dimensions of phonemic error which occur in the syndrome of phonetic disintegration associated with "motor" aphasia. Information regarding the consistency and major directions of phonemic substitutions can then serve to guide more direct approaches to the defective speech gestures by means of electromyography, x-ray cinephotography and other techniques. Our program has these two interrelated aspects: first to obtain an adequate assessment of articulatory function in phonetic terms and secondly to study directly the gestures of speech in order to relate the phonetic description of the disordered speech output to the parameters of muscle movement. The present study is limited to the first aspect.

Method and Results

Subjects

Phonetic studies of speech were made in five patients with lesions of vascular origin involving but not necessarily restricted to the anterior portion of the dominant left cerebral hemisphere. All were patients of the Institute of Physical Medicine and Rehabilitation of New York University Medical Center. The group was composed of intelligent individuals with business and professional backgrounds, selected for their willingness to engage in intensive speech therapy. Each had suffered a stroke six months to seven years prior to the examination. The stroke in each case was followed by right hemiparesis and severe expressive aphasia with preservation of comprehension. At the time of testing, aphasic symptoms were greatly diminished, leaving a major residual deficit in articulation.

The patients' ages at the time of testing ranged from 39 to 61 years; three were under 50. None presented difficulties of chewing or swallowing. Some weakness of the right upper extremity was present in all patients, and in two the leg also was involved. Slight weakness of the right side of the face could be detected. All were able to perform movements of the lips, face and tongue on command, but with less than normal dexterity and speed. No cerebellar signs were present and there was no evidence of lower motor neuron paralysis. Audiometry revealed normal pure tone thresholds for frequencies below 2000 cps. In two cases the episode could be traced to occlusion of the left internal carotid artery. In a third case, angiography showed occlusion of the middle cerebral artery, and in two cases the origin of the lesion is not definitely known.

Although very different degrees of recovery of speech are to be found in the group, the sequence of events during recovery was similar for all. Writing was spontaneously adopted as the way around obstacles to oral communication. With the return of speech, the difficulties proved to be chiefly of an articulatory nature. All patients had reached a definite plateau in recovery at the time of testing. The residual level of articulatory impairment ranged from gross difficulty in producing all classes of speech sounds, with poor intelligibility, to mild impairment shown mainly in production of consonant clusters, with good preservation of intelligibility. None showed evidence of generalized intellectual deterioration.

Much interaction over a long period of time had convinced us on clinical grounds that the patients were nearly intact in comprehension of speech. A control, however, is needed in order to be reasonably certain that the errors in articulation occur on the basis of impaired motor organization, rather than on the basis of perceptual impairment. A "rhyme" test was used to determine whether the acoustic cues which signal phonemic differences could be utilized normally by these patients.

Assessment of speech perception

Each patient listened to a taped recording of three 75 word lists of real word monosyllables. He was to encircle each word he heard in a set of five possible answers for that word printed on an answer sheet. For example, if the word spoken was *pat*, the answer sheet might offer the alternatives *pat*, *mat*, *slat*, *bat*, *cat*. In one-third of the list, the alternatives differed, as in the example given above, in initial sound; one third of the answer sets varied in terminal sound, and one third in vowel. Thus, we tested the patients for the ability to perceive initial, terminal and vowel sounds in words. We made up the words for the vowel part of the test; the initial and terminal section lists were taken from a test described by House et al. (1965). As a further control, the same test was given to six speech therapists. The results for four patients (one left therapy before we could administer the test) and six therapists are shown in Figure 1.

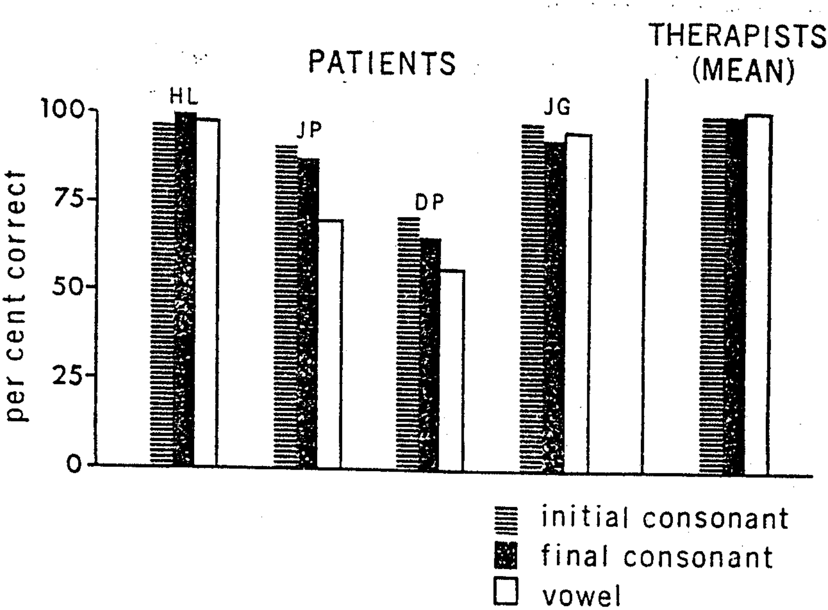

Fig. 1 — *Speech perception test: percent correct identification of initial consonants, terminal consonants, and vowels; shown individually for each of four patients and averaged for six therapists.*

Two patients performed virtually as well as the therapists. Moreover, one of these (JG) showed the greatest impairment of articulation of any member of the group (see Figure 3). This dissociation strongly confirms the impression that severe phonetic disintegration can occur independently of impaired recognition of speech sounds. Two patients performed less well for reasons which are not entirely clear. Some clues can be obtained from examining the pattern of errors. The error pattern in these cases contrasts strikingly to that in *producing* speech; i.e., the greatest incidence of error occurred on the vowel sounds in the rhyme test and on the consonant sounds in articulation. Special difficulty in perceiving vowels is not found in cases of perceptive disability due to sensori-neural hearing loss. Errors in selecting the correct sounds from the multiple-choice sets do not, of course, necessarily reflect misperception. The difficulty may occur on some other basis. Analysis of the errors suggests that some can be attributed to reading impairment.

Assessment of articulation

Since the principal need was to study speech production at the phonological level, the investigation was limited to analysis of the productions of single words. A test consisting of 200 real word monosyllables was assembled. The distribution of phonemes in the word list was such as could be expected to bring into relief the difficulties in articulating the speech sounds of English. The list contains most singleton consonants, a sample of the most frequently occurring consonant clusters, and those vowels which in the regional dialect are not ordinarily characterized by glides. One respect in which this test differs from articulation tests designed for other purposes is in providing the same frequency of occurrence of all phonemes which occur in a given position in the words. Thus [z], a "rare" phoneme, has the same number of occurrences in initial position in the test as [d], a "common" phoneme. Even distribution of phonemes is highly desirable if one wishes to draw inferences about the relative difficulty of speech sounds. The test comprised 25 consonants and consonant clusters in initial position, each of which occurred eight times. Similarly, there were 25 sounds in terminal position, each occurring eight times, and there were eight vowel nuclei, each of which occurred approximately 25 times. The words were recorded on magnetic tape by a trained speaker and presented to the patient through earphones at a comfortable listening level. The patient's task was to repeat each word once. The responses were tape-recorded so as to be available for detailed analysis.

The results of articulation testing were treated in the following manner. The patients' recorded utterances were transcribed by a phonetically-trained listener. The transcription can best be described as broadly phonetic (IPA).[3] The intent was not to make the transcription reflect every phonetic nuance of speech production, for the practical reason that this would involve more categories than could be dealt with without obscuring the main features of the condition. A very broad transcription admittedly ignores features of speech which may have real importance for a physiological understanding of phonetic disintegration, but it has the virtue of allowing the gross features to stand in bold relief. Therefore, we have chosen to ignore narrowly phonetic features in this exploratory phase of our work.

The transcribed utterances for each patient were tabulated as confusion matrices; two such matrices appear as Figure 2. The matrix shows, with respect to each phoneme, the frequency with which it was "correctly" produced or replaced by another phoneme. Each row in the matrix refers to the phonemes occurring in the list, and each column refers to the sounds actually spoken by the patient. Since each initial consonant occurred eight times in the list, the figure *8* in the diagonal indicates that that phoneme was repeated "correctly" on every occasion it occurred. From the diagonal we can quickly discover the relative difficulty of the phonemes, and from the other cells in the matrix, we can discover the degree to which the phonemic substitutions fall into patterns.

Figure 2 gives the matrices of initial consonant substitutions of two patients who illustrate very different degrees of severity. Clinical judgment had placed HL as the least impaired in the group, and the data bear this out. Her errors in articulation were largely confined to a few consonant clusters and certain fricatives [θ, v, z, dʒ]. Clusters involving [l] were produced in a stereotyped manner by splitting the cluster and inserting a vowel in between, as [pəliz] (please) and [kəlin] (clean) thus producing disyllables. The patient lacked sufficient control to produce the cluster as a unitary gesture and had been taught this substitution by her therapist as a way of producing words in which these sounds occurred intelligibly if defectively. The lower matrix in the figure shows initial consonant distortions and substitutions of a severely impaired patient (JP).

[3] In making the transcription, the listener was operating with reference to the normal allophonic ranges of the phonemic categories in the speech structure of English.

INITIAL CONSONANT PRODUCED

Case HL

INITIAL 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
p	8																									
t		8																								
k		1	7																							
b				8																						
d					8																					
g						8																				
m							8																			
n								8																		
w									8																	
r										8																
l											6						2									
f												7	1													
θ		1										3	3				1									
s														7	1											
ʃ															8											
v																1	7									
ð													1				7									
z					2										1			5								
tʃ																			8							
dʒ					1															5						2
h																					8					
pl																						2				6
kl											1												0			7
st																								8		
sm																									8	

Case JP

INITIAL 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	omitted
p	0			5	2																						1
t		0	1	1	5								1														
k			0	1	3	1																					3
b				4			2									1											1
d					8																						
g				1	5	1																					1
m							8																				
n				1	1			5								1											
w				3					4																	1	
r				1	2		1			0							1									3	
l					3	1					4																
f				1								6														1	
θ				1	2			1			1	1	0			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														2			1	1		1				1		2	
tʃ					6	1												1	0								
dʒ					3									1						1				1		2	
h																					1						7
pl				3	3						1									1		0					
kl			2	1	3						1						1						0				
st					2	1								1				1		1				1			1
sm				2	2		3																		0	1	

Fig. 2 — *Confusion matrices of initial consonants and consonant clusters for two patients. Each line of the matrix shows the distribution of sounds the patient produced in response to the sound presented, as indicated on the left margin. Cells forming the diagonal are "correct" productions. Symbols follow usage of the International Phonetic Association. Approximate pronunciations as follows:* [θ] *as in* thin; [ʃ] *as in* shoe; [ð] *as in* then; [tʃ] *as in* chin; [dʒ] *as in* just.

There is a striking tendency to substitute one of the three voiced stop consonants [b, d, g] for almost every other sound in the inventory.

Matrices of this type were made for each patient, one for initial consonants and clusters (e.g., the matrices shown in Figure 2), one for vowel nuclei and one for terminal consonants and clusters. These matrices, in turn, could be summarized by considering the overall percent correct for each matrix, shown in Figure 3.

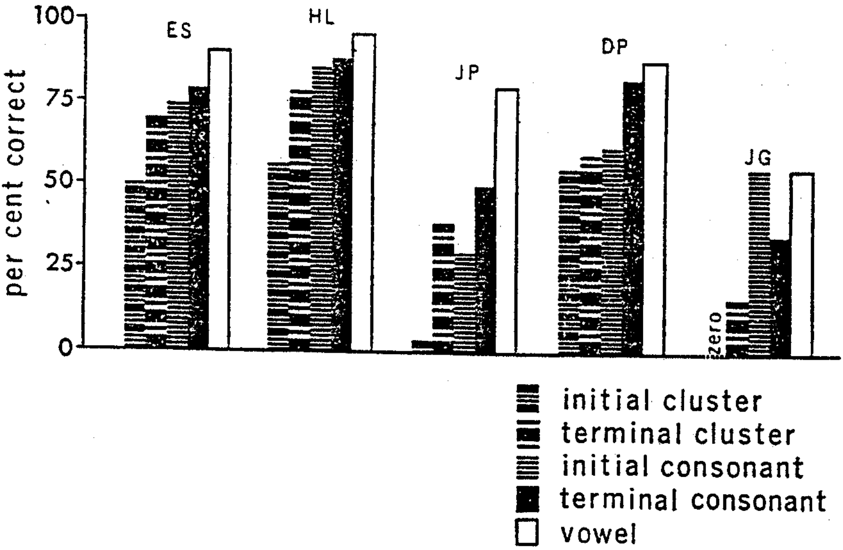

Fig. 3 — *Speech production test: percent correct for each indicated class of sounds for each patient.*

It is apparent from Figure 3 that the errors in articulation are not evenly distributed throughout the word. This figure shows the tabulation of the total number of sounds "correctly" produced in each position in the word for every patient. Not surprisingly, consonant clusters are more difficult to produce adequately than singleton consonants. In every case consonant clusters in the initial portion of the word are the least accurately produced of all sounds. One patient (JG) failed to produce any of these sounds intelligibly. In four of the five cases, we can make the generalization that initial sounds are more difficult to produce than terminal sounds. The vocalic portion of the word is produced with greater accuracy than the nonvocalic portions. This is particularly striking in the case of JP.

Assessment of the production of vowels introduces some special problems owing to the fact that differences in vowel quality are the main sources of phonetic variability between speakers of the same language. In view of this, the listener's assessments of the patients' vowels are more tentative than identification of other portions of the speech signal. In many instances there was uncertainty as to whether a certain feature should be attributed to pathology or to the fact that there may be several "correct" vowels for any given word. This ambiguity might sometimes be resolved by comparing each patient's productions against those of an appropriate control. This should be someone preferably of about the same age as the patient who has shared throughout life the geographic and social environment of the patient. In two cases we found available patients' siblings who met these requirements.

Patient-sibling comparisons were made (in cases HL and JP) by retabulating vowel production using the vowels of their siblings as targets. When this is done, HL's percentage accuracy rises from 97% to 99% and JP's figure changes from 81% to 88%. Although these changes are small, they are a further indication that the production of vowel sounds is very little affected by the disorder. Although the fifth patient, JG, has poor vowel production, we might expect some upward revision if an adequate control were available.

Considering the five cases as a group, there is a great deal of variability in the pattern of sound substitutions which occur, but some sounds were consistently misarticulated. Figure 4 shows the sounds which the group as a whole found difficult to produce.

It includes all phonemes in the inventory for which the wrong sound was produced on at least three of its eight occurrences by at least four of the five patients. The number to the right of each phoneme is the mean per cent error in producing it. It is noteworthy that the lists contain fewer sounds in final position than in initial, an additional indication that these patients have greater difficulty in producing initial sounds. The fricatives and affricates, together with certain consonant clusters, are the classes of speech sounds which are most consistently misarticulated.

The fricatives and affricates are also the most difficult sounds

INITIAL POSITION

Phoneme	% Error
θ	75
v	63
z	65
tʃ	55
dʒ	55
pl	82
kl	73
sm	65

FINAL POSITION

Phoneme	% Error
θ	62
ʃ	58
ð	55
lk	47
ps	65

Fig. 4 — *Speech sounds with highest error rates given as percentages of total opportunity for error.*

to perceive correctly. Confusions are common, particularly among [f], [θ] and [v] (Miller and Nicely, 1955). Therefore we cannot ignore the possibility that some of these errors in production may reflect perceptual confusion, compounded with the likelihood that the transcription also is somewhat unreliable in dealing with sounds of this class. Both possibilities can be checked to some extent by retabulation. Consonant sounds may be classified in terms of the place in the oral cavity at which maximal constriction occurs in forming them (e.g., [b] is labial; [g] is velar), and the manner in which they are produced (e.g., [p] is plosive; [n] is nasal). The errors were classified according to whether the substituted sound differed from the target in place of articulation, manner of articulation, both place and manner, or whether the substituted sounds were unrelated to the target or omitted altogether. When the productions of stop consonants and fricatives were retabulated allowing manner errors, the error rate for fricatives was even greater than indicated by the original tabulation whereas that for stop consonants was less. Thus the fricatives remain the most impaired class of sounds when the tabulation allows as correct those substitutions which are likely to occur on a perceptual basis.

The results of the tabulations for all classes of speech sounds show a similar incidence of errors of place and manner with manner errors slightly predominating. The largest category of misarticulations, which accounted for one-third of all errors, was the category of unrelated substitutions and omissions. Particularly common were the substitutions of consonant clusters for single consonants.

Discussion

A feature of phonetic disintegration which is shared with many other disorders of articulation is the special difficulty in producing fricative and affricate sounds. Speech pathologists have observed that one fricative [s] is the most likely to be impaired in any type of pathological speech whatever the native language of the speaker (see, for example, Luchsinger and Arnold, 1965). The fricative sounds require the use of more muscles and closer control of the amount and timing of movement than, for example, the stop consonants. They are among the last to be added to the child's repertoire of speech sounds (Whetnall and Fry, 1964).

The finding that the fricatives, affricates and some consonant clusters are the only sounds which are consistently misarticulated by patients of our group points to the conclusion that no particular structure or region can be implicated to the exclusion of other parts of the articulatory apparatus. Sharply localized defects of specific muscles or muscle groups were not to be expected in a disorder of this kind. The possibility of dissociated defects of the lips and tongue has been raised (Denny-Brown, 1958), but we have found no evidence of differential involvement of these structures in any patient of our group. The preservation of vowel articulation, which was also observed by Nathan (1947), argues against any selective impairment of the tongue. So does the absence of general impairment of the lingual consonants. Thus, the particular difficulty with the fricatives and clusters, the frequent occurrence of errors of voicing and nasalization and the integrity of the vowels all point to a disturbance of coordinated sequencing of several articulators.

The hypothesis that the most rapid gestures of speech suffer most in phonetic disintegration was suggested by the fact that vowel production, which requires a relatively slow rate of movement, was least disturbed by the disorder. The implication of this hypothesis that production of the stop consonants (requiring the fastest movement) would be most impaired is contrary, however, to what was found.

To what extent do we generally find substitutions of "easy" sounds for "difficult" ones? This question has proved to be a stumbling block in considerations of the nature of phonetic disintegration. One reason is the ambiguity of what is meant by phonological difficulty. A relatively small proportion of the errors represent phonetic simplifications typical of young children (such as substitution of stop consonants for fricatives). A second class of errors must also be regarded as simplifications although they do not occur in children's speech (such as the breaking up of consonant clusters by insertion of a vowel between the normally linked pair of consonants). A third class of substitutions cannot be considered simplifications in any sense. On the contrary, the patients often emitted particularly difficult strings of consonant clusters which do not occur in English words and were nearly impossible to imitate.

Our findings, therefore, give little support to the idea (Jakobson, 1941; Alajouanine and Lhermitte, 1960) that speech in phonetic disintegration mirrors its development in the child. In this we are in agreement with Critchley (1952) and Fry (1958). It is true that our patients find difficult some of the same sounds the young child finds difficult (Morley, 1957), but there is little reason to assume that the difficulty has the same basis.

Phonetic disintegration differs from other disorders of articulation in a number of important ways. Children with developmental articulatory defects and adults with defects of the articulatory structures are predictable in the substitutions they make, whereas variability is one of the striking features of the speech of our group. The errors do not group systematically according to place of articulation. For example, there is no significant tendency for front consonants such as [p] to be better produced than middle or back consonants such as [t] or [k]. A number of errors occurred in the manner of articulation. Chief among these were errors of voicing, particularly the replacement of an unvoiced sound by a voiced one. This type of substitution rarely occurs in children's speech (Fry, 1958).

Many errors can be considered neither as poor approximations to the correct phoneme nor as clear-cut substitutions of related phonemes. The apparent unrelatedness of many of the substituted sounds to their targets, together with the marked lack of consistency of the substitutions, tells us much about the condition. To the extent that these features characterize a given patient's performance, the disorder must stem from disorganization of the process by which phonological units are encoded for production. It is almost inconceivable that residual spasticity or weakness could give rise to errors of this kind.

We have not attempted to describe all pathological features of speech in cases of phonetic disintegration. Certainly the patients have difficulties in producing connected speech which are not revealed by the method of analyzing monosyllables spoken in isolation. Syllabification, in particular, has been indicated as a problem in need of study. Lehiste (1965) and Tikofsky and his co-workers (1965) have shown that the intelligibility of utterances produced by their group of dysarthric patients varied with syllable content.

Even within the present restricted framework there are a number of questions which cannot be answered by studies of the acoustic speech output alone, whether by the trained listener or by spectrographic analysis. Neither can give direct information about the motor gestures of speech. New developments in the application of electromyography to speech research (Harris et al., 1964) make it possible to obtain a description of phonetic disintegration directly in terms of the disordered movements. An application of EMG to the study of a case of developmental dysarthria was illustrated by Rootes and MacNeilage (in press), and we are hopeful that this technique, used in conjunction with the method outlined here, can clarify a number of remaining questions. We would like to know, for example, whether the vowel gestures are as little affected by the disorder as the identification data would suggest.

It is of basic interest to learn whether or not all the normal components of each distinctive gestural unit of productive speech are present in the utterances of these patients, both when the target sound is acceptably produced and when another is substituted for it. If the gestures are intact in form, what errors of timing occur? What proportion of the errors are attributable specifically to problems of co-articulation? In the normal workings of speech all participant processes are so thoroughly fused in their integrated action that the relative contribution of each cannot be understood. We believe that careful examination of these questions in persons with localized interruption of a motor or sensory link in the speech chain can contribute new understanding to the processes of speech production.

Summary

A phonetic analysis was made of speech production in five patients with major residual deficits in articulation following remission of more widespread disturbances of verbal expression. The findings demonstrate major disturbance of speech production at the most molecular level. Maximal difficulty in articulation occurred at the beginning portion of words. Consonant sounds were much more often misarticulated than vowel sounds. Fricative and affricate consonants and certain linked groups of consonants were the most often affected of all sounds of speech. Phonetic simplifications typical of young children were observed less frequently than other errors which are not found in children's speech nor in the speech of adults with defects of the articulatory structures.

Systematic observation of speech in phonetic disintegration may well contribute new understanding of the fundamental processes of speech production.

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