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THE EFFECT OF TIME-ALTERED SPEECH STIMULI ON THE PERFORMANCE OF RIGHT HEMIPLEGIC ADULT APHASICS

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

1. INTRODUCTION

1.1. RATIONALE FOR RESEARCH

Aphasia, in adults, is a disruption in the ability to use the conventional elements of a previously acquired language system (Tikofsky, 1968). As such, it is a serious problem for its victims. Anything that will help identify the conditions under which the aphasic can better use language can be considered a worthwhile area of study.

Current opinion holds that aphasia is caused by damage to the central nervous system, and, more specifically, to the frontal convolution and the posterior part of the superior temporal convolution of one cortical hemisphere, usually the left hemisphere (Howes, 1964). If this is true, the study of aphasia may help us identify and describe those aspects of language behavior which depend for their intactness on the intactness of that part of the central nervous system. It may also help us identify those dimensions of stimuli which must be adequately processed by that part of the central nervous system for successful language performance. Thus, a second reason for doing research of the kind presented here is that it may tell us something about normal language function. Although this research is based on currently held anatomical concepts regarding the localization of lesions causing aphasia, behavioral research cannot test these concepts, and it is not the intent of the present research to do so.

If we are to use the performance of the aphasic to tell us about normal language behavior, it is helpful to demonstrate that the aphasic uses the same mechanisms and strategies as the normal though, perhaps, with less efficiency. Tikofsky (1968, p. 326) states that aphasia " . . . represents a reduction of the efficiency with which a previously-acquired language system can be employed. Such a reduction can be evaluated in terms of the capacity and rate with which the aphasic handles language." The data which his aphasics generated, on verbal and nonverbal learning tasks, looked much like the data of his normal subjects (Carson, Carson and Tikofsky, 1968). The major difference between aphasic and normal was not in the shape of the curves. Rather, differences were in the number of trials to asymtote, the aphasic taking longer, and the level of final achievement, the aphasic's being lower.

West (1968) has shown that aphasics operate with previously acquired grammatical rules. She demonstrated that grammatical complexity influenced ability to repeat sentences, regardless of the length of the stimulus unit, and that nongrammatical strings were more difficult for aphasics than grammatical strings, regardless of length.

Tikofsky (1968) notes that with a careful study of the output of what Wepman calls pragmatic aphasics, those patients whose output is extensive but appears meaningless, one finds their inappropriate words are placed in appropriate grammatical slots. "Even the patients with telegraphic speech or the ones who cannot deal adequately with tense or number still maintain the basic sequential order of the sentence" (Tikofsky, 1968, p. 328).

Howes (1964) applied word-frequency distribution curves to aphasic output and found that "the lognormal law of word frequency distribution holds for aphasic language" (p. 64).

There is evidence, then, that the aphasic performs much like the normal, though not as well. It seems reasonable that the study of the stimulus dimensions that affect aphasic performance may tell us something about normal language.

It is also helpful to demonstrate that aphasia is a unitary disorder rather than a collection of disorders. This will enable us to generalize to the population as a whole from studies done with aphasics, regardless of classification of type of aphasia on traditional lines, and, so, allows for greater freedom in subject selection. Schuell and her associates have demonstrated this (e. g., Schuell and Jenkins, 1959).

Much traditional thought emphasizes sensory and motor aphasia as separable entities. A dichotomy dividing the disorder into semantic aphasia and syntactic aphasia has also been added (see, for example, Wepman, et al., 1956, 1960). Schuell's group, through such techniques as a scale analysis of the performance of a large number of aphasics on a large battery of tests, demonstrated that there is no evidence to divide aphasics into separate groups on the above dichotomies (Schuell and Jenkins, 1959). Aphasia is conceived of as a unitary disorder characterized by a reduced vocabulary and verbal retention span. "There is almost always demonstrable impairment of auditory processes" (Schuell, Jenkins and Jiménez-Pabón, 1964, p. 115).

What this means is that any aphasic can be used to (1) give us information useful in the management of aphasics in general, and (2) give us information about normal language.

1.2. THEORETICAL BACKGROUND -- TIME AS A DIMENSION IN LANGUAGE

There has been much recent interest in time as, perhaps, the most significant dimension in language behavior. This is superficially quite obvious; the speech stimulus is one of acoustic events changing in time.

However, Lenneberg (1967) feels that this idea has not yet been taken to its logical conclusion. He discusses investigations at Haskins Laboratory that have shown that " . . . a great variety of phonemic distinctions are entirely dependent upon timing factors of onset, duration and cessation of voice. . . " (p. 97). He notes that one encounters patients with central nervous system lesions who have difficulty keeping the elements of speech and language in the right order in time. Using such data and observations, Lenneberg develops the theoretical position that language is a neurophysiological process which is basically a sequencing of auditory events. Aphasia is described as a breakdown of such a process.

Another writer, who is strongly impressed with the role that time plays in language, is Hirsh. Some of his research dealt with temporal fusion or the judgment of simultaneity and successiveness. He found differences in behavior between the visual and auditory systems and states that "auditory successiveness . . . can be given by intervals almost an order of magnitude lower than those that characterize the visual system . . . " (Hirsh, 1967, p. 26). Hirsh sees this as suggesting that fusion is a phenomenon limited by the peripheral system and not the central one.

Hirsh's data on another aspect of temporal judgment, that of the judgment of the order of two stimuli (or what is often called temporal sequencing) leads him to a different conclusion. Trained observers can judge which of two stimuli came first when onset difference is about 20 milliseconds. He found this true in the auditory modality, in the visual modality, and where one stimulus was in one modality and the second was in the other modality (Hirsh, 1959; Hirsh and Sherrick, 1961).

He concludes that this ability " . . . is not characteristic of a particular sensory modality, but rather of a more central processing stage" (Hirsh, 1967, p. 26).

His research, though limited, in the auditory modality, to pure tone stimuli, leads Hirsh to ask the following questions regarding its application:

> How wide a time gap must the listener carry in order to let the influence of immediately past words come to bear upon words that are about to be heard? How many previous words are stored in a running listening memory in order to permit a listener to engage in efficient language communication . . . ? How does rate of talking affect storage time? When do words succeed each other too rapidly to be separately identified and when are they spoken too slowly to be associated together in a sequential context? (Hirsh, 1966, p. 108)

Hirsh (1967) is also impressed with the fact that learning ordered sequences of pitch was the first task wherein Neff (1964) and his associates could demonstrate the involvement of cortical function in cats. Extensive cortical ablation of all known auditory areas did not permanently interfere with the animals' learning of onset, loudness, or frequency discriminations, but did interfere with judgment of tonal pattern, i. e., high-low-high vs. low-high-low.

A series of experiments to be reviewed in the next chapter demonstrate that aphasics have more difficulty than nonaphasics in sequencing two tones and in performing some other tasks which seem related to temporal sequencing ability. Sequencing seems impaired in children with aphasia as well as adults.

Clinical reports have indicated that the rate at which one speaks to the aphasic is another time variable which differentially affects his performance (Schuell, Jenkins and Jiménez-Pabón, 1964; Schuell as quoted by Millikan and Darley, 1967, p. 35). The present writer has spoken to aphasics who report increased difficulty when spoken to rapidly. This type of report by aphasics has been noted in the literature by Rolnick and Hoops (1969).

1.3. TIME-ALTERED SPEECH STIMULI

There has been increased use of time-altered speech stimuli for educational and research purposes. These are speech stimuli so altered that the rate, in terms of words per minute, is changed from the rate of an original recording. They are sometimes called rate-controlled speech stimuli. The stimuli may be compressed so that rate increases. Acceleration is another term used to describe this process. The rate then is faster or higher than normal. The stimuli may be expanded so that rate decreases. It is then slower or lower than normal. Equipment allowing for such rate change without frequency change has been extensively used (see, for example, Foulke and Sticht, 1969). Such equipment, which varies rate electromechanically, should prove useful in studying the effects of rate on aphasic performance.

1.4. ASSUMPTIONS AND PROJECTIONS

The present study investigated the differential effect of rate of presentation of spoken commands on the accuracy with which the aphasic could take effective action with respect to the commands. The research owes its inspiration to the theoretical position represented by Lenneberg (1967) and the questions and problems raised by Hirsh (1966, 1967). It proceeded from the following assumptions:

(1) Aphasia is a disorder of the central nervous system.

(2) Aphasics use the same language mechanisms as do normals but with inferior rate and capacity.

(3) Time is an important dimension of language.

(4) Many language performances dependent upon time factors are dependent upon the central nervous system.

(5) Temporal sequencing ability is an ability involving time factors that depends upon the central nervous system.

(6) Temporal sequencing is impaired in aphasia.

(7) The differential effect of rate of stimulus presentation on performance is another example of time factors affecting language behavior.

The following is then projected by the present writer:

(1) In a normal situation, the aphasic's response to speech stimuli will be less accurate than that of the nonaphasic.

(2) In a situation which is abnormally taxing on the individual's ability to respond to the time dimension of the stimulus, specifically, when stimuli are presented rapidly, the aphasic's performance may deteriorate more rapidly than that of the nonaphasic.

(3) In a situation which is less taxing than normal on the individual's ability to respond to the time dimension of the stimulus, specifically, when stimulus presentation is somewhat less rapid than normal, the performance of the aphasic may improve with respect to accurate responses to the stimulus.

1.5. THE PROBLEM

This study investigated the effect of rate of a spoken command on what is inferred to be the auditory comprehension of aphasics. Specifically, it demonstrated whether aphasic auditory comprehension, as inferred from accuracy of a pointing or other non spoken motor response, deteriorates when stimuli are presented more rapidly than normal and improves when stimuli are presented more slowly than normal, as compared to the auditory comprehension of nonaphasics. Stimuli were full sentences in the form of recorded, auditory commands.

1.5.1. VARIABLES

The independent variables studied were:

(1) Rate of stimulus presentation as measured in terms of percent compression or expansion of a standard rate.

(2) Level of stimulus difficulty as determined by length and complexity of the sentence.

(3) Order in which rates are presented within a level of difficulty.

(4) Severity of aphasia as measured by overall score for all commands regardless of rate.

(5) Group -- experimental subjects classified as aphasic or nonaphasic.

The dependent variable measured was auditory comprehension as inferred from degree of accuracy of a motor response to auditory commands. Other researchers have used measurements of this form as a basis for making inferences about the construct usually called auditory comprehension.

1.5.2. NULL HYPOTHESES

The following null hypotheses were tested:

A) Main effects

(1) Rate effect: Subjects will exhibit the same accuracy of response for all rates.

(2) Order effect: The order in which the rates of stimulus presentation are experienced, within a given level of stimulus difficulty, will not differentially affect accuracy of response.

B) Interactions

(1) Rate and Group: Aphasic and nonaphasic subjects will show the same changes in accuracy of response as a function of rate of stimulus

presentation.

(2) Rate and level of stimulus difficulty: There will be no interaction between level of stimulus difficulty and rate of stimulus presentation.

(3) Rate and severity: There will be no interaction between severity of aphasia and rate of stimulus presentation.

1.6. SUMMARY OF CHAPTER ONE

Research has indicated that time is an important dimension of language and one which may, for some tasks, be centrally processed. Aphasia, a disorder in which central language processes are interfered with, is seen here as a disorder in which the effects of time should be studied, both to determine stimulus conditions most beneficial to the aphasic and to learn more about normal language.

Temporal sequencing ability is an ability involving time factors that is known to be disturbed in aphasia. Another ability involving time is the ability to respond to speech stimuli presented at different rates in terms of words per minute. Clinical reports indicate that aphasics may have difficulty responding to rapidly presented stimuli. This ability is experimentally investigated here.

This study proposed to determine whether the aphasic's auditory comprehension, inferred from accuracy of a pointing or other nonspoken motor response to spoken sentences, deteriorates when stimuli are presented more rapidly than normal and improves when stimuli are presented more slowly than normal. Other variables studied were the interaction of rate and level of stimulus difficulty, the interaction of rate and severity of aphasia, and the effect of the order in which the rates were presented.

Full sentence stimuli, which were time-altered electromechanically in a way which changes rate without changing frequency, were used.

2. REVIEW OF THE LITERATURE

2.1. APHASIA AND TEMPORAL SEQUENCING

The cortex is involved in many aspects of audition, some of which may be interpreted as involving time (see, for example, Teuber, 1962; Milner, 1962; Bocca and Calearo, 1963). However, it is in tasks that involve the ordering of two auditory events in time (sequencing) that the role of the hemisphere dominant for speech, which is usually the left hemisphere, becomes noted. This specificity is usually demonstrated by showing a more marked disorder in such an ordering ability in patients with aphasia than those without aphasia.

Efron (1963a) performed an experiment in which he demonstrated that the comparison of the time of occurrence of two sensory stimuli requires the use of the hemisphere dominant for speech. Efron (1963b) then attempted to restrict further the areas of the brain involved in such an ability to those involved in aphasia. He studied eleven subjects with left hemisphere lesions and aphasia, one subject with a left hemisphere lesion and no aphasia, and four subjects with right hemisphere lesions without aphasia. Subjects performed a visual sequencing task in which they indicated which of two lights differing in color came first and an auditory sequencing task in which they indicated which of two tones differing in frequency came first. Performance was assessed in terms of how much time had to separate the two stimuli for an accurate judgment to be made.

Aphasics had significantly more difficulty than nonaphasics in both tasks. An interesting and unexpected result was that those aphasics classified as receptive aphasics performed more poorly on the visual task than on the auditory task, while those classified as expressive, i.e., having little difficulty understanding speech, had more difficulty on the auditory task than on the visual one. In fact, the expressive aphasics performed more poorly than receptive aphasics on the auditory sequencing task.

Holmes (1965) performed a similar experiment in which she studied four groups; (a) aphasics inferred to have lesions in the dominant temporal lobe, (b) subjects with lesions presumably involving the nondominant temporal lobe, (c) subjects with lesions not thought to involve either temporal lobe, and (d) hospitalized subjects without known brain damage. Subjects performed three sequencing tasks: an auditory one, a visual one, and a cross-modal (auditory-visual) one. In all of these, they indicated which of two stimuli came first. Aphasic subjects showed " . . . a specific and severe impairment of auditory sequence discrimination as compared to both the nonaphasic brain damaged subjects and normal controls" (p. 100). Aphasics did not demonstrate impaired visual sequencing when compared to subjects without brain damage although nonaphasic brain damaged subjects exhibited such impairment. There was no correlation between type of aphasia as previously classified or severity of aphasia as previously judged and auditory sequencing ability.

Edwards and Auger (1964) compared the performance of aphasic, nonaphasic brain damaged, and normal subjects on what they called a "precedence" task which was similar to that of Efron (1963b) and of Holmes (1965). Subjects had to judge which of two tones differing in both frequency and loudness came first. The amount of time between the tones varied. In addition, performance on some of the subtests of the Seashore Measures of Musical Talents was measured. Aphasics performed significantly more poorly than the other two groups on the precedence test as measured by amount of separation, in milliseconds, necessary for accurate judgment. There were no significant differences between groups on the Seashore subtests. The aphasics were not divided into subgroups so that only total severity of aphasia was correlated with performance on the precedence test. No correlation was found.

The above three studies can be interpreted as indicating that rate of stimulus presentation affects the ability to order tones accurately, and that aphasics require more time, i.e., a slower rate of presentation, to order tones than do nonaphasics.

2.2. RELATED TASKS AND APHASIA

Aphasics have been found inferior to nonaphasics on other tasks where rate of stimulus presentation may be interpreted as the independent variable. Ebbin and Edwards (1967) presented aphasic and nonaphasic brain damaged subjects with two nonsense syllables and had subjects report whether the two were the same or different. The syllables used were "pa," "ta," "da," "ka," and "sa." There were two possible intervals of time between the two syllables; either as little as splicing would allow or 200 milliseconds. Aphasics demonstrated poorer discrimination than nonaphasics but improved in the 200 millisecond condition. Nonaphasics performed in the same manner during both interval conditions. When aphasics were divided into an interval sensitive (improved with increased interval) group and an interval insensitive group, no differences in overall language deficit was found. The interval sensitive group was found to score lower on one subtest of the Auditory section of the Minnesota Test for Differential Diagnosis of Aphasia. This was the subtest that measures auditory comprehension of a paragraph.

The study by Ebbin and Edwards may be interpreted as demonstrating that rate of stimulus presentation is related to the aphasic's consonant discrimination ability.

Horenstein, Le Zak, and Pitts (1966) presented one to five uniformly spaced fixed frequency tones to aphasics and normal controls. Tone duration varied from 100 to 500 milliseconds with proportionate silent intervals. Subjects were asked to report the number of tones they heard. Aphasics, particularly those said to have auditory agnosia, needed longer durations and longer intervals than normals to report accurately. They usually erred in the direction of reporting fewer tones. It must be noted that nonaphasic brain damaged controls were not used.

Rate of presentation may be viewed here as affecting the subjects' ability to separate discrete signals. This result is in accordance with Efron's belief that the dominant hemisphere makes the time comparisons on which simultaneity judgments are based according to when the stimuli reach the dominant hemisphere (1963a) but contradicts Hirsh's belief that simultaneous versus successive judgments depend on the peripheral rather than the central nervous system (Hirsh, 1967). Support for Hirsh's position can be found in the results of Lowe and Campbell (1967) reviewed below.

To summarize, adult aphasics have more difficulty than nonaphasics in sequencing two tones presented in rapid succession, counting short tones rapidly presented, and discriminating consonants in syllables rapidly presented. Decreasing the rate of presentation improves their scores at rates where normals no longer show improvement. These abilities appear unrelated to severity and type of aphasia except in the case reported by Hornstein, Le Zak, and Pitts (1966). These abilities may be related to the aphasic's ability to understand continuous speech as evidenced by the results of Ebbin and Edwards (1967).

2.3. RELEVANT LITERATURE ABOUT APHASIC CHILDREN

Studies with aphasic children point towards sequencing problems for these children. Lowe and Campbell (1965) found that, when "aphasoid" and normal children were compared regarding ability to indicate simultaneousness or successiveness of tones, there were no significant differences, but that the aphasoid children required a significantly longer interval to order two tones correctly. Stark (1967) found that aphasic children perform significantly below normal on standardized tests of auditory and visual sequencing ability. Stark, Poppen and May (1967) report that when aphasic and normal children hear a sequence of three words and have to press appropriate keys (marked by pictures) in the proper order, the aphasic children, particularly those who fall more than three standard deviations from their age norms on the Illinois Test of Psycholinguistic Abilities, have more difficulty.

Furth and Pufall (1968) compared aphasic, deaf, and normal children of two age groups (6 - 7 and 10 - 11) on a number of visual tasks including discrete paired associates, simultaneous sequencing, and successive sequencing, as well as on an auditory sequencing task. No differences between deaf and aphasic children were noted except on the auditory task where the younger group of aphasics performed more poorly than the younger group of deaf subjects. The younger deaf and aphasic children performed more poorly than the younger normals on the successive visual sequencing task as well as the auditory sequencing task.

McReynolds (1966) demonstrated that, with proper reinforcement contingencies, most aphasic children could discriminate single sounds as often as normal children, though they required more trials to criterion, but they could not discriminate between the same pairs of sounds when they were put in a constant context (hə_ak) as well as normal children. This was interpreted as indicative of a problem in sequencing which caused the children to have difficulty locating the sound to be discriminated.

It must be noted that the studies with children do not indicate that time processing occurs in the hemisphere dominant for speech. Aphasia, in children, cannot be localized as can aphasia in adults. It is at about puberty that there are marked signs of the reduction of equipotentiality of the hemispheres for language. At this time, aphasic symptoms acquired from traumatic lateralized lesions become irreversible (Lenneberg, 1967). Thus, aphasia, in children, which is not a result of a known specific lesion, may involve both hemispheres. What the studies with children do give us is further evidence that the individuals with a language impairment of possible cerebral origin have difficulty in tasks that involve the ordering of events in time.

2.4. THE EFFECTS OF SPEAKING RATE

Since the study reported here deals directly with the effect of speaking rate, it is necessary to examine what is known about such effects. Literature on the effect of speaking rate on normal performance will be reviewed first. Then we will look at how rate affects populations that the aphasic may be part of, such as the brain damaged population in general and the aged. The interaction between rate and other factors that might be present and affecting performance will be reviewed next. Such factors include hearing level, intellectual level, and education level. Finally, literature dealing directly with the question of speaking rate and aphasia will be reviewed.

2.4.1. RATE AND NORMAL PERFORMANCE

The literature on time-accelerated speech has recently been reviewed by Foulke and Sticht (1969). They report results of studies to determine normal speaking and oral reading rate which give means ranging from 125 words per minute to 176.5 words per minute. Kelly and Steer (1949) report extemporaneous speaking rates varying from 125 to 328 words per minute with an average of 208.81. However, they only measured speaking time and did not include pauses when obtaining these figures.

Foulke and Sticht (1969) find that studies they reviewed indicate that "a rapid decline in comprehension commences beyond a word rate of approximately 275 words per minute regardless of the compression which may have been required to achieve that word rate." At rates slower than 275 words per minute, studies show insignificant or slight decreases in comprehension. The studies reviewed generally involved presenting a literary selection to the subject and have him answer questions about it when it was completed. Acceleration was usually achieved electromechanically by a device that changes rate without changing frequency.

There does not appear to be much research demonstrating improved or reduced comprehension of expanded stimuli for normal subjects. A trend in the direction of improvement for all groups was found by Altshuler (1964) when he studied normal young adults, hard of hearing young adults, and aged subjects with and without phonemic regression. Luterman, Welsh and Melrose (1966) found lower scores on intelligibility tests with small amounts of expansion using populations similar to those of Altshuler.

The intelligibility of time-compressed speech, generally determined by score on an articulation test, has been studied. When intelligibility scores are compared to comprehension scores, the intelligibility scores are higher (Foulke, 1968).

2.4.2. RATE AND BRAIN DAMAGE

There is evidence that patients with injury to the central auditory pathways have poorer articulation scores in response to sentences that have been accelerated than to those which have not (Bocca and Calearo, 1963). The deterioration is greatest for patients with diffuse cortical pathology, but also occurs in patients with either left or right temporal lesions. Quiros (1964) found an increase in the Threshold of Detection and the Threshold of Intelligibility for brain injured subjects when sentences were accelerated. Several subjects were reported as "dysphasic." Quiros does not claim that these dysphasic subjects have more difficulty with accelerated speech than other brain damaged subjects, but examination of his data seems to indicate that there were greater shifts in the Threshold of Detection for the subjects with dysphasia than for those without. However, his definition of dysphasia was vague and some of the subjects reported as dysphasic had damage to the right hemisphere of the brain.

The finding of impaired response to accelerated speech for the brain damaged population as a whole necessitates caution in interpreting any results of the present study. Some of the studies reviewed above (Efron, 1963b; Holmes, 1965; Edwards and Auger, 1965; Ebbin and Edwards, 1967) find aphasia specific impairment related to rate of stimulus presentation. Bocca and Calearo (1963) do not report aphasic disturbances in their brain damaged subjects affected by accelerated speech. Quiros (1964) reports such disturbances in a few subjects. These studies involved measures of threshold or intelligibility. Subjects were not required to perform any action indicative of what is referred to as auditory comprehension of the stimuli. It would, therefore, appear important to establish the presence of a defect in comprehension of accelerated speech in the aphasic population. If accelerated speech is found to impede aphasic performance, there are implications for aphasic management whether or not the impairment is specific to aphasia. However, any deterioration of aphasic performance with increased rate that may be found in this study cannot be interpreted as evidence for localizing an area of the cortex as one particularly involved in the processing of accelerated speech. Rather, one must interpret such results as evidence for the desirability of comparing aphasics with other brain damaged populations on the tasks involved.

2.4.3. RATE AND AGE

Sticht and Gray (1969) found a significant interaction between age of subject and amount of compression on an intelligibility test, with aged subjects deteriorating progressively more than young subjects when compression increases. Bocca and Calearo (1963) also report a decrease in the intelligibility of compressed sentences as age increases. In the above two studies, compression was electromechanical. Bergman (1970) administered the CHABA lists of sentences to subjects of different age groups at 1[illegible] and 300 words per minute. Acceleration was achieved by the speaker who made the recording simply speaking more rapidly. Bergman's unpublished results seem to indicate an interaction between age and rate. DiCarlo (1970) reported decreased intelligibility scores when words were compressed for elderly subjects with hearing losses consistant with age.

Luterman, Welsh and Melrose (1966) presented CID W-22 lists that were compressed and expanded by 10% and 20% to young normals, young hard of hearing subjects with sensori-neural losses, and aged subjects. Both expansion and compression increased error rate but there was no interaction between age and rate. The amount of compression used here was small compared to that used in similar experiments. For example, Sticht and Gray (1969) used compressions of 36%, 46% and 59%.

Since aphasics tend to be older than many of the subjects used in experiments establishing normal performance reviewed above, the inclusion of a control group matched for age to the aphasic group seemed warranted in the present study.

2.4.4. RATE AND EDUCATION AND INTELLIGENCE

Some studies which attempted to correlate intelligence or mental aptitude of adults with ability to respond to accelerated speech show that the higher the intelligence or aptitude, the greater the magnitude of decline in listening comprehension with increased rate (Foulke and Sticht, 1969; Fairbanks, 1957). It was felt that this relationship might be a result of the more intelligent subjects achieving higher scores at normal rates and, therefore, having a larger range in which to vary. Sticht (1968) found that his lower aptitude subjects were not able to discriminate time compressed words as well as his higher aptitude subjects.

It is believed, by the present writer, that enough is unknown in this area to warrant matching the control group and aphasic group for educational level in order to obtain at least gross matching of premorbid intelligence.

2.4.5. RATE AND SENSORI-NEURAL HEARING LOSS

The literature indicates no interaction between sensori-neural hearing loss and ability to respond to time-altered speech stimuli (Bocca and Calearo, 1963; Luterman, Welsh and Melrose, 1966; Sticht and Gray, 1969). Therefore, this was not a variable that it was felt necessary to control.

2.4.6. RATE AND APHASIA

There have been some attempts to investigate the effect of expanded speech on aphasic comprehension. Edwards (1969) told aphasic subjects a story and asked them questions about it under normal conditions and under conditions where 150 milliseconds of silence were interspersed around every consonantal sound. Aphasics demonstrated a striking improvement in comprehension under the conditions where the silence was interspersed. Results were so good that tester bias was suspected. No results have been published and the study is being replicated.

Dopheide (1968) used the Eltro Tempo Regulator, the same apparatus used in the present experiment, to expand words. He presented aphasics with a word recognition task and an auditory retention task using words that were expanded to 125%, 150%, and 175% (with original duration set at 100%). Subjects pointed to a picture (recognition task) or a series of pictures (retention task). Each subject was tested on three occassions. At each session he received, for the word recognition task, 25 words at each speed, with all words of a given speed occurring successively. He also received five or six pairs of retention items. Each pair was made up of two items of a given duration (amount of expansion) and a given number of words. All subjects were aphasic and they were divided into a High auditory language disturbance group and a Low auditory language disturbance group.

No significant effect for duration was obtained. There was some interaction between group and duration on the recognition, but not on the retention, task. The interaction appeared to be generated by the High auditory language disturbance group and led the author to conclude that ". . . the possibility exists that aphasic adults with poor auditory language function might profit from increases in the duration of words in terms of being better able to recognize the meaning of the words" (p. 117).

It must be noted that the High auditory disturbance group was significantly older than the other group. This may have affected the results since the literature reviewed above indicates that there is an interaction between effect of rate and age (see pp. 19-20).

Dopheide's sessions lasted from thirty to sixty minutes. The present writer feels that a session of such length could tire the patient, causing changes in performance ability within a session. If such was the case, even with randomization of treatments within a session, experimental effects, if small, might be obliterated by subject variation, particularly on the recognition task where 25 items of a given duration were presented before proceeding to the next expansion level. It is for this reason that the present study employs the use of shorter experimental sessions and switches rate of presentation after every two items within a session.

DiCarlo (1970) reported that, in an intelligibility testing procedure that utilized compressed, expanded, and normal PB words, aphasics performed like elderly subjects with sensori-neural hearing losses consistent with age. Both these groups showed equal deterioration in the compressed condition and no differences between the normal and expanded conditions. His study is not directly comparable to the present one since it attempted to measure intelligibility, and the present study attempts to measure comprehension.

Thompson (1969) studied the effect of both compression and expansion of speech on the comprehension of aphasic children. The children listened to sentences presented at rates 60% (fastest), 80%, 100%, 140%, and 180% (slowest) of normal and pointed to appropriate pictures. Subjects did quite well on all conditions, and there were no significant differences between conditions. A significant difference between the two compressed rates and the moderately expanded rate was found for the youngest children. This was felt to indicate that expansion might be beneficial for this group.

The stimuli appeared easy for the subjects. If materials are such as to produce good performance under the most difficult condition, one would expect equal performance under all conditions. For this reason, an attempt was made, in the present study, to select materials with a range of difficulty varied enough for performance variation among conditions in subjects with different degrees of severity of aphasic involvement.

2.5. THE TOKEN TEST

The stimuli used in this study were modified from the Token Test as developed by De Renzi and Vignolo (1962). The test was originally developed to detect minimal auditory disorders in aphasics. It uses no special apparatus, simply twenty tokens utilizing combinations of two shapes (rectangle and circle), two sizes (large and small), and five colors (red, white, blue, green, and yellow). The test is in the form of spoken commands that are (1) short enough to be memorized by normal adults, (2) intellectually simple, i.e., not containing words or concepts that a subject would not understand because of low education level or limited intellectual ability within normal limits, and (3) linguistically complex in terms of lack of redundancy.

The test consists of five parts. Part I consists of ten items of the form "Pick up the yellow rectangle." Part II consists of ten items of the form "Pick up the small white rectangle." Part III consists of ten items of the form "Take the red circle and the green rectangle," and Part IV consists of ten items of the form "Take the large white circle and the large green rectangle." Part V consists of twenty-one commands that are different from those in the other parts in that new grammatical elements, such as prepositions and adverbs, are added. Such commands appear as "Put the blue circle under the white rectangle," and "Touch the rectangles slowly and the circles quickly." The five subparts of the test are said to progressively increase in difficulty. They determine the level of difficulty variable in the present study.

The Token Test is considered to be a test that only examines verbal understanding (Orgass and Poeck, 1966). However, it reveals impairment in aphasics who were previously diagnosed as having only expressive losses (De Renzi and Vignolo, 1962) and in left hemisphere brain damaged patients who were not previously diagnosed as aphasic (Boller, 1968). Right hemisphere brain damaged subjects were not found to be impaired. There is a correlation between overall severity of aphasic loss and test score rather than one between type of aphasia and test score (Orgass and Poeck, 1966). The test, or modifications of it, has been found to reliably differentiate aphasics from nonaphasics when presented (to native speakers of the given language) in Italian (De Renzi and Vignolo, 1962), German (Orgass and Poeck, 1966), and English (Spellacy and Spreen, 1969).

Swisher and Sarno (1969) found that their normal controls and non-aphasic brain damaged subjects did not do as well as the other control

Figure 2.1. Token display used for the Token Test by De Renzi and Vignolo (1962)

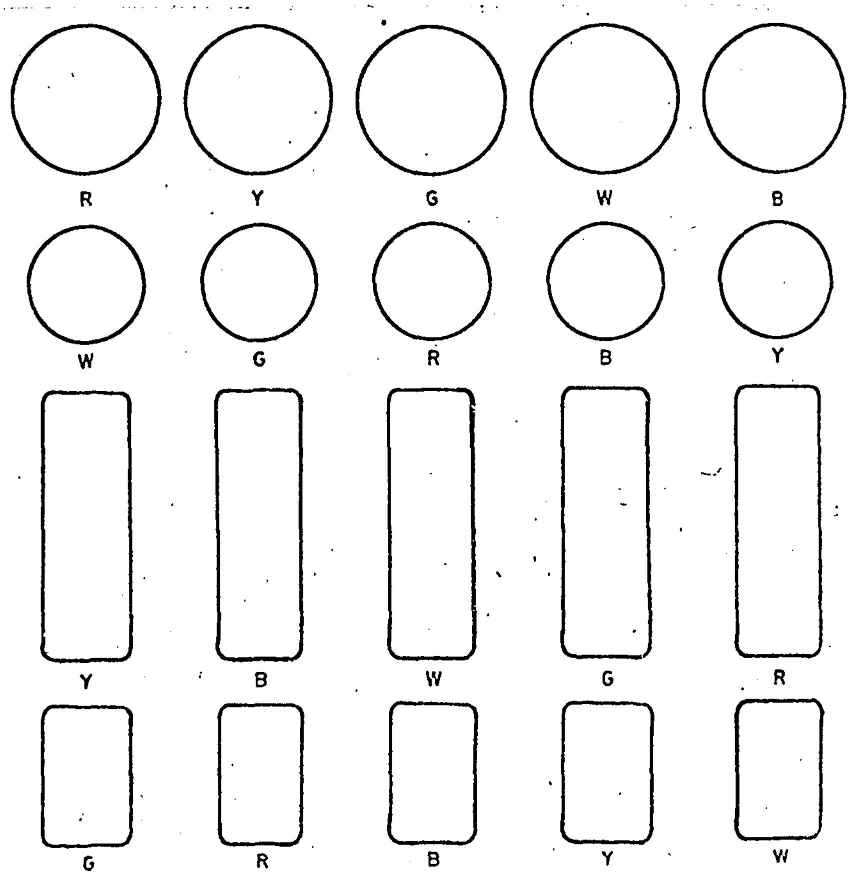


FIG. 1.—R=red, B=blue, G=green, Y=yellow, W=white. Colours are distributed entirely at random.

groups reported in the literature and were not as clearly distinguishable from their aphasics. This may have resulted from the manner in which their stimuli were displayed. De Renzi and Vignolo (1962) display their stimuli as in Figure 1.1, p. 25 for Parts II and IV and remove the small tokens for Parts I, III, and V. As can be seen, each row is restricted to tokens of the same size and shape. Swisher and Sarno used an unsystematic array in which each row was not limited to stimuli of the same size and shape, and all tokens were present throughout the test.

Performance on the Token Test is not correlated with age or sex and is only correlated with education level to the extent that subjects with completed secondary education make fewer errors than those without completed secondary education (Orgass and Poeck, 1966).

Stimuli based upon the Token Test seemed ideal for the present research. The literature seemed to indicate that subjects with mild and minimal impairments would make errors on the more difficult parts of the test. Thus, subjects who could easily understand directions and the nature of the task could be used. Subjects with moderately severe impairments who could understand the necessary directions could also be used because they could be expected to have some success with the easier parts of the test.

It is interesting to note that the abilities tested in both the Token Test and in auditory sequencing tasks appear to be receptive ones. However, for both, patients classified as receptive aphasics do not appear to perform more poorly than those classified as expressive aphasics. Performance on the Token Test gives additional evidence for viewing aphasia as a unitary disorder.

2.6. SUMMARY OF CHAPTER 2

Literature is reviewed that establishes that aphasics have difficulty ordering two tones in time (sequencing) and in performing some related tasks. Rate of stimulus presentation may be viewed as the independent variable in the research reviewed.

The effects of compression and expansion of speech stimuli on comprehension and intelligibility are reviewed. Normal subjects show only slight changes in comprehension of spoken material when speech is compressed to a rate of 275 words per minute. Intelligibility scores are generally better than comprehension scores.

Brain damaged subjects have poorer articulation scores in response to sentences that have been accelerated than to those which have not. This necessitates caution in interpreting results of the present study.

There is an interaction between age and effect of compression that seemed sufficient to warrant the use of a nonaphasic control group matched to the aphasic group for age. There seemed to be enough unknown about the interaction between intelligence and educational level and the effect of compression to warrant matching the control group to the aphasic group on the variable of premorbid educational achievement as well.

The intelligibility scores of aphasics are depressed in response to compressed speech. Some unpublished research indicates that expanding speech stimuli may improve the auditory comprehension of the aphasic. Other research, dealing with time-altered speech stimuli, has not shown significant effects for aphasics as a group. The present research was designed to eliminate factors that might have contaminated results. Such factors could have been fatigue and intrasession variability. A modified form of the Token Test was selected for use as the auditory stimuli in the hope that it would allow for use of material with a range of difficulty wide enough to produce meaningful scores from subjects with a wide range of abilities.

3. METHODS AND PROCEDURES

3.1. SUBJECTS

Subjects were sixteen adult males with aphasia who served as experimental subjects and sixteen adult normal males who served as controls. Subjects were matched for age and education level. These variables are given in Table 3.1, p. 30. Subjects were included in the aphasic group if they met the following criteria: (1) they had a history of right hemiplegia, (2) they were judged, by a qualified speech pathologist with a Certificate of Clinical Competence (as issued by the American Speech and Hearing Association), to evidence even minimal language deficit, whether or not this deficit appeared evident in formal testing procedures, and (3) they could be expected to follow the necessary directions. Subjects were screened for gross color vision defects. The aphasic group included patients with traumatic lesions as well as vascular lesions. Time since onset of the illness associated with aphasia varied from two months to three years and is further specified in Table 3.1, p. 30. Since all testing was done within a short period of time, ranging from two to five days, complete stabilization of aphasic symptoms was not deemed necessary. Therefore, subjects who may not have completed the period of spontaneous recovery were included.

Subjects were included in the control group providing they (1) met the age and educational requirements that allowed them to be matched to the aphasic group for these variables, (2) had no known history of brain damage and (3) had no color vision deficits that would interfere with

Table 3.1. Age, education, and time since onset of illness of subjects.

Group		Age	Grades Completed	Months since onset of illness
	Range	20-80	6-14	2-36
Aphasic	Mean	53	10	10.1
	S.D.	15.4	2.6	11.1
	Range	20-76	5-14	
Normal	Mean	55	10	
	S.D.	13.5	2.7	

performance.

Before the actual test stimuli were presented, a color matching task was administered to the aphasic subjects in order to rule out color vision deficit and observe general ability to follow directions. A circle of each color formed the stimulus array before each subject. The following instructions were given:

> Here are five circles of five different colors. I am holding five more. When I give one to you, I want you to put it by the circle of the same color. That is, put the yellow one by the yellow one, like this. Put the blue one by the blue one, like this. Now you do it. /Subjects were given one circle at a time to match./

All aphasics were able to perform this task accurately.

Control subjects were simply asked if they were color blind. One subject reported difficulty distinguishing the color brown. Another reported that he was once diagnosed as having a minor color vision deficit. Since neither of these subjects made any errors during the entire experimental procedure, their visual problems were considered unimportant, and they were retained as subjects.

3.2. EQUIPMENT

Stimuli were originally recorded on an Ampex Model 300 tape recorder (full track) with a Commercial Radio Sound Corporation consul amplifier and an RCA Model 77-DX microphone. They were then compressed or expanded using an Eltro Rate Changer Model 1024. This piece of equipment alters the time characteristics of a signal without altering its frequency characteristics. It does this by discarding evenly spaced small segments of the signal for an overall reduction of playback time (compression) or by repeating evenly spaced small segments for an overall increase in playback time (expansion) (Allen, 1967).

The time-altered tape was then reproduced four times on an Uher portable tape recorder (half track). After the necessary splicing, which will be discussed in the next section, the stimuli were presented free field to the subjects using the Uher tape recorder and a Lang Electronics Corporation monitor-amplifier.

3.3. STIMULI

Stimuli were spoken commands modified from the Token Test discussed in section 2.5, pp. 23-26. As used here, the test consisted of five subparts, each containing six full sentence commands.

Parts 1 through 4 utilized sentences of the same type as those used by De Renzi and Vignolo (1962) in the first four parts of their test except that the carrier phrase "Point to the . . ." was used instead of "Pick up the. . ." or "Take the . . . ." In published research, the exact form of the carrier phrase varies and does not seem to be an essential part of the test. "Point to the . . ." requires less manipulation on the part of the subject and may, therefore, be more desirable when working with persons with hemiplegia. Use of the phrase "Point to the . . ." allowed for glueing down of the small tokens on a plastic sheet which could be easily removed and replaced by the examiner at appropriate points of the test. Some informal preliminary testing, by the present investigator, indicated that this phrase produced an easily identifiable response.

The word "square" was substituted for the word "rectangle," and the shape of the tokens was changed accordingly. "Square" and "circle" are words that appear to be more equivalent in frequency of occurrence in English than "rectangle" and "circle" (Thorndike and Lorge, 1944). Spellacy and Spreen (1969) made this same substitution in their English modification of the Token Test. Swisher and Sarno (1969) report a normal control subject who did not appear to know the meaning of the word "rectangle" when they administered the test in English.

Part 5 of the present test consisted of the following six commands though not necessarily in this order:

(1) Put the white circle in back of the yellow square.
(2) Put the green square in front of the green circle.
(3) Put the white square in back of the red square.
(4) Put the yellow square on top of the blue circle.
(5) Put the red circle on top of the white square.
(6) Put the blue circle in front of the yellow circle.

These were developed so that all six would have the same form and number of words. In addition, De Renzi and Vignolo (1962) report that prepositions indicating spatial relationships between objects were particularly difficult for aphasics. Since several aphasic subjects had only minimal deficits, it was hoped that inclusion of these sentences would cause the test to have a level of difficulty sufficient to cause all aphasic subjects to make some errors.

The stimuli were originally recorded in three blocks, each containing two sentences from each subpart of the test. The speaker was well practiced and attempted to maintain an even, normal rate using natural inflection; however, he attempted to eliminate intonation cues that could affect subject performance.

The total number of words spoken was 576. The total elapsed time, not counting pauses between sentences, was 192 seconds. This produced a rate of 182 words per minute. Pauses were not counted in total time because they were deliberately made unusually long. This was done for the purpose of maintaining an even rate and for ease of future splicing. It is estimated that, allowing for normal pauses between sentences, the actual rate was approximately 165-170 words per minute. This falls within the ranges cited as average reading and speaking rate by Foulke and Sticht (1969) and Johnson, Darley and Spriesterbach (1963).

Using the Eltro Rate Changer, one block of sentences was compressed by a nominal 32%. These sentences will be referred to as the Fast rate stimuli ("F" in some tables). A second block was expanded by a nominal 37%, and these sentences will be referred to as the Slow rate stimuli (S). A third block was expanded by a nominal 1% so that all stimuli would be processed on the same equipment. These sentences will be referred to as the Normal rate stimuli (N). The amount of compression and expansion was checked as follows. The total elapsed time (including pauses) of the block, as originally recorded, was timed. This was compared to the total elapsed time of the block as altered. Then, each half of the original and the appropriate altered block was timed separately and compared. The amount of compression and expansion appeared to be reliable ($\pm$ 2%) within a block. Since each block had been recorded twice, there were twice as many sentences altered as were finally used. This was done in case of any error in recording or splicing.

Four tapes were reproduced from the master time-altered tape which, at this point consisted of three blocks of sentences, each at a different rate. These four tapes were cut and spliced so that they each consisted of five subparts as in the Token Test. Each part consisted of six sentences, two at each rate. For each of these four tapes, the order of rates within a part was different. On Tape A, for each subpart of the test, the Normal rate stimuli occurred first, the Fast rate stimuli occurred second, and the Slow rate stimuli third. On Tape B, the order was Normal, Slow, Fast; on Tape C it was Fast, Normal, Slow; and on Tape D it was Fast, Slow, Normal. Detailed specification of stimulus sentences, in the order in which they were presented to the subjects, appears in Table A.1, pp. 76-80.

3.4. CONDUCT OF TEST SESSIONS

Each subject was presented with two tapes, one in which the High rate occurred first in each subpart and one in which it did not. This was done to investigate whether presenting compressed stimuli first, in each subpart, would result in more errors than presenting normal stimuli first.

One normal control subject was presented with both tapes on the same day, one in the morning and the other in the afternoon. Other subjects were presented with the two tapes on two separate days within a week. This separation of presentation was used to prevent excess fatigue on the part of the aphasic subjects. This was not judged to be a factor influencing performances of the control subject tested twice on the same day.

Two subjects from each group (aphasic and normal) were presented with each of the following pairs of tapes: AC, CA, BD, DB, AD, DA, BC, CB. As used here, "AC" refers to the conditions where the subject was presented with Tape A on the first testing occasion and Tape C on the second. Other letter combinations were used accordingly. With this stimulus assignment, half of the subjects in each group received an order starting with Normal rate on the first testing occasion ahd half received an order starting with Fast on the first testing occasion. On each day of testing, the following directions, accompanied by appropriate recorded demonstration sentences, were presented:

> Here are some circles and some squares. Some are large and some are small. Listen to the voice that comes from the machines. Sometimes it will tell you to point to one of the circles or squares, like this. Sometimes it will tell you to point to two of them, like this. As you can see, sometimes we use just the large ones and sometimes both the

large and small ones. Sometimes the voice will tell you to move them around in other ways, like this. Sometimes the voice will speak naturally, like this. Sometimes it will speak very quickly, like this. Sometimes it will speak very slowly, like this. You are to do just what it says. But first, let us try some that I say.

The recorded demonstration sentences, accompanying the directions above, were of the same types and rates as those in the actual test but were not identical to any of the test sentences. The actual instructions were spoken, live, by the examiner. Following the instructions, five sentences, one of each type used in the test, were administered, live, by the examiner. For these sentences, if the subject's response was inaccurate, the examiner repeated the sentence while performing the correct response, and the subject imitated the correct response.

During the actual test procedure, the examiner commented as follows:

Before Part 1: "Now you will be asked to point to one of them."

Before Part 2: "Now there are large ones and small ones."

Before Part 3: "Now you will be asked to point to two of them."

Before Part 4: "Now there are large ones and small ones again."

Before Part 5: "Now you will be asked to do other things. You will be asked to move them around."

The examiner did not comment as to the correctness of the responses during the testing procedure.

During the experimental session, the arrangement of circles and squares remained constant except the small tokens were only presented in those parts of the test that required a differentiation between large and small. For Parts 1, 3, and 5, the tokens were arranged as in Figure 3.1, p. 37. For Parts 2 and 4, they were arranged as in Figure 3.2, p. 38.

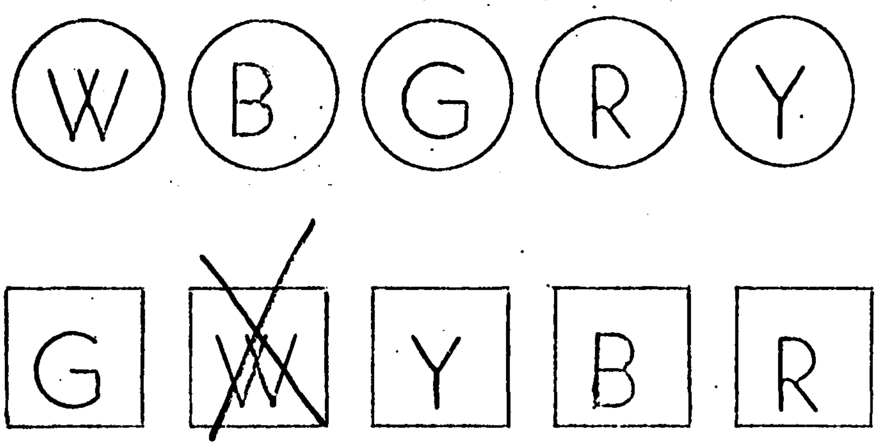
Subjects were allowed to self-correct or change their responses. Their final choice was scored. Subjects were not forced to respond to

Figure 3.1. Token array for Parts 1, 3, and 5 and sample data sheet for Normal -- Part 1.

Subject______________________________

Order____________________ Normal 1

Point to the white square.



Point to the yellow circle.

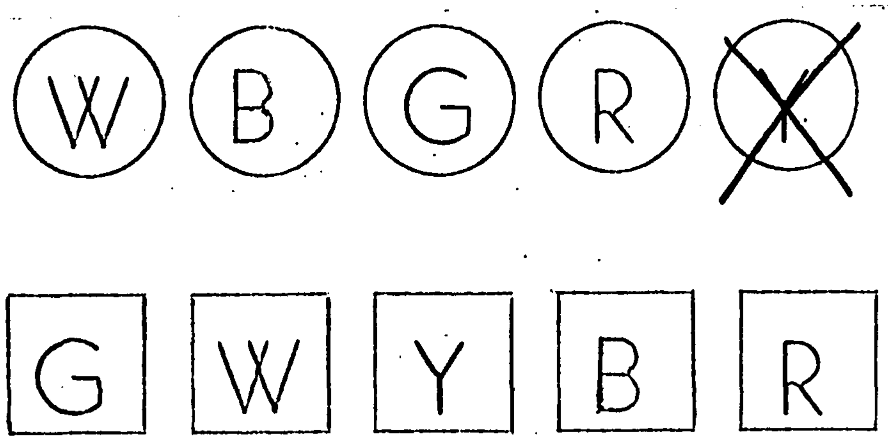
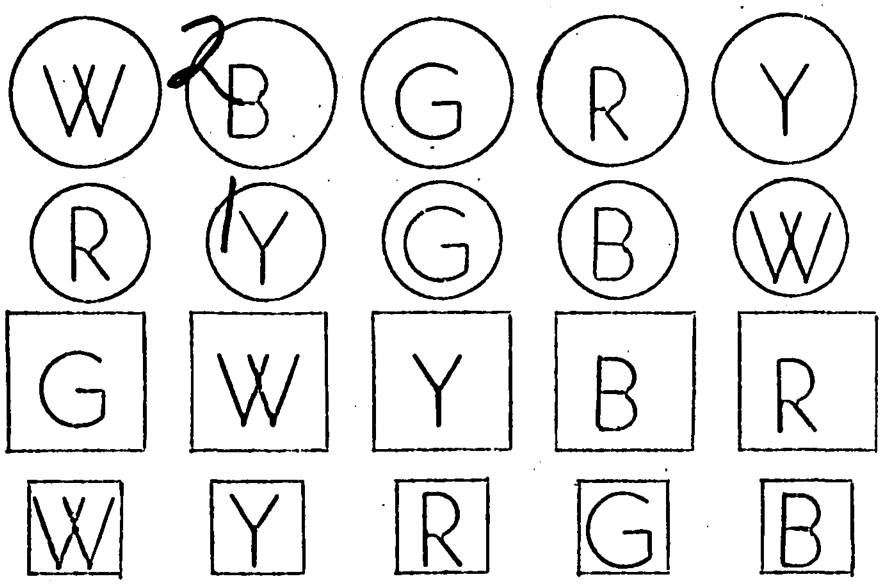


Figure 3.2. Token array for Parts 2 and 4 and sample data sheet for Fast -- Part 4.

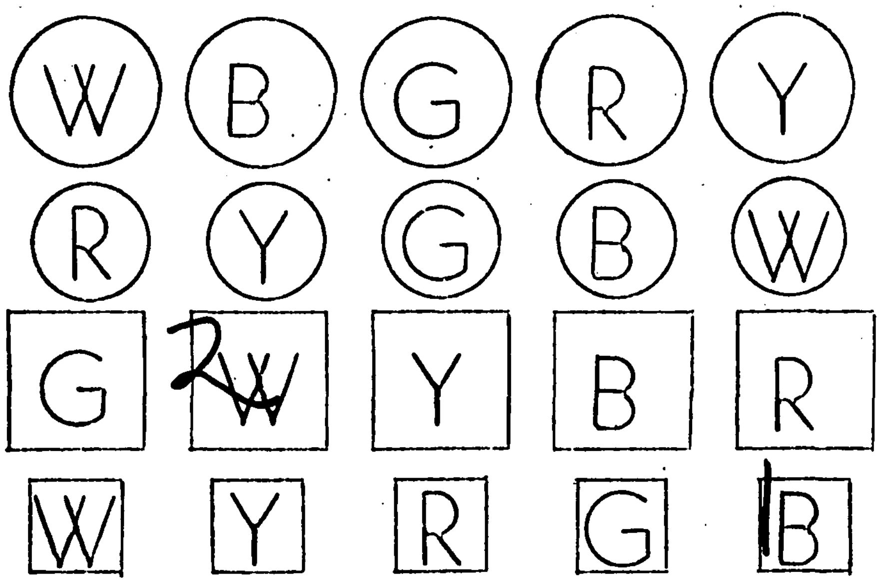
Subject______________________________

Order___________________ Fast 4

Point to the small yellow circle and the large blue circle.



Point to the small blue square and the large white square.



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a sentence. It was evident that all subjects understood when they were supposed to respond.

3.5. DATA ACQUISITION

Responses were recorded on sheets of paper that depicted the allignment of tokens. The examiner indicated subject performance by either drawing a line through the circle or square to which the subject pointed (Parts 1 and 2), numbering the two items to which the subject pointed (Parts 3 and 4), or drawing an arrow from a token to the place where it was moved (Part 5). Figure 3.1, p. 37 and Figure 3.2, p. 38 are sample data sheets which depict the manner in which responses were recorded.

Scoring was done according to the system described by Orgass and Poeck (1966) in which one point was given for each substantive word to which the subject responded appropriately. "Point to the" was not scored since it was a constant in Parts 1 through 4.

For Part 1, the subject could receive 0, 1, or 2 points per command. For example, for the sentence "Point to the white circle," if the response was correct the subject received 2 points. If the color was correct and the shape incorrect, he received 1 point. If the shape was correct and the color incorrect, he also received 1 point. If neither shape nor color were correct, he received no credit.

For Part 2, the subject could receive 0 through 3 points per command, for Part 3, he could receive 0 through 4 points, and for Part 4 he could receive 0 through 6 points. For Part 5, the required manipulation was considered as one substantive item, and the subject could receive 0 through 5 points. If the manipulation was performed backward, i.e., the second token moved in relation to the first, the subject received partial credit. One point was scored for the correct manipulation, and half credit was assigned to color and shape responses.

Part 5 was particularly difficult to score because subjects, both aphasic and normal, differed in what they considered "in front of" and "in back of." Sometimes a subject changed his decision during the procedure. This was quite clear for the normal subjects as they verbalized their decisions. In the case of the aphasics, whenever there was doubt, the subject was given credit for a correct response. For this reason, scores for aphasic subjects for Part 5 may be somewhat higher than they should be.

3.6. ANALYSIS OF DATA

3.6.1. NORMAL SUBJECTS

An examination of the data indicated the normal control subjects made so few errors that formal analysis of their performance would be meaningless. Only the data generated by the aphasic group was analyzed.

3.6.2. APHASIC SUBJECTS

For the purpose of analysis, data from the two days of testing were combined, for each subject, except when the effect of order was analyzed. For the data as a whole, and particularly for some of the subparts, the data were seriously truncated rather than normally distributed or merely skewed. This was evidenced by the fact that some subjects scored 100% on all conditions. The use of normal statistics in such a case would be questionable. Thus, nonparametric statistics were used throughout.

3.6.2.1. Rate Effect -- Aphasic Subjects

The effect of rate was analyzed using a Friedman Two Way Analysis of Variance by Ranks (Siegel, 1956) for the total scores (Parts 1 through 5 combined) at each rate. This test was felt to be appropriate since it determines whether there are differences among several conditions. Since this test yielded a significant χ^2 (see chapter 4, p. 45), a Wilcoxon Matched-Pairs Signed-Rank Test (Runyon and Haber, 1967) was then applied to each pair of rates, i.e., Normal vs. Fast, Slow vs. Fast, Normal vs. Slow, to determine where the differences were.

3.6.2.2. Interaction Between Rate and Level of Difficulty

A Friedman Two Way Analysis of Variance by Ranks was performed for each subpart of the test separately, comparing the scores for each rate for the subpart involved. For those subparts where this test yielded a significant χ^2 ($p. < .05$), a Wilcoxon Matched-Pairs Signed-Rank Test was used to compare each pair of rates for that subpart.

3.6.2.3. Interaction Between Rate and Severity of Aphasia

In order to obtain the relationship between the effect of rate and severity of aphasia, it was first necessary to define the two variables involved. Severity of aphasia was defined by the total score the subject achieved on all experimental conditions combined. The Token Test, on which the present task was based, is reported to be a measure of overall severity of aphasia (Orgass and Poeck, 1966). In addition, scores were available for eleven subjects for the Minnesota Test for Differential Diagnosis of Aphasia (Schuell). The scores that these subjects achieved on the auditory and oral sections of the Minnesota Test were correlated with the scores they achieved on the present test. The Spearman Rank Correlation Coefficient (Siegel, 1956) obtained was .873. This was significant with a probability of less than .001 ($p. < .001$). The data used to obtain this correlation can be found in Table A.2, p. 81.

For the purpose of this comparison, effect of rate, for each subject, was obtained by dividing the score he achieved for the stimuli presented at the Fast rate (Parts 1 through 5 combined) by the score he achieved for the stimuli presented at the Normal rate. This fraction is abbreviated "Fast/Normal." These two rates were chosen because other analyses of the data demonstrated that the most consistant result of this study was that aphasics obtained lower scores when rate was Fast than when it was Normal (see chapter 4, pp. 47-50).

A Spearman Rank Correlation Coefficient was then obtained using, as the two variables, (1) the subject's score under all experimental conditions combined and (2) the fraction "Fast/Normal." The coefficient obtained determined the interaction between rate and severity of aphasia.

3.6.2.4. Order Effect -- Aphasic Subjects

A Wilcoxon Matched-Pairs Signed-Rank Test was performed to determine whether the order of presentation of rates within a subpart affected performance. As was stated on page 34, for each subpart, subjects heard two sentences at each rate. The order in which the rates could be presented could be as follows:

A -- Normal, Fast, Slow;
B -- Normal, Slow, Fast;
C -- Fast, Normal, Slow;
D -- Fast, Slow, Normal.

Each subject heard two tapes, an A or a B and a C or a D. Each subject's score for the order in which Normal came first (A or B) was compared to his score for the order in which Fast came first (C or D).

3.6.2.5. Significance Levels Reported

Only probabilities smaller than .05 will be reported in chapter 4. If the differences between two conditions occurred with greater probability, the conditions will be reported as equal and/or the difference will be called not significant (N. S.). In the case of the Wilcoxon

Matched-Pairs Signed-Rank Test, the probabilities reported will be the more stringent two-tailed probabilities. For this test, significance levels given by Runyon and Haber (1967, p. 226) are used. These are more conservative than the ones appearing in the text by Siegel (1956) which was used for the rest of the analyses.

3.7. SUMMARY OF CHAPTER 3

Sixteen right hemiplegic adults with aphasia who served as experimental subjects and sixteen normal adults who served as control subjects were matched for age and education level. Both groups were administered a tape recorded, modified form of the Token Test. The test, as used in this research, consisted of five subparts with six sentences in each part. A design goal was that the subparts be of increasing difficulty. Speech rate was altered electromechanically. Within each part, two sentences were left as originally recorded except for a nominal 1% expansion to insure all stimuli being processed on the same equipment. Two sentences were compressed by a nominal 32%, and two sentences expanded by a nominal 37%. An Eltro Rate Changer was used to achieve the compression and expansion. The three rates were known as Normal (N), Fast (F), and Slow (S).

From the master tape, four tapes were reproduced and spliced so that, within each subpart of the test, the three rates could be presented as follows:

A -- Normal, Fast, Slow;
B -- Normal, Slow, Fast;
C -- Fast, Normal, Slow;
D -- Fast, Slow, Normal.

Each subject was tested on two separate occasions and received one of the following combinations of tapes: AC, CA, AD, DA, BC, CB, BD, DB.

The scoring system used was one in which the maximum number of points a subject could achieve, for a given response, depended upon the number of substantive words in the sentence stimulus for that response.

The effect of rate on the scores achieved on the test as a whole and on individual subparts of the test was analyzed using the Friedman Two Way Analysis of Variance by Ranks and the Wilcoxon Matched-Pairs Signed-Rank Test. A Spearman Rank Correlation Coefficient was obtained in order to test the interaction between total test score, as a measure of severity of aphasia, and effect of rate. The effect of order of presentation of experimental conditions (rates), within a sub-part, was analyzed using a Wilcoxon Matched-Pairs Signed-Rank Test.

4. RESULTS AND DISCUSSION

4.1. RESULTS

4.1.1. NORMAL DATA

As noted in chapter 3, examination of the data revealed that the normal adults who served as experimental controls made so few errors in performing the experimental task that formal analysis was meaningless. Those errors that did occur were primarily in response to commands on Parts 4 and 5 and about equally divided between commands presented at the Normal and Fast speaking rates. Only two errors occurred in response to commands on Parts 1 through 3, and only one error occurred in response to the Slow rate. Raw scores for these subjects appear in Table A.3, p. 82.

4.1.2. NORMAL VS. APHASIC SUBJECTS

Examination of the data revealed that the differences in total score between aphasic and normal subjects was so great as to make formal comparison unnecessary. Differences were obviously significant with the aphasics achieving the lower scores. Table 4.1, p. 46 presents total scores and mean scores for each group for the test as a whole and for each subpart of the test.

4.1.3. RATE EFFECT -- APHASIC SUBJECTS

The score that each aphasic subject achieved on the test as a whole (Parts 1 through 5 combined), for each rate, is presented in Table A.4, p. 83. A Friedman Two Way Analysis of Variance by Ranks, performed on these scores, yielded a χ^2 of 11.84; d. f. = 2, p. $<$.01. Therefore, it

Table 4.1. Comparison of scores of aphasic and normal groups -- all rates combined.

	Aphasic Group		Normal Group	
	Total	Mean	Total	Mean
All parts	2913.5	182.1	3815.5	238.4
Part 1	331	20.7	383	23.9
Part 2	480	30	576	36
Part 3	579	36.2	767	47.9
Part 4	824	51.5	1139	71.2
Part 5	699.5	43.7	950.5	59.4

was appropriate to reject the null hypothesis that subjects would exhibit the same accuracy of response for all rates. The null hypothesis that aphasic and normal subjects would show the same changes in accuracy of response as a result of stimulus presentation was also rejected since the normal control subjects did not exhibit such a rate effect.

Applying a Wilcoxon Matched-Pairs Signed-Rank Test to scores for each pair of rates yielded the following:

Normal $>$ Fast (p. $<$ .01).
Slow $>$ Fast (p. $<$ .01).
Slow = Normal.

Details of the results reported in this section appear in Tables 4.2 and 4.3, pp. 48 and 49.

It is to be understood that "Normal $>$ Fast" is an abbreviation indicating that the scores obtained in response to stimuli presented at the Normal rate were higher than those obtained in response to the Fast rate. Other such abbreviations are used accordingly.

4.1.4. INTERACTION BETWEEN RATE AND LEVEL OF DIFFICULTY -- APHASIC SUBJECTS

The raw scores achieved by each aphasic, for each rate, on each of the five subparts of the test, appear in Table A.5, p. 84. A Friedman Two Way Analysis of Variance by Ranks was used to compare scores for each rate, for each of these five subparts, with the following results:

Part 1 -- no significant differences (Normal = Fast = Slow).
Part 2 -- no significant differences.
Part 3 -- χ^2 = 6.78, d. f. = 2, p. $<$ .05.
Part 4 -- χ^2 = 9.13, d. f. = 2, p. $<$ .02.
Part 5 -- χ^2 = 8.84, d. f. = 2, p. $<$ .02.

Thus, it was possible to reject the null hypothesis that there would be no interaction between level of stimulus difficulty and rate of stimulus presentation for the aphasic group.

Table 4.2. Results of Friedman Two Way Analysis of Variance by Ranks comparing scores at the three rates -- aphasic subjects.

	χ^2	d.f.	p.
All parts combined	11.84	2	$<.01$
Part 1	.28	2	N.S.
Part 2	1.00	2	N.S.
Part 3	6.78	2	$<.05$
Part 4	9.13	2	$<.02$
Part 5	8.84	2	$<.02$

Table 4.3. Results of Wilcoxen Matched-Pairs Signed-Rank Tests comparing pairs of rates -- aphasic subjects.

		T	N	p.	direction of difference
All parts combined	Normal vs. Fast	2	14	$<.01$	Normal > Fast
	Slow vs. Fast	1	12	$<.01$	Slow > Fast
	Normal vs. Slow	24	13	N.S.	
Part 3	Normal vs. Fast	0	10	$<.01$	Normal > Fast
	Slow vs. Fast	12	9	N.S.	
	Normal vs. Slow	4	8	N.S.	
Part 4	Normal vs. Fast	15	14	$<.02$	Normal > Fast
	Slow vs. Fast	3.5	12	$<.01$	Slow > Fast
	Normal vs. Slow	12	12	$<.05$	Slow > Normal
Part 5	Normal vs. Fast	7	13	$<.01$	Normal > Fast
	Slow vs. Fast	44.5	13	N.S.	
	Normal vs. Slow	1.5	14	$<.01$	Normal > Slow

A Wilcoxon Matched-Pairs Signed-Rank Test was applied to each pair of rates for Parts 3, 4, and 5 with the following results:

Part 3 -- Normal $>$ Fast ($p. < .01$).
Slow = Fast.
Normal = Slow.

Part 4 -- Normal $>$ Fast ($p. < .02$).
Slow $>$ Fast ($p. < .02$).
Slow $>$ Normal ($p. < .02$).

Part 5 -- Normal $>$ Fast ($p. < .01$).
Slow = Fast.
Normal $>$ Slow ($p. < .01$).

Details of these results can be found in Tables 4.2 and 4.3, pp. 48 and 49.

4.1.5. INTERACTION BETWEEN RATE AND SEVERITY OF APHASIA

A Spearman Rank Correlation Coefficient was obtained comparing each subject's total score with the fraction obtained by dividing his score for the Fast rate stimuli by his score for the Normal rate stimuli. The reason for selecting this method of comparison was discussed in chapter 3, pp. 41-42. The resulting r_s was .714; $n = 14$, $p. < .005$. The data used to obtain this correlation appears in Table 4.4, p. 51. The null hypothesis that there would be no interaction between severity of aphasia and rate of stimulus presentation was rejected.

4.1.6. ORDER EFFECT -- APHASIC SUBJECTS

A Wilcoxon Matched-Pairs Signed-Rank Test was used to treat scores generated by responses to the two orders of stimulus presentation which each subject heard. In other words, a subject's responses to Tape A or B were compared with his responses to Tape C or D (see p. 35 for details as to how tapes were assigned to subjects, and Table A.1, pp. 76-80, for detailed specification of the stimulus materials contained on the tapes). No significant difference was obtained. Thus, it was not possible to re-

Table 4.4. Spearman Rank Correlation between effect of rate and severity of aphasia.

Subject Rank[1]	Fast/Normal[2] (Rank)
1	.767 (2)
2	.834 (4)
3	.974 (13)
4	.879 (8)
5	.714 (1)
6	.844 (6)
7	.891 (10)
8	.841 (5)
9	.875 (7)
10	.803 (3)
11	.944 (12)
12	.909 (11)
13	.887 (9)
14	1.013 (16)
15	1.000 (14.5)
16	1.000 (14.5)

Results

$r_s = .714$

p. $< .005$

[1]Subjects ranked in order of total score under all experimental conditions; the subject with the lowest score ranked "1."

[2]Score for Fast rate stimuli divided by score for Normal rate stimuli.

Table 4.5. Wilcoxon Matched-Pairs Signed-Rank Test of the effect of order of presentation of rates within a subpart -- aphasic subjects.

S[1]	Score on Tape A or B	Score on Tape C or D
1	78.5	67.5
2	97	98
3	51	34.5
4	98	106
5	68	76
6	114	106
7	91	92
8	51.5	50
9	117	116
10	101	90
11	120	120
12	94	90
13	60	55.5
14	115	117
15	96.5	110
16	120	120

Results

$T = 40$

$N = 14$

$p. > .05$ (N.S.)

[1]Subjects are listed in the order in which they were tested.

ject the null hypothesis that the order in which the rates of stimulus presentation are experienced, within a given level of stimulus difficulty, will not differentially affect accuracy of response. Data used for this comparison appear in Table 4.5, p. 52.

4.2. DISCUSSION

The discussion that follows will be divided into three major areas. First, the effect of compression of speech stimuli will be discussed. Included will be the interaction between level of stimulus difficulty and effect of compression. Second, the effect of expansion will be discussed. Finally, the problems encountered with Part 5 of the test will be considered. The nonsignificant effect of order and the significant interaction between severity and rate will be discussed only in relation to the three main topics above.

4.2.1. THE EFFECT OF COMPRESSION

The relationship between Fast and Normal rates was a rather consistent one. Subjects' scores were lower in response to stimuli presented at the Fast rate than to those presented at the Normal rate for Parts 3, 4, and 5, and for the test as a whole. For no subparts were scores lower in response to Normal stimuli than to Fast stimuli with a difference that reached statistical significance. It would appear that, for the stimulus materials used in the present experiment, aphasics are affected by compression in ways that normal subjects are not.

4.2.1.1. The Interaction Between Compression and Level of Difficulty

Looking at the data more closely, the above conclusion must be qualified. There was an interaction between rate and level of difficulty in that there was no effect of compression for Parts 1 and 2 while there was one for Parts 3, 4, and 5, and for the test as a whole. In addition, some subjects with minimal impairment had perfect scores under all conditions. The high correlation obtained when severity of aphasia and the effect of compression were compared (see p. 49) also shows that subjects who experienced little difficulty with the task were less affected by compression than subjects who experienced greater difficulty.

The interaction may have resulted from difficulty of each subpart *per se* (measured by percentage of errors on each subpart), from the length of the sentence, or from the type of response required. Each of these possibilities will now be discussed.

4.2.1.1.1. Level of Difficulty

The data presented in Table 4.6, p. 55, show a progressively increasing proportion of errors occurring from Part 1 to Part 4. It would seem that Part 5 was not as difficult as was expected. This will be discussed separately. The raw scores presented in Tables A.4 and A.5, pp. 83 and 84, show that, as expected, those subjects who scored best on the test as a whole made fewest errors in the earlier (less difficult) parts of the test.

What appears, then, is a situation in which aphasic subjects perform more poorly at the compressed rate used in this experiment than at the Normal rate, in response to materials to which they would also have some difficulty responding at the Normal rate. The literature reviewed by Foulke and Sticht (1969) indicates that, sometimes, normal subjects show slight deterioration in performance on a comprehension task at rates comparable to the Fast rate used here. The tasks involved in the studies reported can be considered more difficult than the one used here. Aphasics, therefore, may be performing in a manner similar to that of normal subjects. Their reduced capacity makes them break down more at

Table 4.6. Percentage correct for each subpart -- aphasic group.

Part	% Correct
1	86
2	83
3	75
4	71
5	73

rapid rates than at normal rates for materials that normal subjects handle with little difficulty. Normal subjects may exhibit the same effect, at the same rate, with more difficult materials, or they may exhibit it at a more rapid rate with the same materials.

4.2.1.1.2. Stimulus Length

The second interpretation of the interaction between rate and level of stimulus difficulty grows from the fact that the sentences in the earlier part of the test were shorter than those in the later part. It is possible that sentence length must be sufficiently long for rapid rate to adversely affect aphasic performance. Examination of the error pattern of those subjects who did make many errors on Parts 1 and 2 gives some support to this belief. Those subjects did not seem to exhibit a rate effect for Parts 1 and 2 despite their many errors. It is possible, of course, that increasing the rate to one faster than that used in this experiment might be accompanied by a further increase in errors. DiCarlo (1970) found a rate effect for single word stimuli, but he was measuring intelligibility. His results, therefore, are not directly comparable to those of the present study.

4.2.1.1.3. Motoric Complexity

A final interpretation of the interaction between rate and level of difficulty is related to the type of response required. For Parts 1 and 2, subjects had to make only one pointing response, as opposed to two pointing responses in Parts 3 and 4. In Part 5, a manipulation of one token with respect to another was required. It is possible that, for rate of stimulus presentation to affect performance on a task, the task must be of sufficient motoric complexity.

4.2.1.2. <u>Summary of the Effect of Compression</u>

The results of this experiment lend credence to the belief that aphasics have difficulty responding to certain stimuli presented at a rate more rapid than normal. Therefore, the results leave open the possibility, suggested in chapter 1, that this involves an ability dependent upon the intactness of the dominant cerebral hemisphere which is presumed to be damaged when aphasia is present.

4.2.2. THE EFFECT OF EXPANSION

The effects of expanding the sentences appeared contradictory and inconclusive. It will be recalled that the following results were obtained from analysis of the data generated by the aphasic subjects (see Table 4.3, p. 49):

For the data as a whole -- Normal = Slow.
For Part 3 -- Normal = Slow.
For Part 4 -- Slow > Normal.
For Part 5 -- Normal > Slow.

4.2.2.1. <u>Explanation of the Effects of Expansion</u>

There are several possible explanations for these findings. They involve factors such as (1) guessing biases, (2) lengthened time between halves of a multiple command, (3) actual elapsed time of the expanded sentence, (4) electromechanical distortion, and (5) order of presentation of rates. Each of these will be discussed in turn.

4.2.2.1.1. Guessing Biases

The most probable explanation for the variety of relationships between the scores for the Slow sentences and the scores for the Normal sentences has to do with subject bias in guessing. Observation of the actual responses and examination of the data indicated that, at least for the first part of a command, subjects who guessed tended to point to a token in the top row (the row furthest from the subject). This row consisted of large circles. On Part 4, both Slow sentences required that the first response be to a large circle. This was not true for both commands at the other rates. Scores for the Slow rate could have been artificially elevated for this subpart because the Slow commands required a response that was congruent with guessing bias.

It was also noted that, on Part 5, subjects, when guessing, would move a circle toward a square. Neither Slow sentence ("Put the yellow square on top of the blue circle," "Put the white square in back of the red square") demanded this. One Fast sentence ("Put the white circle in back of the yellow square") and one Normal sentence ("Put the red circle on top of the white square") did so. This could have caused an artificial lowering of Slow rate scores for Part 5.

It was felt that the relationship between Normal and Fast was too stable to be seriously affected by such guessing biases. Scores for the Fast rate sentences were equal to or lower than scores for the Normal rate sentences for all subparts. Prediction on the basis of observed guessing bias might lead one to predict higher scores for Fast rate sentences than for Normal rate sentences on Part 3. This did not occur. However, these biases must be kept in mind when interpreting all results of this study.

4.2.2.1.2. Time Between Halves of a Multiple Command

An explanation which might account for improved Part 4 performance with Slow stimuli lies in the lengthened time between the two halves of the command. It was noticed that, under this stimulus condition, some aphasics completed the first half of the command before the second half was fully presented. For example, for the command "Point to the large white circle and the large green square," some subjects would make their first pointing response after the word "circle" and the second at the end of the sentence. This type of responding decreased the subject's memory load and may have caused elevation of score. It is understandable that subjects did not respond in this manner to the expanded stimuli on Part 5 since the sentences could be conceived of as a single command. It is not so clear why no such behavior was noted in response to the expanded stimuli on Part 3. Perhaps the subject did not interpret the task to be difficult enough to necessitate this type of performance. Or, perhaps, these being shorter commands, enough time had not yet elapsed for processing of the first substantive word of the sentence by the time the first half of the command was completed. The word "processing," as used here and throughout this chapter, should be understood as designating a construct referring to all activity that must take place between the time the stimulus reaches the cortex and the time that effective action can be taken with relation to the stimulus. The actual motoric aspects of the action, such as pointing, are not included.

The belief that the aphasic may need more processing time than the normal subject is supported by a related informal observation. Not only did some normal subjects respond after the first half of the command to the Slow stimuli on Part 4, some of them responded after the first half of the Normal stimuli on Part 4. No aphasic did this. This could be interpreted as indicating that, although some normal subjects could process the first half of the normally presented command rapidly enough to respond in this way, aphasic subjects required the longer time afforded by the Slow stimuli.

It should be emphasized that this interpretation is based solely on a few informal observations of subject behavior. The experiment was in no way designed to measure the variables that might be involved. The only related measure obtained was total elapsed time during the scored part of the experimental session. The aphasics, as a group, used more time than the normals, as a group, but there was no way of determining whether this was due to processing time or to such factors as necessity of responding with the previously unpreferred hand or a weakened hand.

4.2.2.1.3. Elapsed Time of Expanded Sentences

Another possible explanation for the fact that, except for Part 4, expanded stimuli did not improve performance may lie in the fact that the expanded sentences took more time. The subjects had to remember parts of these sentences for a longer period of time than comparable parts of Normal sentences. This seems an unlikely explanation of performance because examination of the data shows no tendency toward poorer performance in response to earlier parts of a command. In fact, the earlier parts of commands appeared, in general, more accurately performed. It is possible to conceive of early parts of a command as both easier, because of longer available processing time, and more difficult, because of longer memory time requirements. If such an interaction occurs, it may cancel any effects of expanding stimuli.

4.2.2.1.4. Electromechanical Distortion

The next possible explanation for the failure of the aphasic subject to demonstrate overall improved comprehension, in response to expanded stimuli, lies in the distortion introduced by electromechanical expansion. The Eltro Rate Changer achieves expansion by repeating periodic small segments of the original recording. This introduces a "waver" into the voice. Although intelligibility of the sentences was good, they may have sounded somewhat unpleasant and caused some distraction or inattention.

4.2.2.1.5. Order of Presentation of Rates

A final factor that may be viewed as affecting responses to expanded stimuli is related to order of presentation of rates within a subpart. When the experiment was designed, the effect of Fast occurring first was the factor of interest. Therefore, Slow never occurred first within a subpart as did Fast and Normal. It is possible that scores for Slow would be slightly higher if the Slow rate was sometimes presented first within a subpart.

4.2.2.2. Summary of the Effect of Expansion

Thus, we have a situation where, contrary to clinical reports, expansion of speech stimuli is not found to improve aphasic comprehension except in a response condition which may have been affected by guessing biases. It is not likely that simply increasing the amount of expansion would suffice to improve performance because Dopheide (1968) used much greater amounts of expansion without finding improvement. There is not yet a suitable explanation for this discrepancy between clinical reports and experimental findings. A fruitful avenue of inquiry might be the investigation of the interaction between processing time and memory time.

4.2.3. PROBLEMS ENCOUNTERED WITH PART 5

As was mentioned in chapter 2, it was hoped that Parts 4 and 5 of the task would be sufficiently difficult as to result in some errors for evenly minimally impaired subjects. This was not the case. Two experimental subjects scored perfectly under all conditions, and one other scored as highly as one of the normal control subjects. This could be due to the possibility that Part 5 of the present test was not as difficult as Part 5 of the original Token Test (De Renzi and Vignolo, 1962). The commands chosen for Part 5 of the present test were selected because of De Renzi and Vignolo's report that this type of command was particularly difficult for aphasics. However, aphasic subjects in the present study performed proportionately better on Part 5 than on Part 4. Part of the explanation for this may lie in Part 5 sentences being shorter than Part 4 sentences. Despite this, De Renzi and Vignolo's subjects had more difficulty with these sentences. In their test, this type of sentence occurred along with other sentences which varied in structure and required different types of responses. Thus, the type of stimulus and type of response were not as predictable as in the present test. De Renzi and Vignolo's subjects may be conceived of as having had to handle a greater informational load than did the subjects of the present experiment.

In addition, the higher scores on Part 5, as opposed to Part 4, may be, in part, a result of the difficulties encountered scoring this subpart. Because, as mentioned in chapter 3, it was often difficult to determine what a subject's decision was regarding "front" and "back," credit was given in some cases where it may not have been warranted. This would have caused some false elevation of Part 5 scores.

4.2.3.1. Analysis of the Data Without Part 5

Because of the difficulties presented by Part 5, the data were analyzed excluding the Part 5 data. Results are presented in Table 4.7, p. 63. No differences in significance level were found for the aphasic data as a whole (Parts 1 through 4 inclusive). Analysis of the subpart data was unaffected by the elimination of Part 5. The order effect remained insignificant.

Eliminating the Part 5 changed the correlation between effect of

Table 4.7. Results of analyses without Part 5 data.

Table 4.7.1. Friedman Two Way Analysis of Variance by Ranks for effect of rate -- aphasic group.

	χ^2	d.f.	p.
All parts	12.8	2	$<.01$
Part 1	.28	2	N.S.
Part 2	1.00	2	N.S.
Part 3	6.78	2	$<.05$
Part 4	9.13	2	$<.02$

Table 4.7.2. Wilcoxon Matched-Pairs Signed-Rank Tests comparing pairs of rates.

		T	N	p.	Direction of Difference
All parts	Normal vs. Fast	6	14	$<.01$	Normal > Fast
	Slow vs. Fast	5.5	13	$<.01$	Slow > Fast
	Normal vs. Slow	28	12	N.S.	
Part 3	Normal vs. Fast	0	10	$<.01$	Normal > Fast
	Slow vs. Fast	12	9	N.S.	
	Normal vs. Slow	7*	8	N.S.	
Part 4	Normal vs. Fast	15	14	$<.02$	Normal > Fast
	Slow vs. Fast	3.5	12	$<.02$	Slow > Fast
	Normal vs. Slow	11.5*	12	$<.05$	Slow > Normal

*One subject made errors he would not have made were Part 5 not included in the test. He was re-scored for this analysis. This accounts for slight differences from Table 4.2, where they would not be expected.

Table 4.7.3. Spearman Rank Correlation between effect of rate and severity of aphasia.

$r_s = .415$ $n = 14$ $p. > .05$ (N.S.)

Table 4.7.4. Wilcoxon Matched-Pairs Signed-Rank Test for effect of order of rates within a subpart.

$T = 37.5$ $N = 14$ $p. > .05$ (N.S.)

rate and severity of aphasia. The coefficient obtained was no longer significant. A closer examination of the data revealed the following;

The original correlation resulted from a lesser rate effect for the mildly impaired subjects than for the other subjects. The data without Part 5 revealed that both the mildest and the most severe subjects now showed less of a rate effect than those in between. The change may have resulted from the greater number of errors made by the severely impaired subjects than by the other subjects on Parts 1 and 2. Eliminating Part 5 increases the importance of Parts 1 and 2 since they now form a greater part of the total test. As previously noted (see p. 56) it does not appear sufficient for stimuli to be difficult for the subject for a rate effect to occur. They must be sufficiently long or, perhaps, motorically complex as well. The more severly impaired subjects, who make errors in response to comparatively short stimuli, show a decreased rate effect as the contribution of the shorter sentences (Parts 1 and 2) becomes greater.

4.3. CONCLUSIONS

The aphasic subjects demonstrated decreased comprehension scores on the test sentences of this study when those sentences were time-compressed by 32%, providing the sentences were long enough and the subject's deficit was severe unough to cause him to have some difficulty with similar sentences under normal conditions. Motoric complexity of the required response may have been another, or substitutable, condition necessary for the emergence of such a rate effect.

The aphasics did not demonstrate consistently higher comprehension scores with expanded stimuli. It is reasonable to believe that they may exhibit this in a situation which increases processing time while decreasing memory load. Such a situation was the stimulus condition afforded by Slow-Part 4 wherein subjects were able to respond after the first half of a slow command.

4.3.1. CLINICAL IMPLICATIONS OF CONCLUSIONS

It may be helpful to train aphasics to respond to rapid sentences since these may be presented by his environment. Kelly and Steer (1949) report that some individuals normally speak at rates faster than the Fast rate used in the present experiment. It is certainly feasible to create a series of Language Master cards in which a sentence is spoken at progressively more rapid rates. The Language Master is a piece of equipment which allows the subject to hear a recorded speech stimulus while observing a card with a picture and/or written representation of the stimulus.

Although expansion of stimuli was not generally helpful to the aphasics who served as subjects in this research, a stimulus situation such as that afforded by Slow-Part 4 may be useful in initial training of responses to multiple commands. The command would be presented as a single sentence, but with enough time, at critical points, for the subject to execute each element of the command as it occurs.

4.3.2. THEORETICAL IMPLICATIONS OF CONCLUSIONS

It is possible that the areas of the brain that are damaged when aphasia is present are the same areas that determine the speed with which we can process incoming auditory stimuli. The areas damaged in aphasics certainly seem to be those necessary (not sufficient) for language function in its most general sense. If cerebral damage of the type that occurs in aphasia also slows down processing time, it is possible that language skill can be conceived of as dependent upon a critical speed of processing and that the aphasic deficit can be conceived of, not as a loss of words or associations as it was conceived of in the nineteenth century or as a loss of symbolization, as proposed by Head (1926), but rather as a failure to process rapidly enough to make adequate language skills possible.

The limitations placed on the above theory regarding processing are serious and must be considered. First, the rate effect, though present, is small. Second, it is not yet known whether the decrease in comprehension accompanying Fast rate is aphasia specific or whether it occurs about equally in the whole of the brain damaged population. "Auditory comprehension" is a construct. What was measured here was accuracy of a nonverbal response. "Processing" is also a construct which was not directly measured. Any statements about localization of function within the brain are made with the understanding that the localization of language and the localization of damage accompanying aphasia are not synonymous nor are either indisputable at the present time.

The ideas presented in this section differ to some extent from the ideas of Hirsh and of Lenneberg referred to in chapter 1. As stated, their ideas form part of the theoretical background for this study. These writers believe that language involves the sequencing of events. Lenneberg (1967) seems to see aphasia as representing a difficulty in sequencing events. What the present writer is discussing is an ability to rapidly process events with the construct "process" referring to many possible activities. A deficit in temporal sequencing is here viewed as <u>one example</u> of a deficit in rapid processing rather than the only example of such. Such a view helps make understandable the reported result that a deficit in sequencing two tones, while aphasia specific, is not related to amount of aphasic loss (Holmes, 1965; Edwards and Auger, 1965). It is possible that an impairment of such an ability is not the basis of aphasic deficit, but, rather, results from the same impairment that results in aphasic deficit. This impairment, in its most general sense, may be described as slower than normal processing of stimuli.

4.4. SUGGESTIONS FOR FUTURE RESEARCH

The effects of compression should be further studied. It would be valuable to compare aphasics with nonaphasic brain damaged subjects utilizing the task and rates used in the present experiment to determine whether the rate effect noted is aphasia specific.

It is truly difficult to adequately compare normal subjects and aphasics on a verbal task because those tasks which are easy enough for meaningful performance on the part of the aphasics are too easy for normal subjects. To further investigate the theory that aphasics perform much like normal subjects, only with diminished capacity and efficiency, it would be interesting to present normal subjects with a task that would be as difficult for them as the present one was for aphasics and to compress the stimuli by the amount that they were compressed in the present study. If the results of aphasia research can be generalized to the population as a whole, rather than just the aphasic population, a deterioration of normal performance should occur.

No effect of rate was found for Parts 1 and 2. This may have resulted because stimulus length was too short or because only one rather simple motoric response was required. In addition, of course, the variable of difficulty may have been a factor. Further research can separate the effects of stimulus difficulty, stimulus length, and simplicity of response. It can also be determined whether greater amounts of compression than were used in the present experiment would result in reduced comprehension of such stimuli.

Electromechanical expansion of speech stimuli does not appear to be a fruitful line of investigation to continue, as such, in aphasia research. However, results of its use raise some interesting questions regarding what has been referred to in this chapter as processing time. This latter is an area in which much further study would be desirable. For example, one could formally study the ability of the aphasic to respond halfway through a multiple command, varying the interval between the two halves of the command. Another researchable question involves the effect of stimulus length, in terms of words, information load and actual elapsed time, on response latency and accuracy. Normal subjects, nonaphasic brain damaged subjects, and aphasics could be compared.

4.5. SUMMARY OF CHAPTER 4

Results of the present study indicated that aphasics obtained lower scores when stimuli were time-compressed than when they were presented at a normal rate. This was not true for normal subjects. For such a rate effect to be present, it appears that the stimuli must be of sufficient difficulty that the subjects make errors under normal rate conditions. In addition, for a rate effect to result from the amount of compression used in the present study, the stimuli must probably be of sufficient length or require a response of sufficient motoric complexity. It is conceivable that normal subjects would show a rate effect, with the amount of compression used here, if the stimuli were sufficiently difficult for them.

Expansion of speech did not produce any consistent effect. On Part 4 of the experimental task, the aphasic subjects exhibited higher scores in the Slow rate condition. This may, for some, have resulted from their being able to respond to the first half of the command before the second half was presented. On the other hand, guessing biases probably contributed to the higher scores on this subpart.

Results are interpreted in terms of their application to the clinical management of aphasia. They are also discussed in terms of a construct called "processing." It is hypothesized that language requires processing at a critical speed and that the aphasic deficit may be, at least in part, a diminution in processing speed.

5. SUMMARY

Aphasia is a disorder in which the ability to use a previously acquired language system is disrupted. It should be studied both to determine stimulus conditions most beneficial for the aphasic and to learn more about normal language.

Time is viewed as an important dimension of language. Previous research indicates that one ability involving time, that of the temporal sequencing of auditory stimuli, is impaired in aphasics. Clinical reports indicate that another, the ability to understand rapid speech, may be impaired. This study was designed to formally investigate the ability of the aphasic to understand speech presented to him at different rates. Specifically, it proposed to determine whether the aphasic's auditory comprehension, as inferred from accuracy of a pointing or other nonspoken motor response to spoken sentences, deteriorates when the sentence stimuli are presented more rapidly than normal and improves when stimuli are presented more slowly than normal.

Following, are the null hypotheses that the research was designed to test:

A) Main effects

(1) Rate effect: Subjects will exhibit the same accuracy of response for all rates.

(2) Order effect: The order in which the rates of stimulus presentation are experienced, within a given level of stimulus difficulty, will not differentially affect accuracy of response.

B) Interactions

(1) Rate and group: Aphasic and nonaphasic subjects will show the same changes in accuracy of response as a function of rate of stimulus presentation.

(2) Rate and level of stimulus difficulty: There will be no interaction between level of stimulus difficulty and rate of stimulus presentation.

(3) Rate and severity: There will be no interaction between severity of aphasic and rate of stimulus presentation.

The literature dealing with aphasia and temporal sequencing, as well as some other related tasks, is interpreted in a way that views rate of stimulus presentation as the independent variable in the studies reviewed. Previous research on the effects of compression and expansion of speech stimuli are reviewed in terms of the implications that the reviewed studies have for the design and interpretation of the present study.

After normal performance in response to time-altered speech stimuli is reported, it is noted that the brain damaged show greater deterioration of articulation scores in response to accelerated speech than individuals without brain damage. This finding necessitates caution in interpreting results of the present study.

The known interaction between age and effect of compression is seen as warranting the inclusion of a nonaphasic control group matched for age to the aphasic group in the present experiment. Enough appeared unknown about the interaction between response to time-altered speech stimuli and the education and intelligence of the subjects to warrant matching the groups for educational achievement as well.

Intelligibility scores of aphasics are affected by compressed speech.

Some unpublished research on the effect of rate on the auditory comprehension of aphasics has indicated that expansion may be beneficial for the aphasic. The expansion process involved splicing in intervals of silence rather than using the Eltro Rate Changer. Other research dealing with time-altered speech stimuli and aphasia has not shown significant effects for aphasics as a group. The present research was designed to eliminate or reduce the factors of subject fatigue, intrasession variability, and inadequate range of stimulus difficulty since the present investigator believes that these factors may have affected the results of those studies with negative findings.

The present study utilized sixteen right hemiplegic adult aphasics and sixteen normal adults, the latter group serving as controls. Groups were matched for age and educational achievement. All subjects were administered a modified form of the Token Test which, as used in this research, consisted of five subparts with six sentences in each subpart. The subparts were considered to be of increasing difficulty. The stimuli were recorded and then time-altered using an Eltro Rate Changer. The result was a tape wherein, for each subpart, two of the six sentences were expanded by a nominal 1%, two sentences were compressed by a nominal 32%, and two were expanded by a nominal 37%. The three rates that emerged were known as Normal (N), Fast (F), and Slow (S).

From the master tape, four tapes were reproduced and spliced so that, within each subpart of the test, the three rates could be presented as follows: A -- Normal, Fast, Slow;
B -- Normal, Slow, Fast;
C -- Fast, Normal, Slow;
D -- Fast, Slow, Normal.

Each subject was tested on two separate occasions and received one of the following combinations of tapes: AC, CA, AD, DA, BC, CB, BD, DB.

The test was scored in such a way that the maximum number of points a subject could achieve for a given response depended upon the number of substantive items in the sentence that served as stimulus for that response. For example, for a response to the Part 1 sentence "Point to the red square," the subject could be awarded 0, 1, or 2 points depending on whether he pointed to the correct color (1 point), correct form (1 point), both (2 points), or neither (0 points). For a response to the Part 2 sentence "Point to the large yellow square," he could be awarded 0, 1, 2, or 3 points.

Because the data were truncated, nonparametric methods of analysis were used. For all analyses, except the one involving the effect of order, data from the two days of testing were pooled. The effect of rate on the scores achieved on the test as a whole and on individual subparts of the test was analyzed using the Friedman Two Way Analysis of Variance by Ranks and the Wilcoxon Matched-Pairs Signed-Rank Test. A Spearman Rank Correlation Coefficient was obtained in order to test the interaction between total test score, as a measure of severity of aphasia, and effect of rate. The effect of order of presentation of experimental conditions (rates) within a subpart, was analyzed using a Wilcoxon Matched-Pairs Signed-Rank Test.

Results demonstrated that the aphasic subjects had poorer scores in response to the Fast stimuli than to the Normal stimuli. Normal subjects did not demonstrate such a rate effect. There was an interaction between rate and level of stimulus difficulty in that compressed speech affected the aphasics' scores for the test as a whole and for Parts 3, 4, and 5 but did not adversely affect their Part 1 and Part 2 scores. It appears that for the effect of compression to occur, the stimuli must be of sufficient difficulty that the subject make errors under normal conditions. In addition, for such an effect to result from the amount of compression used in the present study, the stimuli must probably be of sufficient length or require a response of sufficient motoric complexity.

Expansion of speech (Slow rate) did not produce a consistant effect. The aphasic subjects scored higher on Part 4 in response to the Slow sentences than they did in response to the Normal sentences. This may have resulted from their being able to respond to the first half of the command before the second half was presented. However, guessing biases probably contributed to the higher scores achieved in response to the Slow stimuli on this subpart.

The results have some implications for the clinical management of aphasics. They may also be interpreted in terms of a construct called "processing." When interpreted in these terms, they appear consistant with a belief that language requires processing at a critical speed at the cortical level and that the aphasic deficit may be, at least in part, a diminution of processing speed.

APPENDIX

Table A.1. Sentence stimuli as presented to subjects.

Tape A

Part	Rate	Sentence
D*	Normal	Point to the red circle.
	Normal	Point to the small yellow square and the large blue circle.
	Normal	Put the yellow circle in back of the red square.
	Fast	Point to the large white circle.
	Slow	Point to the green circle.
E+		Point to the green circle.
		Point to the small green square.
		Point to the red circle and the yellow square.
		Point to the large green circle and the small white square.
		Put the green circle in back of the red square.
1	Normal	Point to the white square.
	Normal	Point to the yellow circle.
	Fast	Point to the blue circle.
	Fast	Point to the green square.
	Slow	Point to the red square.
	Slow	Point to the white circle.
2	Normal	Point to the large yellow square
	Normal	Point to the small blue square.
	Fast	Point to the small red circle.
	Fast	Point to the large red square.
	Slow	Point to the large green circle.
	Slow	Point to the small white circle.
3	Normal	Point to the white circle and the yellow circle.
	Normal	Point to the blue circle and the red square.
	Fast	Point to the yellow circle and the green square.
	Fast	Point to the blue square and the red square.
	Slow	Point to the green circle and the yellow circle.
	Slow	Point to the blue square and the green square.
4	Normal	Point to the small green circle and the small yellow square.
	Normal	Point to the large blue square and the small red square.

*Sentences in the "D" category were recorded and presented to the subject to demonstrate what he was going to hear. The subject was not required to respond.

+Sentences in the "E" category were not actually part of the tape. They were presented live by the examiner. Subjects were required to respond, but responses were not scored.

Table A.1. (continued)

Tape A (continued)

Part	Rate	Sentence
4	Fast	Point to the small yellow circle and the large blue circle.
	Fast	Point to the small blue square and the large white square.
	Slow	Point to the large red circle and the small white circle.
	Slow	Point to the large white circle and the large green square.
5	Normal	Put the blue circle in front of the yellow circle.
	Normal	Put the red circle on top of the white square.
	Fast	Put the white circle in back of the yellow square.
	Fast	Put the green square in front of the green circle.
	Slow	Put the yellow square on top of the blue circle.
	Slow	Put the white square in back of the red square.

Tape B

Part	Rate	Sentence
D		Same five sentences as on Tape A, in same order, at same rates.
E		Same five sentences as accompanying Tape A, in same order.
1	Normal	Point to the white square.
	Normal	Point to the yellow circle
	Slow	Point to the red square.
	Slow	Point to the white circle.
	Fast	Point to the blue circle.
	Fast	Point to the green square.
2	Normal	Point to the large yellow square.
	Normal	Point to the small blue square.
	Slow	Point to the large green circle.
	Slow	Point to the small white circle.
	Fast	Point to the small red circle.
	Fast	Point to the large red square.
3	Normal	Point to the white circle and the yellow circle.
	Normal	Point to the blue circle and the red square.
	Slow	Point to the green circle and the yellow circle.
	Slow	Point to the blue square and the green square.
	Fast	Point to the yellow circle and the green square.
	Fast	Point to the blue square and the red square.

Table A.1. (continued)

Tape B (continued)

Part	Rate	Sentence
4	Normal	Point to the small green circle and the small yellow square.
	Normal	Point to the large blue square and the small red square.
	Slow	Point to the large red circle and the small white circle.
	Slow	Point to the large white circle and the large green square.
	Fast	Point to the small yellow circle and the large blue circle.
	Fast	Point to the small blue square and the large white square.
5	Normal	Put the blue circle in front of the yellow circle.
	Normal	Put the red circle on top of the white square.
	Slow	Put the yellow square on top of the blue circle.
	Slow	Put the white square in back of the red square.
	Fast	Put the white circle in back of the yellow square.
	Fast	Put the green square in front of the green circle.

Tape C

Part	Rate	Sentence
D		Same as Tapes A and B.
E		Same as Tapes A and B.
1	Fast	Point to the blue circle.
	Fast	Point to the green square.
	Normal	Point to the white square.
	Normal	Point to the yellow circle.
	Slow	Point to the red square.
	Slow	Point to the white circle.
2	Fast	Point to the small red circle
	Fast	Point to the large red square.
	Normal	Point to the large yellow square.
	Normal	Point to the small blue square.
	Slow	Point to the large green circle.
	Slow	Point to the small white circle.
3	Fast	Point to the yellow circle and the green square.
	Fast	Point to the blue square and the red square.
	Normal	Point to the white circle and the yellow circle.
	Normal	Point to the blue circle and the red square.

Table A.1. (continued)

Tape C (continued)

Part	Rate	Sentence
3	Slow	Point to the green circle and the yellow circle.
	Slow	Point to the blue square and the green square.
4	Fast	Point to the small yellow circle and the large blue circle.
	Fast	Point to the small blue square and the large white square.
	Normal	Point to the small green circle and the small yellow square.
	Normal	Point to the large blue square and the small red square.
	Slow	Point to the large red circle and the small white circle.
	Slow	Point to the large white circle and the large green square.
5	Fast	Put the white circle in back of the yellow square.
	Fast	Put the green square in front of the green circle.
	Normal	Put the blue circle in front of the yellow circle.
	Normal	Put the red circle on top of the white square.
	Slow	Put the yellow square on top of the blue circle.
	Slow	Put the white square in back of the red square.

Tape D

Part	Rate	Sentence
D		Same as Tapes A, B, and C.
E		Same as Tapes A, B, and C.
1	Fast	Point to the blue circle.
	Fast	Point to the green square.
	Slow	Point to the red square.
	Slow	Point to the white circle.
	Normal	Point to the white square.
	Normal	Point to the yellow circle.
2	Fast	Point to the small red circle.
	Fast	Point to the large red square.
	Slow	Point to the large green circle.
	Slow	Point to the small white circle.
	Normal	Point to the large yellow square.
	Normal	Point to the small blue square.
3	Fast	Point to the yellow circle and the green square.
	Fast	Point to the blue square and the red square.

Table A.1. (continued)

Tape D (continued)

Part	Rate	Sentence
3	Slow	Point to the green circle and the yellow circle.
	Slow	Point to the blue square and the green square.
	Normal	Point to the white circle and the yellow circle.
	Normal	Point to the blue circle and the red square.
4	Fast	Point to the small yellow circle and the large blue circle.
	Fast	Point to the small blue square and the large white square.
	Slow	Point to the large red circle and the small white circle.
	Slow	Point to the large white circle and the large green square.
	Normal	Point to the small green circle and the small yellow square.
	Normal	Point to the large blue square and the small red square.
5	Fast	Put the white circle in back of the yellow square.
	Fast	Put the green square in front of the green circle.
	Slow	Put the yellow square on top of the blue circle.
	Slow	Put the white square in back of the red square.
	Normal	Put the blue circle in front of the yellow circle.
	Normal	Put the red circle on top of the white square.

Table A.2. Spearman Rank Correlation between the present modification of the Token Test and the Oral and Auditory Subsections of the Minnesota Test for Differential Diagnosis of Aphasia -- 11 subjects.

Subject rank[1] on Modified Token Test	Subject rank on Minnesota Test
1	2
2	1
3	3
4	7
5	4
6	5
7	6
8	9
9	11
10	10
11	8

Results

$r_s = .873$

$n = 9$

$p. < .001$

[1]Subject with the lowest score ranked "1."

Table A.3. Raw scores of normal subjects for all parts combined and each subpart -- both days combined.

S[1]	All Parts N	All Parts F	All Parts S	Part 1 N	Part 1 F	Part 1 S	Part 2 N	Part 2 F	Part 2 S	Part 3 N	Part 3 F	Part 3 S	Part 4 N	Part 4 F	Part 4 S	Part 5 N	Part 5 F	Part 5 S
1	77+	76+	80	8	7+	8	12	12	12	16	16	16	22+	21+	24	19+	20	20
2	80	74.5+	80	8	8	8	12	12	12	16	16	16	24	23+	24	20	15.5+	20
3	79+	79+	79+	8	8	8	12	12	12	16	16	15+	23+	24	24	20	19+	20
4	80	78+	80	8	8	8	12	12	12	16	16	16	24	22+	24	20	20	20
5	78+	80	80	8	8	8	12	12	12	16	16	16	23+	24	24	19+	20	20
6	78+	80	80	8	8	8	12	12	12	16	16	16	23+	24	24	19+	20	20
7	80	79+	80	8	8	8	12	12	12	16	16	16	24	23+	24	20	20	20
8	79+	80	80	8	8	8	12	12	12	16	16	16	23+	24	24	20	20	20
9	79+	80	80	8	8	8	12	12	12	16	16	16	24	24	24	19+	20	20
10	80	80	80	8	8	8	12	12	12	16	16	16	24	24	24	20	20	20
11	80	80	80	8	8	8	12	12	12	16	16	16	24	24	24	20	20	20
12	80	80	80	8	8	8	12	12	12	16	16	16	24	24	24	20	20	20
13	80	80	80	8	8	8	12	12	12	16	16	16	24	24	24	20	20	20
14	80	80	80	8	8	8	12	12	12	16	16	16	24	24	24	20	20	20
15	80	80	80	8	8	8	12	12	12	16	16	16	24	24	24	20	20	20
16	80	80	80	8	8	8	12	12	12	16	16	16	24	24	24	20	20	20

[1] Subjects are listed in order of total score with the subject achieving the lowest score listed first.

+Indicates that the score is not the maximum obtainable in that column

Table A.4. Scores of aphasic subjects for all parts combined.

Subject[1]	Normal rate	Fast rate	Slow rate
1	30	23	32.5
2	36	30	36
3	38.5	37.5	39.5
4	49.5	43.5	43
5	56	40	48
6	64	54	65
7	64	57	63
8	69	58	64
9	71	62	64
10	71	57	76
11	71	67	68.5
12	77	70	73
13	78	77	77
14	77	78	78
15	80*	80*	80*
16	80*	80*	80*

[1]Subjects are listed in order of total score, the subject achieving the lowest score listed first.

*Indicates that the score is the maximum possible score for that column.

Table A.5. Raw scores of aphasic subjects for each subpart -- both days combined.

S[1]	Part 1			Part 2			Part 3			Part 4			Part 5		
	N	F	S	N	F	S	N	F	S	N	F	S	N	F	S
1	3	7	2	5	8	2	4	2	6	9	2	13	9	4	9.5
2	4	3	5	5	8	2	4	2	6	9	10	13	11	6	9
3	4	4	4	10	6	9	11	9	9	6	11	11	7.5	7.5	7.5
4	8*	7	6	6	9	7	9	8	8	15	14	11	11.5	7.5	6.5
5	5	7	7	9	10	10	11	5	7	16	11	18	15	7	6
6	8*	7	6	9	11	10	12	9	12	16	13	21	19	14	16
7	8*	8*	8*	10	11	12	14	14	13	19	9	18	13	15	12
8	7	7	8*	12*	12*	9	14	10	11	18	12	22	18	17	14
9	7	8*	8*	12*	12*	9	13	12	11	21	14	22	18	16	14
10	7	8*	8*	11	12*	12*	15	12	15	20	12	24*	18	13	17
11	8*	8*	8*	12*	12*	12*	14	14	14	19	18	19	18	15	15.5
12	8*	8*	8*	12*	12*	12*	16*	16*	16*	22	14	19	19	20*	18
13	8*	8*	8*	11	12*	12*	16*	15	16*	24*	22	24*	19	20*	17
14	8*	8*	8*	12*	12*	12*	16*	16*	16*	21	24*	24*	20*	18	18
15	8*	8*	8*	12*	12*	12*	16*	16*	16*	24*	24*	24*	20*	20*	20*
16	8*	8*	8*	12*	12*	12*	16*	16*	16*	24*	24*	24*	20*	20*	20*

[1]Subjects listed in order of total score, the subject achieving the lowest score listed first.

*Indicates that the score is the maximum possible score for that column.

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