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**DURATIONAL FACTORS IN THE PHONETIC PERCEPTION OF APHASICS**

*City University of New York*

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DURATIONAL FACTORS IN THE PHONETIC PERCEPTION  
OF APHASICS

By  
Karen Riedel

A dissertation submitted to the Graduate Faculty in  
Speech and Hearing Science in partial fulfillment of  
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## Abstract

### DURATIONAL FACTORS IN THE PHONETIC PERCEPTION OF APHASICS

by

Karen Riedel

Advisor: Michael Studdert-Kennedy

This study used synthetic speech and sine-wave control stimuli to investigate aphasics' ability to identify and discriminate speech and nonspeech distinctions conveyed by acoustic duration. The results revealed no evidence to support the claim that the primary deficit underlying aphasics' difficulty in understanding spoken language is a failure to extract relevant acoustic information from rapid changes in the speech signal. Rather, findings indicated that aphasics with marked impairment in spoken language comprehension were able to discriminate brief formant transitions which accompany changes in the place of articulation and no consistent improvement in phonological performance was obtained when these spectral changes occurred more slowly. Aphasic subjects also demonstrated sensitivity to manipulations in syllable duration which are known to result in a shift in the phonetic perception of normal listeners.

Specifically, aphasic subjects showed a displacement of the category boundary or peak of discrimination dependent on syllable duration for synthetic speech continua appropriate for a contrast in manner /b-w/ or voicing /d-t/. In addition, aphasics' perception of voicing of the final stop consonant in a CVC syllable was affected by a variation in the duration of the syllable-initial formant transitions to the same degree as was found in normal listeners. Since for both populations, the effects produced by durational manipulations were confined to synthetic speech stimuli, results support the notion that speech processing engages a special set of perceptual mechanisms different from those which govern the perception of nonspeech auditory signals.

Although even aphasics with rather severe comprehension deficits were able to discriminate small changes in acoustic duration, they manifested selective difficulty identifying test stimuli reliably. The failure to maintain consistent category judgments was not specific to fluent or nonfluent aphasics, but was specific to aphasics manifesting reduced Token Test scores, and as a group, overall phonological task performance was highly correlated with Token Test score. These findings suggest that the performance deficit found in some aphasics is not a failure

to perceive small changes in the acoustic signal, but a general inability to assign a category label to the stimulus.

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## CHAPTER I

### INTRODUCTION

A substantial body of research has been devoted to the study of the nature of the auditory-verbal perceptual impairment in aphasia. The experimental evidence derived from such investigations is considered to have direct bearing not only on our attempts to describe and understand aphasic syndromes, but also on our understanding of the process by which a stream of acoustic events is perceived as spoken language by a normal listener. Among several controversies in this area is whether aphasics' difficulty in understanding speech is due to an auditory deficit affecting their ability to extract acoustic information from the speech signal, or whether the problem is at a higher level--for example, a deficit in phonetic coding for short term memory or a cognitive impairment affecting their ability to associate a signal with a referent.

If there is a defect in the auditory system, research suggests that it may be in processing the rapidly changing acoustic energy that segments the

speech stream. But how we should expect this deficiency to affect the processing of speech sounds and the overall comprehension ability of aphasics is not clear.

A more precise definition of the perceptual impairment in aphasia might be facilitated by an examination in both speech and non-speech stimuli of perceptual response to a single acoustic dimension, known to carry important phonetic information. Since temporal factors have often been emphasized for their role in the speech reception of aphasics, the dimension of duration seems a likely candidate for such an investigation. Moreover, studies of the speech reception of normal listeners provide a baseline for comparison.

The aim of this study was to manipulate acoustic duration in a variety of speech and non-speech contexts in an attempt to assess the role of temporal processing defects in aphasia. The study examined the hypothesis that aphasics' failure to perceive specific phonemes is due to an underlying defect in the processing of rapid acoustic transitions. (Tallal and Newcombe, 1978). In addition to exploring the effects of variations in duration on aphasics' phonemic perception, this study

also explored to what extent aphasics' performance deficits on phonological tasks could be attributed to the nature of the stimuli (speech versus non-speech), the type of task employed (identification versus discrimination), or the form of the required response (linguistic versus non-linguistic). The purpose of studying these aspects of perceptual function was to re-examine the definitions of the relation between performance on various perceptual tasks and (1) the magnitude of language comprehension impairment, (2) the type of aphasic syndrome, and (3) overall severity of aphasia, and to explore the implications of the findings on our understanding of the normal speech perception process.

Reported here are the findings of seven experiments which employed synthetic speech and non-speech stimuli in order to examine the perception of phonetic distinctions conveyed by the acoustic parameter of duration, in an aphasic and a normal control population. In Chapter II, the results of an experiment designed to replicate the findings of Tallal and Newcombe (1978) are presented.

Chapter III describes the results of two experiments which assessed aphasics' ability, relative to the

normal control group to identify and discriminate a manner class distinction, the stop /b/ and the glide /w/. To demonstrate the effect of duration on the perception of manner class, stimulus patterns of two overall syllable lengths were employed. The results of the speech pattern identification tests were then compared with the findings when non-speech control patterns were used and a non-linguistic response was required.

Chapter IV presents the results of an examination of the effect of overall stimulus duration on aphasics' identification and discrimination of Voice Onset Time (VOT).

Chapter V reports two experiments concerned with aphasics' identification of the voicing of the final consonant in a CVC syllable and compares these findings with aphasics' judgements of duration of both speech and non-speech stimuli.

Chapter VII is an analysis and discussion of the findings of the seven experiments with respect to their implications for aphasia research and theory.

#### REVIEW OF THE LITERATURE

There are several approaches to the study of

auditory perception in aphasia. One line of investigation has explored the connection between aphasics' ability to recognize meaningful environmental sounds and to comprehend spoken language. The findings of Spinnler and Vignolo (1966), Faglioni, Spinnler and Vignolo (1969) and Varney (1980) suggest that deficits in the two abilities are frequently related and can be attributed to an underlying cognitive impairment of an "associative-semantic" nature. This notion is supported by two findings: the prevalence of semantically related (e.g. sabre duel) as opposed to acoustically related errors (e.g. stones falling on a wooden floor) on a sound to picture matching task (e.g. the sound of gun shots with the picture of a pistol) and the dissociation demonstrated between intact discrimination of complex nonverbal sounds and a reduced ability to identify meaningful environmental noises.

Strohner, Cohen, Kelter and Woll (1978) have, however, questioned the validity of a conclusion based on error type analysis, since if acoustic and semantic properties of pictured alternatives are properly controlled, the difference in frequency of error types becomes insignificant. Both acoustic and semantic errors are more prevalent in the performance of aphasics than in

the performance of non-aphasic brain-damaged individuals. This finding, they suggest, is due to a cognitive deficit specific to aphasia affecting sound analysis and association. They maintain, furthermore, that basic auditory perceptual function is intact.

A contrasting point of view is the notion that the fundamental defect in aphasia is a failure at a very early stage of acoustic processing. Efron (1963) demonstrated that aphasics require much longer intervals between stimuli to judge which of two sounds or lights comes first. Efron reasoned that since perception of spoken language requires sequencing of speech sounds the language impairment found in aphasia is epiphenomenal to a basic deficit in temporal processing.

Many investigations have explored aphasics' ability relative to other brain-damaged and normal subjects, to cope with the temporal demands of sequential visual or auditory stimuli. Although a defect in precedence judgement in aphasics was reported by Edwards and Auger (1965), Swisher and Hirsh (1974) and Bond (1976), reduced ability to order sequential stimuli has been found not only in aphasics but also in non-aphasic left brain-damaged subjects (Carmon and Nachson, 1971). In fact, Sherwin and Efron (1980) found elevated thresholds in

precedence judgements in both right and left anterior temporal lobectomy patients, none of whom manifested aphasia.

Apart from the study of temporal order, research has documented that aphasics' discrimination of signal duration and intensity is less accurate than that of normals (Needham and Black, 1970). Aphasics have also been shown to be impaired in click resolution: they report hearing one click at temporal separations at which normal subjects hear two (Lachner and Teuber, 1973). It is not clear, however, that the time sensitivity defect is associated with any particular speech or language symptom found in aphasia or that the defect has any relation to the speech process. Auerbach, Naeser and Mazurski (1981) found a wide range of click fusion threshold asymmetries among an aphasic population, but the abnormalities of click fusion were unrelated to performance on a phoneme discrimination task and independent of language comprehension ability and aphasia severity.

A few studies have considered deficits in temporal parameters of the speech signal. Studying acoustic cue discrimination in aphasia, Carpenter and Rutherford (1973) found that aphasics were significantly

more impaired in their ability to discriminate temporal cues, such as the duration of the vowel preceding the stop consonant (hit/hid) than they were in discriminating spectral cues, e.g. the direction and extent of the final second formant transition (fig/fib).

Tallal and Newcombe (1978) attempted to define the connection among nonverbal auditory processing, phonological analysis, and spoken language comprehension in aphasia. In their experiment, left and right hemisphere brain-damaged<sup>1</sup> and normal subjects were trained to respond to two basic tasks in which synthetically generated verbal and nonverbal auditory stimuli were used. There were three verbal sets: a vowel set /ɛ/ and /a/, a BA-DA syllable short (40 msec) formant transition set and a BA-DA syllable extended (80 msec) formant transition set. The overall duration of the syllables was held constant at 250 msec. Two 250 msec complex tones composed of three formants differing only in fundamental frequency served as stimuli for the nonverbal series. The first task required that subjects associate two different acoustic signals with different buttons on a response panel. In the second task, subjects were trained to identify each of four possible two element combinations in sequence. For the sequence

task, interstimulus intervals were systematically varied over 428, 305, 150, 60, 30, and 8 msec.

Tallal and Newcombe reported that although aphasics' performance was no different from the control groups on either the nonverbal association task or the sequencing task at long interstimulus intervals, the accuracy of their performance decreased with shortened ISIs. Aphasics also showed no particular difficulty processing vowel sounds, but they performed poorly on tasks involving CV stimuli in which the crucial formant transitions were short. The performance of many aphasics improved for the extended formant transition series. Moreover, the same subjects who made errors on the nonverbal sequencing task at reduced ISIs also failed to discriminate the verbal stimuli with short formant transitions. The performance on the nonverbal sequencing task correlated with performance on the Token Test, a test of auditory comprehension used widely in the assessment of aphasia.

The researchers hypothesized that underlying the receptive impairment in aphasia is an auditory perceptual deficit affecting the individual's ability both to temporally sequence nonverbal auditory stimuli and to process rapid acoustic transitions. This deficit

is said to cause not only a failure to perceive specific phonemes, but because of the crucial role of formant transitions in sequencing and segmenting the speech stream, a profound disturbance in the comprehension of spoken utterances.

It seems, however, premature to conclude that the fundamental difficulty linking the three relatively dissimilar defective performances: impaired nonverbal processing, abnormal phonological analysis, and poor auditory-verbal comprehension, is a perceptual disturbance. In fact, there may be no direct connection between impaired sequencing of nonverbal sounds under increased temporal demands and deficits in phoneme perception. The mere fact of a correlation does not necessarily imply that the several tasks have a common mechanism, but merely that the same subjects fail or succeed on all tasks. In other words, the results may simply reflect a more global defect which impairs a whole range of performances.

Finally, the relation between nonverbal auditory perception and speech perception has not been satisfactorily explored. Kellar (1979) attempted to test aphasics' ability to identify and discriminate synthetic sawtoothed waves (i.e. periodic buzzes), but the task

difficult for normal subjects, proved impossible for aphasics. This omission in the literature is understandable, since it is very difficult to construct nonverbal stimuli sufficiently similar to speech to serve as a control, yet sufficiently different not to be heard as speech.

In addition to the Tallal and Newcombe (1978) study several other experiments have used synthetically generated stimuli to examine the speech perception abilities of aphasics. The value of synthetic speech is that it is possible to assess perception of a single acoustic parameter by constructing stimuli which vary systematically on that parameter. These investigations have borrowed the methodology used in the study of speech perception in normals to explore phonological disturbances in aphasic subjects. So far, the studies have been limited to the investigation of voice-onset-time (VOT).<sup>2</sup> In this type of experiment, a continuum is synthetically constructed in which the acoustic patterns range in VOT from those signaling /da/ to those signaling /ta/. When normal listeners are asked to identify stimuli varying in these parameters, they assign stimuli from the continuum to two distinct classes, /t/ or /d/. When asked to discriminate between pairs

of stimuli differing by some acoustic amount, they discriminate poorly between stimuli they have assigned to the same class, but reliably between those they have assigned to two separate classes.

Phonological processing studies in aphasia have used this paradigm to investigate several basic issues: the specificity of speech perception deficits to Wernicke's aphasia; the connection between speech perception deficits and phonemic errors in speech production; and the association of deficits in phonological perception with disorders in spoken language comprehension.

The results of investigations using synthetic speech stimuli have provided contradictory evidence with respect to phonological disturbances and aphasia type. Basso, Casati, and Vignolo (1977) found that although seventy percent of the aphasics tested were unable to assign stimuli reliably to voiced or voiceless classes, the defect was more common in nonfluent (Broca's) aphasia than in fluent (Wernicke's) aphasia. In fact, the impairment was found in all the Broca's aphasics tested regardless of the severity of the comprehension impairment, whereas one-third of the Wernicke's aphasics who evidenced severe auditory comprehension difficulty

demonstrated normal phonemic identification.

Blumstein, Cooper, Zurif and Caramazza (1977) studied both identification and discrimination of VOT in aphasic subjects. They described three patterns of performance among their study population: a group which performed similarly to normals on both the identification and discrimination tasks; a group which failed to reliably identify or discriminate stimuli; and a group which performed the discrimination task normally, but failed to identify reliably two classes of stimuli. They suggest that for the last group, which included primarily Wernicke's aphasics, the problem is not an inability to discriminate phonological contrasts, but rather a defect in assigning a categorical label to the stimuli, i.e. an inability to use the phonological information in a linguistically relevant way. These findings were supported by Kellar (1979) who found, in addition, that the use of real word stimuli (dot-tot) did not enhance VOT identification and discrimination. Thus, with respect to type of aphasia, findings regarding deficits in identification of phonological classes are conflicting. Broca's aphasics were significantly more impaired as a group than Wernicke's aphasics on the identification task in

Basso's study, whereas, the labeling defect reported by Blumstein et al. (1977) was more common in Wernicke's aphasia.

As far as discrimination goes, the VOT study findings are consistent with studies using natural speech stimuli, in their lack of support for the hypothesis that phonological deficits are confined to or more prevalent in Wernicke's aphasia. Rather, investigations which have used natural speech stimuli have revealed that the majority of aphasics evidence deficits in discriminating phonological contrasts (Blumstein, Baker, and Goodglass, 1977; Jauhianen and Nuutili, 1977; Miceli, et al., 1978, Miceli, et al., 1980).

With respect to the connection between phonological deficits in speech perception and phonological disturbances in speech production, the results of synthetic speech perception studies are also inconclusive. Basso, Casati, and Vignolo (1977) found the phonological identification defect to be selective to aphasics manifesting phonemic errors in their speech production. However, Blumstein, Cooper, Zurif, and Caramazza (1977) reported the ability to perceive VOT categorically in no way related to the ability to

produce voice and voiceless stops. These two findings are not necessarily in opposition. They merely suggest that an aphasic who manifests a type of aphasia characterized by phonemic production difficulty may have difficulty identifying and discriminating phonological contrasts but still the subject may be able to orally produce the VOT distinction on laboratory tests. In studies of aphasics' phonemic discrimination that have used natural speech stimuli, partial correlations between phonemic disturbances in discrimination and production have been reported. Shewan (1980) and Miceli et al. (1980), found some aphasics for whom the severity of deficits in phonemic production and in phonological identification seemed associated, but there were also aphasics whose discrimination performance was unrelated to the severity of phonological errors in speech production.

The most perplexing dissociation found in these studies of aphasia is the weakness of the connection between speech perception and language comprehension. If phonological analysis is a prerequisite for further linguistic and semantic analysis, then deficits in phonological perception should be correlated with impaired overall comprehension of speech. However,

experimental studies using synthetic speech have found little support for a direct connection between phonological disorders and reduced general comprehension of speech. In fact, Basso et al. (1977), Blumstein et al. (1977) and Auerbach et al. (1981) emphasize the strength of the dissociation, the number of patients who, despite severe comprehension impairment, are nevertheless able either to discriminate or to identify CV syllables normally, or the reverse, individuals who demonstrate near normal comprehension of speech, but fail phonological tasks. A similar trend appears in the several investigations which have used natural speech stimuli (Carpenter and Rutherford, 1973; Blumstein, Baker, and Goodglass, 1977; Jauhianen and Nuutili, 1977; Miceli, Gainotti, Caltagirone, and Masullo, 1980; Shewan, 1980; and Varney and Benton, 1980). In these natural speech studies, however, there is usually some portion of the aphasic population for whom phonological impairment and auditory comprehension disturbance seem to be somehow linked.

Several explanations have been offered for the frequent dissociation between phonological disturbance and auditory comprehension ability. Blumstein, Cooper, Zurif, and Caramazza (1977) suggest that a preserved ability to analyze phonological contrasts despite poor

language comprehension implies that the defect affecting comprehension is at some other level of linguistic processing. This in turn may imply that phonological analysis plays a limited role in normal auditory comprehension. Similarly, aphasics who demonstrate near normal comprehension of spoken language, but fail to perform specific phonological tasks reveal the complexity of the linguistic reception process, in that, despite major deficiencies in the decoding of phonological information, they are able to employ semantic context, syntax, prosody, and situational cues to understand speech.

There is also the possibility that the apparent difficulty with phonological tasks is a function of a general categorization defect in aphasia. The majority of aphasics may be able to discriminate the small acoustic differences required to differentiate phonological contrasts, but be impaired in their ability to recognize that the sound defines a phonetic class. Moreover, the inability to link a given stimulus with its category may extend beyond language and include tasks which require the categorization of nonspeech auditory stimuli. The disability might be a function of the severity of aphasia, or some aphasic symptom as

yet undefined, which may or may not be directly associated with the degree of comprehension impairment.

This suggestion implies a certain parallel between the findings of perceptual studies using speech and those which have examined nonverbal (environmental) sound processing. It may well be that it is not the analysis of the acoustic information that is impaired in most aphasics, but the association of the sound with a referent.

In conclusion, despite the varying approaches to the study of auditory perception in aphasia, there is common interest in exploring the connection between disturbances in nonspeech auditory processing and the linguistic impairment. Since the link between acoustic and linguistic structure is tightest at the phonological level of language processing, it is natural that this aspect would receive attention in perceptual studies. Of particular interest for further investigation is the effect of durational factors on phonetic perception, the connection between deficits in auditory perception and deficits in speech perception, the possible association of these deficits with particular varieties of aphasia, and with speech comprehension ability.

## GENERAL DESIGN OF STUDY

### Stimuli

All speech stimuli were synthetic speech patterns generated on the Haskins Laboratories parallel resonance synthesizer. The non-speech stimuli were sinusoidal wave patterns also produced at Haskins Laboratories using a special program.<sup>3</sup> The sine-wave stimuli were time varying sinusoidal waves which followed the changing formant center frequencies of the corresponding synthetic syllables. Frequency and amplitude values were matched every ten msec for the center frequency of the first three formants. The three tone patterns differ from the synthetic speech patterns in several ways. The principle differences are in the overall energy spectrum, since the sine waves simply consist of nonharmonic single frequencies, and therefore, lack any perceptible fundamental frequency. A second way in which they differ is that the frequencies do not vary in their relative amplitudes over time, so that the slight changes in relative energy of the harmonic frequencies present in a synthetic or normal utterance are absent (Remez, Rubin, Pisoni and Carrell, 1981).

### Subjects

The experimental population comprised 12 adult

aphasics who were either out-patients or former patients of the Institute of Rehabilitation Medicine, New York University Medical Center, New York City. The control population of 8 normal subjects was drawn from members of the staff of the Institute of Rehabilitation Medicine. All were native English speakers who reported no history of a speech or hearing disorder.

The aphasic population was limited to individuals who had sustained a left hemisphere CVA, were native English speakers and prior to the onset of aphasia, had no history of neurological impairment. All patients were screened for normal peripheral hearing through the speech frequencies. The mean length of time post-onset was 3.2 years with a range of 1 to 6 years. The mean age was 55 years, with a range of 36 to 66 years.

An attempt was made to include aphasics who represented a fairly wide range of aphasia severity and whose speech characteristics permitted assignment to either a fluent or non-fluent category. (See Tables 1 and 2). This convenient scheme has become one of the keys to modern analysis of aphasias, since it not only assists in diagnostic classification (Goodglass and Kaplan, 1972) but provides an indication for the location of the lesion (Benson, 1967). Auditory comprehension

Table 1  
Summary of Characteristics of Aphasic Subjects

<u>Category</u>	<u>Speech Symptoms</u>	<u>Severity (FCP)*</u>	<u>Compre- hension**</u>
1 Fluent	minimal reduction of noun vocabulary circumlocution	89%	163 (perfect) <sup>4</sup>
2 Fluent	mild phonemic paraphasia, circumlocution	82%	163
3 Fluent	empty speech verbal paraphasia circumlocution	68%	95
4 Fluent	hyperfluency circumlocution	79%	73
5 Fluent	Neologistic jargon	34%	57

\* Overall Functional Communication Profile Score--%  
indicates percent of estimated premorbid language  
proficiency

\*\* Token Test raw score

Table 1 (continued)

<u>Category</u>	<u>Speech Symptoms</u>	<u>Severity (FCP)*</u>	<u>Compre- hension**</u>
6 Nonfluent	mild reduction in rate, imprecise articulation, mild reduction in vocabulary	84%	163
7 Nonfluent	minimal reduction in vocabulary, hesitancy <sup>5</sup>	91%	161
8 Nonfluent	hesitancy, imprecise articulation, mild-moderate vocabulary reduction	72%	161
9 Nonfluent	slow imprecise articulation, moderate reduction of vocabulary agrammatism	68%	128
10 Nonfluent	effortful articulation severely reduced vocabulary, telegraphic style	43%	126
11 Nonfluent	imprecise articulation slow rate verbal paraphasia <sup>6</sup>	52%	85
12 Nonfluent	telegraphic style severely reduced vocabulary	53%	38

Table 2Additional Information on Aphasic Subjects

<u>Subject</u>	<u>Age</u>	<u>Sex</u>	<u>Education</u>	<u>Duration of Aphasia</u>	<u>Medical Diagnosis</u>	<u>Right-sided Motor Impairment</u>
1	55	F	12 yr.	4 yr. 6 mo.	L CVA	*
2	36	M	12 yr.	1 yr. 9 mo.	L CVA	*
3	61	M	20 yr.	2 yr. 3 mo.	L CVA	*
4	57	M	14 yr.	6 yr. 0 mo.	L CVA	*
5	55	M	12 yr.	2 yr. 3 mo.	L CVA	*
6	59	M	16 yr.	5 yr. 5 mo.	L CVA	*
7	63	F	16 yr.	3 yr. 5 mo.	L CVA	+
8	47	M	15 yr.	2 yr. 5 mo.	L CVA	+
9	66	M	20 yr.	5 yr. 10 mo.	L CVA	*
10	51	M	20 yr.	1 yr. 0 mo.	L CVA	+
11	62	M	13 yr.	1 yr. 7 mo.	L CVA	+
12	50	M	20 yr.	2 yr. 0 mo.	L CVA	+

\*Denotes the presence of minimal motor symptoms affecting the right extremities, but which were not of sufficient severity to necessitate a shift in handedness. All study subjects were ambulatory.

A(+) denotes significant right hemiplegia.

impairment was assessed using the Token Test (Spreen and Benton, 1967) and overall severity of impairment was determined by the overall score on the Functional Communication Profile (Sarno, 1967).

#### Procedure

Subjects were tested individually in an IAC sound proof chamber. The tapes used were played on a Wollensak 1520 tape recorder and were presented free field at a comfortable loudness level.

Subjects were asked to listen to the taped stimuli and to indicate their judgements by checking the appropriate response on a prepared answer sheet. (See appendix). Testing required from 2 to 10 sessions, depending on the subject's availability and ability to cope with the testing procedure. At the end of each test, subjects were asked if they chose to continue. If not, they were given a break and another session was scheduled. Care was taken to insure that aphasic subjects understood the task demands. This included, depending on the individual need, presenting a good prototype, orally, of the stimulus they were about to hear or presenting simpler response modes until subjects were able to respond with the standard ones. In addition,

tests were preceded by a practice set which permitted the experimenter to provide assistance and feedback. Stimuli were presented with either a 3 or 4 sec inter-stimulus interval. Upon occasion, however, it was necessary to control stimulus presentation manually to permit aphasic subjects sufficient time to respond.

## CHAPTER I

Footnotes

1. The brain-damaged population tested by Tallal and Newcombe were ex-servicemen who had sustained missile wounds from 20 to 30 years prior to testing. They reported that residual aphasia was found in all ten left brain-damaged subjects, but they did not specify either diagnostic classification or overall severity of aphasia.
2. Although it is the timing relation between the release of the burst in a stop consonant and the onset of glottal pulsing that defines VOT, the stimuli also contain a variety of acoustic cues, e.g. the starting frequency and duration of the transition of the first formant and voiced portions of the upper formants, the intensity and duration of the burst release, the presence and duration of friction noise, all of which contribute to the perception of voicing.
3. The special program for sine-wave synthesis was designed by Philip E. Rubin of Haskin Laboratories, New Haven, Connecticut.
4. A perfect Token Test score is relatively rare in aphasia. Of 350 aphasics selected for longitudinal study in the past 15 years by the Speech Pathology Department, Institute of Rehabilitation Medicine, New York University Medical Center, there are 18 cases in which normal Token Test performance has been obtained (5%). Study subjects for this investigation were selected on the basis of speech characteristics. Subsequent testing revealed a perfect Token Test score in three cases, Subjects 1, 2, and 6.
5. Subject's original diagnosis in the acute phase was nonfluent aphasia, characterized by marked word-finding difficulty, fragmentary and agrammatic sentence structure. This diagnosis was

verified by a language test profile consistent with non-fluent aphasia. Speech characteristics and language function have evolved and subject shows the closest to normal language behavior of any included in this study. (i.e. FCP overall score of 91% of estimated premorbid language proficiency). However, formal language test findings reveal mild persisting language deficits.

6. Subject's aphasia is atypical of either syndrome. Although spontaneous speech is markedly nonfluent, characterized by effortful initiation of speech, articulatory errors, simplified and fragmented sentence structure, verbal paraphasia is relatively common. Language test profile is characteristic of nonfluent aphasia.

CHAPTER II

Experiments I and II represent an attempt to replicate the Tallal and Newcombe (1978) study that found that (1.) aphasics with impaired comprehension of spoken language profit from formant transition extension; (2.) those aphasics who profit from formant transition extension are also sensitive to a reduction in inter-stimulus interval (ISI).

Before an interpretation of Tallal and Newcombe's findings can be attempted, it is necessary to examine some aspects of their methodology. It is well-documented in research on normal perception that listeners' judgements of CV stimuli change when all three of the formant transitions serving to distinguish /b/ from /d/ are extended from 30 to 80 msec. This is particularly true for the bilabial. When listeners identify extended formants for /b/ they typically identify the sound as the semi-vowel /w/. The boundary between the two classes of sounds averages 40 msec (Liberman, Delattre, Gerstman and Cooper, 1956). This means there is not only a difference in place but also a difference in manner between the two stimulus patterns with extended formants.

This problem in stimulus construction can be resolved by confining formant extension to those formants (F2 and F3) that carry most of the place of articulation information while leaving the formant that carries manner information (F1) unchanged.

## EXPERIMENT I

### METHOD

#### Stimuli and Task Design

This experiment consisted of three identification tests. Three sets of syllables were synthesized which differed only in the formant patterns used to render /ba/ versus /da/. The stimulus patterns for series 1 and 2 were modeled after those described by Tallal and Piercy (1974 and 1975).<sup>1</sup> All stimulus patterns began with 13 msec of prevoicing and were followed by a three formant pattern of values depicted in Table 3. The

Table 3

Onset and Ending Values of the Three Formant Transition  
Patterns Used in Experiment I and II

	<u>/b/</u>		<u>/d/</u>	
	<u>Onset</u>	<u>Ending</u>	<u>Onset</u>	<u>Ending</u>
F1	202	688	202	688
F2	848	1077	1535	1077
F3	2193	2527	3029	2527

durations of all three formant transitions were 30 msec in the first series and 82 msec in the second series. For series 3, the first formant transition remained at a fixed value of 688 Hz after only 30 msec transition, and the second and third formant are identical to series 2. Formant transitions were followed by a steady state vowel portion sufficient to produce an overall stimulus duration of 250 msec.

Each series consisted of a demonstration of the two stimulus patterns presented four times in succession, a practice set of twelve items and a randomized 24 item test.

### Subjects

Subjects were the twelve aphasic subjects described above.

### Procedure

Subjects were informed that they would hear computer generated syllables which sounded like "ba" or "da". The display was presented and the proper response was demonstrated by the experimenter. Subjects were instructed to mark or point to the appropriate syllable on a prepared answer sheet. Twelve practice

items were presented and repeated when necessary to insure that subjects were able to cope with the task. This was followed by the twenty-four item test.

Each identification test was followed by the two discrimination tests for each set. The entire identification and discrimination experiments were then repeated in reverse order. Testing for these two experiments was accomplished in 2-3 sessions.

#### RESULTS

The findings of Experiment I are depicted in Figure 1. The group means for set 1, 2 and 3 were 18.6, 19.3, 19.3 respectively. For all subjects whose score on set 1 was less than 100%, the means for set 1, 2 and 3 were 16.8, 17.8, and 17.7. For subjects whose score on set 1 was less than 100% (N=8), a Wilcoxon Matched Pairs Test of 1 versus 2, 2 versus 3, and 1 versus the average of 2+3 yielded  $T=10.11$ , and 10,  $P$  for all three tests  $> .05$ . No statistically significant difference was found when only subjects whose score on set one was less than 90% (N=6) were considered,  $T=5.5$ ,  $P > .05$  (1 versus 2),  $T=7$ ,  $P > .05$  (1 versus 3),  $T=2$ ,  $P > .05$  (1 versus  $\frac{2+3}{2}$ ).

Figure 1. Identification of [ba-da] as a function of the duration of the initial formant transition.

Figure 1

## IDENTIFICATION

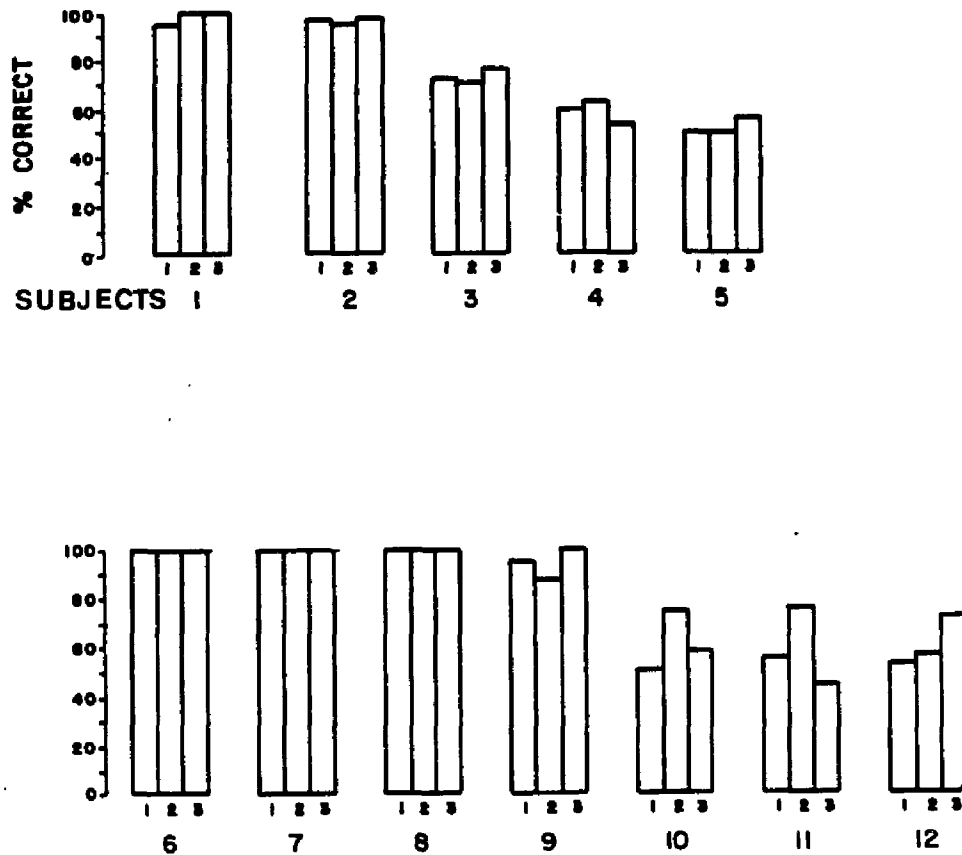


Fig. 1 - Identification of [ba-da] as a function of variations in duration of the initial formant transitions. The scores of three identification tests for each aphasic subject are presented in the order originally described (Table 1).

There was also no statistically significant difference between identification by the two categories of aphasics. Some patients in both groups are prone to errors in identification, and some, usually the milder aphasics, encountered no difficulty whatever. Since the results for both groups are presented in the order of the subjects' Token Test scores, the significant rank order correlation between identification scores is obvious ( $r = .83, P > .01$ ). A significant rank order correlation also exists between identification scores and the overall score of the Functional Communication Profile ( $r = .79, P > .01$ ). That is, for this population, performance on either measure of aphasia predicts performance on the phoneme identification test.

## EXPERIMENT II

### METHOD

#### Stimuli and Task Design

This experiment consisted of six discrimination tests and used paired stimulus patterns from the identification tests used in Experiment I. Two same-different discrimination tests for each identification series were constructed. The two tests differed only in the interstimulus interval (ISI) which was 500 msec for the first test and 50 msec for the second test. The intertrial interval was 4 seconds.

### Subjects

Eleven of the subjects who participated in Experiment I were subjects for Experiment II. One aphasic (5) failed to understand the task demands after repeated trials and therefore was eliminated from discrimination testing.

### Procedure

Subjects were informed that they would hear the two syllables presented previously in pairs. Four demonstration pairs were presented and the experimenter modeled the appropriate response. A practice set of eight items was presented. Subjects were instructed to decide whether the two stimuli were the same or different and to mark their choice on a printed answer sheet. The answer sheet contained the letter S for same and D for different. If subjects were confused by this format, a second answer sheet was provided which used simple symbols to convey the concept (two circles for same, a circle and square for different). A practice set of eight items was repeated, until it was certain that the task was understood.

## RESULTS

As is evident in Figure 2, the length of ISI had no consistent effect on discrimination performance. It was not unusual for subjects to show slightly increased scores on the short ISI set in one series, only to show the opposite pattern for another series. Differences dependent on ISI duration were insignificant.

The results of discrimination testing also fail to demonstrate a significant improvement in discrimination of /ba/ and /da/ for the group as a function of formant transition extension. The differences between series 1, 2 and 3 are generally small and follow no consistent pattern. Within the fluent population, there is a slight tendency for series 3 to result in higher scores. Two of the fluent subjects with deficits in spoken language comprehension demonstrate their highest performance on this series. In comparing performance on series 1 and 2 in which the stimulus parameters were closely modeled on those described by Tallal and Piercy (1974, 1975), the results of the present study do not replicate those reported by Tallal and Newcombe (1978). In fact, Table 4 shows that performance on their extended formant series is poorer than on the

Figure 2. Discrimination of [ba-da] at two ISI.

Figure 2

# DISCRIMINATION

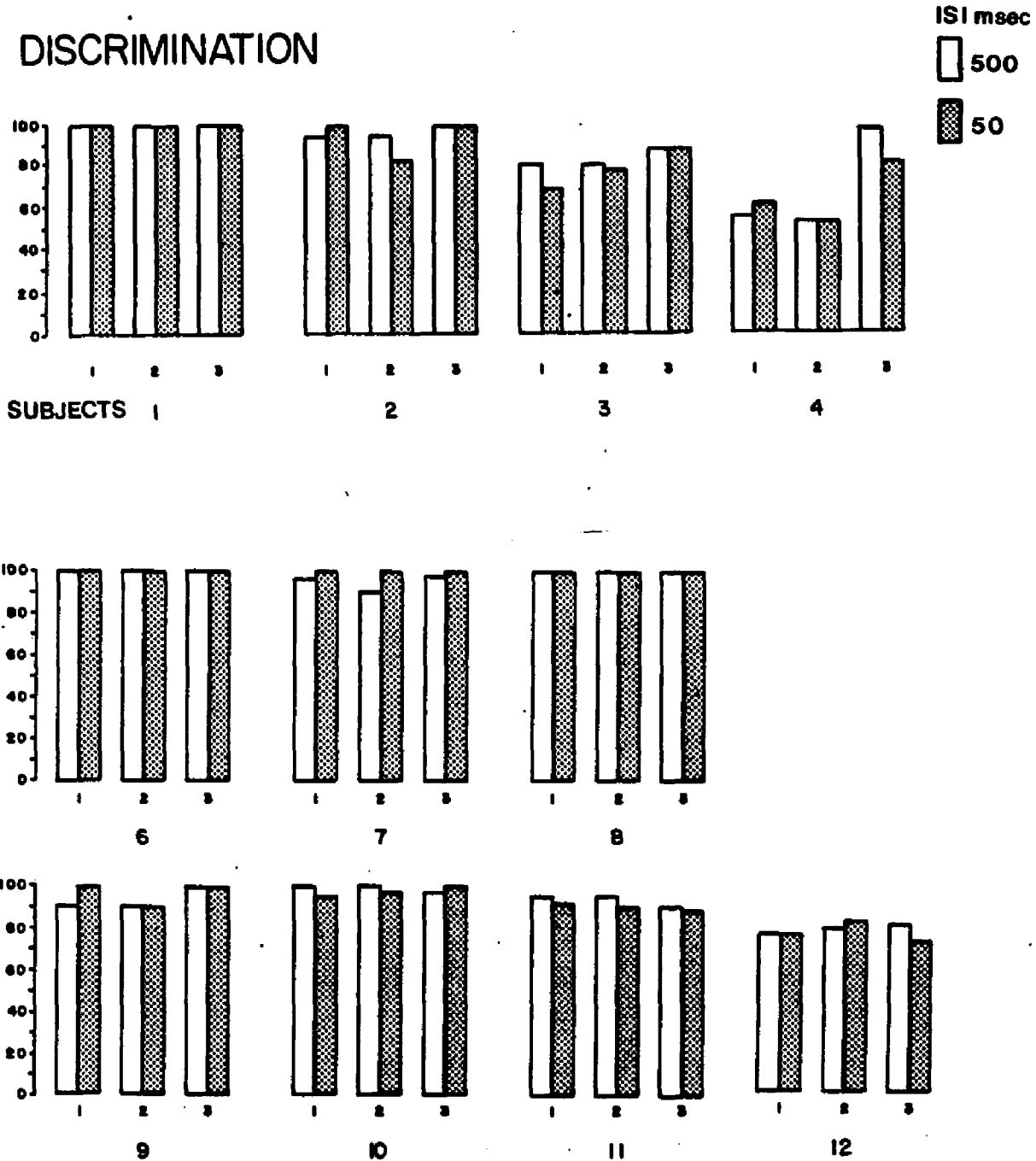


Figure 2 - Discrimination of [ba-da] at 500 and 50 msec ISI. Scores for 6 discrimination tests, 2 for each stimuli series are illustrated for 11 aphasics tested. Subject 5 (Table 1) was eliminated from discrimination testing.

Table 4

Mean % Correct and Standard Deviation of Identification  
and Discrimination Scores

	<u>Identification</u>		<u>Discrimination</u>			
	<u>%</u>	<u>S.D.</u>	<u>500 msec (ISI)</u>	<u>50 msec</u>	<u>%</u>	<u>S.D.</u>
<u>Fluent</u> <u>N=5</u>						
Series						
1	76	5.2	83	4.0	83	3.8
2	76	5.1	91	4.3	78	3.9
3	78	5.1	96	.96	93	1.9
<u>Nonfluent</u> <u>N=7</u>						
1	79	5.9	94	1.8	95	1.8
2	83	4.3	93	1.6	93	1.3
3	82	5.7	94	1.4	94	2.1

brief series, particularly when stimulus members are separated by the short 50 msec interstimulus interval.

Although the subject groups are too small to generalize their data, there is no consistent or reliable pattern associated with aphasia type. Regardless of the duration of the initial formant transition, the performance of both categories of aphasics is noticeably better on the discrimination series than it is on the identification series (Table 4). As with identification performance there is a significant rank order correlation between discrimination performance and Token Test score ( $r = .86, P > .01$ ).

The most significant outcome of the two experiments was not the difference based on stimulus parameters, but the difference between discriminating and identifying the syllables. Aphasics as a whole experienced considerably less difficulty discriminating than identifying the stimuli. Furthermore, performance on both tasks correlated significantly with performance on the Token Test. Although there was a high rank order correlation between identification scores and the overall score on the Functional Communication Profile, those patients who were rated as clinically more impaired, did not necessarily experience more difficulty judging whether pairs of stimuli

were the same or different. The Spearman rank correlation coefficient between these two scores is  $r=.42$  which is not significant at the .05 level.

In summary, the results of Experiment I and II provide little evidence to support the hypothesis that aphasics who display frank comprehension deficits, profit from formant transition extension in performance of phonological tasks. With the possible exception for series 3 stimulus patterns to result in slightly better discrimination performance in two fluent aphasics, differences based on stimulus parameters are not significant. In addition, the decrease in ISI from 500 to 50 msec did not result in any significant decrease in phoneme discrimination scores.

Secondly, the discrepancy between identification and discrimination of phonological contrasts deserves further examination. If aphasics have more difficulty labeling the stimuli than they do in discriminating acoustic parameters which signal the phonetic class, the variations in duration must be explored in both contexts.

Finally, the relation between perceptual abilities and language comprehension requires clarification. For this group, Token Test scores predicted relative success

on both the identification and discrimination tests. It is therefore of considerable interest to observe this connection for other stimulus parameters, tasks, and modes of response.

## CHAPTER II

Footnotes

1. Tallal and Piercy (1974), p. 86 provide a table of  $F_2$  and  $F_3$  transition patterns for their two stimuli representing /ba/ and /da/. However, Tallal and Piercy (1975) in a footnote (FP 72) state that the description of Tallal and Piercy (1974) are incorrect. The authors provide spectrograms of the corrected syllables (their figure 2) without listing the actual formant values. The center frequencies of the present stimuli listed in Table 3 were estimated from these spectrograms.

CHAPTER III

Having found little evidence of an auditory deficit in the discrimination of brief formant transitions according to the paradigm of Tallal and Piercy (1974), it seemed reasonable to test the aphasic subjects somewhat more rigorously by examining their capacity to identify and discriminate between synthetic CV syllables in which formant transitions, varying from even briefer values than in the previous experiment to an extended value, were used to convey a manner contrast between a stop and a glide.

The next two experiments represent an attempt to explore the effect of variations in acoustic duration in aphasics' perception of the manner class distinction /b/ versus /w/. This is a natural extension of Experiment I and II since the cue being varied is the duration of the initial formant transition.

For the first experiment, speech patterns were synthesized which varied systematically the duration of the initial formant transition representing the continuum from /b/ to /w/. Since Miller and Liberman (1979) demonstrated that normal listeners adjust their perception

of the stop consonant /b/ and the semi-vowel /w/ relative to the overall duration of the syllable, two series of stimuli were constructed which differed only in overall syllable duration. An increase in syllable duration is expected to result in a displacement of the /b-w/ category boundary so that more of the stimuli are judged as /b/. This perceptual normalization effect was tested in both an identification and a discrimination series.

For the second experiment, sinusoidal wave patterns were constructed to explore the perceptual normalization effect with non-speech stimuli. Sine-wave patterns are useful non-speech control stimuli since they replicate the changing formant center frequencies of speech patterns, yet are not usually heard as speech without special training or instruction (Remez, Rubin, Pisoni, and Carrell, 1981).

### EXPERIMENT III

This experiment serves two purposes. First, bearing in mind that Tallal and Newcombe (1978) reported that aphasics perceived the stimulus patterns containing both brief and extended formant transitions as /b/, whereas research with normals has indicated that listeners perceive the stimulus patterns with brief

transitions as /b/ and extended transitions as /w/, and in Experiment II most aphasics were able to discriminate brief formant transitions, it seemed crucial to examine aphasics' perception of the distinction dependent on the duration of formant transitions.

Second, since normal listeners shift their judgements of the /b-w/ distinction as a function of syllable duration, it was of interest to find out if aphasics' perception is governed by the same temporal properties. Only if they are less sensitive than normal listeners to the manipulation of duration is it possible to conclude that they possess a specific temporal processing deficit.

#### METHOD

##### Stimuli

Two series of stimuli patterns were constructed: one in which the overall syllable duration was 150 msec and one in which the syllable duration was 300 msec. Stimulus pattern specifications are based on Miller and Liberman (1979). They consisted of 20 msec of prevoicing, and transition durations suitable for producing the continuum from /b/ to /w/ varying from 15 msec to 75 msec in 10 msec steps for a total of 7 stimuli per

Table 5Stimulus Specifications for the Three Formant  
Patterns Used in Experiment III

	<u>Frequency in Hz</u>	
	<u>Initial</u>	<u>Final</u>
F1	227	765
F2	619	1232
F3	2862	2861

series. Table 5 lists these values and Figure 3 illustrates the paths of the center frequencies of the first three formants.

#### Description of Identification Series

Each identification tape consisted of 6 display pairs, a 21 item practice set using stimulus patterns from the end points of the continuum, and a randomized 70 item identification test. As the task proved too long and difficult for the aphasic subjects, the test was reduced to 35 judgements. The interstimulus interval was 3 sec.

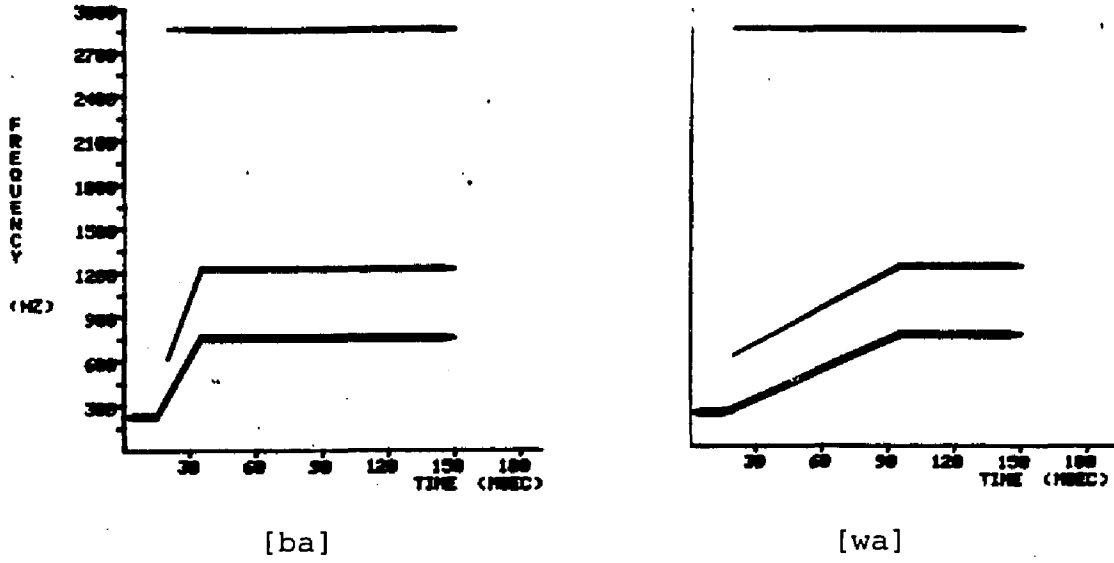
#### Description of Discrimination Tests

Two same-different discrimination series were constructed: a 150 and a 300 msec set. Each consisted of the random presentation of stimulus pairs in which the members were either the same or differed from each other by 20 msec of transition duration (i.e. 15 and 35, 25 and 45, 35 and 55, 45 and 65, and 55 and 75 msec). The members of each pair were separated by 500 msec of silence and the intertrial interval was 4 seconds. The discrimination test consisted of 8 permutations of 17 stimulus pairs, 10 pairs in which the items differed

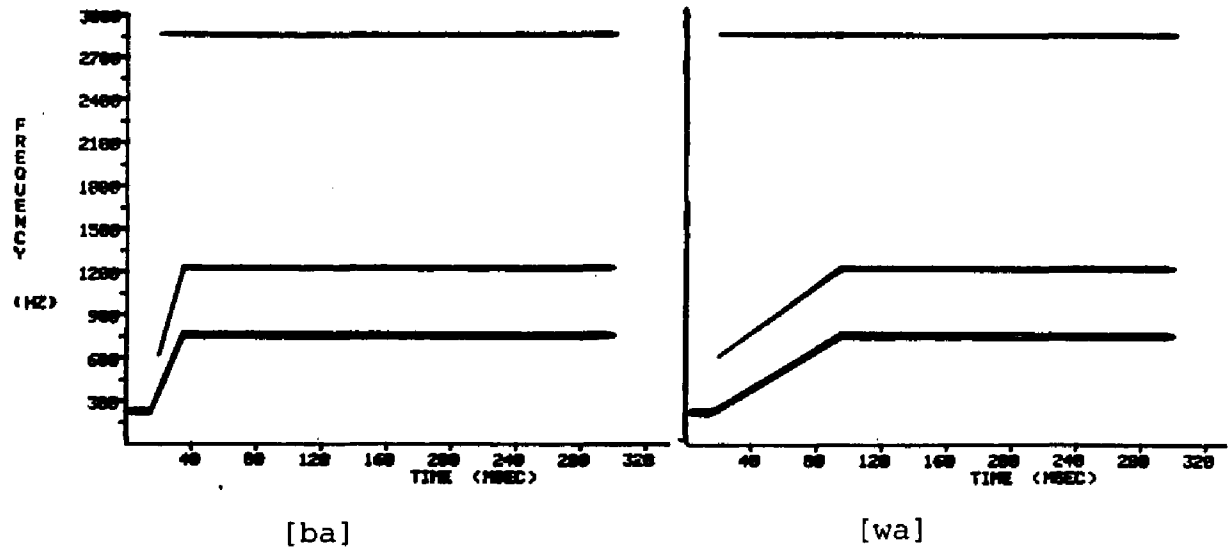
Figure 3. Stylized spectrogram illustrating center frequencies of the first three formants of the endpoints of the [ba-wa] series.

Figure 3

150 msec Series



300 msec Series



and 7 in which they were the same, for a total of 136 judgements. This task was also reduced for aphasic subjects to 5 permutations of 17 stimulus pairs, a total of 85 judgements.

### Subjects

The same 12 aphasic subjects who served as subjects in Experiment I and II were used as subjects for these experiments. Since subject 5 had failed to master the previous discrimination test, only 11 subjects were used for discrimination testing.

In addition, 8 normal control subjects were tested.

### Procedure

Subjects were informed that they would hear syllables which sounded like "ba" or "wa". They were asked to identify each stimulus by checking the appropriate syllable on a printed answer sheet. To train subjects to perform the test, a six item demonstration using alternating stimulus patterns from the end points of the continuum was presented, during which the experimenter indicated the correct responses. This was followed by a 21 item practice set in which the experimenter provided assistance and feedback.

For the discrimination testing, subjects were required to determine whether the members of the stimulus pairs were the same or different and to indicate their choice by checking S or D on a printed answer sheet. Since subjects were those who had already demonstrated their ability to understand discrimination testing, no training task was used, but 10 samples taken randomly from the first 17 items were presented to familiarize them with the sound patterns.

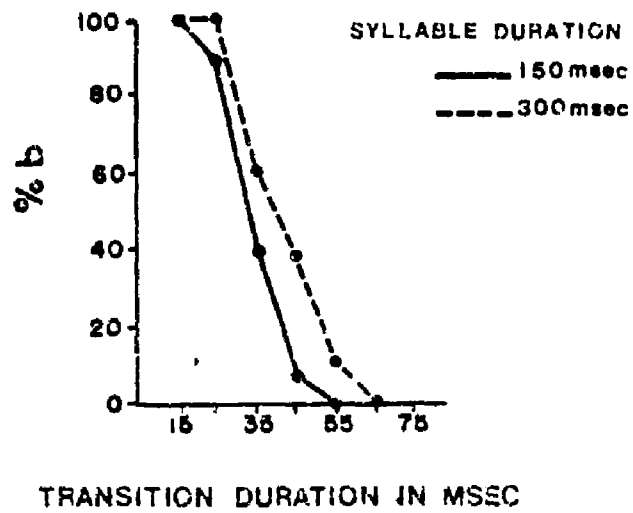
## RESULTS

### Identification of /b-w/: Normal Subjects

As can be seen in Figure 4, there was the predicted effect of syllable duration on the identification of the stop consonant /b/ and the semi-vowel /w/: that is, with the 300 msec series, a longer duration of transition was required to perceive /w/. Boundary values were computed for each subject by fitting a normal ogive according to the method of least squares (Woodsworth, 1938). All control subjects but one showed the predicted boundary shift. The mean difference of 4.21 msec between boundary values for the two series is significant. ( $t=4.99$ ,  $P < .005$  one-tailed test).

The boundary shift is slightly smaller than Miller

Figure 4. Performance of normal group: Percent  
/b/ response illustrating the effect  
of syllable duration on /b-w/ distinction.

Figure 4**EXPERIMENT III**

and Liberman (1979) found. For syllable durations of 152 msec, they report a mean boundary value of 40.9, and for syllable durations of 296 msec, a value of 46.6, for a mean boundary shift of 5.7 msec.

The absolute positions of the boundaries are also at somewhat shorter transition values than Miller and Liberman found. See Table 6. In the present study, the boundary values ranged from 28.6 to 41.67 msec (150 msec series) and 34.8 to 44.8 (300 msec series) as compared with those obtained by Miller and Liberman; 37.6 to 46.6 msec (152 msec series) and 41.6 to 50.4 msec (296 msec series). Since the location of the boundary in the identification series is at rather short transition values, we would expect the location of the peak of discrimination for the two phonetic classes also to fall at relatively short transition values.

#### Identification of /b-w/: Aphasic Subjects

The identification function for both syllable durations were plotted for each aphasic subject (see Figure 5). The arrangement of the graphs follows the same order as was used in Experiments I and II. However, for this experiment, the presentation is further subdivided into two categories, normal and abnormal

Table 6  
Individual Mean /b-w/ Boundary Values for the Two  
Syllable Durations, 150 and 300 msec  
Normal Subjects

<u>Subject</u>	<u>150</u>	<u>300</u>
1	34.09	37.07
2	39.59	44.73
3	38.52	43.14
4	38.19	41.33
5	28.60	34.80
6	38.19	44.84
7	41.67	47.32
8	39.59	38.90
X	37.31	41.52

Token Test performance, for each clinical group, fluent and nonfluent.

Figure 5 indicates that on the short duration series, seven subjects demonstrate an essentially normal boundary effect in identification of the two phonetic categories, /b/ and /w/. That is, there was an 80% difference between the end points of the continuum and a sharp shift in judgements around 35-45 msec. Two additional subjects, 4 and 10, met the 80% criterion, but failed to show as sharp a boundary as is normally found.

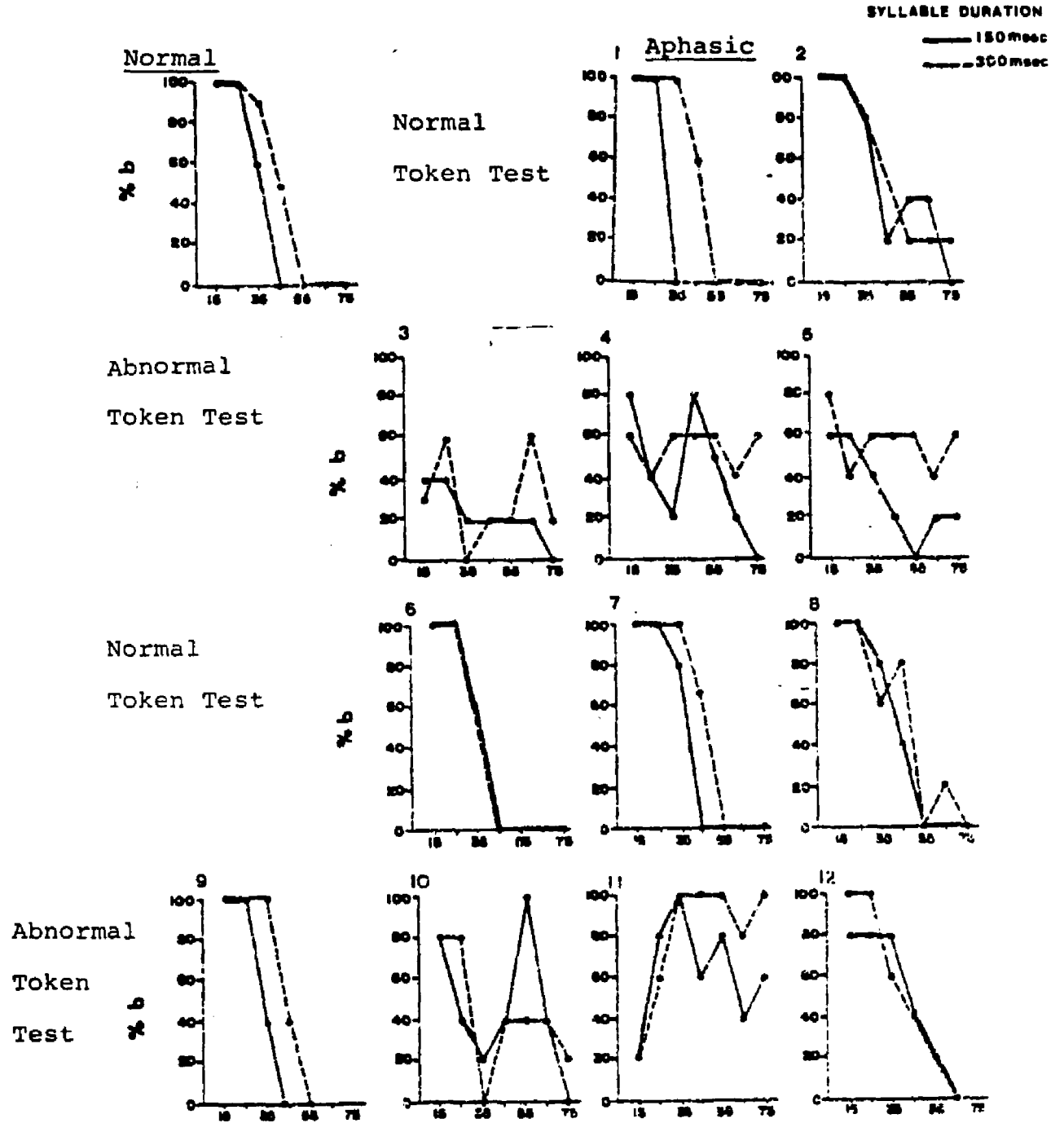
For the 300 msec series, once again the same seven subjects demonstrated an essentially normal identification function. This suggests that lengthening the overall duration of the syllable has little effect on subjects' ability to identify the two phoneme classes. In fact, the curves obtained from the longer syllable duration series appear somewhat less regular than those obtained from the short series.

To observe the effect of lengthening the syllable duration on the boundary values of aphasic subjects who showed relatively normal identification functions, boundary values were computed by fitting a normal ogive according to the method of least squares. The mean

Figure 5. Performance of individual aphasics (N=12):  
Percent /b/ response as a function of  
syllable duration. Identification of aphasic  
subjects is compared with one representative  
normal subject (Upper left corner). Subjects  
arranged as described in Table 1.

Figure 5

EXPERIMENT III



boundary value for the 150 msec series was 39.5 and for the 300 msec, it was 45.0 msec, a difference of 5.5 msec. The difference in boundary values between the two series is significant ( $t = 3.61, p > .01$ ). Thus, subjects who were able to do the task, displayed normal sensitivity to temporal variations.

#### Discrimination of /b-w/: Normal Subjects

Discrimination functions for the two syllable durations were plotted for each subject. Group data are not reported, but a representative discrimination function for a normal subject is displayed in Figure 6.

Six of the eight normal subjects showed a shift of the peak of discrimination at the locus of the phoneme boundary, i.e. for stimulus pairs in which the formant transition duration values are 15 and 35 msec for the 150 msec series, and 25 and 45 msec for the 300 msec series. There was some individual variation, with some subjects showing a broader peak of discrimination for the short series, extending into the next value (25 and 45 msec). Two subjects showed a larger shift in phoneme boundary, and the peak of discrimination was at transition values of 45 and 65 msec. Formant transition duration values of 55 and 75 msec were not reliably discriminated. The

150 msec series tended to be more easily discriminated than the 300 msec series as evidenced by both a steeper and higher discrimination function for the short than for the long series.

#### Discrimination of /b-w/: Aphasic Subjects

Discrimination functions were plotted for each of the eleven subjects tested, see Figure 6. Although when compared to normal discrimination function, aphasics performance appears poor, most aphasic subjects showed a discrimination peak for stimulus pairs in which the formant transition duration was 15 and 35 msec.

Criteria for acceptable discrimination which could be met by all normal subjects were established for the aphasic data. This included having a peak of discrimination at the predicted normal value or one of its neighbor-values and a difference between a high and low point of discrimination of at least 50%.

Seven of the aphasics met these criteria for the 150 msec series, but only 5 for the 300 msec series. These subjects whose performance met the established standards were not the same for both series. Three subjects who showed reliable discrimination ability on the 150 msec series, did not reach the 50% difference

Figure 6. Individual aphasics (N=11): Percent "different" responses, discrimination of [ba-wa] as a function of syllable duration compared with one representative normal subject.



criterion on the 300 msec series. Subject 4, however, showed the reverse pattern. But for the majority of aphasic subjects, syllable duration does not appear to enhance their discrimination of small acoustic variations.

As a measure of reasonable performance on the discrimination tests, the % correct "same" responses was computed for each subject and averaged across subjects. This information is depicted in Table 7.

#### Identification Versus Discrimination

While it is obvious (Table 8) that 3 of the more severely impaired aphasics (4, 10, 11) discriminate the manner contrast stimuli better than they are able to identify them, discrimination ability of the /b-w/ distinction for this group of subjects is not necessarily superior to identification function.<sup>1</sup>

With respect to perceptual normalization, a noticeable shift in the peak of discrimination function in the predicted direction was found in only one case (10). Since this is an individual whose identification function was too irregular to reveal the predicted effect on identification tests, this suggests that normal sensitivity to acoustic variations is present despite the

Table 7

Mean Correct "Same" and Standard Deviation for Normal  
and Aphasic Subjects for 150 and 300 msec Syllables

	150		300	
	<u>Mean</u>	<u>S.D.</u>	<u>Mean</u>	<u>S.D.</u>
Normals	94.9	5.7	93.1	5.4
Aphasics	87.4	14.3	87.5	14.2

inability to identify reliably the phoneme categories. There is also a slight trace of a shift in the discrimination peak for three other subjects all of whom manifest a nonfluent variety of aphasia.

Phonological Test Findings and Degree of Comprehension  
Defect and Type of Aphasia

Although relative performance on the Token Test usually predicts performance on the identification tests, there are some exceptions. (See Figure 5). Subject 12, the lowest ranking aphasic with respect to Token Test score, demonstrates a fairly normal identification function. However, Token Test performance does not appear in any way to predict relative ability to perform discrimination tests. See Figure 6. Discrimination performance somewhat more preserved than identification of the manner class distinction, particularly in aphasics with abnormal Token Test scores. See Table 8. Although two fluent subjects (3 and 5) were unable to either identify or discriminate the stimuli, no particular performance pattern seems associated with aphasia type.

In summary, the examination of aphasics' perception of the manner class distinction /b-w/ disclosed that the majority of aphasics did perceive the class distinction

for the three formant patterns which varied in the duration of formant transitions from 15 msec to 75 msec. The boundary value at which perception changed from /b/ to /w/ was similar for aphasic and normal subjects. The identification performance of seven of the twelve aphasic subjects revealed the category boundary at values ranging from 25-45 msec and three additional aphasics showed a peak of discrimination at similar values though their identification function was too irregular to reveal the class distinction. It should be pointed out that the end point value signaling /w/ in the present study (an initial formant transition duration of 75 msec) is briefer than the duration of the initial formant transition in Tallal and Newcombe (1978) extended series which reportedly improved aphasics' perception of /ba/.

Neither identification nor discrimination findings lend any firm support to the notion that aphasics are less sensitive to temporal variations than are normal subjects. When able to perform the phonological task, they show indications of a shift in perception in the predicted direction. Consistent with the results obtained from the normal population, the discrimination shift is somewhat less pronounced than in identification testing.

Table 8

Performance of Each Aphasic Subject on Discrimination and Identification of the Formant Transition Duration Continuum Representing /b-w/ Including the Presence + on Absence (-) of a Boundary Shift as a Function of Syllable Duration. A plus (+) Indicates that Performance Has Met Criterion, and a (-) Indicates Unacceptable Performance

<u>Type</u>	<u>Identification</u>			<u>Discrimination</u>		
	<u>150</u>	<u>300</u>	<u>Shift</u>	<u>150</u>	<u>300</u>	<u>Shift</u>
<u>Fluent</u>						
1	+	+	+	+	+	-
2	+	+	+	+	+	-
3	-	-		-	-	
4	-	-		-	+	-
5	-	-				
<u>Nonfluent</u>						
6	+	+	-	+	+	-
7	+	+	+	-	-	+*
8	+	+	+	+	-	+*
9	+	+	+	-	-	-
10	-	-		+	+	+
11	-	-		+	-	-
12	+	+	-	+	-	+*

\* Indicates those instances where a trace of a boundary effect can be seen though performance does not meet criteria.

Moreover, both populations tended to show poorer discrimination of the stimulus pairs derived from the 300 msec series than from the 150 msec series.

Finally, in general, performance on the Token Test predicts relative ability to identify the phonological classes, but is dissociated from the ability to discriminate the small acoustic differences that define the phonetic category.

#### EXPERIMENT IV

This experiment was designed as a non-speech control study to the investigation of perceptual normalization which used synthetic speech. The purpose of the experiment was to investigate the effect of manipulations in duration on aphasic and normal listeners' perception of two non-speech classes, and to compare the results with those obtained in Experiment III. It was also of interest to explore whether the identification difficulty manifested by several aphasics was specific to speech or included both speech and non-speech stimuli.


#### METHOD

##### Stimuli

The non-speech stimuli were sinusoidal wave

patterns which replicated the changing formant center frequencies and which were presented in the same test order as the speech patterns. Two test tapes were constructed, a 150 msec and a 300 msec series. The tapes consisted of 6 demonstration pairs, a 21-item practice set and a 70-item identification test which again was reduced to 35 items for aphasic subjects.

#### Procedure

Subjects were informed that they would hear two "whistle" like sounds, one with a sharp abrupt onset, and one with a gradual onset. The demonstration was presented during which the experimenter demonstrated the appropriate response. The response sheet contained two symbols — (abrupt) and  (gradual) onset. The 21-item practice set was presented and the experimenter provided whatever assistance was necessary to train the subjects to do the task. This was followed by the presentation of the identification test.

### RESULTS

#### Identification of Sine-Wave Patterns: Normal Subjects

It is evident from the group data depicted in Figure 7 that the perceptual normalization effect when

Table 9

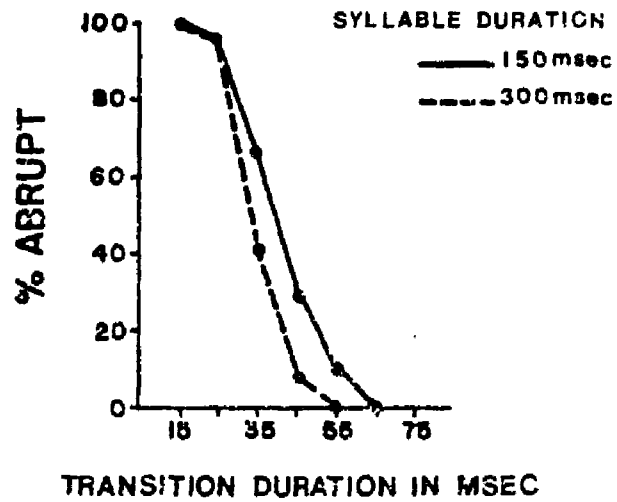
Mean - -/ Boundary Values for the Two Stimulus  
Durations of Sine-Wave Patterns

<u>Subject</u>	<u>Stimulus Duration</u>		<u>Shift</u>
	<u>150</u>	<u>300</u>	
1	45.36	39.44	-
2	38.19	39.99	+
3	43.62	40.40	-
4	41.75	37.31	-
5	44.64	45.27	+
6	36.69	38.01	+
7	39.55	39.60	+
8	47.53	43.79	-

+ indicates a shift in the predicted direction

- indicates a shift in the opposite direction

Figure 7. Normal group: (Sine-wave control stimuli)  
Percent "abrupt" judgements--illustrates  
the effect of stimulus duration on identi-  
fication of two nonspeech categories.

Figure 7**EXPERIMENT IV**

sine-wave patterns were used and a non-speech judgement is required was somewhat different from that observed when speech patterns were used and a phonetic judgement was required. For normal subjects, the boundary shift is both smaller and in the opposite direction from that obtained in the speech condition.

#### Identification of Sine-Wave Patterns: Aphasic Subjects

Individual data obtained from aphasic subjects are shown in Figure 8. For the 150 msec series, the identification function of nine subjects satisfies the requirement of an 80% difference between judgements at the end points of the continuum. The identification function of only five of these is sufficiently regular to observe a boundary effect. Within the group for which a category boundary can be detected, the slope and placement of the boundary varies considerably, from 25 msec to 65 msec.

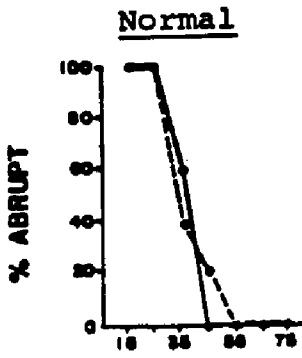
For the 300 msec series, the number of subjects meeting the 80% requirement drops to six. Aphasics show slightly more difficulty identifying the continuum end points of the longer sine-wave patterns than they have categorizing the shorter stimuli.

With respect to perceptual normalization, it is

Figure 8. Individual aphasics (N=12): Percent "abrupt" judgements as a function of syllable duration (Sine-wave control stimuli).

# EXPERIMENT IV

— 150 msec  
- - - 300 msec



apparent from Figure 8 that boundary shifts due to an increase in overall stimulus duration are less frequently in the predicted direction and the extent of the displacement is smaller with sine-wave patterns than with the speech patterns shown in Figure 5. The mean boundary shifts for the five aphasics showing acceptable identification function is .79. The difference in mean boundary between the two series of non-speech stimuli is not significant.

When results of Experiment III are compared with the non-speech control condition, the similarity of aphasics' performance subject by subject is apparent. In general, if a subject failed to identify /b/ and /w/, he also failed to identify the two non-speech categories. For at least two subjects, the sine-wave series proved slightly more difficult than the speech series. Only one subject (10) performed consistently and significantly better on the non-speech than on the speech task.

To summarize the results obtained on the sine-wave identification tests, neither the normal control nor the aphasic subjects demonstrate the predicted shift in the boundary between two non-speech classes in response to increased duration that was found in their

perception of the phonological contrast /b-w/. In other respects aphasics' performance on the series employing sine-waves is remarkably similar to their performance on the synthesized speech pattern series, suggesting that whatever factor contributes to the quality of their performance affects both performances relatively equally.

## CHAPTER III

Footnotes

1. The two subjects (7, 9) whose identification function were essentially normal but who failed to reach criteria on the discrimination of manner class, are the oldest subjects included in the study population. Whether the age of the subjects played a role in this finding is unknown, but the effects of the normal aging process on speech discrimination are well-documented (Bergman, 1980).

## CHAPTER IV

### EXPERIMENT V

Experiment V was designed to investigate perceptual normalization in aphasics' identification and discrimination of voicing in the initial position (VOT).

#### METHOD

##### Stimuli

To test identification of the phonetic category [da-ta], two series of stimulus patterns ranging in VOT from 0 to 60 msec in 10 msec steps were synthesized. The series differed only in overall syllable duration which was 185 msec in one series, and 350 msec in the other. The stimuli were initiated by a 10 msec burst at 3000 Hz. The /d/ end of the continuum (0 onset stimulus) consisted of the burst plus a three formant pattern appropriate to an alveolar stop and a steady state portion appropriate to the vowel /a/. The entire stimulus is accompanied by a 100 Hz fundamental. The transition duration is 50 msec. Transition values are

depicted in Table 10 and a schematic spectrogram of VOT stimulus patterns is found in Figure 9.

The identification series consisted of 10 tokens of the seven stimulus patterns for a total of 70 items. The ISI was 4 sec.

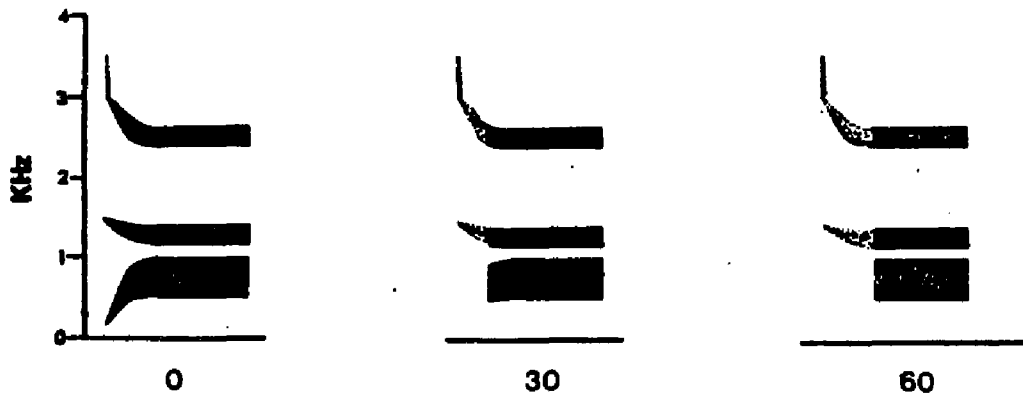
The two same-different discrimination tests consisted of randomized pairs in which the two stimulus patterns were either identical or differed from each other by 20 msec of VOT (i.e. 0 and 20, 10 and 30, 20 and 40, 30 and 50, and 40 and 60 msec). The ISI was 500 msec and the silent interval between trials was 4 seconds. Each different pair was presented 6 times, three times in two different orders. The identical stimulus pairs occurred 3 times. Each series consisted of a total of 51 items, 30 pairs in which the stimulus patterns differed, and 21 in which they were the same.

### Procedure

For the identification series, subjects were instructed to identify "da" or "ta" by marking the appropriate syllable on a printed answer sheet. To be sure that the aphasic subjects were able to perform the task, they were asked to point to the correct syllable in response to the spoken syllables said by the

Figure 9. Schematic spectrograms illustrating the first three formants and at 0, 30 and 60 msec VOT.

**VOT & PERCEPTION:**  
**SYNTHETIC STIMULI (t-u)**



**VOICE ONSET TIME IN MSEC.**

Table 10  
Stimulus Specifications for the Three Formant  
Patterns Used in Experiment V

	<u>Frequency in Hz</u>	
	<u>Initial</u>	<u>Ending</u>
F1	181	769
F2	1465	1232
F3	3530	2525

experimenter. A few samples of the taped stimuli were played to familiarize the subject with the sound of the synthetic speech patterns.

For the discrimination tests, subjects were asked to decide whether the members of a stimulus pair were the same or different and to mark their choice on a printed answer sheet similar to those used in the previous discrimination tests. To orient subjects to the task, they were requested to point to S or D for "same" or "different" in response to natural speech examples of the pairs spoken by the experimenter.

## RESULTS

### Perceptual Normalization of VOT: Normal Subjects

Boundary values were computed for each normal subject by fitting a normal ogive according to the method of least squares. The group mean for the short syllable series was 29.05 msec and for the long syllable duration series, 31.20 msec. That is, there was a small 2.15 msec shift in the boundary in response to increasing the syllable duration from 185 to 350 msec. See Figure 10. Although seven of the eight normal subjects tested demonstrated this effect, the size of the boundary displacement falls just short of significance

Figure 10. Normal group: Percent /d/ responses--  
illustrates the effect of syllable  
duration on VOT /d-t/ boundary.

Figure 10

## EXPERIMENT V

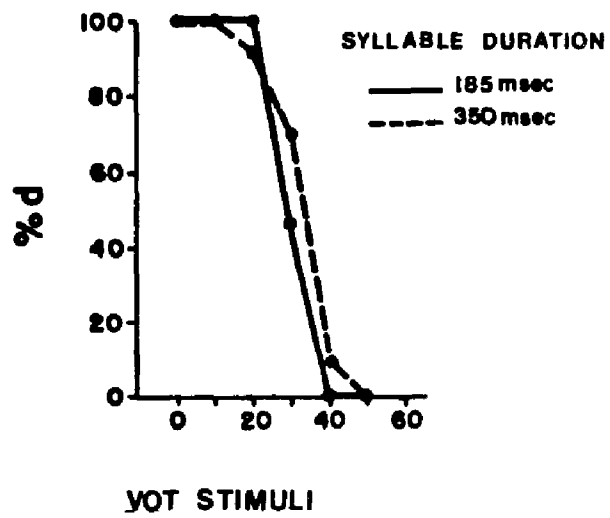
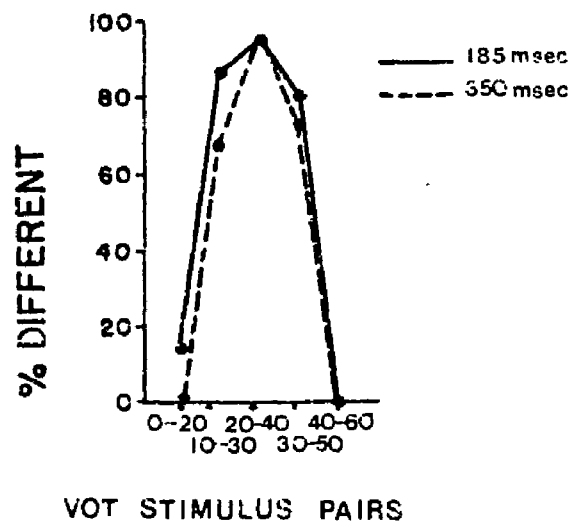


Figure 11. Normal group. Illustrates effect of syllable duration on discrimination of /d-t/.

Figure 11

## EXPERIMENT V



( $t = 1.51$ ,  $p < .10$ , one-tailed).

Discrimination functions were plotted for each normal subject. Only one of the eight subjects showed the predicted shift in the peak of discrimination. Discrimination function of the 350 msec series tended to be narrower than that of the 150 msec series, in which the peak often included one of the neighboring values, either 10 and 30, or 40 and 60 or both. Group data are depicted in Figure 11.

#### Perceptual Normalization of VOT: Aphasic Subjects

Five of the twelve aphasic subjects performed essentially normally on the identification tests. See Figure 12. Of these five, four showed the predicted shift of the category boundary as a function of increased stimulus duration.

Mean boundary values were computed and the findings are on the order of those obtained from the normal population, 29.40 and 30.39, for the 185 and 350 msec syllable durations respectively.

The discrimination function of all twelve aphasics demonstrated a peak at the predicted values of VOT. The performance of aphasic subjects is represented in Figure 13. Although the peaks of discrimination

Figure 12. Individual aphasics (N=12): Identification of /d-t/ as a function of syllable duration.

Figure 12

EXPERIMENT V

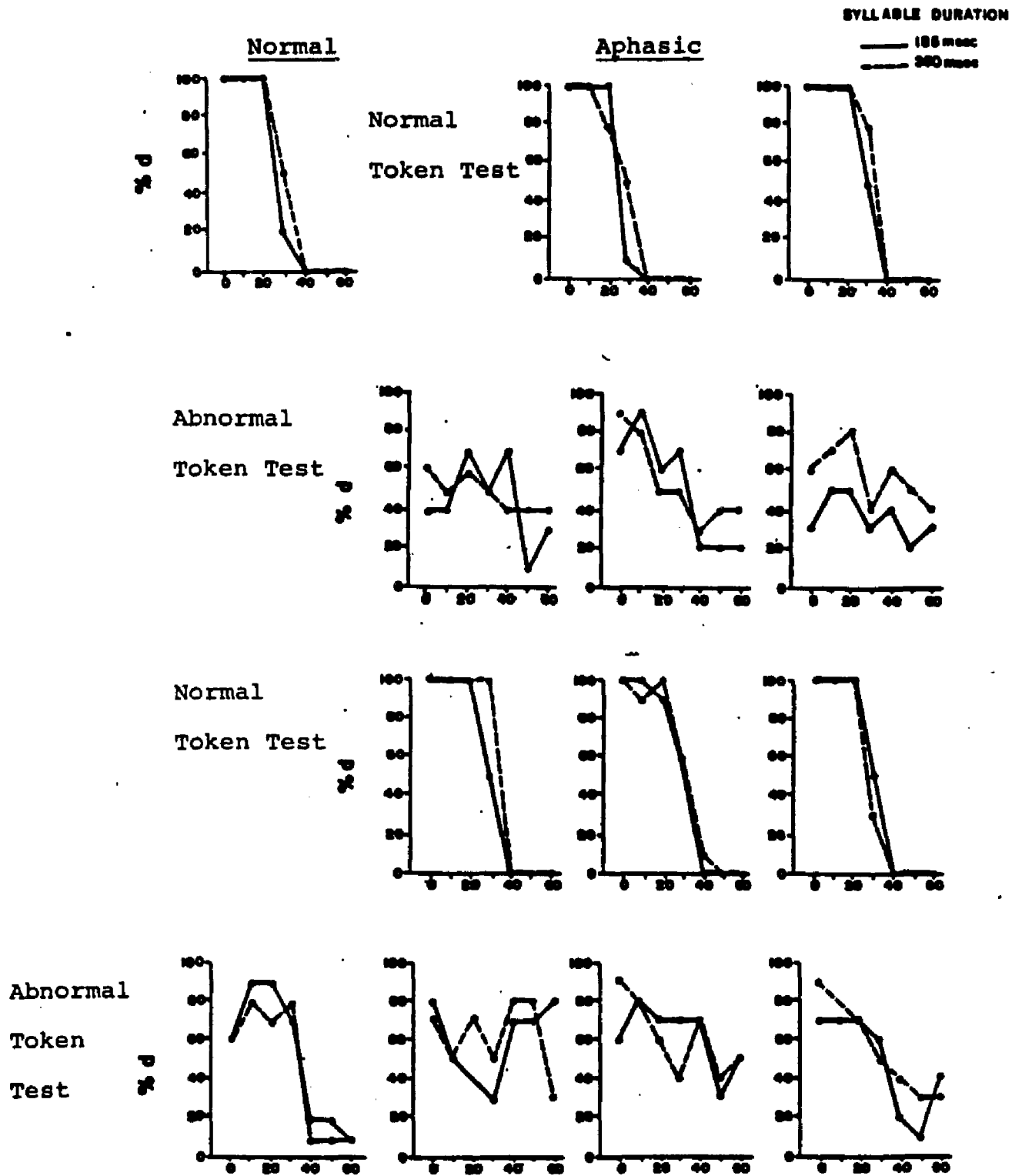
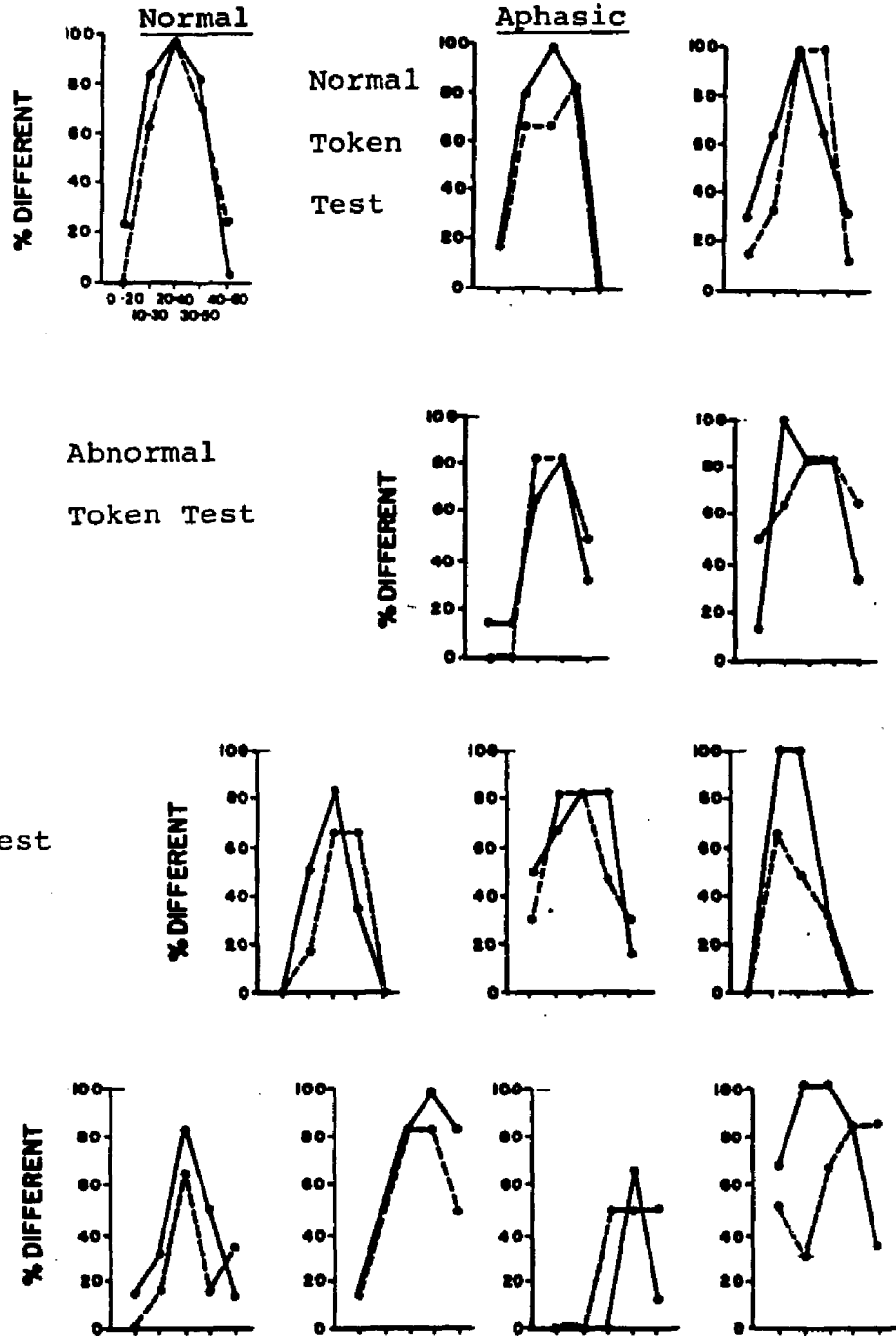


Figure 13. Individual aphasics (N=11): % correct  
different responses as a function of  
syllable duration.

# EXPERIMENT V

SYLLABLE DURATION

— 168 msec  
- - - 380 msec



tended to be a little lower than those found in the normal population, the discrimination function of all but one aphasic on only the 350 msec series met the criteria for acceptable performance. One other subject (12) failed to judge 50% of the "same" pairs correctly. The mean and standard deviation were computed for the normal and aphasic population. See Table 11. Performance variability in both populations was greater for the 350 msec series, but ten of the twelve aphasics made fewer "same" errors on this series than the most variable normal subject.

Five of the twelve subjects showed a shift in the peak of discrimination of one interval: a peak at VOT values of 20 and 40 msec for the 185 msec series, and 30 and 50 for the longer syllables.

#### Identification Versus Discrimination of VOT

Although the performance of aphasics in the previous experiments revealed an interesting relation between identification and discrimination, the difference in performance is most dramatic for the tasks assessing perception of VOT. Only the subjects with essentially normal Token Test scores were able to identify the test stimuli reliably, but all subjects

Table 11

Mean % Correct "Same" and Standard Deviation for Normal  
and Aphasic Subjects for 185 and 350 msec Syllables

	185		350	
	<u>Mean</u>	<u>S.D.</u>	<u>Mean</u>	<u>S.D.</u>
Normals	96.88	3.7	90.25	8.87
Aphasics	85.72	13.21	84.81	21.64

regardless of the severity of auditory comprehension demonstrated a peak of discrimination at the locus of the phoneme boundary. This pattern of performance was not specific to aphasia type. See Table 12.

In summary, the exploration of perceptual normalization in the identification of VOT revealed a small displacement of the /d-t/ boundary in the predicted direction for the majority of normal and aphasic subjects who evidence normal identification function. Neither group is particularly sensitive to variations in syllable duration as evidenced in their discrimination performance.

Aphasics' performance deficits on perceptual tests of VOT were found solely on the identification series. Discrimination of VOT regardless of aphasia severity is relatively preserved.

Table 12

Performance of Each Aphasic Subject on Identification and Discrimination of VOT Including Presence (+) or Absence (-) of a Boundary Shift as a Function of Syllable Duration.

A (+) Indicates Acceptable Performance, a (-) Indicates Unacceptable Performance.

<u>Type</u>	<u>Identification</u>		<u>Discrimination</u>	
	<u>Boundary</u>	<u>Shift</u>	<u>Peak</u>	<u>Shift</u>
<u>Fluent</u>				
1	+	-	+	+
2	+	+	+	+
3	-		+	-
4	-		+	+
5	-			
<u>Nonfluent</u>				
6	+	+	+	+
7	+	+	+	-
8	+	-	+	-
9	-		+	-
10	-		+	-
11	-		+	-
12	-		+	+

CHAPTER V

This chapter deals with two experiments which investigated aphasics' perception of voicing in the final position of a CVC syllable. The aim of the experiments was to study aphasics' ability to employ the durational cues of the initial formant transitions of a CVC syllable to determine the voicing characteristic of the final consonant.

Studies have shown that the duration of segments preceding a final consonant are important in determining the voicing class of the consonant. According to Raphael, Dorman, and Liberman (1980), this effect pertains not only to the length of the steady state portion, but also to the duration of the initial formant transitions representing the initial stop consonant. They found that listeners' judgements of the final consonant in a CVC syllable were affected by the absolute duration of the initial formant transition. That is, for a 30 msec increase in the duration of the initial formant transition the /d-t/ phoneme boundary (expressed as a function of steady state formant duration) decreased almost equally (27 msec).

Experiment VI focuses on this perceptual effect in aphasics' judgements of the CVC syllable [dɛt-dɛd] and compares the findings with those obtained from normal subjects. This experiment consists of two parts: first, a test in which subjects were asked to classify the syllables according to their perception of the final phoneme; second, in a condition in which subjects were requested to judge the duration of the speech patterns.

Experiment VII examines the effect of variations in the duration of the initial transitions of sine-wave patterns on the placement of a boundary between (1) two non-speech categories, (2) two speech categories.

## EXPERIMENT VI

### METHOD

#### Stimuli

For this experiment, two series of synthesized speech patterns for [dɛt-dɛd] were constructed: one in which the initial /d/ transitions were 30 msec, and one in which they were 60 msec. The duration of the steady state portion ranged from 30 to 150 msec in 20 msec steps for a total of 7 stimuli per series. Five tokens of each stimulus pattern from both series were randomized into a single test order (7 X 2 X 5) for a

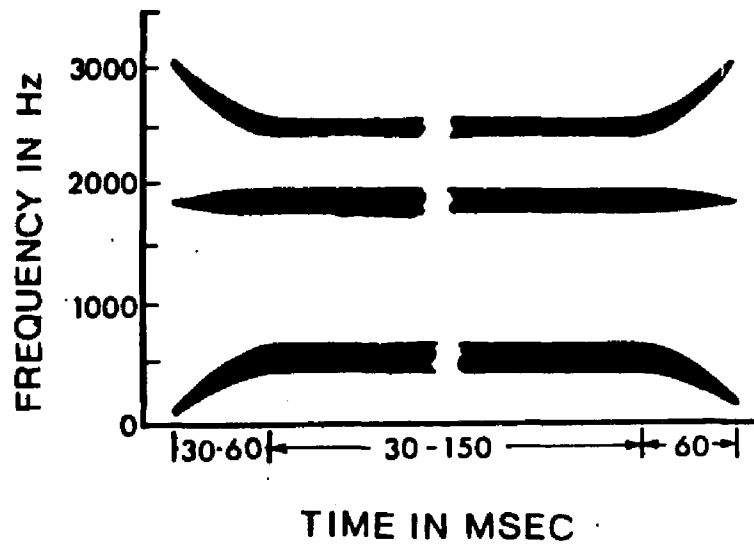
total of 70 items. The ISI was 4 sec. A practice set of 21 items using the end points of the continua was also constructed. See Figure 14.

### Procedure

For the speech stimuli/speech response condition, subjects were told that they would hear synthesized speech patterns which sounded like /dɛt/ or /dɛd/. A nine item demonstration of contrasting stimulus patterns taken from the end points of the two continua was presented, while the examiner pointed to the appropriate written syllable. Subjects were asked to indicate their choices by marking the syllable on a response sheet. The practice set was presented and this was followed by the test.

For the speech stimuli/non-speech response condition, subjects were informed that they would hear the same series as before, but this time would be asked to judge the length of the syllable. They were given a response sheet which contained two symbols depicting duration ( - ) ( ——— ). A nine item demonstration of contrasting stimulus patterns was presented and the appropriate response was indicated by the experimenter. This was followed by a 21 item practice set and the 70 item test.

Figure 14. Schematic spectrogram of pattern  
sufficient to cue perception of  
[dɛt-dɛd].

Figure 14

## RESULTS

### Speech/Speech Condition: Normal Subjects

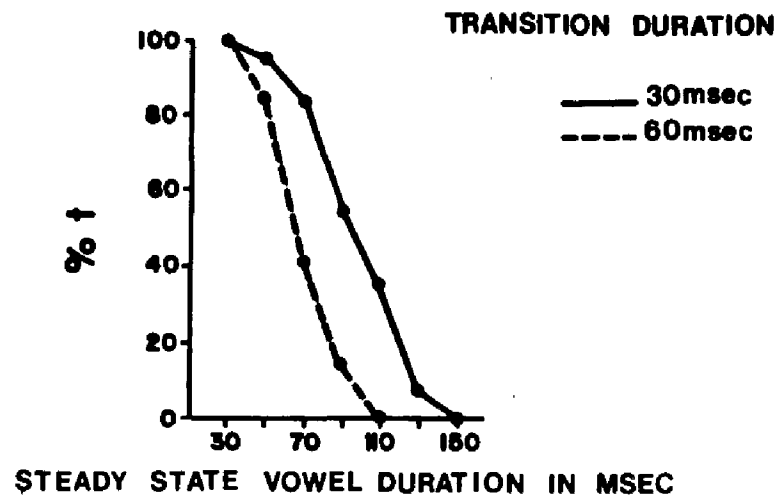
Normal group data are represented in Figure 15. As can be seen from this figure, the variation in duration of the initial formant transition of the syllable [dɛt-dɛd] resulted in a marked displacement of the /d-t/ phoneme boundary. That is, the 30 msec increase in duration resulted in a significant increase in the number of /d/ judgements. The effect was pronounced in all listeners.

Boundary values were obtained by fitting a normal ogive according to the method of least squares. The displacement in individual boundary values ranged from 7.1 to 37.5 msec, i.e. from 23% to 125% of the absolute length of the formant transition duration. The mean displacement was 22.4 msec, slightly less than that obtained by Raphael et al. (1980). The absolute position of the boundary is also somewhat different from that reported in the previous study, 94 msec of steady state duration for the 30 msec series, and 71 msec for the 60 msec series, as compared to 77 msec for the 30 msec series and 50 msec for the 60 msec series by Raphael et al. (1980).

Figure 15. Normal group % identification of /t/ as a function of the duration of initial transition on perceptuon of final /d-t/ voicing, expressed in steady state vowel duration. Speech/Speech Condition.

Figure 15

## EXPERIMENT VI



### Speech/Speech Condition: Aphasic Subjects

The identification function of each aphasic is shown in Figure 16. The performance of ten aphasic subjects was sufficiently intact to evidence the predicted shift in the category boundary of the final consonant due to variations in the duration of the initial formant transition. Boundary values were computed for nine subjects on the 30 msec series and eight subjects on the 60 msec series and averaged across subjects. Mean boundary values are depicted in Table 13.

When these findings are compared with those obtained from normal subjects, the differences dependent on the duration of the initial formant transition appear insignificant. Aphasics are obviously as sensitive as normals to the absolute duration of the initial transitions in making judgements of the voicing characteristic of the final consonant.

### Speech/Non-speech Condition: Normal Subjects

Group data are presented in Figure 17. When making judgements of the duration of the syllable, normal listeners do take into account the duration of the initial transition. In fact, the boundary shift observed was

Figure 16. Aphasics (N=12): % /t/ response as function of the duration of initial transition on perception of final /d-t/ voicing. Speech/Speech Condition.

Figure 16

# EXPERIMENT VI

TRANSITION DURATION

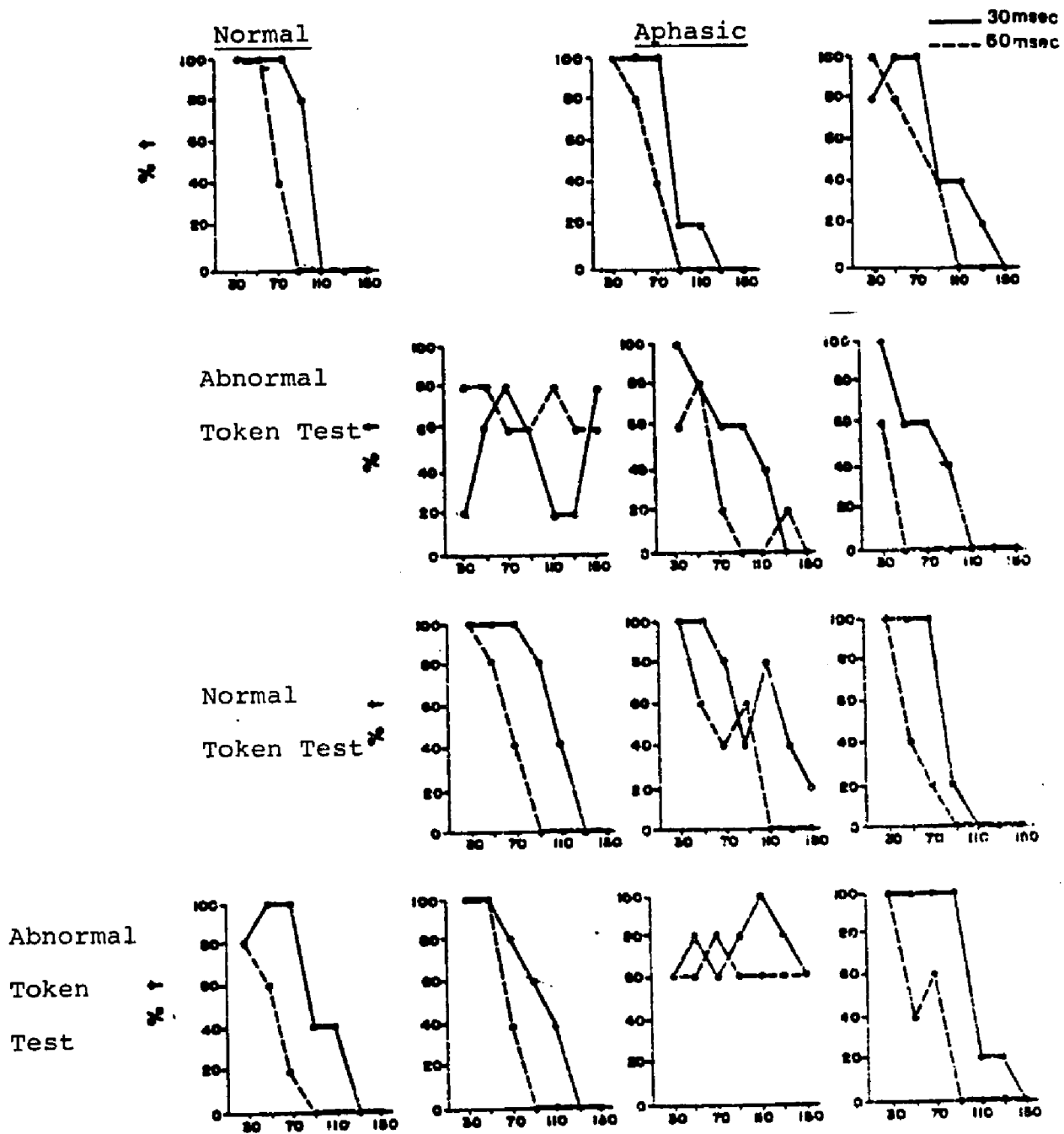


Table 13

Mean Boundary Values for Synthesized Speech Patterns. Two Response Conditions (Speech and Non-Speech) and for Two Populations. Mean Values are in msec of Steady State Duration

<u>Response Condition</u>	<u>Series</u>	<u>APHASICS N=8* Mean</u>	<u>NORMALS N=8* Means</u>
<u>Speech**</u>	30	92.5	93.6
	60	67.5	71.5
		N=11	N=8
<u>Non-speech***</u>	30	87.7	91.2
	60	62.3	57.1

\* When the identification function is too irregular, it is impossible to obtain a reliable mean boundary value by fitting a normal ogive according to the method of least squares. In the speech condition, it was possible to fit a normal ogive to the data of eight out of ten aphasics, in the non-speech condition, it was possible in eleven out of twelve cases.

\*\* Speech Response

t = 6.28, P < .0005, one-tailed (Normals)

t = 8.58, P < .005, one-tailed (Aphasics)

\*\*\* Non-speech Response

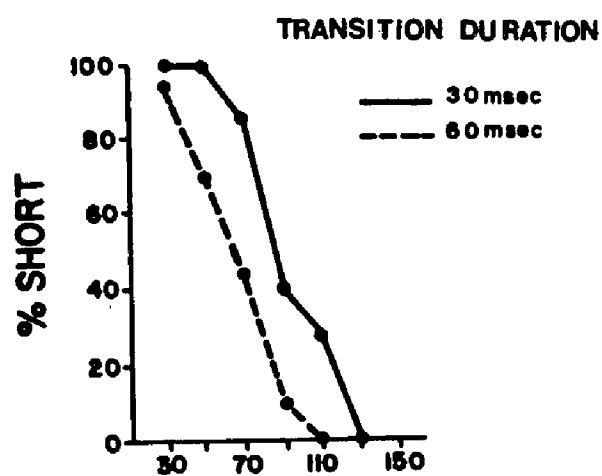
t = 5.97, P < .0005, one-tailed (Normals)

t = 8.51, P < .0005, one-tailed (Aphasics)

Figure 17. Normal group. percent short responses as a function of the duration on the initial formant transition. (Speech/Non-speech Condition).

Figure 17

## EXPERIMENT VI



STEADY STATE VOWEL DURATION IN MSEC

greater when normals were asked to judge syllable duration than when they were asked to make a phonetic judgement. The mean boundary value for the 30 msec series was 91.2 msec and for the 60 msec series, 57.1, a shift of 34.1 msec of steady state duration. Differences between boundary values for the two series are statistically significant.

Speech/Non-speech Condition: Aphasic Subjects

Figure 18 reveals that aphasics also attend to the duration of the initial formant transitions of speech stimuli in making judgements of syllable duration. A shift in the category boundary for the two non-speech classes is seen in the data from every subject. Boundary values were computed and averaged across subjects. The mean boundary value of the 30 msec series was 87.7 msec and for the 60 msec series it was 62.3 msec, an average shift of 25.4 msec. This is nearly the same magnitude as the displacement seen in the speech/speech condition. See also Table 13.

A comparison of the performance of aphasics on the two response conditions (i.e. Figure 16 with Figure 18) suggest that the speech judgement is slightly more difficult than the non-speech judgement. That is,

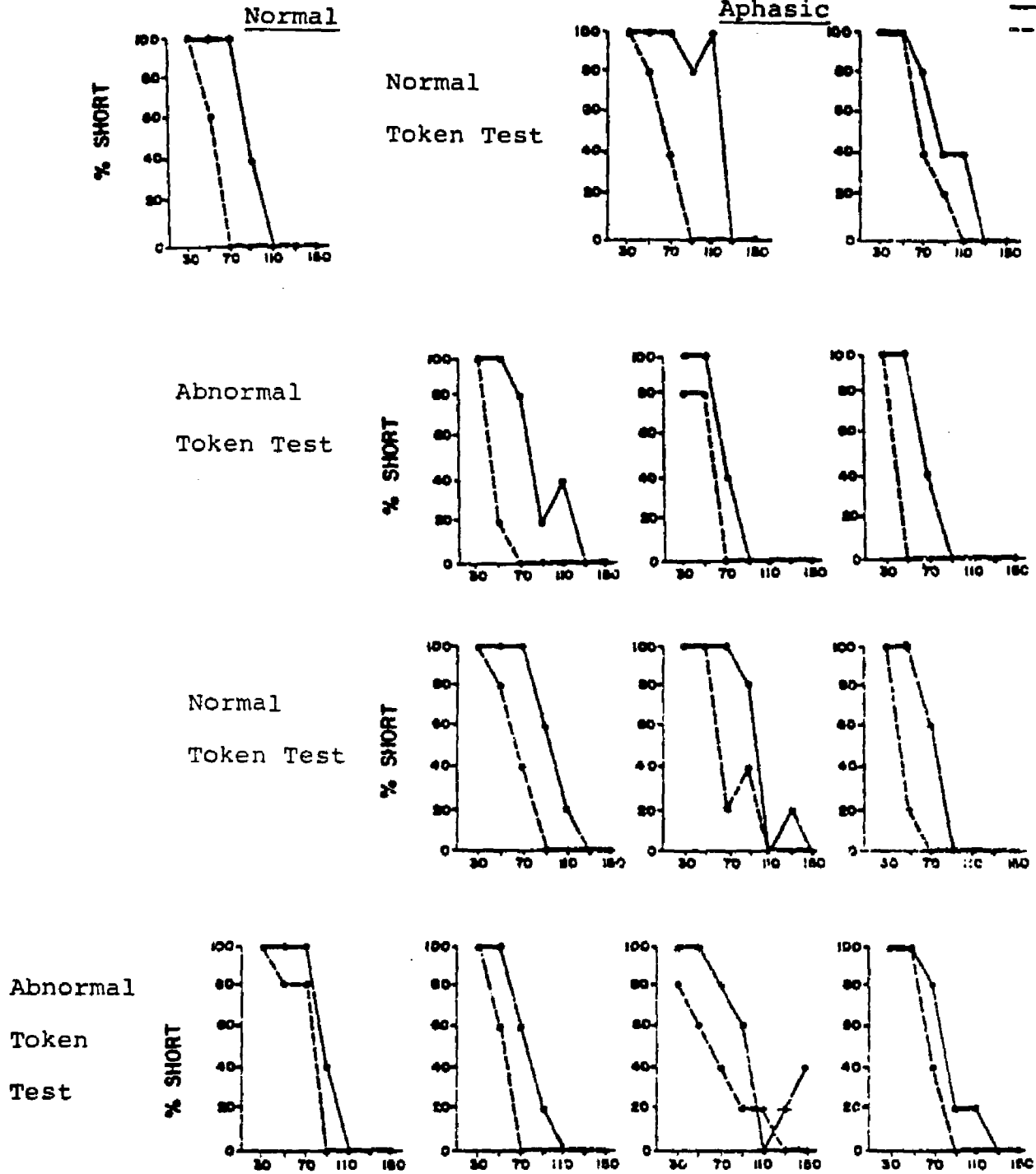
Figure 18. Aphasic subjects (12): % "short" responses as a function of the duration of initial formant transition on the perception of syllable length. (Speech/ Non-speech Condition).

Figure 18

EXPERIMENT VI

TRANSITION DURATION

— 30msec  
 - - - 60msec



evidence of a regular boundary is more prevalent in the non-speech condition. Performance on the speech/speech condition is in many ways similar to other identification series. That is, difficulty in identifying phonological contrasts is specific to aphasics with poorer Token Test scores.

### EXPERIMENT VII

#### Stimuli

The stimuli for this experiment were sinusoidal wave patterns which replicated the formant center frequencies of the first three formants of the speech patterns used in the last experiment. Two series of sine-wave patterns were constructed: one with an initial sine-wave transition of 30 msec and one with an initial transition of 60 msec. Each series consisted of a demonstration of six contrasting items taken from the end points of the continua, a practice set of 21 items, and an identification test. The identification test consisted of five permutations of seven stimulus patterns for a total test length of 35 items. The ISI was 4 sec.<sup>1</sup>

#### Procedure

For the non-speech stimulus/non-speech response

condition, subjects were told that they would hear computer generated non-speech sounds which differed in duration. They were asked to decide whether they were short or long and to mark their choice on an answer sheet. The two category response was depicted on the answer sheet by a ( - ) short and a (——) long line. The six item demonstration was presented and the appropriate responses were indicated. This was followed by the practice set and the identification test.

For the non-speech/speech condition, subjects were informed they would hear the non-speech sounds presented previously, but this time they were asked to classify the syllables as /dɛt/ or /dɛd/. The demonstration was presented, during which the experimenter accompanied the taped sounds with orally presented spoken syllables. The response sheet, which contained the syllables DET and DED was presented and the practice set was played. This was followed by the test.

## RESULTS

### Non-speech/Non-speech Condition: Normal Subjects

In judging the length of the sine-wave patterns, normal listeners apparently paid little attention to the absolute duration of the initial transitions. The

boundary shift for this condition is considerably smaller than that observed when listeners judged the duration of speech stimuli. Group data is depicted in Figure 19.

Mean boundary values were computed for each subject and are presented in Table 14. The group mean boundary shift is 4 msec and the difference in performance based on the duration of the initial transition is not significant ( $t = 1.58, P > .05$ , one-tailed).

Non-speech/Non-speech Condition: Aphasic Subjects

The results of this condition are presented in Figure 20. The graphs show small boundary shifts in about half of the cases although in three cases it is in the opposite direction. In general, the shift is in the same direction as obtained with speech stimuli.

It was possible to compute mean boundary values for all twelve aphasics for the 30 msec series, and all but one for the 60 msec series. When boundary values of the two populations are compared, not only are the mean values quite similar (see Table 14), but so are the range and direction of the boundary shifts: from 19 msec (same direction) to 7 msec (opposite direction as speech stimuli) for the aphasic population, and 18 msec (same) and 6 msec (opposite) for the normal

Figure 19. Normal group. % "short" responses as a function of the duration of initial transition of sine-wave stimuli. (Non-speech/Non-speech Condition).

Figure 19

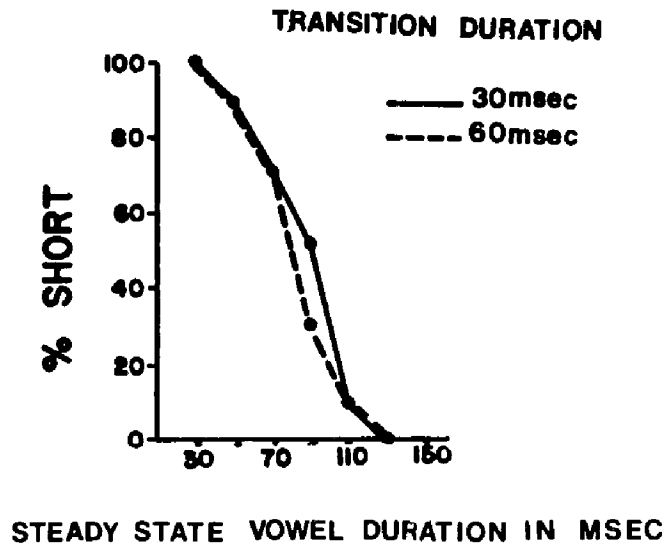
**EXPERIMENT VII**

Table 14

Mean Boundary Values for Sine-Wave Patterns for the  
Two Response Conditions, Speech and Non-speech

<u>Response Condition</u>	<u>Series</u>	<u>APHASICS</u> N=11 <u>Mean</u>	<u>NORMALS</u> N=8 <u>Mean</u>
<u>Speech**</u>	30	83.17	84.05
	60	78.17	82.30
		N=12	N=8
<u>Non-speech ***</u>	30	88.68	87.02
	60	82.14	82.17

\* It was possible to fit a normal ogive to the performance of eleven out of twelve aphasics in the speech condition and twelve aphasics in the non-speech condition.

\*\*Speech Response

t = .53, N.S. (Normals)

t = .05, N.S. (Aphasics)

\*\*\*Non-speech Response

t = 1.53, P < .10, one-tailed (Normals)

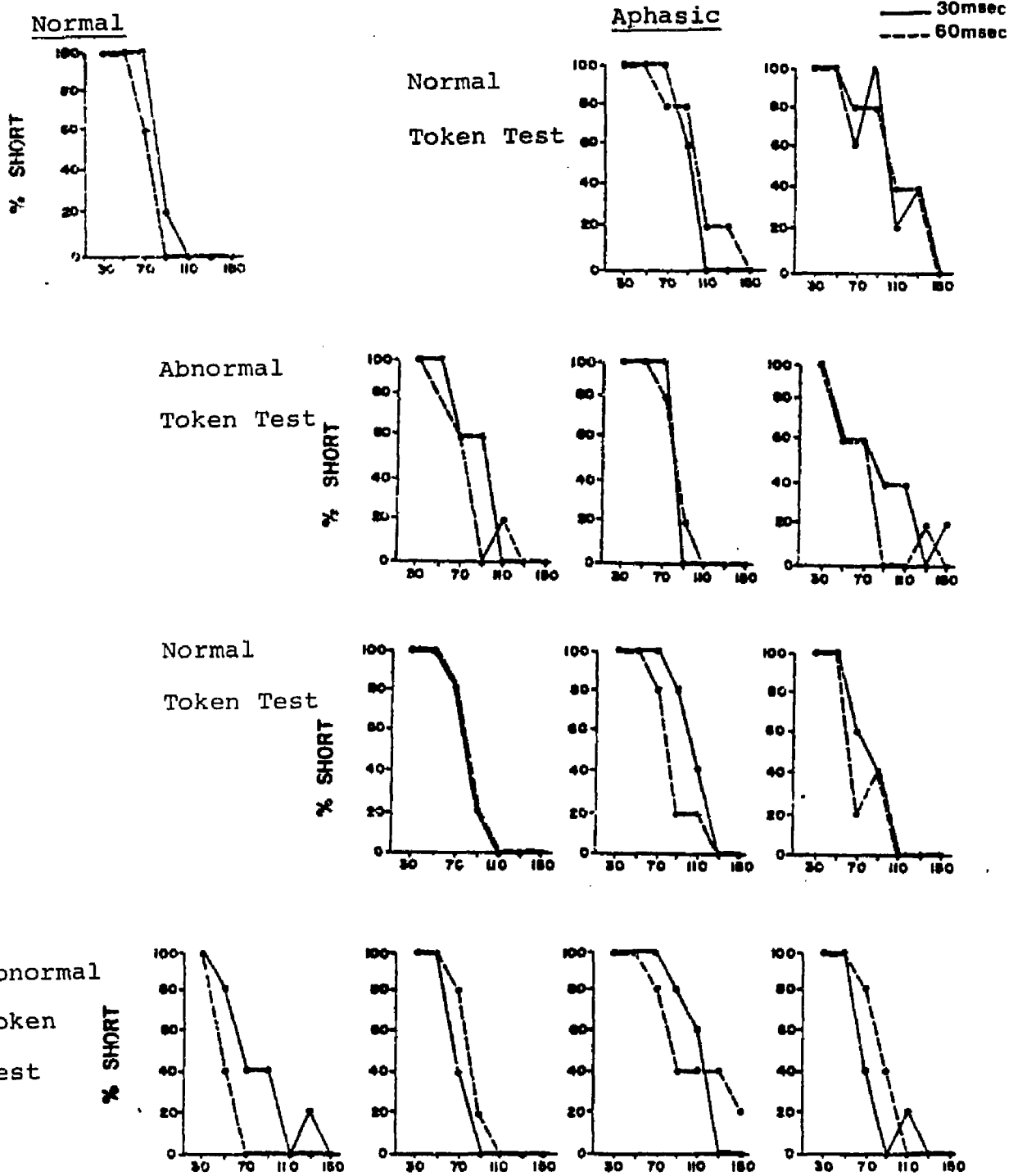
t = 1.32, P > .10, one-tailed (Aphasics)

Figure 20. Aphasic subjects (12). % "short" responses as a function of the duration of initial transition of sine-wave stimuli. (Non-speech/Non-speech Condition).

Figure 20

# EXPERIMENT VII

TRANSITION DURATION



population.

Non-speech/Speech Condition: Normal Subjects

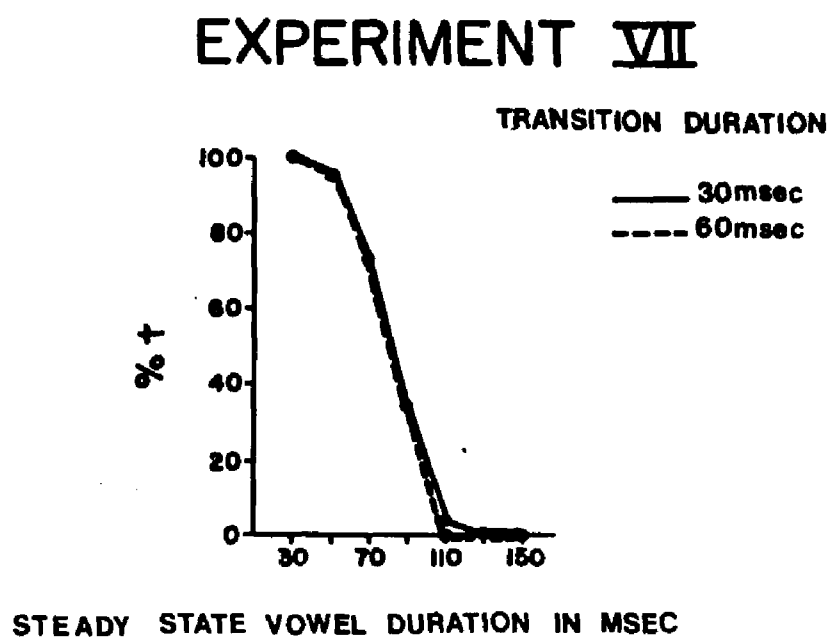
From Figure 21, it is obvious that when speech judgements are applied to sine-wave stimuli the effects of variations in the duration of initial transitions are small.

Boundary values were computed for each subject. The average of these values is found in Table 14. The mean boundary shift is 1.75 msec and far smaller than that obtained on the speech/speech condition, but similar to the shift observed in the non-speech/non-speech condition. These findings indicate that at least for the normal population, differences in the magnitude of the boundary displacement for the two stimulus and two response conditions are due to the nature of the stimulus (speech versus sine-wave patterns) rather than the form of the response required.

Non-speech/Speech Condition: Aphasic Subjects

When asked to decide whether the sine-wave patterns sounded more like [dɛt] or more like [dɛd], the responses of aphasics, like those of normals, indicate that the duration of the initial transitions

Figure 21. Normal Group. % /t/ responses as a function of the duration of initial transitions of sine-wave stimuli. (Non-speech/Speech Condition).

Figure 21

produced little change in the placement of the boundary between the two "phonetic" classes. The displacement of the boundary is not only fairly small, but also for some subjects, in the opposite direction. See Figure 22.

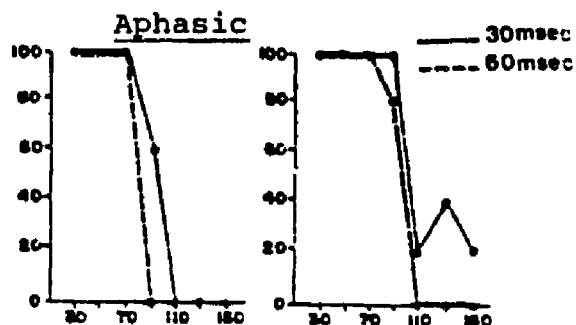
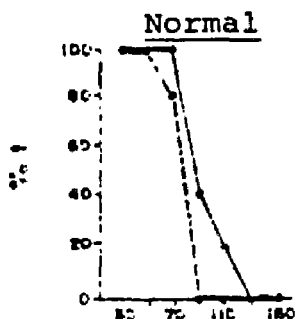
Boundary values were computed for all twelve aphasics for the 30 msec series, and eleven for the 60 msec series. The mean values are also presented in Table 14. The range of displacement values for the aphasic group is almost identical to that obtained in the non-speech/non-speech condition.

To summarize the findings of Experiment VI and VII, for both populations, when synthesized speech patterns were used, variations in the duration of the initial formant transitions resulted in the predicted displacement of the boundary for both the speech and non-speech response conditions. However, when the stimulus patterns were synthesized sine-waves, the variation in the length of the initial transition produced only a minimal mean displacement of the boundary. This finding held whether or not subjects treated the stimuli as speech or non-speech material. Not only were the magnitudes of the shifts in both conditions similar in the two populations, but the absolute position of the boundary and the range of displacement

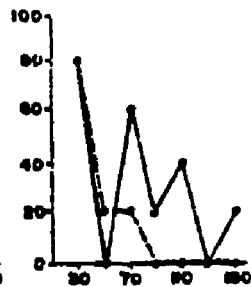
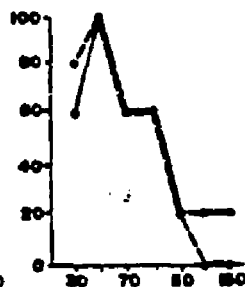
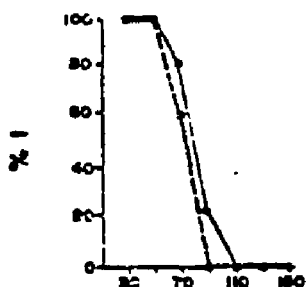
Figure 22. Aphasic subjects (N=12): % of /t/ responses as a function of the duration of initial transitions of sine-wave stimuli. (Non-speech/  
Speech Condition).

# EXPERIMENT VII

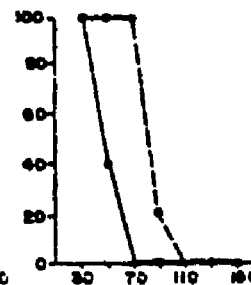
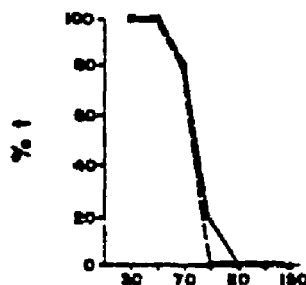
TRANSITION DURATION



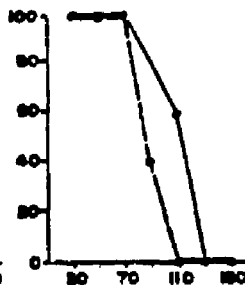
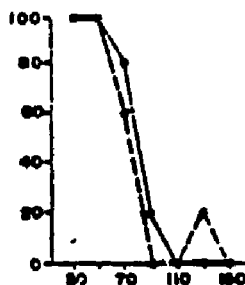
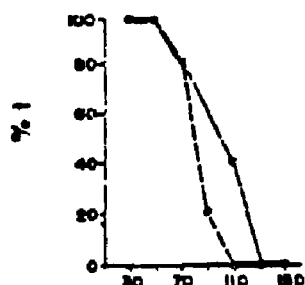
Abnormal  
Token Test



Normal  
Token Test



Abnormal  
Token  
Test



values were also very similar among the individuals of the two populations.

With respect to the aphasic population, nearly all aphasic subjects, regardless of the severity of their comprehension impairment, were able to make the required judgements. Individual performance was strikingly similar across the four conditions, with intra-subject variability observed primarily on the speech stimulus/speech response condition.

## CHAPTER V

Footnotes

1. Due to an error that was not noticed until after the test was run, when compiled by the computer, the tests for the speech and non-speech tests were not identical. The speech series consisted of items from both the 30 and 60 msec series randomized into a single test order, whereas the non-speech series consisted of two separate (a 30 msec and a 60 msec) tests .

## CHAPTER VI

## DISCUSSION

In order to support the claim that the primary deficit in receptive aphasia is an inability to process certain acoustic properties of the speech signal, it is necessary to show that the performance of aphasic listeners either improves or deteriorates in response to appropriate manipulations of both speech and non-speech control signals. If the supposed deficit is an inability to process rapid changes in spectral structure, as in the brief formant transitions which accompany certain changes in place of articulation, study findings should demonstrate that aphasic performance improves when these spectral changes occur more slowly. If the supposed deficit is in judgements of certain temporal properties known to govern normal phonetic perception, such as voice onset time, or relative duration of syllable nucleus to syllable onset or offset, the experimental results should show that aphasic listeners are less sensitive than normals to these properties in both speech and in non-speech controls. The results of this

investigation have failed to demonstrate any of these findings. Rather, the evidence indicates that certain aspects of the auditory processing of speech signals are remarkably preserved even in fairly severe aphasics.

The Perception of Brief and Artificially  
Lengthened Formant Transitions

The auditory perceptual deficit hypothesis was first tested in two experiments with stimulus patterns closely modeled on those used by Tallal and Piercy (1974, 1975). However, no consistent changes in performance which could be attributed to formant transition extension could be found in aphasics' identification performance. The discrimination performance of a few fluent aphasics (3, 4) seemed slightly facilitated by formant transition lengthening when the lengthening was applied only to F2 and F3, and not F1 (i.e. Series 3). But further examination of the perceptual abilities of these subjects disclosed no consistent difficulty in processing rapid acoustic cues. In addition, the aphasics tested in this study showed little sensitivity to variations in ISI; reducing the length of the interval between stimulus patterns in discrimination tests from 500 msec to 50 msec had no

significant effect on their performance.

It is noteworthy that stimulus series 2, modeled after the Tallal and Piercy (1974) extended formant transition stimulus patterns, elicited a variety of identifications among aphasic subjects. Although some subjects reported [ba-da], others reported [wa-la], [bwa-dla], [wa-da] and one reported [ra-ya]. The series 3 stimulus patterns in which the abrupt F1 onset was preserved were always judged as [ba-da]. The informal judgements by the author and other normal subjects give the same pattern. Tallal and Newcombe (1978) do not report how subjects identified their stimuli, but if, as seems likely, a similar shift in judged manner class occurred, the improved performance with lengthened transitions would be rendered ambiguous. It is not clear whether the improvement in performance with extended formant transitions was the result of a facilitation of auditory processing or simply improved synthesis of a different phonological contrast. In the present study, aphasics' performance was not facilitated by the extension of all three formant transitions (Series 2). In fact, performance on the discrimination--50 msec ISI--was negatively affected.

In any event, since the stimulus parameters of

Series 1 and 2 were closely modeled on those of the earlier study, the difference in the outcome of the two studies must be due to other variables, such as type of task, experimental procedure, or the nature of the study population. Whatever the source of the differences, the results of Experiment I and II are consistent with those of Blumstein (1981), who refers to her own unpublished study which demonstrated that formant transition extension had no effect on aphasics' ability to identify or discriminate place of articulation. Auerbach, Naeser, and Mazurski (1981) found that only aphasics who manifested a "word deafness" component benefitted from formant transition extension in a phonemic discrimination task. However, none of the subjects included in this study evidenced this unimodal deficit.

#### Normalized Judgements of Syllables Varying in Duration

The experiments designed to explore perceptual normalization for duration (or rate) of CV syllables varying the manner of the initial consonant from stop to glide, demonstrated that these aphasics were no less sensitive to variations in acoustic duration than normal subjects. If they were able to perform any particular

task at all, their perceptual response displayed the predicted normalizing effect. Perhaps more importantly, some aphasics who were unable to identify the stimulus patterns consistently, nonetheless demonstrated the predicted shift of peak discrimination. Evidently, they were able to extract the relevant acoustic properties, but were not able to accomplish consistently the auditory-to-phonetic transformation necessary to identify the syllable.

Neither aphasics nor normal subjects showed the predicted normalizing effect of stimulus duration on the perception of two non-speech classes. That is, for both populations, perceptual normalization was specific to speech stimuli.

The findings are less clear-cut for the comparison of aphasics identification of non-speech patterns versus their identification of speech patterns. More aphasics identified reliably the 150 msec sine-wave patterns as "abrupt" or "gradual" in onset than identified the 150 msec speech patterns for the syllables [ba-wa]. However, fewer aphasics produced acceptable identification functions for the 300 msec sine-wave patterns than for the speech patterns of equal length. Whatever the reasons for this, it should be noted that normal subjects

also tended to find the longer sine-wave patterns difficult to identify: in fact, two normal subjects required a repetition of the series before they were able to make consistent judgements of abrupt and gradual onset even for the end point stimuli.

The responses of certain individual aphasics are interesting. Although the majority of aphasics displayed equal ability to identify sine-wave and speech stimuli, subject 10's non-speech identification of the sine-wave patterns proved markedly superior to his phoneme identification. It seems that two different types of processing deficits may occur in aphasia. One is more general and affects both speech and non-speech identification, while the other is specific to linguistic stimuli.

#### The Perception of CV Syllable-Initial Voicing as a Function of Voice-Onset-Time and Syllable Duration

The results of the experiment designed to explore perceptual normalization of duration of CV syllables varying in VOT from /da/ to /ta/ also indicate that aphasics' performance essentially parallels the performance of normal subjects. A small but not statistically significant displacement of the /d-t/ boundary as a

function of syllable duration was found in the majority of normal subjects. It was also found in the aphasic subjects who showed a regular identification function. Neither group was particularly sensitive to the manipulation of syllable duration in their discrimination performance. A shift in the peak of discrimination was found in only one out of eight normal subjects, and in five out of 11 aphasic subjects.

This experiment on perceptual normalization of VOT was included because a small shift in the /d-t/ boundary as a function of syllable duration had been obtained by Summerfield (1981). On the basis of the present findings, the effect appears marginal and likely unreliable.

The Perception of CVC Syllable-Final Voicing  
as a Function of Syllable Onset Duration

A small variation in the duration of the initial formant transition has a powerful effect on the perceptual boundary of the final phoneme in the CVC syllable [d&t-d&d]; the magnitude of the boundary shift, similar across the two response conditions, approximates the difference in absolute duration of the initial transition portion between the two series (i.e. 30 msec). The predicted effect was found in all normal subjects, in

ten out of 12 aphasic subjects in the speech response condition, and in all subjects in the non-speech condition.

Since even aphasics who consistently failed to identify stimuli differing in manner and VOT were able to classify the stimuli of the [dæt-dəd] series, it is possible that a different kind of judgement was involved in these decisions. In this series, the variation in length is quite perceptible as such to the listener, and it might be argued that identification was accomplished by a two-stage auditory labeling process, similar to that used in any non-speech arbitrary labeling task, rather than by a direct phonetic decision. Against this interpretation is the fact that context effects (that is, the shift in boundary with a shift in stimulus duration) were confined to the speech series, suggesting that more than basic psychoacoustic processes were involved. This finding demonstrates once again that aphasics may be no less sensitive to small (30 msec) variations in transition duration than normals.

In contrast to the pronounced effect on category boundaries produced by a variation in the duration of the initial formant transitions of synthetic CVC

patterns, no consistent boundary effect was demonstrated when sine-wave patterns were used. The performance of both normal and aphasic subjects showed this insensitivity to a durational manipulation in sine-wave control stimuli.<sup>1</sup> Since in this case, most aphasics were able to accomplish the identification task, these findings give support to the specificity of context effects to speech stimuli suggested by the findings of the [ba-wa] sine-wave control study.

Although a few aphasics failed to consistently classify the sine-wave patterns representing [dɛt-dɛd] into two speech response categories, the sine-wave stimuli were easily classified into two non-speech response categories by all aphasics tested. This proved, in fact, to be the easiest task of the entire investigation. However, aphasics displayed little difficulty with judgements of length regardless of whether the stimulus patterns were speech or non-speech.

#### The Relation Between Auditory Deficits and Disturbances in Speech Processing

The performance of these aphasics on phonological tasks was not characterized by a connection between auditory defects and disturbances in speech processing.

Rather, the study revealed a disparity between the relative inability of many aphasics to identify discrete phonetic classes and their preserved ability to discriminate the small acoustic changes upon which phonetic decisions are based. The pervasiveness of identification deficits in aphasia has been emphasized by Basso, Casati, and Vignolo (1977) and by Blumstein, Cooper, Zurif, and Caramazza (1977). The degree of disparity between auditory and phonetic functions in aphasia seems to depend on a variety of factors some of which are determined by features of the stimulus patterns, some by the type of aphasia and the severity of comprehension impairment.

The results of the study of VOT present the most striking example of the special relation between identification and discrimination abilities in aphasia. Only those aphasics with normal Token Test scores were able to identify stimuli varying in VOT reliably, whereas all subjects showed a peak in discrimination at the normal phoneme boundary. Blumstein et al. (1977) also report a relative preservation of discrimination function despite significant deficits in identification, but they go on to describe a third type of performance not evidenced in the VOT study--failure both to identify

and to discriminate VOT. Since stimulus specifications were similar for the test series used in the two studies, this difference may simply reflect differences in the variety of aphasics tested in the two studies. However, this pattern of performance was revealed in the investigation of manner class perception by two fluent aphasics (4, 5).

The results of the investigation of the manner class [ba-wa] show a less defined pattern. Discrimination in the more severely impaired aphasic subjects was superior to identification and most aphasics displayed the predicted peak of discrimination at the normal phoneme boundary. However, aphasics varied considerably in their ability to discriminate the phonological differences. In fact, two subjects demonstrated poorer discrimination of the stimuli than identification. These were the oldest subjects tested and it is possible that this reduction reflects the normal reduction of speech discrimination found in an elderly population rather than a fourth type of performance in aphasia.

Blumstein et al. (1977) assert that aphasics' difficulty with phonological identification is due to a failure to maintain a consistent category label rather than to an absolute incapacity for labeling.

This seems to be an accurate description of the behavior of many aphasic subjects. Nearly all subjects who failed to demonstrate a clear cut boundary between phonological classes were nonetheless able to label the stimulus patterns consistently for short periods of time: an entire section might be properly identified with the ends of the continuum and values in between being assigned normally, only for the pattern to be totally reversed in the next section.

However, Blumstein et al.'s claim that aphasics' inconsistency represents a ". . . to use phonological information in a linguistically relevant way." (p. 381) requires modification. The majority of aphasics with identification deficits in the present study displayed similar identification difficulty with the sine-wave control patterns for [ba-wa] as with the speech patterns, and only one aphasic demonstrated specific difficulty with the speech patterns. This suggests a general deficit in the ability to maintain the line between a sound and its name or label whether the stimulus pattern is linguistic or nonlinguistic. The primary feature of the disturbance is specifically linguistic in only isolated cases.

Comparison of Phonological Deficits in  
Different Diagnostic Categories

The subjects of this study were subdivided into two groups with respect to the fluency of their speech production, though the members of each category differ among themselves with respect to specific speech symptoms and the severity of their speech and auditory comprehension deficits.

Among the fluent aphasics, two types of task performance were observed: (1) success on all or nearly all tasks or (2) marked impairment in identification, with the exception of identification as cued by perceptible length. Discrimination performance was variable, but in general significantly better than identification. Although two fluent subjects seemed to be aided in their discrimination of place of articulation by the lengthening of formant transition duration in Experiment II, their relatively preserved discrimination functions and categorical responses to minute acoustic differences on other tasks militates against a specific auditory basis for their speech perception deficits. Instead, their impairment of identification of speech and some types of non-speech stimuli appears more global and is best described as a failure to maintain a consistent

association between the stimulus and the response category.

It should however be pointed out that the fluent category was represented by fewer individuals and by fewer aphasic types than the nonfluent. It included what might be described as an anomic (1) a very mild conduction aphasic (2) and three Wernicke's aphasics (3, 4, 5) modeled after descriptions of Goodglass and Kaplan (1972). The conduction aphasic was obviously less impaired than those described by Basso et al. (1977) who presented disproportionate difficulty in phoneme identification. None of the Wernicke's aphasics presented normal phoneme identification as found in earlier VOT studies (Blumstein et al., 1977, and Basso et al., 1977). The absence of this pattern of performance is likely due to the limited number of Wernicke's aphasics included in the present study. Nonetheless, it is clear that Wernicke's aphasics may be quite variable as a group, in their identification function.

The nonfluent aphasics differed more among themselves in their relative abilities to accomplish the various phonological tasks than did the fluent aphasics. Although the nonfluent aphasic with the lowest Token Test score (12) failed more phonological

tasks than other members of his group, his task performance was sometimes superior to that of less severely affected nonfluents and nearly always better than the Wernicke's aphasics (fluent with impaired comprehension). Specifically the subject's ability to identify stimulus patterns frequently met the 80% criterion, implying that the association defect is not as profound as in some aphasics with far better comprehension on clinical testing.

Another interesting comparison was presented by subjects 10 and 11. Both subjects were able to discriminate stimuli better than they could identify them, but subject 10 identified non-speech stimuli normally, whereas subject 11 failed nearly all identification tests administered and manifested the disparity between identification and discrimination to a greater degree than any of the other aphasic subjects. Subject 10 is a classic Broca's aphasic who manifests a pronounced pattern of phonetic disintegration, labored production and agrammatism, but verbal paraphasia is rare. Subject 11, despite the characteristic reduction in speech fluency, the presence of articulatory difficulty, evidences verbal paraphasia more typical of the Wernicke's aphasic. This finding merely suggests that aphasia types based

on the fluency dimension are not homogenous groups.

In contrast to the findings of Basso et al. (1977), phonological identification defects were not specific to individuals manifesting phonemic errors in their speech production. Although subjects 2, 5, 6, 8, 9, 10, and 11 evidence phonological errors in speech ranging from infrequent to pervasive, the presence of production defects did not predict identification function.

With respect to aphasia type and phonological task performance, members of both categories present a pattern of more preserved discrimination than identification, but within each category there may be various types of task performance. Due to the limited size of the study sample, this variety was found primarily in the nonfluent category, but it is likely that those individuals manifesting the range of fluent syndromes found in the general aphasic population would also present individual patterns consistent with linguistic/cognitive impairment.

#### The Relation Between Phoneme Perception and Comprehension Disorders

The findings of this investigation are consistent with the many investigations that have found phoneme

discrimination to be either unrelated or only partially related to the severity of the comprehension disorder (Carpenter and Rutherford, 1973; Blumstein, Baker, and Goodglass, 1977; Jauhianen and Nuutila, 1977 and Miceli, Gainotti, Caltagirone and Masullo, 1980). However, the results conflict with Blumstein, Cooper, Zurif and Caramazza (1977) and Basso, Casati, and Vignolo (1977), who stress a similar dissociation in identification of phonemes and comprehension ability. The striking ability of the Token Test to predict impairment on phonological identification tasks is apparent on all but the final series of identification tests.

The difference between this study and the others probably results from differences in the population, in the instruments used to assess comprehension, and in the criteria used to categorize patients into such groups as "good" comprehension and "poor" comprehension. Although Basso et al. (1977) used the Token Test to assess comprehension impairment, not only was the version used and scoring procedure slightly different, but the cut off for their comprehension groups was also considerably lower than in this study. They included individuals in their "good" comprehension group who failed as many as 50% of the Token Test items (i.e. 18

out of 36 was considered "good" comprehension). If a similar criterion were applied to the scores of this population, subjects 3, 9, 10, would be considered in their "good" comprehension group. None of the aphasic subjects included in the former study had perfect scores, whereas three subjects in the present study made no errors on the Token Test. Two of these subjects (subjects 1 and 6) displayed normal performance on all 27 phonological tasks. Table 15 modeled after Table 1 of Blumstein et al. (1977) tabulates these results. The table lists the twelve aphasic subjects in order and represents their performance on all tasks. The standard for having met criteria is a score of 80% or better on the identification (Experiment I) and discrimination tasks (Experiment II), a difference of 80% between judgements of the end-points of the continuum on the identification of manner and voicing distinctions, and a peak of discrimination at the normal value or one of its neighboring values plus a difference between the peak and trough of at least 50%.

The apparent discrepancy between the present data and those of Basso et al. (1977) would appear to be due to an absence of the upper range of comprehension ability in the former study, and to the absence of

Table 15

Summary of aphasic subjects performance on all tasks. A (+) indicates performance has met established criteria, a (-) indicates failure.

Experiment I				II					III				IV		V				VI				VII				Total		
Series	1	2	3	1	1	2	2	3	3	150	300	150	300	150	300	185	350	185	350	30	60	30	60	30	60	30		60	
S's																													
1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	27
2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	26
3	-	-	-	+	-	+	+	+	+	-	-	-	-	+	-	-	-	+	+	-	-	+	+	+	+	+	+	+	14
4	-	-	-	-	-	-	-	+	+	-	-	-	+	-	-	-	-	+	-	+	-	+	+	+	+	+	+	+	10
5	-	-	-							-	-			-	-	-	-			+	-	+	+	+	+	+	+	+	6
6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	27
7	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	25
8	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	26
9	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	23
10	-	-	-	+	+	+	+	+	+	-	-	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	20
11	-	-	-	+	+	+	+	+	+	-	-	+	-	-	-	-	-	+	+	-	-	+	+	+	+	+	+	+	15
12	-	-	-	-	-	+	-	+	-	+	+	+	-	+	-	-	-	+	-	+	+	+	+	+	+	+	+	+	15
Total	6	6	6	9	8	10	9	11	10	7	7	7	5	9	6	5	5	11	9	10	8	12	12	12	12	12	12	10	12

certain varieties of aphasics in the present study, varieties in which the dissociation between phonological identification and speech comprehension is possibly the most extreme.<sup>1</sup> It should also be noted that Basso and coworkers did find a significant correlation between phonemic identification and the Token Test, but chose to emphasize the exceptions.

Although the abnormal Token Test group showed some variability in their relative abilities to identify phonemes, the correlation between Token Test score and the rank order of the number of phonological tasks in which acceptable performance was found is highly significant ( $r = .92$ ,  $P < .01$ ). The rank order correlation coefficient is only slightly lower for the entire group than for the two subgroups,  $r = .97$  for the fluent group and  $.99$  for the nonfluent group.

Thus, in contrast to previous studies, this investigation found identification deficits only in aphasics with impaired auditory comprehension (i.e. reduced Token Test scores). Individuals with normal Token Test scores performed normally on all or nearly all phonological tests and no aphasic subject with severe comprehension deficits out-performed aphasics with little or no comprehension impairment when

performance on all phonological tasks is considered (Table 15). In addition, fluent aphasics with comprehension deficits performed more poorly than nonfluent aphasics with comprehension deficits.

It is possible that phonological identification and the Token Test require and tap a similar ability, that is, the association of a relatively neutral word or sound with a neutral referent. Semantic context is unavailable to support identification. Moreover, both tasks are extremely artificial and require consistent levels of attention for relatively long periods of time. It is also possible that no single factor underlies performance difficulties on the two tasks. Rather, both phonemic identification and Token Test performance may be sensitive indices of aphasia for different, unrelated reasons.

At any rate, the investigation presented here failed to disclose any firm support for the notion that the link between deficits on phonological tests and the Token Test is due to a basic failure in the processing of rapidly changing acoustic events. Those aphasics manifesting consistent phonological performance deficits show a well-preserved capacity for the discrimination of a variety of temporally defined acoustic dimensions, but

have difficulty on tasks requiring the identification of a stimulus.

Although the correlation is not as great, there is a significant rank order correlation between the index of overall severity, i.e. the Functional Communication Profile overall score, and phonological task performance ( $r = .68$ ,  $P > .05$ ). In general, overall FCP score predicts relative performance on the series of phonological tasks, but there are also some striking exceptions, particularly subjects 3 and 4, both of whom are fluent aphasics with comprehension deficits, but function relatively well in naturalistic situations.

It is not clear why so many aphasics are prone to identification errors. Since no aphasic tested failed all tasks and identification performance was enhanced by the presence of salient durational cues, those perceptible changes in duration available in the [dɛt-dɛd] series, it is impossible to suggest a complete failure to associate a sound with a response category or that aphasics simply did not understand the task. Rather, the association between the sound and its referent seems weakened and readily confused by the presence of ambiguous and minimally different stimulus patterns. Subjects succeed for a time, only to become

confused later and to misidentify even the least ambiguous end-point stimuli. Although practice may have a beneficial effect for some aphasics, performance on identification tasks tends to deteriorate over time, and the longer the series, the worse the overall performance. For example, it is possible that fewer aphasic subjects demonstrated normal identification on the VOT series than on the manner class because the identification test was longer (70 items as compared to 35).

Discrimination performance, on the other hand, tends to improve over time and over series. All subjects who were exposed to a repeat series in Experiment II showed improved discrimination scores on the second run. This is not to say that aphasic discrimination performance is "normal." Aphasics had lower mean % same correct (i.e. misidentified more same pairs) than normal subjects and their peak of discrimination tended to be somewhat lower than normal subjects.

In conclusion, the difference between identification and discrimination performance in the aphasics with spoken language comprehension deficits taken with their demonstrated sensitivity to durational cues, lends strong support to the assertion that the failure in aphasia is

not an inability to extract acoustic information from the speech signal, but a deficit of a different order-- possibly a conceptual impairment which transcends the speech signal and affects their ability to associate a stimulus with its label.

Some Implication for the Study of  
Normal Speech Processing

The study of context-dependent effects in the processing of speech and non-speech acoustic signals addresses one of the fundamental issues in speech perception research. That is, does the perception of speech patterns involve a characteristic set of functions specific to speech, or are the perceptual phenomena produced by manipulating various acoustic dimensions simply the result of more general perceptual principles which affect all auditory processing whether the stimulus patterns used are speech or non-speech.

The findings of both sine-wave experiments with normal subjects lend support to the claim that the perception of non-speech stimuli is different from the perception of speech patterns. In both experiments, the effect on the category boundary between two non-speech classes as a function of stimulus duration was

reduced, if not eliminated, when sine-wave patterns replicating the changing formant center frequencies were used. When subjects classified the sine-wave patterns replicating the speech patterns for the [ba-wa] series as specified by Miller and Liberman (1979), the category boundary shifted only slightly and in the reverse direction for the normal group. Aphasics who were able to identify the stimulus patterns evidenced a similar trend in their performance. This finding conflicts with that of Carrell, Pisoni, and Gans (1980) whose subjects demonstrated the predicted "speech" shift in the category boundary with non-speech sine-wave stimuli.

A similar finding emerged when sine-wave control patterns replicating the [d&t-d&d] syllables were classified into two speech and two non-speech categories. The marked shift in the /d-t/ boundary found in both response conditions when subjects judged the speech stimuli virtually disappeared when the same judgements were made with non-speech stimuli. That is, it appeared to make no difference for either speech or non-speech patterns whether subjects treated the stimulus as speech or as non-speech, but it did make a difference that the stimulus was in fact speech.

The findings of both Blumstein et al. (1977) and

the present study are inconsistent with the standard notion in studies of categorical perception that the presence of peaks of discrimination at the phoneme boundary are based on the listener's classification of the stimuli into phonetic categories. This notion assumes that a listener can discriminate no better than he can identify. However, it is clear that many aphasics evidence the reverse pattern.

The major findings of this investigation were that: (i.) many aphasics, deprived of the ability to reliably identify stimuli, are nonetheless able to discriminate between acoustic stimuli distinguishing phonetic classes, (ii.) aphasics' perceptual judgements show the predicted context dependent effects specific to speech signals. These results argue for a different account than has sometimes been offered.

Aphasics' discrimination facility at the phoneme boundary can not be based on the ability to categorize stimuli, but must be due to a level of auditory perception, left relatively intact despite the inability to classify linguistic stimuli. It was the separability of identification and discrimination that led Blumstein et al. (1977) to argue that two levels of perception are required for normal speech processing: a prelinguistic

auditory level in which selective differences are detected and a linguistic level in which categories derived from the prelinguistic level are used to distinguish functionally different speech sounds. This view is consistent with the distinction between auditory and phonetic processes frequently drawn in theoretical discussions of speech perception (e.g. Liberman, 1970; Studdert-Kennedy, 1974). However, it differs from the standard accounts of categorical perception by proposing a psychoacoustic rather than a phonological origin for the categories (cf. Stevens, 1972; Pastore, Ahroon, Baffuto, Friedman, Puelo, and Fink, 1977).

#### Summary

This study, using synthetic speech and sine-wave stimuli to investigate aphasics' perception of speech and non-speech distinctions, conveyed by variations in acoustic duration, failed to reveal any firm evidence to support the claim that the basic failure underlying aphasics' speech comprehension deficits is a primary defect in the process of rapidly changing acoustic events.

The results of the experiments designed to replicate Tallal and Newcombe (1978) (who had found that formant transition extension facilitated aphasics')

ability to process phonological information) did not demonstrate a consistent improvement in aphasics' identification or discrimination of a place contrast (/b/ versus /d/) due to formant transition lengthening. Moreover, in contrast to the previous study, the aphasics tested were not sensitive to variations in the interstimulus interval used in the AX discrimination task. While differences in the stimulus parameters seemed to have little effect on overall performance, there was a marked difference, for subjects with reduced auditory comprehension ability, between their ability to identify and their ability to discriminate the same stimulus patterns.

The investigation of aphasics' perception of a manner class distinction (/b/ versus /w/) in two test series in which the overall duration of the syllable was varied, produced several pertinent findings. First, aphasics who showed normal identification function demonstrated the same predicted shift in the category boundary as a function of syllable duration as did the normal subjects tested. Second, a shift in the peak of discrimination as a function of syllable duration was found in the performance of several aphasic subjects whose identification function was too irregular to

permit the perceptual normalization effect to be revealed. When non-speech control stimuli which replicated the time varying properties of the [ba-wa] stimuli were used and a non-speech judgement was required, no consistent boundary effect was found in the performance of either the normal or the aphasic population. For the majority of aphasics, identification of the non-speech stimulus patterns proved as difficult as the identification of speech patterns, though a reversal of this trend was observed in an isolated case.

The results of the examination aphasics' perception of VOT [da-ta] further demonstrated the disparity between aphasics' relative inability to identify phonological contrasts and their relatively preserved ability to discriminate the minute acoustic cues on which phonetic decisions are based. Specifically, only subjects with normal Token Test scores were able to identify test stimuli reliably, whereas all subjects, regardless of the severity of their auditory comprehension impairment, demonstrated a peak of discrimination at the locus of the normal phoneme boundary. The study was inconclusive with respect to the effect of stimulus duration on the placement of the phonetic boundary. A small but insignificant displacement of

the /d-t/ boundary in the predicted direction was found in the majority of normal subjects and for the aphasic subjects who evidenced normal identification function. A peak of discrimination shift was found in only one of the eight normal subjects' discrimination performance and in 45% of the aphasics tested.

The exploration of the effect of variations in the duration of the initial formant transition in CVC syllables [dɛt-dɛd] and in sine-wave replica of the syllables on categorization of the stimuli into speech and non-speech classes yielded striking similarities between aphasics and normal subjects' performance. For both populations, when CVC syllables were used, the variation in the duration of the initial formant transition resulted in predicted displacement of both the speech response and the non-speech response category boundaries. However, when the non-speech control patterns were used, the variation in the length of the initial sine-wave transition effected only a minimal insignificant shift in the speech response and non-speech response category boundaries. The findings with respect to the magnitude of the shift, the range of displacement values, and absolute boundary values were similar for the two populations. In contrast to

the other experiments in which many aphasics failed to reliably identify stimuli, nearly all aphasics were able to make the judgements required in these test series. In fact non-speech judgements of relative duration were accomplished by all twelve aphasic subjects tested.

In conclusion, the study of durational factors in aphasics' phonological perception demonstrated that even aphasics with marked comprehension deficits display normal sensitivity to durational cues embodied in synthetic speech stimuli under certain conditions. Specifically, they showed a shift in the phonemic boundary as a function of syllable duration in their discrimination performance and a shift in the category boundary was effected in both speech and non-speech judgements as a function of a variation in the duration of the initial formant transition of CVC syllables. Taken together, the study of context dependent effects in aphasia suggests a level of phonemic processing is spared in spite of marked difficulty in identification of phonemic contrasts.

Since reliable context effects were not found when sine-wave stimulus patterns were used and the perceptual normalization phenomena was found to be

specific to speech stimuli, the results of this investigation support the claim that speech processing engages a specific kind of perceptual processing mechanism.

Although the results fail to support the temporal processing deficit hypothesis, they do support in part the findings of Blumstein, Cooper, Zurif, and Caramazza (1977) and Kellar (1979) who also found that a substantial portion of aphasics demonstrate a pattern of performance characterized by specific difficulty identifying synthetic speech in spite of a relatively preserved ability to discriminate acoustic differences in the locus of the normal phoneme boundary. Where the findings of this study differ from those of others who have used synthetic speech to study aphasics' phonemic perception is in the high association between phonological identification and overall phonological performance and performance on the instrument used to assess auditory comprehension, i.e. the Token Test, and in the finding that the pattern of performance was not specific to fluent aphasics with comprehension deficits (Blumstein et. al. 1977) or to individuals who manifest phonemic disturbances in their speech production (Basso, Casati, and Vignolo, 1977). While it

is perhaps premature to postulate a single factor underlying both performance on phonological identification tasks and the Token Test, the two tasks seem equally sensitive to auditory processing deficits in aphasia.

When all experimental findings are summarized and examined it is apparent that disturbances in speech comprehension of these aphasics can not be attributed to a failure to extract relevant acoustic information from the speech signal. Rather, the aphasics with comprehension deficits demonstrated a failure to maintain consistent category judgement for both speech and non-speech stimuli, a defect which appears associated with a more general defect in stimulus identification.

## CHAPTER VI

Footnotes

1. The failure to obtain a shift with the non-speech series would be of great interest if it were valid. Due to the format of the tests in Experiment VI and VII, this conclusion is open to question. The ranges of stimuli in the two test series were different. It is known that the positions of boundaries vary depending on the range of stimuli. This reservation does not apply to the [ba-wa] series since the test orders for the speech and non-speech control series were in that case identical.
2. This study population differs in other respects from that used by Basso et al. (1977). The present study included only CVA's with an embolic or thrombotic origin, whereas, in Basso's study, the etiology of the aphasic condition included in addition to CVA, neoplasms and trauma. The present study population is also characterized by better than average education (12 to 20 years), whereas the former population included individuals with little formal education.

APPENDIXES



## NEW YORK UNIVERSITY MEDICAL CENTER

*A private university in the public service*

Institute of Rehabilitation Medicine  
 400 EAST 34TH STREET, NEW YORK, N.Y. 10016  
 CABLE ADDRESS: NYUMEDIC  
 (212) 340-

Project Title: Rate Normalization in Aphasia

### Informed Consent Form

This study is designed to learn whether or not changes in rate (duration) affect aphasic patients' perception of speech. If there is a relationship between speech rate and aphasics' understanding of speech, we will be able to use this information in patients' rehabilitation management

I hereby give my consent to the following procedures:

1. Various subtests of a standardized test of aphasia.
2. An interview.
3. A test which involves listening to pre-recorded tapes of machine produced words.

I understand that there are no health risks involved in these procedures. Furthermore, I have been assured that my identity will be kept confidential and that I may withdraw from the project at any time. Records or results of evaluation may be released only at my own request or with my permission. I understand that I will have the opportunity to have any questions pertaining to the study answered by the investigator. Information regarding the study may be obtained from Karen Riedel, Principal Investigator, 212- 340-6027.

### Investigator's Statement

I have fully explained the study to the above.

\_\_\_\_\_  
 Signature of patient/family member

\_\_\_\_\_  
 Date

\_\_\_\_\_  
 Signature of Investigator

\_\_\_\_\_  
 Witness signature

\_\_\_\_\_  
 Date

\_\_\_\_\_  
 Date

SESQUI  
 CENTEN  
 NIAL  
 CELE  
 BRATION

Initials \_\_\_\_\_

Experiment I (identification)

Date \_\_\_\_\_

Tape \_\_\_\_\_

## Practice:

1. BA DA
2. BA DA
3. BA DA
4. BA DA
5. BA DA
6. BA DA
7. BA DA
8. BA DA
9. BA DA
10. BA DA
11. BA DA
12. BA DA

## Test:

1. BA DA
2. BA DA
3. BA DA
4. BA DA
5. BA DA
6. BA DA
7. BA DA
8. BA DA
9. BA DA
10. BA DA
11. BA DA
12. BA DA
13. BA DA
14. BA DA
15. BA DA
16. BA DA
17. BA DA
18. BA DA
19. BA DA
20. BA DA
21. BA DA
22. BA DA
23. BA DA
24. BA DA

Initials \_\_\_\_\_

Experiment II

Date \_\_\_\_\_

Tape \_\_\_\_\_

## Practice:

1. S D  
\*\* \*-
2. S D  
\*\* \*-
3. S D  
\*\* \*-
4. S D  
\*\* \*-
5. S D  
\*\* \*-
6. S D  
\*\* \*-
7. S D  
\*\* \*-
8. S D  
\*\* \*-

## Test:

1. S D
2. S D
3. S D
4. S D
5. S D
6. S D
7. S D
8. S D
9. S D
10. S D
11. S D
12. S D
13. S D
14. S D
15. S D
16. S D
17. S D
18. S D
19. S D
20. S D

Initials \_\_\_\_\_

Experiment III

Date \_\_\_\_\_

Tape \_\_\_\_\_

## Practice:

1. BA WA
2. BA WA
3. BA WA
4. BA WA
5. BA WA
6. BA WA
7. BA WA
8. BA WA
9. BA WA
10. BA WA
11. BA WA
12. BA WA
13. BA WA
14. BA WA
15. BA WA
16. BA WA
17. BA WA
18. BA WA
19. BA WA
20. BA WA
21. BA WA

## Test:

- |           |           |
|-----------|-----------|
| 1. BA WA  | 22. BA WA |
| 2. BA WA  | 23. BA WA |
| 3. BA WA  | 24. BA WA |
| 4. BA WA  | 25. BA WA |
| 5. BA WA  | 26. BA WA |
| 6. BA WA  | 27. BA WA |
| 7. BA WA  | 28. BA WA |
| _____     |           |
| 8. BA WA  | 29. BA WA |
| 9. BA WA  | 30. BA WA |
| 10. BA WA | 31. BA WA |
| 11. BA WA | 32. BA WA |
| 12. BA WA | 33. BA WA |
| 13. BA WA | 34. BA WA |
| 14. BA WA | 35. BA WA |
| _____     |           |
| 14. BA WA |           |
| 15. BA WA |           |
| 16. BA WA |           |
| 17. BA WA |           |
| 18. BA WA |           |
| 19. BA WA |           |
| 20. BA WA |           |
| 21. BA WA |           |

## Experiment III

Initials \_\_\_\_\_

Tape \_\_\_\_\_

36. BA WA

37. BA WA

38. BA WA

39. BA WA

40. BA WA

41. BA WA

42. BA WA

---

43. BA WA

44. BA WA

45. BA WA

46. BA WA

47. BA WA

48. BA WA

49. BA WA

---

50. BA WA

51. BA WA

52. BA WA

53. BA WA

54. BA WA

55. BA WA

56. BA WA

57. BA WA

58. BA WA

59. BA WA

60. BA WA

61. BA WA

62. BA WA

63. BA WA

---

64. BA WA

65. BA WA

66. BA WA

67. BA WA

68. BA WA

69. BA WA

70. BA WA

## Experiment III

Initials _____			Tape _____					
1.	S	D	18.	S	D	44.	S	D
2.	S	D	19.	S	D	45.	S	D
3.	S	D	20.	S	D	46.	S	D
4.	S	D	21.	S	D	47.	S	D
5.	S	D	22.	S	D	48.	S	D
6.	S	D	23.	S	D	49.	S	D
7.	S	D	24.	S	D	50.	S	D
8.	S	D	25.	S	D	51.	S	D
9.	S	D	26.	S	D	-----		
10.	S	D	27.	S	D	52.	S	D
11.	S	D	28.	S	D	53.	S	D
12.	S	D	29.	S	D	54.	S	D
13.	S	D	30.	S	D	55.	S	D
14.	S	D	31.	S	D	56.	S	D
15.	S	D	32.	S	D	57.	S	D
16.	S	D	33.	S	D	58.	S	D
17.	S	D	34.	S	D	59.	S	D
			-----			60.	S	D
			35.	S	D	61.	S	D
			36.	S	D	62.	S	D
			37.	S	D	63.	S	D
			38.	S	D	64.	S	D
			39.	S	D	65.	S	D
			40.	S	D	66.	S	D
			41.	S	D	67.	S	D
			42.	S	D	68.	S	D
			43.	S	D			

Initials _____	Experiment III Tape _____	
86. S D	103. S D	120. S D
87. S D	104. S D	121. S D
88. S D	105. S D	122. S D
89. S D	106. S D	123. S D
90. S D	107. S D	124. S D
91. S D	108. S D	125. S D
92. S D	109. S D	126. S D
93. S D	110. S D	127. S D
94. S D	111. S D	128. S D
95. S D	112. S D	129. S D
96. S D	113. S D	130. S D
97. S D	114. S D	131. S D
98. S D	115. S D	132. S D
99. S D	116. S D	133. S D
100. S D	117. S D	134. S D
101. S D	118. S D	135. S D
102. S D	119. S D	136. S D






















Initials: \_\_\_\_\_






















Experiment IV















Date: \_\_\_\_\_

Practice:

Test:

- 1. — 
- 2. — 
- 3. — 
- 4. — 
- 5. — 
- 6. — 
- 7. — 
- 8. — 
- 9. — 
- 10. — 
- 11. — 
- 12. — 
- 13. — 
- 14. — 
- 15. — 
- 16. — 
- 17. — 
- 18. — 
- 19. — 
- 20. — 
- 21. — 

- 1. — 
- 2. — 
- 3. — 
- 4. — 
- 5. — 
- 6. — 
- 7. — 
- \_\_\_\_\_
- 8. — 
- 9. — 
- 10. — 
- 11. — 
- 12. — 
- 13. — 
- 14. — 
- \_\_\_\_\_
- 15. — 
- 16. — 
- 17. — 
- 18. — 
- 19. — 
- 20. — 
- 21. — 

- 22. — 
- 23. — 
- 24. — 
- 25. — 
- 26. — 
- 27. — 
- 28. — 
- \_\_\_\_\_
- 29. — 
- 30. — 
- 31. — 
- 32. — 
- 33. — 
- 34. — 
- 35. — 

Initials \_\_\_\_\_

Experiment IV

Tape \_\_\_\_\_

36. — 57. — 37. — 58. — 38. — 59. — 39. — 60. — 40. — 61. — 41. — 62. — 42. — 63. — 43. — 64. — 44. — 65. — 45. — 66. — 46. — 67. — 47. — 68. — 48. — 69. — 49. — 70. — 50. — 51. — 52. — 53. — 54. — 55. — 56. — 

## Experiment V

Initials			Tape			
1. DA	TA		25. DA	TA	48. DA	TA
2. DA	TA		26. DA	TA	49. DA	TA
3. DA	TA		27. DA	TA		
4. DA	TA		28. DA	TA	50. DA	TA
5. DA	TA		29. DA	TA	51. DA	TA
6. DA	TA				52. DA	TA
7. DA	TA		30. DA	TA	53. DA	TA
8. DA	TA		31. DA	TA	54. DA	TA
9. DA	TA		32. DA	TA	55. DA	TA
-----			33. DA	TA	56. DA	TA
10. DA	TA		34. DA	TA	57. DA	TA
11. DA	TA		35. DA	TA	58. DA	TA
12. DA	TA		36. DA	TA	59. DA	TA
13. DA	TA		37. DA	TA		
14. DA	TA		38. DA	TA	60. DA	TA
15. DA	TA		39. DA	TA	61. DA	TA
16. DA	TA				62. DA	TA
17. DA	TA		40. DA	TA	63. DA	TA
18. DA	TA		41. DA	TA	64. DA	TA
19. DA	TA		42. DA	TA	65. DA	TA
-----			43. DA	TA	66. DA	TA
20. DA	TA		44. DA	TA	67. DA	TA
21. DA	TA		45. DA	TA	68. DA	TA
22. DA	TA		46. DA	TA	69. DA	TA
23. DA	TA		47. DA	TA	70. DA	TA
24. DA	TA					

## Experiment V

Initials \_\_\_\_\_

Tape \_\_\_\_\_

1. S D	20. S D	40. S D
2. S D	21. S D	41. S D
3. S D	22. S D	42. S D
4. S D	23. S D	43. S D
5. S D	24. S D	44. S D
6. S D	25. S D	45. S D
7. S D	26. S D	46. S D
8. S D	27. S D	47. S D
9. S D	28. S D	48. S D
_____	29. S D	49. S D
10. S D		
11. S D	30. S D	50. S D
12. S D	31. S D	51. S D
13. S D	32. S D	
14. S D	33. S D	
15. S D	34. S D	
16. S D	35. S D	
17. S D	36. S D	
18. S D	37. S D	
19. S D	38. S D	
	39. S D	

## Experiment VI

Initials \_\_\_\_\_

Practice:

Test:

1. DET DED	1. DET DED	26. DET DED	50. DET DED
2. DET DED	2. DET DED	27. DET DED	51. DET DED
3. DET DED	3. DET DED	28. DET DED	52. DET DED
4. DET DED	4. DET DED	29. DET DED	53. DET DED
5. DET DED	5. DET DED	30. DET DED	54. DET DED
6. DET DED	6. DET DED	31. DET DED	55. DET DED
7. DET DED	7. DET DED	32. DET DED	56. DET DED
8. DET DED	8. DET DED	33. DET DED	57. DET DED
9. DET DED	9. DET DED	34. DET DED	58. DET DED
10. DET DED	10. DET DED	35. DET DED	59. DET DED
11. DET DED	11. DET DED	36. DET DED	60. DET DED
12. DET DED	12. DET DED	37. DET DED	61. DET DED
13. DET DED	13. DET DED	38. DET DED	62. DET DED
14. DET DED	14. DET DED	39. DET DED	63. DET DED
15. DET DED	15. DET DED	40. DET DED	64. DET DED
16. DET DED	16. DET DED	41. DET DED	65. DET DED
17. DET DED	17. DET DED	42. DET DED	66. DET DED
18. DET DED	18. DET DED	_____	67. DET DED
19. DET DED	19. DET DED	43. DET DED	68. DET DED
20. DET DED	20. DET DED	44. DET DED	69. DET DED
21. DET DED	21. DET DED	45. DET DED	70. DET DED
	22. DET DED	46. DET DED	
	23. DET DED	47. DET DED	
	24. DET DED	48. DET DED	
	25. DET DED	49. DET DED	

## Experiment VI

Initials \_\_\_\_\_

Practice:	Test	
1. - —	1. - —	25. - —
2. - —	2. - —	26. - —
3. - —	3. - —	27. - —
4. - —	4. - —	28. - —
5. - —	5. - —	29. - —
6. - —	6. - —	30. - —
7. - —	7. - —	31. - —
8. - —	8. - —	32. - —
9. - —	9. - —	33. - —
10. - —	10. - —	34. - —
11. - —	11. - —	35. - —
12. - —	12. - —	36. - —
13. - —	13. - —	37. - —
14. - —	14. - —	38. - —
15. - —	_____	39. - —
16. - —	15. - —	40. - —
17. - —	16. - —	41. - —
18. - —	17. - —	42. - —
19. - —	18. - —	_____
20. - —	19. - —	
21. - —	20. - —	
22. - —	21. - —	
23. - —	22. - —	
24. - —	23. - —	
	24. - —	

## Experiment VI

2

Initials \_\_\_\_\_ Tape \_\_\_\_\_

43. - — 66. - —

44. - — 67. - —

45. - — 68. - —

46. - — 69. - —

47. - — 70. - —

48. - —

49. - —

50. - —

51. - —

52. - —

53. - —

54. - —

55. - —

56. - —

57. - —

58. - —

59. - —

60. - —

61. - —

62. - —

63. - —

64. - —

65. - —

## Experiment VII

Initials \_\_\_\_\_

Tape \_\_\_\_\_

## Practice:

1. - —
2. - —
3. - —
4. - —
5. - —
6. - —
7. - —
8. - —
9. - —
10. - —
11. - —
12. - —
13. - —
14. - —
15. - —
16. - —
17. - —
18. - —
19. - —
20. - —

## Test:

1. - —
2. - —
3. - —
4. - —
5. - —
6. - —
7. - —
- \_\_\_\_\_
8. - —
9. - —
10. - —
11. - —
12. - —
13. - —
14. - —
- \_\_\_\_\_
15. - —
16. - —
17. - —
18. - —
19. - —
20. - —
21. - —

22. - —
23. - —
24. - —
25. - —
26. - —
27. - —
28. - —
- \_\_\_\_\_
29. - —
30. - —
31. - —
32. - —
33. - —
34. - —
35. - —

## Experiment VII

Initials \_\_\_\_\_

Tape \_\_\_\_\_

## Practice:

1. DET DED
2. DET DED
3. DET DED
4. DET DED
5. DET DED
6. DET DED
7. DET DED
8. DET DED
9. DET DED
10. DET DED
11. DET DED
12. DET DED
13. DET DED
14. DET DED
15. DET DED
16. DET DED
17. DET DED
18. DET DED
19. DET DED
20. DET DED

## Test:

- |             |             |
|-------------|-------------|
| 1. DET DED  | 22. DET DED |
| 2. DET DED  | 23. DET DED |
| 3. DET DED  | 24. DET DED |
| 4. DET DED  | 25. DET DED |
| 5. DET DED  | 26. DET DED |
| 6. DET DED  | 27. DET DED |
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