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The Frequency of Occurrence of Phonemes in the Speech of Aphasics

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THE FREQUENCY OF OCCURRENCE OF PHONEMES IN THE SPEECH OF APHASICS

by
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This thesis meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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ABSTRACT

This study was designed to investigate the phoneme selection patterns in the spontaneous speech of Broca's and Wernicke's aphasics. The frequency distributions of phonemes for the aphasic subjects was compared to the normal distribution curve of English consonantal phonemes. Differences in the frequency of occurrence of phonemes subsequent to neurological impairment may be linked to the nature of the impairment. In addition, this study described and compared the occurrence of phonological processes in the single word responses of the subject groups. The frequency of phonemes and the occurrence of phonological processes were then analyzed jointly for possible trends.

Analysis of the spontaneous language samples of the aphasic subjects revealed that the frequency of occurrence of phonemes was not significantly different than the normal distribution, nor was it different between the subject groups. This finding held true with regards to the values of the phoneme frequencies and the ranking within the phoneme distributions. The Assessment of Phonological Processes-Revised (Hodson, 1986) was used to analyze the single word responses to confrontation tasks. It was found

that both the Broca's and Wernicke's aphasics exhibited phonological processes in their speech, but the Broca's aphasics produced significantly more errors.

The results of this study reveal that, although aphasics exhibit phonological processes in their speech, these errors are not reflected in a change in the frequency of occurrence of phonemes. Interpretation of this finding may indicate that the phonological processes demonstrated in the speech of aphasics are not the result of a dysfunction of the rule-based structure of the linguistic system, but rather of the processing links within this system. As well, the nature of the phonological processes exhibited may serve to differentiate the nature of the two aphasic disorders; Broca's aphasia as a motor programming deficit, and Wernicke's aphasia as a deficiency in selection and retrieval.

CHAPTER 1

INTRODUCTION AND REVIEW OF LITERATURE

Introduction

Lexical avoidance has been studied in normal speakers as well as in individuals with various speech and language disorders. Locke (1983) suggests that a relationship exists between the ease of acquisition of sounds and their representation in languages. He suggests that an internal mechanism exists within persons which allows the individual to avoid difficult sounds. Investigations into the acquisition of language in children reveal that phonology is acquired in a logical sequence, that is, children acquire easier and more frequently-used sounds first (Ingram, 1981). It would appear that a general tendency exists across sectors of the population to favor the use of phonetically simpler elements and to avoid those elements which pose difficulty.

Within the human brain, localized areas have been deemed responsible for various aspects of language (Whitaker, 1971). Cerebrovascular accident (CVA) refers to the disrupted flow of blood to the brain, which may result in a neurological lesion. If a CVA-induced lesion is within an area of the brain designated for language,

aphasia may result. Aphasia is a language impairment in the expressive and receptive modalities resulting from neurological damage to the areas of the brain responsible for language (Davis, 1983; Eisenson, 1984; Sarno, 1981). Lesions may be in the anterior or posterior portions of the brain, which result in non-fluent and fluent aphasias respectively.

Studies have shown that aphasics (Broca's and Wernicke's) display certain phonological processes in picture-naming confrontation tasks (Blumstein, 1973; Smith, 1987). However, the phonological processes which consistently occur during confrontation tasks do not appear to be present in the same subjects during spontaneous speech (Smith, 1987). A possible explanation of this phenomenon is that the processes are not present in spontaneous speech because the individual is able to choose the words and sounds to be used. As such, if an individual exhibits processes on certain phonological patterns, the individual has the option to avoid using these phoneme patterns in spontaneous speech (Locke, 1983; Smith, 1987). This premise serves as the basis for the present study.

The purpose of this study was to identify possible differences in the frequency of occurrence of English phonemes in the spontaneous speech of aphasics as compared to a normal distribution curve of English phonemes. Non-

fluent aphasics classified as Broca's and fluent aphasics classified as Wernicke's were used for this study.

Review of Literature

Researchers in the past have studied many aspects of the phonological deficits in adult aphasic patients (Blumstein, 1973; Nespoulous, Joanette, Beland, Caplan, & Lecours, 1984; Shewan, 1980, Smith, 1987). Phonemic paraphasia is one of the primary deficits associated with aphasia. "Phonemic paraphasia has implied that, at a cognitive level of planning verbal production, the phonological rules of speech sound selection and combination are misrepresented" (Davis, 1983, p. 109). Thus, the phonemic errors found in the speech of aphasics can be discussed from a phonological framework.

A pioneering study of phonological characteristics of aphasic speech was conducted by Blumstein (1973). Blumstein used a distinctive features approach to investigate the phonemic errors of aphasic speech. A distinctive feature is defined as "a characteristic of a phoneme which is essential to its identity as distinct from other phonemes" (Hodson, 1986, p. 100). Blumstein found that most substitution errors occurred between phonemes which differed by only one distinctive feature. This finding suggests that an underlying rule-based system affects phonological error selection.

Further studies of phonological deficits in aphasic speech have revealed similar and expanding results. Shewan (1980), in her study of nine Broca's aphasics, suggested that common phonological processes contributed to receptive and productive impairments. Research has also been conducted focusing on the phonological deficits associated with different clinical types of aphasia: Guyard, Sabouraud, and Gagnepain (1980) investigated the phonological disturbances in Broca's and Wernicke's aphasics; Nespoulous et al. (1984) contrasted the phonological deficits in Broca's and conduction aphasics; Smith (1987) reported the occurrence of phonological processes in the speech of Broca's and Wernicke's aphasics.

Many of the past studies discuss a `markedness effect' in the phonemic deficits in aphasic speech (Blumstein, 1973; Nespoulous et al., 1984). Markedness is generally discussed in terms of distinctive features and refers to the presence or absence or particular features in a phoneme (Nespoulous et al., 1984). As such, the `markedness effect' can be interpreted to fit a more current framework in communicative development; phonological patterns and processes. Smith (1987) applied a phonological process model to the phonemic errors in aphasic speech and found that the errors could be classified and described in terms of the process which the error represents.

In investigating disordered language, and in

In investigating disordered language, and in particular, disorders of phonemic expression, phonology is an especially useful tool. Phonology describes the sound system of a language in terms of phonemic patterns rather than dealing with individual speech sounds. The concept of phonology has been used to systematically explain the acquisition of language in children. Phonology can be defined as the collection of meaningful sounds and the rules for combining these sounds within a given langua e (Hodson & Paden, 1983). Identifying speech deficits in terms of phonological processes allows the errors to be classified systematically rather than being distinguished individually. Adult phonology is comprised of three components; an inventory of phonemes, distributional and sequence rules, and phonetic change rules (Hixon, Shriberg, & Saxman, 1980).

The theoretical basis of phonology suggests that children acquire a rule-based sound system in a series of patterns, the use of which allows them to communicate within a linguistic community. Hodson and Paden (1983) suggest that systemic patterns underlie disordered speech in much the same way as normally developed speech. Normally developed speech and disordered speech are characterized by phonological patterns and phonological processes respectively. A phonological pattern is defined as "the standard adult speech patterns of a linguistic

community including sound classes, syllable shapes, and syllable sequences"; a phonological process is defined as "a regularly occurring deviation from standard adult speech patterns (which) may occur across a class of sounds, a syllable shape, or syllable sequence" (Hodson & Paden, 1983, p. 102). Phonemes are classified into patterns by acoustic and articulatory characteristics, or distinctive features (Blumstein in Sarno, 1981). A phonological process is a deviation across these patterns. Hodson describes 30 such phonological processes (see appendix A).

Much of the past research into phonemic disturbances in the speech of adult aphasics has focused on articulation and distinctive feature deficits (Blumstein, 1973; Shankweiler & Harris, 1966). As phonology is viewed as a distinctive features approach to speech development, these past studies provide a basis for applying a phonological processes model to aphasic speech. According to Blumstein (1973):

> despite any differences which may underlie the specific aphasic disorders, the patterns of phonological disintegration remain constant (suggesting) that the phonological system is hierarchically organized according to the principles inherent to the language system, and it is this hierarchical organization of phonological relations which is reflected in the phonological patterns of aphasic speech (p. 75).

In studying the speech of aphasics, each type of aphasia can be described in terms of its phonological characteristics (Guyard et al., 1980; Shewan, 1980).

Neurolinguistic models of language suggest that within the left cortical hemisphere, specific areas of the brain can be identified as the centers for specific language functions (Whitaker & Whitaker, 1976). Eisenson (1984) states that "with regard to language, the assumption and implication is that there are areas of the brain that are essential for particular functions, such as articulation, speech perceptions, reading, and writing" (p. 57). Phonology, as a component of language, can also be localized within the brain.

> The three-part structure incorporating Heschl's Gyrus, some of Wernicke's area, the arcuate fasciculus, Broca's area, and perhaps the vocal tract area of the motor cortex, constitutes the phonological component of the grammar and its interface or contact with the primary production and recognition system--the auditory and verbal (Whitaker, 1971, p. 61).

The neurolinguistic theory provides support for the assumption that phonology, along with the other components of language, may be affected in adults who have suffered neurological damage due to lesions in the language centers in the left cortical hemisphere.

An interruption in the cortical pathway of language processing can result in an impairment in the encoding or decoding of language. Thus aphasia, which is the language impairment due to neurological insult, presents linguistic deficits across a number of parameters. More specifically, aphasia can be defined as "an acquired impairment underlying receptive and expressive modalities and caused

by damage to areas of the brain which are primarily responsible for the language function" (Davis, 1983, p. 1). Insult to the major language centers in the brain often result in neurological lesions in these areas. Neurological lesions to the left cortical hemisphere may result from a number of neuropathologies; a disruption of the blood supply to the brain, or a stroke; an abnormal growth of brain tissue, or a tumor; or sudden heard injury, or trauma (Davis, 1983).

Classification of the types of aphasia is done by grouping the primary deficits found in the various syndromes. For the purpose of this study, two of the aphasic syndromes will be discussed, Broca's aphasia and Wernicke's aphasia. These aphasias may be approached in terms of general characteristics as well as the phonological characteristics of each type.

Broca's aphasia has also been termed expressive aphasia. The associated speech in non-fluent and generally telegraphic. Auditory comprehension is usually intact, although word and sentence repetition may be problematic. In addition, Broca's aphasics most often display some degree of right-sided hemiparesis. Wernicke's aphasia can be directly contrasted with Broca's aphasia as a receptive aphasia. Speech is fluent and syntactically intact with numerous semantic paraphasias. Impaired auditory comprehension is the primary deficit in Wernicke's

aphasics. Word and sentence repetition are generally impaired along with reading and writing.

Blumstein (1973) suggests that differential patterns of phonological production may be distinguished for the different types of aphasia. She states that "the underlying mechanisms producing the phonological patterns under investigation may indeed be different in each aphasic group" (p. 75). This does not suggest that aphasics groups can be differentiated on the basis of phonological patterns, but rather that such patterns do exist. It has been stated that "the errors which do occur seem to affect the abstract properties of speech sounds and thus implicate a deficit at the level of phonological organization or planning" (Shinn & Blumstein, 1983, p. 91).

Kohn, Schonle, and Hawkins (1984) suggest that Broca's aphasics do not express any deficits at a phonological level. They propose that the phonemic paraphasias of Broca's aphasics are phonetically based. However, Nespoulous et al., in their 1984 study, revealed consistent cluster reduction and devoicing, both of which are marked phonological processes, in the productions of Broca's aphasics. "The Wernicke's aphasic exhibits primarily a phonemic or phonological planning deficit" (Shinn & Blumstein, 1983, p. 90).

While many studies support the differential phonological characteristics among types of aphasics, some

evidence to the contrary has been presented. In their report of Blumstein's 1973 study, Guyard et al. state that "there is no difference in the frequency of four types of aphasic errors (substitution, simplification, environment, addition) among three groups of patients; Broca's, conduction, and Wernicke's" (Guyard et al., 1981, p. 20). Despite contradictions regarding the nature of the phonological deficits within and among aphasic types, the general consensus is that these deficits do indeed exist.

The theoretical model of developmental phonology suggests that sound patterns are acquired with respect to complexity. More precisely, linguistically simpler sounds are acquired earlier than those sounds that are more complex. This linguistic acquisition of sounds may also be represented in a phoneme's use across lexical settings, or its frequency of distribution (Denes, 1963). The interrelation between these two phenomenon (i.e., sound acquisition and phoneme representation) may be discovered in a third phenomena, that being lexical avoidance. According to Locke (1983), "if there is a relationship between the ease of acquisition of sounds and their universal representation, one might suppose there is a mechanism that allows adults to avoid difficult phonetic elements" (p. 153). Locke also quotes statistical evidence supporting lexical avoidances in adult speakers (p. 143). These findings are supported by the data gathered by Denes

(1963) regarding the frequency distribution of English phonemes. Denes found that those phonemes which develop earlier in the sequence (e.g., /t, n, d/) occur in speech more frequently than those sounds which are develop later (e.g., /ʒ, tʃ, dʒ/).

Blumstein (1973) compared the frequency of occurrence of individual phonemes between normal speakers and aphasic speakers. Her study did not discover a significant difference in the frequency of occurrence of the individual phonemes between the populations. However, in her study, Blumstein investigated the frequency of occurrence of individual phonemes rather than frequencies across phonological patterns.

The purpose of this study was to investigate lexical avoidances in the speech of aphasics across phonological patterns. The primary research question addressed in this study was: is there a significant difference in the frequency of occurrence of phonemes in the spontaneous speech of aphasics as compared to the normal distribution curve of English phonemes? In addition, the following subsidiary questions were addressed:

1. Does phoneme frequency in spontaneous speech differ for individuals with Broca's and Wernicke's aphasia?

2. What phonological processes occur consistently in the speech of individuals with Broca's and Wernicke's aphasia?

3. How do the differences in phoneme usage between the aphasic and normal distributions in spontaneous speech compare to the phonological processes exhibited by the aphasics in confrontation tasks?

CHAPTER II

METHODOLOGY

The present study investigated the phonological processes and phoneme choosing tendencies in aphasics. The subjects consisted of 17 individuals who have suffered neurological impairment due to a cerebrovascular accident (CVA) which has resulted in a diagnosis of Broca's or Wernicke's aphasia. Each subject was interviewed by the researcher during a 45 minute audiotaped one-on-one interaction. The language samples gathered from each subject included; single-word utterances elicited through confrontation tasks using the picture stimuli suggested in the Assessment of Phonological Processes-Revised (APP-R) (Hodson, 1986), and a spontaneous conversation sample. The single word utterances were analyzed for phonological processes according to the APP-R and the spontaneous speech samples were analyzed for the frequency of occurrence of English consonantal phonemes. This data was subjected to reliability checks, frequency distributions, tests of significant difference, and measures of central tendency and dispersion.

Subjects

The subject pool consisted of 17 individuals who have suffered a CVA resulting in neurological impairment in the left cerebral hemisphere. Ten of the subjects had been previously diagnosed as demonstrating characteristics of Broca's aphasia, as a result of an anterior lesion; seven of the subjects had been diagnosed as demonstrating characteristics of Wernicke's aphasia, as a result of a posterior lesion. All diagnoses were made by a certified speech-language pathologist on the basis of speech and language deficits resulting from neurological impairment. Individuals with speech, language, or hearing deficits prior to the onset of the CVA were not included in this study. Information regarding age, sex, and length of time post-mortem was gathered and reported post-hoc.

Subjects diagnosed with Broca's aphasia ranged in age from 62 to 95 years (mean age of 78.3 years). Length of time post-onset of the CVA ranged from one month to 38 months for this subjects group (mean length of time post-onset of 6.7 months). Subjects diagnosed as Wernicke's aphasics ranged in age from 57 to 91 years (mean age 77.1 years). Length of time post-onset for the Wernicke's aphasics ranged from one month to 36 months (mean length of time post-onset of 13.6 months). Three of the subjects had suffered multiple infarcts. For these individuals, length of time post-onset was considered from the date of the most

recent CVA. Appendix B provides a summary of subject identifying information.

Consent for participation forms, which described the nature of the study, were signed by each subject, or by a family member if the situation warranted. This consent form is shown in appendix C.

Instrumentation

Instruments for this study included the APP-R, picture cards for confrontation tasks, BASF 90 CR-E II chromdioxide audiotapes, and a TCM-19V model Sony tape recorder.

Design

This study was a descriptive study with multiple subjects. The phonological processes exhibited in confrontation tasks and the phoneme frequency in spontaneous speech of the two subject groups were described and compared.

Procedure

Data were gathered from the subjects during an interview with the researcher. Picture-naming confrontation tasks were administered using the stimuli suggested in the APP-R. As well, a spontaneous language sample was taken from each subject. Topics were provided by the researcher as warranted to initiate conversation.

The language samples were gathered by the researcher during a one-on-one audiotaped interview, which was

approximately 45 minutes in length. The samples were collected in a setting suitable to the subject; in the hospital, in the subject's home, or in an outside meeting place. Each language sample was labelled numerically and was preceded by a brief statement of the type of aphasia. Age, sex, and length of time post-mortem were noted for comparative purposes during later analysis.

The spontaneous conversational samples were analyzed for the frequency of occurrence of each English consonantal phoneme. Each conversation sample was transcribed and the number of occurrences of each phoneme was calculated. The frequency of occurrence of the individual phonemes was expressed as a percentage of the total number of phonemes within the sample. Vocalic phonemes were totalled cumulatively in the frequency calculations.

The frequency of phoneme occurrence data were analyzed for individual subjects, within subject groups, and between subject groups. In addition, these data were compared to the frequency of occurrence of English phonemes in the general population (Denes, 1963).

The second portion of the language sample consisted of the picture-naming responses in accordance with Hodson's APP-R (1986). The picture stimuli suggested by Hodson consist of 50 single-word objects which are designed to elicit 32 phonological patterns (see appendix A). Picture-naming confrontation tasks were used to elicit responses as

this method supplied no information to the subject regarding the sounds in the target word. For those subjects who were unable to perform the picture-naming tasks, responses were elicited imitatively.

The elicited single-word responses were analyzed using the phonological processes presented by Hodson (1986) in her APP-R (see appendix A). Hodson describes individual sound errors in terms of their relationship to broader categorical deficits. She groups these errors as sound omissions, class deficiencies, phoneme substitutions, assimilations, voicing alterations, and place shifts. These categories are further subdivided based on articulatory distinctive features (e.g., labial, lingual, dental, palatal, velar) and acoustic distinctive features (e.g., nasal, stop, fricative, glide, liquid).

Comparisons of the type and quantity of the phonological processes in the confrontation tasks were made. These data were analyzed within each group of subjects as well as among the groups (i.e., groups defined by the type of aphasia). The occurrence of each process, as well as the processes as a whole, was compared among the groups of Broca's and Wernicke's aphasics.

Data

Phoneme frequency of occurrence data were compared between the two groups and with a normal distribution curve of English phonemes (Denes, 1963). The phonological

processes data were analyzed and displayed in accordance with the APP-R (Hodson, 1986).

Intrajudge reliability checks were performed on the transcription of the language samples, calculation of phoneme frequency, and the evaluation of the phonological processes. Language samples from each aphasic group were subjected to interjudge reliability testing performed by individuals trained in phonetic transcription and familiar with Hodson's description of phonological processes.

Frequency distributions (Keppel & Saufley, 1980) for the occurrence of individual consonantal phonemes in the spontaneous language samples were calculated as a percentage of total phonemes. Similar frequency data were calculated for the phonological processes in the confrontation tasks (i.e., percentage of total processes). A Wilcoxon-Mann-Whitney test of (Siegel & Castellan, 1988) was performed to determine statistical differences in phoneme frequency among the two subject groups and normal speakers. Spearman Rank-Order Correlation Coefficient, Wilcoxon Sign test, and Chi-Square Goodness-of-Fit tests (Siegel & Castellan, 1988) were utilized post-hoc to further examine the data. A t-test (Keppel & Saufley, 1980) was performed to determine statistical differences in the frequency of occurrence of the phonological processes between the two subject groups. The Wilcoxon-Mann-Whitney test and the Spearman Rank-Order Correlation Coefficient

(Siegel & Castellan, 1988) were used for post-hoc analysis of this portion of the data.

CHAPTER III

RESULTS AND DISCUSSION

The purpose of this study was to investigate lexical differences in the speech of aphasics as compared to normal speakers. This purpose was accomplished by analyzing the language samples of individuals diagnosed as Broca's and Wernicke's aphasics. Spontaneous, multi-word language samples were analyzed for the frequency of occurrence of consonantal phonemes; single word responses were analyzed for the occurrence of phonological processes. The primary research question addressed whether there was a significant difference in the frequency of occurrence of phonemes in the spontaneous speech of aphasics as compared to the normal distribution curve of English phonemes. The following subsidiary research questions were also explored:

1. Does phoneme frequency in spontaneous speech differ for individuals with Broca's and Wernicke's aphasia?

2. What phonological processes occur consistently in the speech of individuals with Broca's and Wernicke's aphasia?

3. How do the differences in phoneme usage between the aphasic and normal distributions in spontaneous speech compare to the phonological processes exhibited by aphasics in confrontation tasks?

Frequency of Occurrence of Phonemes

The frequency of occurrence of phonemes for the aphasic subjects was obtained by analyzing the spontaneous language sample of each subject. The number of occurrences of each consonantal phoneme was tallied and then divided by the total number of phonemes (consonants and vowels) in the language sample to obtain a percentage of occurrence for each phoneme. All vocalic phonemes were tallied together. The percentage of occurrence for the aphasic subjects was compared to the normal distribution curve of English consonantal phonemes (Denes, 1963).

Intrajudge reliability checks were performed on approximately 20 percent of the language samples (n=3); interjudge reliability checks were performed 25 percent (n=4) of the language samples. Respective percentage of agreements of 97 percent and 94 percent were obtained.

Occurrence of Phonemes for Broca's Aphasics

Results

Spontaneous language samples were gathered from nine of the ten Broca's aphasics. One of the subjects was unable to complete this task. Samples ranged from 61 to 731 words (mean of 367 words). The frequency distribution for the consonantal phonemes for the Broca's aphasic subjects, along with the normal distribution curve, is shown in Table 1. Consonantal phonemes comprised 59.457

percent of all phonemes, with the remaining 40.543 percent being vocalic phonemes. In the normal distribution curve (Denes, 1963) consonantal phonemes comprised 60.726 percent of all phonemes, and the remaining 39.274 percent of the phonemes were vocalic.

The frequency distribution of phonemes for the Broca's aphasics was compared to the normal distribution

TABLE 1

Frequency of Occurrence of Phonemes for Broca's aphasics

Phoneme	Broca's Subjects Percentage	Broca's Frequency Ranking	Normals Percentage	Normals Frequency Ranking
t	8.907	1	8.403	1
n	8.534	2	7.085	2
s	4.345	4	5.089	3
d	5.516	3	4.177	4
l	3.660	5	3.689	5
m	2.966	7	3.289	6
ɚ	2.634	8	2.993	7
k	3.111	6	2.899	8
r	2.281	10	2.770	9
w	2.354	9	2.566	10
z	2.105	11	2.493	11
b	1.773	13	2.084	12
v	1.265	16	1.852	13
p	0.944	20	1.770	14
f	1.099	18	1.728	15
h	1.815	12	1.673	16
j	1.389	15	1.530	17
ŋ	1.151	17	1.244	18
g	1.597	14	1.162	19
ʃ	0.342	22	0.702	20
θ	1.037	19	0.596	21
dʒ	0.280	23	0.514	22
tʃ	0.353	21	0.368	23
ʒ	0.000	24	0.051	24

using the Wilcoxon-Mann-Whitney test (Siegel & Castellan, 1988). A Z score of 0.189 was obtained, which was not found to be significant. In addition to the Wilcoxon-Mann-Whitney test, the data were subjected to post-hoc analysis using the Spearman Rank-Order Correlation Coefficient and the Wilcoxon Sign test (Siegel & Castellan, 1988). The results of these tests support the findings of the Wilcoxon-Mann-Whitney test. The Chi-Square Goodness-of-Fit test (Siegel & Castellan, 1988) was used to determine if a significant difference existed between the expected frequencies (i.e., the normal distribution) and the observed frequencies (i.e., the distribution for the Broca's aphasics). The results of this test were also non-significant, consistent with the findings of the other statistical tests. A summary of the results of these tests is found in appendix D.

Discussion

Results of these tests indicate that there is no significant difference in the frequency distribution of phonemes for Broca's aphasics as compared to the normal distribution. These findings are in accordance with previous studies of aphasic speech (Blumstein, 1973; Smith, 1987). In the normal distribution curve, the four most frequently occuring phonemes (/t, n, s, d/) comprise 24.8 percent of the total phonemes; in the Broca's distribution curve, these same four phonemes comprise 27.3 percent of

Figure 1.
Percentage of Occurrence of Consonantal Phonemes

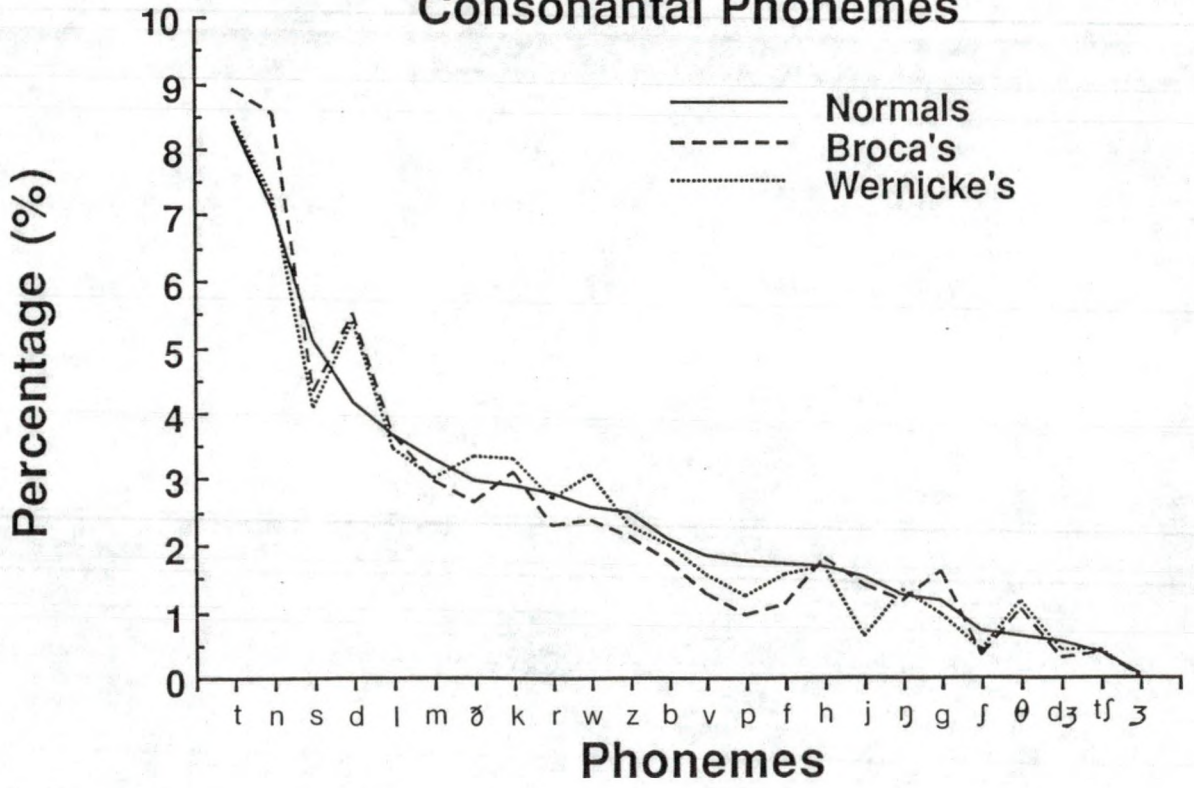


TABLE 2

Chi Squared Values for
Aphasic versus Normal Speakers

Phoneme	Broca's Chi Square Values	Wernicke's Chi Square Values
t	0.030	0.000
n	0.296	0.005
s	0.109	0.192
d	0.429	0.347
l	0.000	0.011
m	0.032	0.022
ə˞	0.043	0.037
k	0.016	0.057
r	0.086	0.002
w	0.018	0.095
z	0.060	0.019
b	0.046	0.004
v	0.186	0.045
p	0.385	0.162
f	0.229	0.014
h	0.012	0.000
j	0.013	0.540
ŋ	0.007	0.003
g	0.163	0.038
ʃ	0.185	0.131
θ	0.326	0.487
dʒ	0.107	0.023
tʃ	0.001	0.003
ʒ	1.000	0.036

the total. The nature of both distribution curves is such that both the curves are positively skewed. Because of this phenomenon, it is reasonable to expect that the rank order distribution of phonemes within the curves would be similar (see Table 1). Figure 1 portrays the frequency distributions for the Broca's and normal populations; Table 2 specifies the differences between the observed (Broca's)

and the expected (normal distribution) frequencies for each consonantal phoneme. The numerical values given are a result of the following portion of the Chi Square formula:

$$(O_i - E_i)^2 / E_i$$

where $_i$ = the individual phonemes

Using these calculations, the phonemes /ʒ, p, d, ɵ/ appear to deviate the most from the normal curve (see Figure 2).

Occurrence of Phonemes for Wernicke's Aphasics

Results

Spontaneous language samples were gathered from six of the seven Wernicke's aphasics. One of the subjects was unable to complete this task. Samples ranged from 626 to 771 words (mean of 724 words). The frequency distribution for the consonantal phonemes for the Wernicke's aphasic subjects, along with the normal distribution curve, is shown in Table 3. Consonantal phonemes comprised 59.678 percent of all phonemes, with the remaining 40.322 percent being vocalic phonemes.

The frequency distribution of phonemes for the Wernicke's aphasics was compared to the normal distribution curve using the Wilcoxon-Mann-Whitney test (Siegel & Castellan, 1988). A Z score of 0.072 was obtained, which was not found to be significant. In addition to the Wilcoxon-Mann-Whitney test, the Spearman Rank-Order Correlation Coefficient and the Wilcoxon Sign test (Siegel

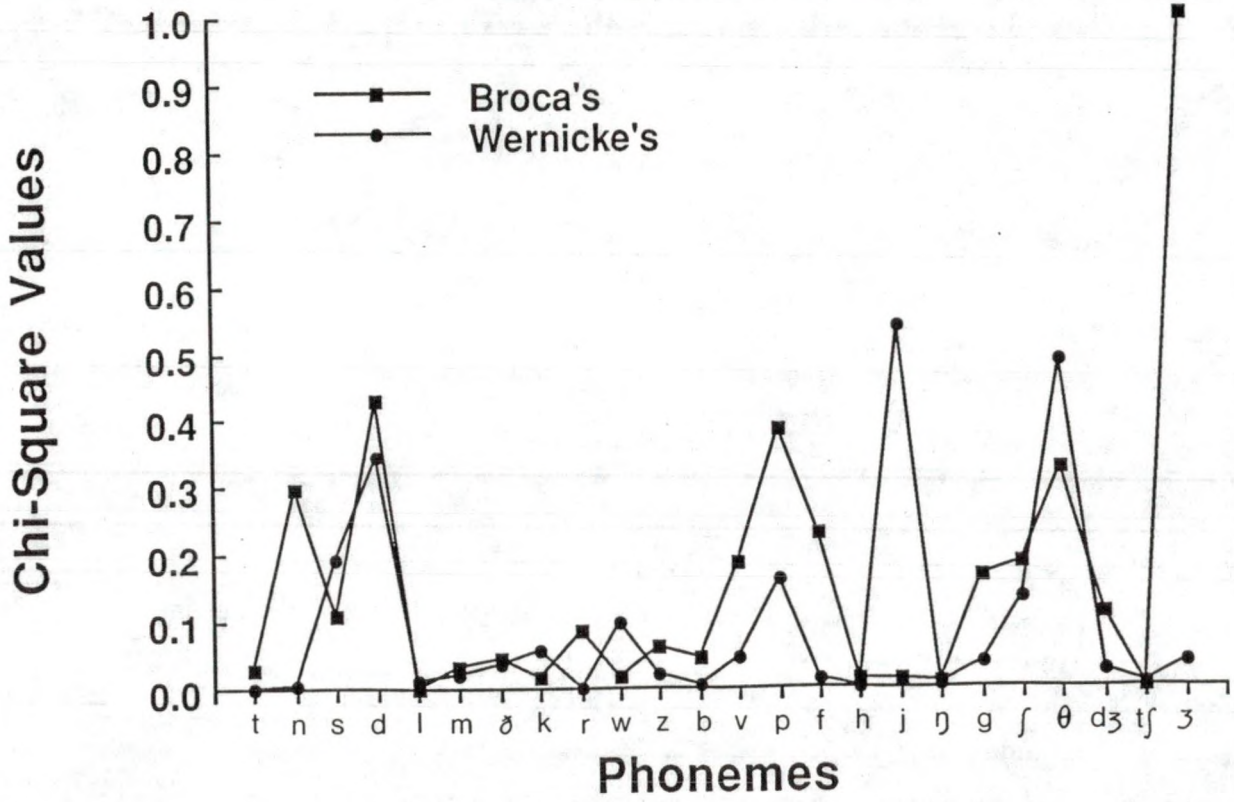
& Castellan, 1988) were performed on the data post-hoc. The results of these tests support the findings of the Wilcoxon-Mann-Whitney test. The Chi-Square Goodness-of-Fit test (Siegel & Castellan, 1988) was used to determine if a significant difference existed between the expected frequencies (i.e., the normal distribution) and the observed frequencies (i.e., the distribution for the Wernicke's aphasics). The results of this test were also

TABLE 3

Frequency of Occurrence of Phonemes for Wernicke's aphasics

Phoneme	Wernicke's Subjects Percentage	Wernicke's Frequency Ranking	Normals Percentage	Normals Frequency Ranking
t	8.486	1	8.403	1
n	7.267	2	7.085	2
s	4.101	4	5.089	3
d	5.381	3	4.177	4
l	3.488	5	3.689	5
m	3.020	9	3.289	6
ɚ	3.327	6	2.993	7
k	3.304	7	2.899	8
r	2.698	10	2.770	9
w	3.059	8	2.566	10
z	2.277	11	2.493	11
b	1.993	12	2.084	12
v	1.564	15	1.852	13
p	1.234	17	1.770	14
f	1.571	14	1.728	15
h	1.686	13	1.673	16
j	0.621	20	1.530	17
ŋ	1.303	16	1.244	18
g	0.951	19	1.162	19
ʃ	0.399	22.5	0.702	20
θ	1.135	18	0.596	21
dʒ	0.406	21	0.514	22
tʃ	0.399	22.5	0.368	23
ʒ	0.008	24	0.051	24

Figure 2.
Chi-Square Values



non-significant, consistent with the findings of the other statistical tests. A summary of the results of these tests is found in appendix D.

Discussion

Results of these tests indicate that there is no significant difference in the frequency distribution of phonemes for Wernicke's aphasics as compared to the normal distribution. These findings are in accordance with previous studies of aphasic speech (Blumstein, 1973; Smith, 1987). In the normal distribution curve, the four most frequently occuring phonemes (/t, n, s, d/) comprise 24.8 percent of the total phonemes; in the Wernicke's distribution curve, these same four phonemes comprise 25.2 percent of the total. The nature of both distribution curves is such that the curves are positively skewed. Because of this phenomenon, it is reasonable to expect that the rank order distribution of phonemes within the curves would be similar (see Table 2). Figure 1 portrays the frequency distributions for the Wernicke's and normal populations; Table 2 specifies the differences between the observed (Wernicke's) and the expected (normal distribution) frequencies for each consonantal phoneme. The numerical values given are a result of the computations of the following portion of the Chi-Square formula:

$$(O_i - E_i)^2 / E_i$$

where $_i$ = the individual phonemes

Using these calculations, the phonemes /j, ɵ, d/ appear to deviate the most from the normal curve (see Figure 2).

Phoneme Frequency in Broca's versus Wernicke's Aphasics

Results

The frequency distribution of the consonantal phonemes in language samples of the Broca's aphasics and the Wernicke's aphasics. The percentage of occurrence and frequency rankings for the two populations are presented in Tables 1 and 3. The frequency distributions were compared using the Wilcoxon-Mann-Whitney test (Siegel & Castellan, 1988). A Z score of 0.158 was obtained, which was not found to be significant. A Spearman Rank-Order Correlation Coefficient (Siegel & Castellan, 1988) was also found to be non-significant (see appendix D). A t-test (Keppel & Saufley, 1980) was performed to investigate the differences between the two sample groups with regards to their variances from the normal distribution. A non-significant t value was obtained. A summary of the difference values between the Broca's and normal distributions and the Wernicke's and normal distributions is found in Table 4.

TABLE 4

Difference Values in Phoneme Frequency for Aphasic and Normal Populations

Phoneme	Broca's Difference Values	Wernicke's Difference Values
t	0.504	0.083
n	1.449	0.182
s	0.744	0.988
d	1.339	1.204
l	0.029	0.201
m	0.323	0.269
ɣ	0.359	0.334
k	0.212	0.405
r	0.489	0.072
w	0.212	0.493
z	0.388	0.216
b	0.311	0.091
v	0.587	0.288
p	0.826	0.536
f	0.629	0.157
h	0.142	0.013
j	0.141	0.909
ŋ	0.093	0.059
g	0.435	0.211
ʃ	0.360	0.303
θ	0.441	0.539
dʒ	0.234	0.108
tʃ	0.015	0.031
ʒ	0.051	0.043

$$\text{Difference} = \left| \text{Frequency}_{\text{Normal}} - \text{Frequency}_{\text{Aphasic}} \right|$$

Discussion

These results indicate that the frequency distributions of consonantal phonemes for Broca's and Wernicke's aphasics follow a similar pattern. As well, the pattern of distribution for aphasic subjects appears to parallel the normal phoneme distribution. These findings

concur with the conclusions drawn by Blumstein (1973) and Smith (1987) in their respective studies. Although no significant difference was found in the frequency distributions among the populations, it is interesting to note trends in the variability between the aphasic distributions and the normal distribution. An examination of Figure 2 reveals larger differences on /ʒ, p, d,ɵ/ for the Broca's aphasics and /j,ɵ, d/ for the Wernicke's aphasics; small variances are present on /l, tʃ, ŋ, h, j, k, w/ for the Broca's aphasics and /t, h, r,ŋ , tʃ, b, n, l, f, z/ for the Wernicke's aphasics. Trends in these differences indicate a moderate degree of consistency in the patterns of deviation of aphasic phoneme distributions from the normal distribution.

Occurrence of Phonological Processes

Confrontation naming tasks were used to elicit 50 single word utterances from each subject. The picture stimuli suggested by Hodson (1986) in the Assessment of Phonological Processes-Revised (APP-R) were used to elicit the responses. For the subjects who were unable to complete the picture naming tasks, the stimuli were presented in imitation or sentence completion tasks. The 50 single word responses were then analyzed for phonological errors according to the procedure set forth in the APP-R. This assessment tool categorizes the phonological errors into 30 processes (see appendix A for a

list of processes). Hodson (1986) subdivides the error patterns into basic phonological processes (n=10), which include phonological omissions and class deficiencies; and miscellaneous error patterns, which include phonemic substitutions, assimilations, voicing alterations, and other error patterns. Although Hodson lists 30 specific processes, only 22 of these processes were noted to occur on the single word responses of the aphasic subjects included in this study. Therefore, only the error patterns which occurred in the Broca's samples, the Wernicke's samples, or both samples were analyzed.

Results for Broca's Aphasia

The number and percentage of occurrences of the phonological processes displayed by the Broca's aphasics are shown in Table 5. In total, the ten Broca's subjects demonstrated 236 errors which covered 22 different phonological processes. Of these errors, 151 or 63.99 percent fell within the ten processes defined as the basic phonological processes. Consonant sequence reduction was the most frequently occurring process at 21.61 percent, followed by strident deficiency at 16.53 percent, other error patterns at 9.32 percent, stopping at 7.63 percent, velar deficiency at 6.36 percent, and liquid /r/ deficiency at 5.93 percent. The remaining processes occurred less than five percent of the total number.

TABLE 5

Occurrence of Phonological Processes
for Broca's aphasics

Phonological Process	Frequency of Occurrence	Percentage of Occurrence
Consonant Sequence Reduction	51	21.610
Strident Deficiency	39	16.525
Other Error Patterns	22	9.322
Stopping	18	7.627
Velar Deficiency	15	6.356
Liquid /r/ Deficiency	14	5.932
Liquid /l/ Deficiency	9	3.814
Voicing Alterations	9	3.814
Postvocalic Singleton Consonant Omission	8	3.390
Epenthesis	8	3.390
Fronting	8	3.390
Nasal Deficiency	5	2.119
Deaffrication	5	2.119
Glide Deficiency	4	1.695
Vowel Deviation	4	1.695
Coalescence	4	1.695
Syllable Reduction	3	1.271
Prevocalic Singleton Consonant Omission	3	1.271
Vowelization	3	1.271
Backing	2	0.847
Gliding	2	0.847
Reduplication	2	0.847
TOTAL OCCURRENCE OF PROCESSES (n=10)	236	

Results for Wernicke's Aphasics

The number and percentage of occurrences of the phonological processes displayed by the Wernicke's aphasics are shown in Table 6. In total, the seven Wernicke's subjects demonstrated 49 errors which covered 18 different phonological processes. Of these errors, 28 or 57.14 percent fell within the ten processes defined as the basic

TABLE 6

Occurrence of Phonological Processes
for Wernicke's aphasics

Phonological Process	Frequency of Occurrence	Percentage of Occurrence
Consonant Sequence Reduction	11	22.449
Other Error Patterns	7	14.286
Strident Deficiency	6	12.245
Reduplication	4	8.163
Syllable Reduction	3	6.122
Postvocalic Singleton Consonant Omission	3	6.122
Epenthesis	3	6.122
Vowel Deviations	3	6.122
Liquid /r/ Deficiency	2	4.082
Stopping	2	4.082
Prevocalic Singleton Consonant Omission	1	2.041
Liquid /l/ Deficiency	1	2.041
Nasal Deficiency	1	2.041
Backing	1	2.041
Voicing Alterations	1	2.041
TOTAL OCCURRENCE OF PROCESSES (n=7)	49	

phonological processes. Consonant sequence reduction was the most frequently occuring process at 22.45 percent, followed by, other error patterns at 14.29 percent, strident deficiency at 12.25 percent, and reduplication at 8.16 percent. Syllable omission, postvocalic consonant singleton omission, epenthesis, and vowel deviations all occurred at a frequency of 6.12 percent. The remaining processes occurred less than five percent of the total number.

Comparison of Broca's and Wernicke's Aphasics
on the Occurrence of Phonological Processes

Results

The types of phonological processes and their respective frequency of occurrence for Broca's and Wernicke's aphasics are presented in Figure 3. A t-test (Keppel & Saufley, 1980) was performed on the 22 processes that occurred in one or both of the subject groups to determine if there was a significant difference in the frequency of occurrence of phonological processes between the two groups. A t score of 3.13 was obtained, which was significant at the .01 level of significance. Table 7 displays the results of the t-test analysis. In addition, the Wilcoxon-Mann-Whitney test (Siegel & Castellan, 1988) was used to investigate whether there was a significant difference in the rank ordering of the frequencies of phonological processes for the two subject groups. A Z score of 0.158 indicated that there was not a significant

TABLE 7

t-Test Value for the Phonological Processes
Displayed by Broca's and Wernicke's Aphasics

t - statistic	3.134
Mean - Broca's	10.818
Mean - Wernicke's	2.227
Degrees of Freedom	26
significant at $p < .01$	

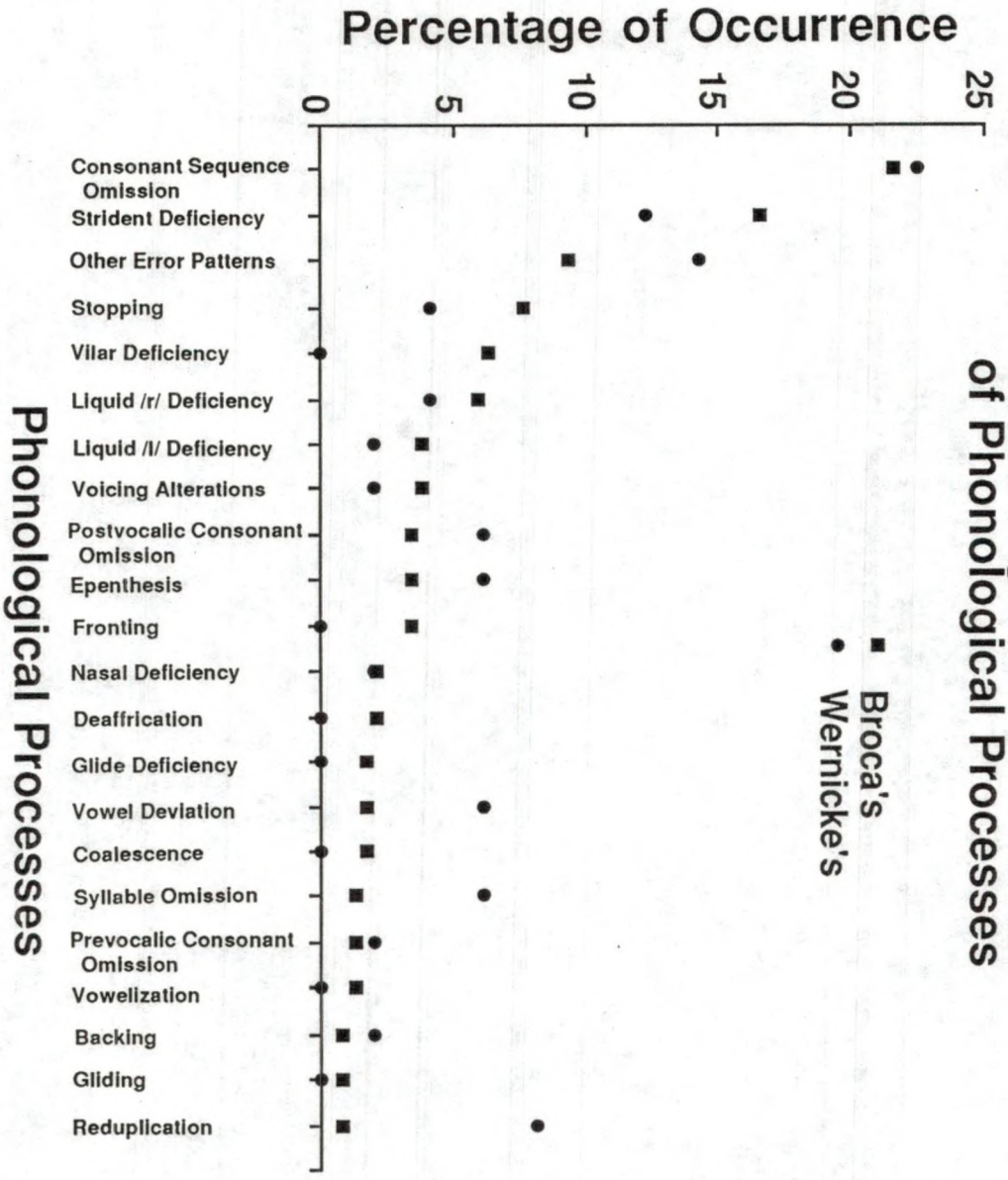


Figure 3.
Percentage of Occurrence
of Phonological Processes

difference in the ranking of the processes for the two groups.

Discussion

The results of this portion of the study indicate that both the Broca's and Wernicke's aphasics displayed numerous phonological processes in confrontation tasks. The Broca's aphasics produced significantly more processes, with an average of 23.6 processes per subject (i.e., ten subjects with a total of 236 process errors); the Wernicke's aphasics produced an average of 7 processes per subject (i.e., seven subjects with a total of 49 process errors). These findings would be in accordance with the theory of Broca's aphasia being the primary expressive aphasic disorder, while Wernicke's aphasia is considered primarily a receptive disorder. These results also support the findings of previous studies concerning the phonological behaviors of aphasics. Smith (1987), in her study of phonological processes in aphasics, found that the five Broca's aphasics produced a total of 107 errors in the single-word responses while the Wernicke's aphasics produced only 39 errors. Blumstein (1973) reported similar findings.

Qualitative differences are also evident in the analysis of the Broca's and Wernicke's samples. These differences in the process errors of the two aphasic groups may be reflective of the differential neurological insult

associated with each of the classifications. Broca's aphasia is considered to be a motor programming disorder. The individual errors noted in the speech of the Broca's aphasics may be indicative of difficulties in formulating the production of the phonemes. As such, these errors can be considered in the realm of apraxic behaviors. Conversely, Wernicke's aphasia is considered to be disorder of auditory comprehension. Therefore, the errors in the Wernicke's samples may reflect difficulties in the selection and processing of the speech sounds rather than neuromuscular dysfunction. This concept of differential phonemic errors between Broca's and Wernicke's aphasics has been previously investigated in a study by Guyard et. al. (1981). This study describes the errors made by Broca's aphasics as a disintegration in the production of sounds and the errors in the Wernicke's aphasics as difficulties in selection. The findings of the present study, as well as past studies, may indicate that the speech sound errors made by aphasics reveal disturbances in different levels of the linguistic processing system rather than in the rule-base of the phonological system.

Phoneme Frequency and Phonological Processes

Results

The frequency of occurrence of the individual phonemes for Broca's and Wernicke's aphasics may be found in Figure

1. The occurrence of phonological processes for both subject groups is illustrated in Figure 3. A non-statistical comparison of the data in Figures 1 and 3 was used to examine the two sets of data. The data were analyzed for trends in the variations in the phoneme frequency distributions and the phonological processes. In the Broca's samples, the phonemes which deviated the most from the normal distribution curve were /ʒ, p, d,ɵ/; in the Wernicke's samples /j,ɵ, d/ deviated the most from the normal distribution curve. The most frequently occuring processes were consonant sequence reduction, strident deficiency, and stopping for the Broca's aphasics and consonant sequence reduction, strident deficiency, and reduplication for the Wernicke's aphasics. No relationship could be drawn between the two sets of data (i.e., phoneme frequency and phonological processes) based on this study.

Discussion

The comparison of the phoneme usage data and the occurrence of phonological processes indicates that there is little connection between these two sets of data. The purpose of this comparison was to investigate whether the phonemes involved in frequently occurring phonological processes (e.g., the strident phonemes for strident deficiency) were the same phonemes which exhibited a large difference between the frequency distributions of the aphasics and normal populations. However, no significant

differences were found to exists in the patterns of phoneme usage between the aphasic and normal distributions. As well, there was no consistencies between the phonemes which exhibited the largest differences in frequency of occurrence and the phoneme patterns represented by the most frequently occurring phonological processes. This conclusion, when taken into consideration with the previously mentioned findings in this study, leads to a general interpretation regarding aphasic speech. It has been shown that the aphasic groups in this study demonstrated a considerable number of phonological processes in confrontation tasks. However, these same individuals did not differ from the normal population with regards to the distribution of phonemes in spontaneous speech. As the speech errors are not represented in the frequency of phoneme selection, it may be interpreted that the errors are not phonologically based. That is, they are not the result of a dysfunction within the rule-base structure of the language system. Rather, the errors appear to be associated to deficits in the retrieving and processing of sounds. These findings concur with Whitaker's (1971) theory of a `Central Language System'. This theory states that language is stored within linguistic components. When a neurological insult occurs, the content of these components may remain intact, but the processing links within the system may be impaired.

Therefore, the phonological system is intact but the individual is unable to successfully process the information from its neurological state to a communicative level.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Conclusions

It was the intention of this study to investigate the phoneme selection patterns in the speech of Broca's and Wernicke's aphasics. The frequency of occurrence of English consonantal phonemes in spontaneous speech was calculated and then compared to the normal distribution curve for English speakers (Denes, 1963). In addition, phonological processes in single-word responses to confrontation tasks were analyzed using the Assessment of Phonological Processes-Revised (Hodson, 1986).

The results of this study show that the distribution curves for the frequency of phonemes in the speech of the aphasic subjects was not statistically different from the normal distribution curve. Although differences were noted among the three distributions which were compared, these variations did not significantly affect the pattern of distribution along the curve or the frequency values for the individual phonemes. Locke (1983), in his discussion of lexical avoidances, notes that adult speakers compensate for linguistic complexities in sound production by avoiding these phonemes. The normal distribution curve of English

phonemes (Denes, 1963) reflects this theory in that the most frequently occurring sounds are linguistically simpler. The phonemes which are structurally more complex and later developing in the phonological system are found to have a much lower frequency of occurrence in conversational speech.

Phonological errors were seen in the single-word responses for the Broca's and Wernicke's aphasics. However, quantitative and qualitative differences could be seen in the processes exhibited by the two subject groups. The Broca's aphasics demonstrated a higher number of errors overall. This group also tended to use processes which reflected difficulties with the more complex linguistic patterns. This finding may suggest that the phonological deficits associated with the Broca's aphasics are apraxic in nature and indicate a motor planning disorder. The Wernicke's aphasics exhibited less total errors. As well, many of the processes utilized by this group (e.g., epenthesis, reduplication) may reflect selection and retrieval deficits.

The idea that the errors seen in the speech of the aphasics may be based in the linguistic processing of the speech signals rather than in the phonological make-up of the individual sounds is reinforced by the findings of the frequency analyses. The consistency in frequency distribution among the Broca's, Wernicke's, and normal

populations indicate that the engramming of spontaneous phoneme selection is not impaired in those individuals who have suffered neurological insults. This finding, which is consistent with past studies (Blumstein, 1973; Smith, 1987), may have important implications to further research in aphasic speech. The fact that phoneme selection is similar across the normal and pathological populations implies that studies can be done on the speech of aphasic populations without regard to biases due to unequal frequency distributions.

Limitations

Limitations to the generalization of the results of this study to other populations may arise because of the limited size of the subject groups. As well, because of the pathological nature of the disorder studied, there was considerable variation within each of the subject groups. This variation is reflected in the severity of the aphasias and in the length of time post-onset from the CVA for the different individuals. These factors reflect the heterogeneous nature of aphasic disorders, even within the classification types.

Future research in this area should examine phoneme use and phonological errors in the speech of other neurologically impaired populations, including conduction aphasia, transcortical motor and sensory aphasia, and right-hemisphere lesions. By studying all of these sub-

populations, conclusions may be drawn about acquired neurological disorders as a whole.

APPENDICES

APPENDIX A

Phonological Processes

as defined by Hodson (1986)

PHONOLOGICAL PROCESSES

Omissions

1. SYLLABLE REDUCTION--where the syllable nucleus has been omitted in a word that has more than one syllable.

2. CONSONANT SEQUENCE REDUCTION--where a consonant appearing with another consonant in a sequence is omitted. Can occur within or across syllable boundaries.

3. PREVOCALIC SINGLETON CONSONANT OMISSION--where the syllable initiating single consonant is omitted.

4. POSTVOCALIC SINGLETON CONSONANT OMISSION--where the syllable terminating single consonant is omitted.

Class Deficiency

5. STRIDENT DEFICIENCY--where stridency is substituted by a non-strident phoneme, or omitted.

6. VELAR DEFICIENCY--where the velar stop is omitted or substituted.

7. LIQUID /l/ DEFICIENCY--where the liquid /l/ is omitted or substituted.

8. LIQUID /r/ DEFICIENCY--where the liquid /r/ is omitted or substituted.

9. NASAL DEFICIENCY--where the nasal is substituted by a non-nasal phoneme, or omitted.

10. GLIDE DEFICIENCY--where the glide is substituted by a non-gliding phoneme, or omitted.

Phonemic Substitutions

11. GLOTTAL REPLACEMENT--where a glottal stop is substituted for another phoneme.

12. EPENTHESIS--where consonants or vowels are added.

13. STOPPING--where a stop is substituted for a continuant phoneme.

14. FRONTING--where the articulation of a phoneme is made further toward the front of the mouth.

15. BACKING--where the articulation of a phoneme is made further toward the back of the mouth.

16. GLIDING--where a glide is substituted for another phoneme.

17. VOWELIZATION--where a consonant is replaced by a vowel.

18. VOWEL DEVIATIONS--where one vowel is substituted for another (not including dialectical differences).

19. METATHESIS--where the position of phonemes or syllable are changed or switched.

20. MIGRATION--where the position of a single phoneme is changed.

21. REDUPLICATION--where a phoneme or syllable is repeated.

22. COALESCENCE--where two phonemes are substituted by one that carries characteristics of both the original phonemes.

23. AFFRICATION--where a stop component is added to a continuant phoneme.

24. DEAFFRICATION--where the continuant or stop component (but not both) is removed from an affricate phoneme.

25. PALATALIZATION--where the palatal component is added to a non-palatal phoneme.

26. DEPALATALIZATION--where the palatal component is removed from a palatal phoneme.

Assimilations

27. ASSIMILATIONS--where a phoneme is produced similar to another phoneme in the word.

Voicing Alterations

28. PRE + VOICE ALTERATIONS--where voicing is added to a phoneme.

29. PRE - VOICE ALTERATIONS--where voicing is omitted from a phoneme that occurs before the vowel.

30. POST - VOICE ALTERATIONS--where voicing is omitted from a phoneme that occurs after the vowel.

Place Shifts

31. SIBILANT DISTORTION--where distortion of a sibilant occurs.

32. SUBSTITUTION OF ANTERIOR STRIDENTS FOR INTERDENTAL PHONEMES.

APPENDIX B

Identifying Information for Aphasic Subjects

IDENTIFYING INFORMATION FOR APHASIC SUBJECTS

Subject Number	Diagnosis	Age	Sex	Time Post-Onset (months)	
1	Broca's	68	F	2	
2	Broca's	77	F	2	*
3	Broca's	89	F	38	
4	Broca's	70	F	NA	
5	Broca's	62	F	1	*
6	Broca's	82	F	NA	
7	Broca's	79	F	1	*
8	Broca's	95	F	15	
9	Broca's	88	F	1	
10	Broca's	73	F	7	
11	Wernicke's	62	M	19	
12	Wernicke's	87	F	36	
13	Wernicke's	73	F	18	
14	Wernicke's	57	M	8	
15	Wernicke's	85	F	1	
16	Wernicke's	85	F	25	
17	Wernicke's	91	M	6	

* indicates multiple infarct
NA indicates information not available

APPENDIX C

Consent for Participation

CONSENT FOR PARTICIPATION
in a study of
ADULT APHASIC SPEECH

This study is being done as part of a thesis by Rita Vis (204-837-4482) in the Department of Communication Disorders at the University of North Dakota to look at the errors in the speech of people that have lost some of their ability to speak because of a stroke (this is called aphasia). The speech-language pathologist at your hospital has referred you as an appropriate subject for this study. This study will help to add to the information already available on the speech of people who have suffered a stroke. It may also help in the rehabilitation of these people.

As a subject, you will be asked to do the following: name pictures of objects and actions; and carry on a short conversation, all to the best of your ability. This will be recorded on a tape recorder, and your speech will be identified by a number and your type of aphasia. Your name will not be used. Permission from your doctor will obtained before any testing is begun.

If you decide to participate in this study, you may choose to withdraw at any time without penalty. This will not affect your relationship with the hospital or the medical staff.

I have read all of the above and willingly agree to participate in this study described to me by Rita Vis.

_____ _____
Patient's Signature Date

_____ _____
Immediate Family Member/ Date
Legal Guardian, if necessary

_____ _____
Witness Date

APPENDIX D

Results of Statistical Analysis

FREQUENCY OF OCCURRENCE OF PHONEMES

Broca's versus Normal Distribution

Wilcoxon-Mann-Whitney test *
$Z = 0.189$
(for $p < .05$, Z must equal 1.960 for significance)

Spearman Rank-Order Correlation Coefficient *
$r_s = 0.042$
(for $p < .05$, r_s must equal 0.415 for significance)

Chi-Square test *
$\chi^2 = 5.77$
(for $p < .05$, χ^2 must equal 35.17 for significance)

Wilcoxon Sign test *
$T = 109.5$
(for $p < .05$, T must be less than 74 for significance)

Wernicke's versus Normal Distribution

Wilcoxon-Mann-Whitney test *
$Z = 0.072$
(for $p < .05$, Z must equal 1.960 for significance)

Spearman Rank-Order Correlation Coefficient *
$r_s = 0.042$
(for $p < .05$, r_s must equal 0.415 for significance)

Chi-Square test *
$\chi^2 = 2.273$
(for $p < .05$, χ^2 must equal 35.17 for significance)

Wilcoxon Sign test *
$T = 120.0$
(for $p < .05$, T must be less than 74 for significance)

Broca's versus Wernicke's

t-test of Significant Difference (Keppel & Saufley, 1980)
$t = 1.08$
(for $p < .05$, t must equal 2.02 for significance)

Wilcoxon-Mann-Whitney test *
$Z = 0.158$
(for $p < .05$, Z must equal 1.960 for significance)

Spearman Rank-Order Correlation Coefficient *
$r_s = 0.042$
(for $p < .05$, r_s must equal 0.415)

* Siegel & Castellan, 1988

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