THE INFLUENCE OF INCREASED DURATIONS OF SPEECH STIMULI ON THE RECOGNITION AND RETENTION OF WORDS BY APHASIC ADULTS

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ABSTRACT

THE INFLUENCE OF INCREASED DURATIONS OF SPEECH STIMULI ON THE RECOGNITION AND RETENTION OF WORDS BY APHASIC ADULTS

by William R. Dopheide

Recognizing the importance of auditory language reception in the total rehabilitative effort directed toward the language problems of the aphasic adult, speech pathologists have sought to develop modifications of the auditory language stimulus that will make the stimulus more adequate for the aphasic adult. One recommended modification that appears to have rather widespread clinical application is increasing the duration of the words spoken to the aphasic adult.

The purpose of this investigation was to assess the effectiveness of temporal expansions in the phonemic segments of words on the aphasic adult's performance in recognizing and retaining words. In addition, two independent (control) variables were employed: meaningfulness of the stimulus word and subjects' adequacy in auditory language function.

The dependent variables were performance on a word recognition task and performance on a retention span task, with stimuli being presented auditorily on both tasks. These tasks were selected since they seemed highly related

to significant characteristics of the aphasic language deficit, according to reports in the literature.

For the word recognition task, the stimulus words, derived from the Peabody Picture Vocabulary Test, were arranged in a manner that provided four equivalent lists of 75 words each. Each list was divided arbitrarily into three sets of 25 words each that were regarded as reflecting three levels of meaningfulness. The stimuli for the retention span task varied in complexity from two word series to five word series, with all complexity levels equally represented at all stimulus durations. The variations from the normal durations of the stimulus words were produced by an electromechanical process to the niminal levels of 125%, 150%, and 175% expansions of the original recorded duration (100%); hence, four stimulus duration conditions were available. Subjects were assigned to a High auditory language disturbance group or a Low auditory language disturbance group on the basis of their scores on the Auditory Disturbance section of the Minnesota Test for Differential Diagnosis of Aphasia.

The data were treated by analysis of variance: three factor (repeated measures) for Meaningfulness, Groups, and Durations on the word recognition task; and two factor (repeated measures) for Groups and Durations on the retention span task. An inter-task comparison was made employing a Spearman rank correlation at each stimulus duration condition.

No significant main effect for Duration was observed on either task; however, Groups displayed some interaction with Durations on the word recognition task (but not on the retention task). The interaction appeared to be generated by the High auditory language disturbance group. The Meaningfulness interaction with Durations, which was of interest, was not statistically significant. Of importance to the design of the experiment, the main effects for Groups and Meaningfulness levels were statistically significant and manifested no interaction. The inter-task comparison revealed statistically significant correlations in the High auditory language disturbance group at three of the four duration conditions. This finding might be interpreted as meaning less independence of available vocabulary and retention span in aphasic adults with poor auditory language function.

On the basis of this investigation, increased stimulus durations, as produced for use in this study, do not have a general positive influence on word recognition and retention span. Increasing the duration of the stimulus may have a positive effect on word recognition for subjects with poor auditory language function, but further research is necessary.

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CHAPTER I

INTRODUCTION

Man can experience no more abrupt loss of his uniqueness than to lose his ability to communicate. For as Gibran has written

> When you meet your friend, . . . let the spirit in you move your lips and direct your tongue.
> Let the voice within your voice speak to the ear of his ear;
> For his soul will keep the truth of your heart as the taste of the wine is remembered
> When the colour is forgotten and the vessel is no more.[1]

To experience disability of the "voice within your voice" is to suffer deprivation in perhaps the most essential and sustaining of human behaviors. As Goldstein has stated

> The different views regarding the nature of man reflect themselves in the discussions of man's outstanding capacity: language.[2]

The abrupt disruption of this capacity is aphasia. It is a language disorder associated with cerebral insult and as such is very frequently accompanied by other physical and behavioral disabilities.

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[1]Kahil Gibran, The Prophet (1923) (New York: Alfred A. Knopf, Inc., 1964), p. 61.

[2]Kurt Goldstein, Language and Language Disturbances (New York: Grune and Stratton, 1948), p. 345.

Aphasia has been recorded in the literature over the centuries.[1] However, as man's nature has lead him to increase his life expectancy, to improve his means of dealing with disease and disability, and to invent more traumatic ways of doing harm, the problems of the aphasic adult have drawn increased attention. Within the last 100 years, over 30,000 books and articles have dealt with the problems of the aphasic adult.[2] In this time, Esti Freud has seen the investigations as taking three distinct approaches: direct anatomical-physiological investigations; psychological observations of the total behavior of the patient from which central nervous system dysfunction might be inferred; and structural, linguistic analyses of the language behavior itself.[3]

The responsibilities of speech pathology in this interdisciplinary approach have been centered, of course, on the language behavior itself. The increased demands for language rehabilitation services during and after World War II[4] seem to have intensified the search for better

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[1] Arthur L. Benton and Robert J. Joynt, "Early Descriptions of Aphasia," AMA Archives of Neurology, III (1960), pp. 205-22.

[2] Esti D. Freud, "Recent Trends in Aphasia," American Journal of Psychiatry, CX (1953), p. 186.

[3] *Ibid*., pp. 186-93.

[4] Joseph M. Wepman, Recovery from Aphasia (New York: Ronald Press Company, 1951), p. 4.

diagnostic and treatment procedures with which to assist the aphasic adult. It was from this clinical viewpoint that the present experimental investigation was undertaken.

Purpose of the Study

The purpose of this study was to examine the effectiveness of a treatment procedure used by clinicians in language therapy with aphasic adults. The study was directed at investigating, experimentally, the influence of increased durations of selected speech stimuli on the receptive language performance of aphasic adults. Six questions concerning aphasic adults were posed for investigation.

1. What influence does increasing the duration of speech stimuli have on the performance of an auditory word recognition task?
2. Is there a relationship between the meaningfulness of the speech stimuli and the influence of increases in stimulus duration on performance of an auditory word recognition task?
3. Does the influence of increased durations of the speech stimuli vary as a function of the severity of the subject's disturbance in auditory language reception on tasks requiring the auditory recognition of words?
4. What influence does increasing the duration of the speech stimuli have on the performance

of a retention span task in which words are presented auditorily and in series?

5. Does the influence of increased durations of the speech stimuli vary in relation to the severity of the subject's disturbance in auditory language reception on a task requiring the retention of stimuli presented auditorily?
6. What relationship exists between performance on an auditory word recognition task and an auditory retention span task at several levels of increased stimulus duration?

Importance of the Study

It has been said ". . . in the investigation of problems as complex as aphasia almost any question one could raise would be worth study."[1] This subcommittee of the American Speech and Hearing Association, studying the research needs in aphasia, was indicating the strong need for investigating any and all aspects of the clinical management of the language problems of the aphasic adult. This subcommittee did indicate the significance of questions related to the differential effectiveness of therapeutic

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[1]Walter Amster, *et al.*, "V. Report of Subcommittee on Problems of Aphasia," in *Research Needs in Speech Pathology and Audiology* (Washington: American Speech and Hearing Association, 1959), p. 42.

processes with different aphasic categories.[1]

These different categories are not the classical categories of the last century which are being perpetuated today by psychological and neurological textbooks.[2] Major investigations within the last thirty years have denied strongly the classical dichotomy between sensory and motor language deficits. With increasing emphasis on the objective assessment of the language behavior itself, concern has focused on the general nature of the aphasic language deficit and the definition of its dimensions which have diagnostic and treatment significance.[3]

Two facts have made the definition of aphasia difficult. The disabilities of the aphasic adult, stemming as they do from some cerebral insult, require the professional attention of several disciplines.[4] Secondly, attempting to understand disordered language function, masked by other disabling physical and psychological problems, is extremely difficult, especially when one considers that normal language processes are only now becoming clearer

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[1] Ibid.

[2] James J. Jenkins and Hildred Schuell, "Changing Concepts of Aphasia," Perceptual and Motor Skills, XIII (1961), p. 270.

[3] Charles E. Osgood and Murray S. Miron, Approaches to the Study of Aphasia (Urbana: University of Illinois Press, 1963), p. 126.

[4] Ibid., p. 3.

through scientific investigation.[1] The definition of aphasia adopted for use in this study was one derived from extended empirical research by Schuell and Jenkins.[2] This definition, which recognizes a general dimension of language, has received a good deal of clinical interest since it operationalizes the concept of aphasia in terms which are quite amenable to clinical management in language therapy. The two major characteristics of aphasia given in this definition suggested clear-cut tasks upon which the experimental variable could be tested.

Recognizing the coexistence of some degree of both receptive and expressive disability in all patients, there appears to be rather substantial support for the opinion that auditory language problems are generally an aspect of the total language dysfunction of the aphasic adult. As Schuell has stated

> Probably all aphasic patients show some impairment of auditory processes, because language, learned by ear, remains dependent upon discrimination, recognition, and recall of learned auditory patterns, and upon auditory feedback processes.[3]

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[1] Ibid.

[2] Hildred Schuell and James J. Jenkins, "The Nature of the Language Deficit in Aphasia," Psychological Review, LXVI (1959), pp. 50-51. James J. Jenkins and Hildred Schuell, "Further Work on Language Deficit in Aphasia," Psychological Review, LXXI (1964), pp. 87-93.

[3] Hildred Schuell, Differential Diagnosis of Aphasia with the Minnesota Test (Minneapolis: University of Minnesota Press, 1965), p. 5.

It appeared that any investigation of techniques for facilitating auditory language reception would have relevance to the broad range of problems in aphasia.

Explaining improved language function in aphasia on the basis of treatment procedures is difficult since there is insufficient knowledge of cerebral function in such complex functions as language.[1] However, there have been several theories of cerebral function advanced which give reason to believe certain modifications of an auditory language stimulus may elicit improved recognition or retention of the linguistic significance of the stimulus,[2] while other current theories would suggest no improvement from such modifications of the stimulus itself.[3]

The particular modification of the auditory language stimuli to be studied is increased duration. Clinical practice has indicated that giving greater temporal value to the phonemes of a word is a means of improving its

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[1]Osgood and Miron, Approaches to Aphasia, pp. 33-37.

[2]Aleksandor Romanovich Luria, Higher Cortical Functions in Man, trans. by Basil Haigh (New York: Basic Books, Inc., 1966), pp. 97-103. Wilder Penfield and Lamar Roberts, Speech and Brain Mechanisms (Princeton, N.J.: Princeton University Press, 1959), pp. 21-22. Karl Pribram, "Neocortical Function in Behavior," in Biological and Biochemical Bases of Behavior, eds. Harry F. Harlow and Clinton N. Woolsey (Madison: University of Wisconsin Press, 1958), pp. 167-168.

[3]Norman Geschwind, "Disconnexion Syndromes in Animals and Man, Parts I and II," Brain, LXXXVIII (1965), pp. 237-293 and 585-644.

recognition by aphasic adults.[1] Other variables which have appeared to influence the adequacy of the stimulus for the patient were recognized and were considered in evaluating the influence of the experimental variable. The availability of a device capable of producing these expansions in word duration[2] offered promise of providing the speech pathologist with another clinical tool. It seemed worthwhile to make a test of its potential effectiveness in the language rehabilitation of the aphasic adult.

Definitions

Aphasia.--This nonfunctional language disturbance is characterized by a reduction or loss of a centralized ability to cope with the arbitrary meanings, associations, and relationships which exist in an individual's system of communication. This basically unidimensional behavior may be further impaired by independent but related transmissive dysfunctions, variously referred to as agnosias, apraxias, or sensorimotor deficits.

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[1]Hildred Schuell, James J. Jenkins and Edward Jimenez-Pabon, *Aphasia in Adults: Diagnosis, Prognosis, and Treatment* (New York: Harper and Row, Publishers, 1964), pp. 340-41.

[2]Hugh S. Allen, Jr., "The Eltro Information Rate Changer - Mark II: Simple Quality Speech Compression" (paper presented at Conference on Compressed Speech, University of Louisville, October 19, 1966).

While this definition was drawn from several theoretical positions regarding the nature of the disorder, it is admittedly biased in the direction of the Schuell and Jenkins definition which characterizes aphasia as a reduction of available vocabulary, impaired verbal retention span, and impaired perception and production of messages. The impaired perception and production of messages, they have stated, may be secondary to the impairment of available vocabulary and verbal retention span.[1]

The definition recognized also, the contributions of Wepman, _et al_., who have viewed aphasia as a disruption in the central nervous system's capacity to integrate language stimuli once such stimuli are free of their input modalities, with the disruption having the potential of falling at any point in the process; in the arousal of meaning, in the semantic word selection, or in the syntactic process.[2]

Subjects in this study were identified as "aphasic" on the basis of competent clinical diagnosis employing one or both of the following recognized diagnostic tools: the Language Modalities Test for Aphasia[3] and The Minnesota

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[1] Schuell, Jenkins and Jimenez-Pabon, _Aphasia in Adults_, p. 113.

[2] Joseph M. Wepman, _et al_., "Studies in Aphasia: Background and Theoretical Formulations," _Journal of Speech and Hearing Disorders_ (_JSHD_), XXV (1960), p. 328.

[3] Joseph M. Wepman and Lyle V. Jones, _The Language Modalities Test for Aphasia_ (Chicago: Education-Industry Service, 1961).

Test for Differential Diagnosis of Aphasia.[1] Hence, "aphasia" was operationalized on the basis of performance on one or both of these tests.

Auditory language disturbance.--Deficits in ability to deal with receptive language, auditorily, was defined on the basis of a subject's score on seven subtests of the Auditory Disturbances Section of the Minnesota Test.[2] The subtests used from this section of the test were as follows: recognizing common words; discriminating between paired words; recognizing letters; identifying items named serially; following directions; repeating digits; and repeating sentences. All of the stimulus material for these tasks were presented auditorily.

It was reported, on the basis of a factor analysis, that all these tests loaded heavily on a general language factor, indicating the importance of auditory processes in language.[3]

Meaningfulness: levels of hearing vocabulary. The meaningfulness of a word was determined by the developmental period in which the word was expected to have become

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[1]Hildred Schuell, Minnesota Test for Differential Diagnosis of Aphasia: Administrative Manual (Minneapolis: University of Minnesota, 1965).

[2]Ibid., pp. 5-8.

[3]Hildred Schuell, Differential Diagnosis of Aphasia, p. 25.

a part of subject's hearing vocabulary, i.e., his auditory receptive vocabulary. Those words from the earliest developmental period were considered more meaningful than words from the later developmental period.

The word stimuli used were those appearing in the Peabody Picture Vocabulary Test.[1] This test provided an empirically derived set of words, scaled in terms of the chronological development of hearing vocabulary through at least the first eighteen years of life.[2] On the basis of age group data, the stimulus words of the test were arranged in the empirically-determined order of difficulty. The order of difficulty was based solely on the number of correct responses rendered by successively older age groups.

A subject's hearing vocabulary was assessed on the basis of his word recognition score obtained on the Peabody Test; it was assumed the subject recognized the stimulus word if he correctly identified the response picture associated with the stimulus word. Levels of hearing vocabulary were defined by arbitrarily dividing the scaled set of words into three groups. The division points were at words indexing mean expectations for five year old subjects, and for subjects approximately 15 years-6 months of age. This

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[1] Lloyd Dunn, Peabody Picture Vocabulary Test: Expanded Manual (Minneapolis: American Guidance Service, Inc., 1965).

[2] Ibid., p. 25.

division assigned test items 1-50 to Level I, items 51-100 to Level II, and items 101-150 to Level III. By determining the number of correct responses made by the subject within each of the three levels, his available hearing vocabulary for single words was analyzed in terms of words associated with the initial, intermediate, and late phases of the early development of hearing vocabulary development.

Increased stimulus duration.--As used in this study, increased stimulus duration referred to increasing the temporal value of phonemic segments of the words. By a process to be described, the increases were produced as a percentage of the duration of the word as originally recorded. Three nominal levels of increase were employed: 125%, 150%, and 175% increase. Hence, if a word (as originally recorded) had a duration of 500 msec., it would approximate 750 msec. at the 150% level of increased duration. This processing is frequently referred to as expanded speech.

Organization of the Report

In Chapter I, the direction in which concepts of aphasia have moved in recent years has been indicated, and the special concerns and interests of speech pathologists have been identified. The questions posed by this study were presented and related to the needs of the aphasic adult in his efforts to regain better language function. In addition, terms of particular importance to this study are defined.

Chapter II consists of a comprehensive review of literature pertinent to: (1) the development of current concepts of aphasia, (2) the neurophysiological basis for the possible outcomes from the experimental treatment, (3) clinical observations which suggested the selection of the experimental variable, and (4) matters related to the selection, design and development of the language tasks and the preparation of the stimulus materials.

The following topics are discussed in Chapter III: procedures employed in developing materials for the experimental tasks; selection and grouping of subjects; and procedures followed in presenting the tasks to the subjects. Included also is a discussion of procedures used in verifying the expanded durations of the stimulus material, plus a description of the characteristics of the two groups of subjects.

In Chapter IV the results of the statistical analyses are discussed in terms of the null hypotheses generated from the six questions stated in Chapter I. The results are discussed in terms of relevant theoretical notions, clinical observations and research findings.

Chapter V summarizes the present study and presents conclusions that can be drawn within the limitations imposed. Recommendations for future research are suggested.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter presents a review of the theoretical, clinical and research literature relevant to this investigation. Beginning with a consideration of the development of understandings of aphasia, the importance of auditory language reception problems in aphasia is indicated. The discussion focuses on theories of neurophysiological function that might account for the possible outcomes of the experimental treatment employed in this investigation. This review reports the clinical observations that prompted the investigation, as well as factors reported to influence auditory language reception in adult aphasics. The chapter concludes with a consideration of reports concerning the process employed to produce increases in the duration of the stimuli.

Development of Concepts of Aphasia

The history of the study of aphasia has been marked by a great deal of variation in the concepts concerning the nature of the language disorder. This is not at all unusual when one considers the comment of Osgood and Miron, who observe that

> . . . the problems of aphasia represented a natural intersection of the interests of neurologists, clinical psychologists, linguists, speech pathologists, and experimental psychologists specializing in language. Even a simplified definition of aphasia as "disturbance of language behavior" gives balanced weight to these fields: "disturbance" (neurology and clinical psychology), "language" (linguistics and speech pathology), and "behavior" (experimental psychology).[1]

While the early reports appear to have been largely descriptive medical accounts, later efforts tried to explain the language deficit in terms of an underlying neurological dysfunction. In more recent years, emphasis appears to have shifted to a more systematic investigation, aimed at describing the actual language deficits in ways meaningful to the treatment of the language disorder itself.

In the brief review that follows, the intention is to indicate the direction in which the concepts of aphasia have moved in a little over 100 years. The review reflects the development of the realization that any concept of the language disturbances in aphasia must include consideration of both receptive and expressive language functions.

Early developments.--A considerable amount of descriptive clinical material had been accumulated up to the beginning of the nineteenth century. This was the conclusion

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[1]Charles E. Osgood and Murray S. Miron, Approaches to the Study of Aphasia (Urbana: University of Illinois Press, 1963), p. 3.

reached by Benton and Joynt[1] after their reasonably extensive review of literature dating from Hippocratic writing to 1800. They felt that the writers of this period (largely physicians) had recorded a rather broad range of aphasic disturbances, with one notable exception. Other than one reference, Benton and Joynt found no mention of specific impairment in speech comprehension as an aspect of aphasic disturbances. Benton and Joynt state

> . . . sensory aphasia remained virtually unrecognized as a specific language deficit for another three-quarters of a century, until the appearance of Wernicke's monograph in 1874.[2]

Wernicke regarded the disturbance discussed by Broca[3] as a motor aphasia. Wernicke proposed another type of language disturbance which he labelled sensory aphasia. He reasoned that, while the two language deficits (sensory and motor aphasia) could exist as separate aspects of an aphasic disturbance, he was not convinced that in pure motor aphasia the ability to understand speech always remained unimpaired. The coexistence of the two deficits he seemed to ascribe to another concept of conduction aphasia, about which he had some uncertainty. Wernicke defined sensory

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[1]Arthur L. Benton and Robert J. Joynt, "Early Descriptions of Aphasia," AMA Archives of Neurology, III (1960), pp. 205-22.

[2]*Ibid.*, p. 220.

[3]Jules Kann, "A Translation of Broca's Original Article on the Location of the Speech Center," Journal of Speech and Hearing Disorders (JSHD), XV (1950), pp. 16-20.

aphasia as loss of understanding of speech, with hearing and articulation intact, and writing severely disturbed. He stated that sensory aphasia resulted from temporal lobe lesions in the area of the auditory center of the first temporal convolution--"Wernicke's area" in classical neurology.[1]

A little over a decade later in 1887, Kussmaul had formulated a definition of aphasia which seemed to accommodate more comfortably the sensory and motor aspects of language. To understand aphasia, he wrote, it was important to understand the development of speech in its linguistic and utilitarian contexts. He defined aphasia as "the impairment of execution, expression or understanding of any symbols by which one man communicates his ideas or feelings to another."[2] With this broad view of the problem, it is not surprising to find that Kussmaul did not support a strict neurological localization point of view, as did Broca and Wernicke.

Hughlings Jackson, initiating some thirty years

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[1]Carl Wernicke, "Symptom-Complex of Aphasia (German-1874)," in Diseases of the Nervous System, ed. by A. Church (New York: Appleton, 1908), pp. 265-324, cited by Hildred Schuell, James J. Jenkins and Edward Jimenez-Pabon, Aphasia in Adults: Diagnosis, Prognosis, and Treatment (New York: Harper & Row, Publishers, 1964), p. 17.

[2]Adolph Kussmaul, "Disturbances of Speech: An Attempt in the Pathology of Speech," in Cyclopedia of the Practice of Medicine, ed. by H. vonZiemssen (New York: Frank Wood, 1887), pp. 581-870.

of careful clinical observation at about this same time, was also unable to accept popular theories of localization. While his work was not widely recognized until the early twentieth century, he made some very significant contributions to the study of this disorder.[1] Jackson's study of aphasia caused him to search for a dynamic concept of cerebral function which involved the dependency of lower functional centers upon higher levels of functional organization. He was aware of the distinct receptive language deficit manifested by aphasic patients, although he concentrated more attention on deficits in expressive language. However, Jackson certainly perceived the reciprocal relationship between the receptive and the expressive aspects in aphasic disorders. He discussed the apparent word loss of the aphasic as more a matter of words not being available for propositional expression than an absolute loss of the words.[2]

Recent developments.--It appeared that the first recognition (in the United States) that aphasia was neither purely receptive nor purely expressive was in the 1935

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[1]Theodore Weisenberg and Katherine E. McBride, Aphasia: A Clinical and Psychological Study (originally published 1935), (New York: Hafner Publishing Company, Inc., 1964), p. 11.

[2]J. Hughlings Jackson, The Selected Writings (2 vols.; New York: Basic Books, Inc., 1958), II, pp. 365-392.

work of Weisenberg and McBride.[1] In introducing their fourfold division of aphasic disorders, they state

> . . . it must be emphasized that none of the terms is other than descriptive and that none does more than point out the most marked characteristics of the case. Neither patients of the expressive nor those of the receptive group are handicapped solely in expressive functions or solely in receptive. The disorders are predominantly expressive or receptive; the other processes in either case are always more or less affected.[2]

The four classifications of expressive, receptive, expressive-receptive, and amnesic were derived from an empirical study of sixty aphasic patients.

While there was a good deal to criticize in this study,[3] the explicit statement concerning the coexistence of receptive and expressive deficits is noteworthy. It seemed Weisenberg and McBride were more explicit in this regard than was Head.[4] Head also avoided the sensory-motor dichotomy in his classifications of verbal, syntactical, and nominal. It will be noted that Head's observations lead him to a linguistically oriented classification.

Closer to the present time, one finds a nomenclature for aphasic language disturbances in Eisenson's work

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[1]Weisenberg and McBride, Aphasia, pp. 145-149.

[2]Ibid., p. 144.

[3]Hildred Schuell, James J. Jenkins and Edward Jimenez-Pabon, Aphasia in Adults: Diagnosis, Prognosis, and Treatment (New York: Harper and Row, Publishers, 1964), pp. 41-42.

[4]Henry Head, Aphasia and Kindred Disorders of Speech (2 vols.; New York: Macmillan, 1926), I, pp. 221-68.

which is apparently a modification of the Weisenberg and McBride work. Eisenson[1] avoided the sensory-motor dichotomy in proposing the following four classes: predominantly evaluative (receptive or sensory); predominantly productive (expressive); subsymbolic disturbances on evaluative side (agnosias); and subsymbolic disturbances on the productive side (apraxias and dysarthrias). Pointing out that these categories were the predominant area of disturbance, not pure disturbances, he suggested that this classification system points to the area in which the major treatment emphasis should be focused. It is worth noting that Eisenson allowed, in his nomenclature, for separate behavioral deficits of agnosia, apraxia, and dysarthria. This recognition of nonlanguage disabilities, coexisting with aphasia, has been reflected in other recent theoretical positions.

Present status.--In 1960, Wepman, et al.,[2] developed their formulation of aphasia as a disruption in the central nervous system's capacity to integrate language stimuli once such stimuli are free of their input modalities, with the disruption having the potential of falling at any point

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[1] Jon Eisenson, Examining for Aphasia (rev. ed.; New York: Psychological Corporation, 1954), pp. 12-19.

[2] Joseph M. Wepman, et al., "Studies in Aphasia: Background and Theoretical Formulations," Journal of Speech and Hearing Disorders, XXV (1960), pp. 323-32.

in the process. They have suggested such points as being in the arousal of meaning, in the semantic word selection process, or in the syntactic process. They regarded agnosias and apraxias as nonsymbolic transmissive disorders related to receptive and expressive language modalities, while the aphasias were viewed as disruptions in the symbolic language process.

In setting out to research this concept of aphasia, Wepman and Jones developed the Language Modalities Test for Aphasia (LMTA)[1]. This test was designed to explore not only the stimulus-response relationship along common input and output modalities but also three types of linguistic involvement commonly found in aphasic patients. Their research indicated, to them, that one way to differentiate among symbolic disorders associated with central nervous system impairment was to classify them in terms of the loss or dysfunction in one or more of three processes. The three processes that they defined and labeled were pragmatic aphasia, semantic aphasia and syntatic aphasia. They added a fourth category (jargon aphasia) for patients generally unintelligible; and a fifth category (global aphasia) for patients unable to produce a real verbal response to stimuli. From a study by Spiegel, Jones and

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[1]Joseph M. Wepman and Lyle V. Jones, The Language Modalities Test for Aphasia (Chicago: Education-Industry Service, 1961).

Wepman,[1] it was concluded that aphasic patients evaluated with the LMTA were distributed along a continuum of general language disability. In addition, the patients also distributed themselves along other dimensions indicative of specific losses in more specialized language abilities related to input and output modalities.

The theoretical position that most strongly supports the concept of a general language deficit in aphasia is expressed by Schuell, Jenkins, and Jimenez-Pabon.[2] They have viewed aphasia as a general language deficit crossing all language modalities and as a deficit that may or may not be further complicated by impairment of auditory, visual and sensorimotor processes. In fifteen years of empirical, systematic observations of some 1000 aphasic patients, these investigators saw the language deficit itself as characterized by a reduction of available vocabulary, impaired verbal retention span, and impaired perception and production of messages. The impaired perception and production of messages, they have stated, may be secondary to the impairment of available vocabulary and verbal retention span.

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[1]Douglas K. Spiegel, Lyle V. Jones, Joseph M. Wepman, "Test Responses as Predictors of Free-Speech Characteristics in Aphasic Patients," Journal of Speech and Hearing Research (JSHR), VIII (1965), pp. 349-362.

[2]Schuell, Jenkins, and Jimenez-Pabon, Aphasia in Adults, pp. 113-133.

A major outcome of the work of Schuell and her associates was the Minnesota Test for Differential Diagnosis of Aphasia,[1] a test intended to provide an operational description of aphasia through observation of the level at which language performance breaks down in each of the principal language modalities. This, Schuell stated,[2] is essentially what there is to observe in aphasia. A section of the Minnesota Test for Differential Diagnosis of Aphasia was used in this study.

This review of several major contributions supported the position that an investigation of an aspect of the receptive auditory language ability of adult aphasics was an investigation having relevance to general problems of aphasia. Receptive language and expressive language cannot be dichotomized, and the auditory modality is certainly a principal receptive language modality.

Among the more recent descriptive studies of aphasia, the empirically derived concepts presented by Schuell and her associates provided the basis for this investigation of the influence of increased durations of speech stimuli on the receptive language performance of aphasics. Their

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[1] Hildred Schuell, Differential Diagnosis of Aphasia with the Minnesota Test (Minneapolis: University of Minnesota Press, 1965).

[2] Schuell, Jenkins, and Jimenez-Pabon, Aphasia in Adults, p. 170.

two principal characteristics of the language deficit in aphasia, a reduction in available vocabulary and an impairment in verbal retention span, suggested the two tasks on which the experimental variable will be tested.

Neurophysiological Rationale

While this study was primarily concerned with the language behavior of aphasics, an attempt was made to find some neurophysiological basis for the possible influences of the increased durations of the auditory stimuli. Several current theories of the functional organization of the cerebrum were explored. One of these seemed to predict no positive effect, and three which appeared to offer some suggestion of a positive effect from increasing the duration of the stimuli. At the outset it was realized the task could not be completed with a high degree of clarity, since the perceptual and cognitive aspects of auditory language reception were still cloaked in too much uncertainty, ambiguity and conflicting opinion. Yet the undertaking seemed a necessary preliminary step in this investigation.

Localization position.--A present day reflection of more classical neurophysiological concepts appeared in the work of Geschwind.[1] Geschwind has presented a rather

[1]Norman Geschwind, "Disconnexion Syndromes in Animals and Man, Parts I and II," Brain, LXXXVIII (1965), pp. 277-291, and pp. 604-44.

extensive discussion of disconnection syndromes and their influence on language behavior. In addition to dealing with disruptions in connections between primary and secondary (or associative) areas of the cortex, he placed importance on the inferior parietal lobule (roughly Brodmann's areas 39 and 40) as a key site in cortical integration. This area is uniquely developed in man, Geschwind points out. Not essentially concentric with any of the primary sensory or motor projection areas, this area--"the association area of association areas"--may be capable of powerful intermodal associations. The loss or reduction of intermodal associations between audition, vision and some kinesthetic sensations would undoubtedly lead to impaired language function. He discussed the disconnections in terms of both intra-hemispheric and inter-hemispheric fibers. From Geschwind's position, it appeared that once the connections are disrupted the resulting loss or attenuation of function is permanent and irreversible. The mediating influence of the "association area of association areas" over the transactions of the sensory and motor areas is no longer as effective or efficient as it was prior to the cerebral insult.

It seemed that, from the viewpoint of Geschwind's transcortical model, the experimental treatment of the speech stimuli in this study would have no positive influence on the aphasic subject's ability to recognize or retain the stimuli.

Moderate localization position.--An orientation toward cerebral function that appeared to hold more promise in terms of the experimental treatment is the Pavlovian reflex theory of sensation and his concept of cortical "analyzers." These views have been investigated and set forth by Luria, a very thorough presentation appearing in 1962.[1] According to Luria, the reflex theory of sensation

> . . . is always an active reflex process associated with the selection of the essential (signal) components of the stimuli and the inhibition of the nonessential, subsidiary components. It always incorporates effector mechanisms leading to the tuning of the peripheral receptor apparatus and responsible for carrying out the selective reactions to determine the signal components of the stimulus. It envisages a continuous process of increased excitability in respect to some components of the stimulus and of decreased excitability in respect to others . . . In other words sensation incorporates the process of analysis and synthesis of signals while they are still in the first stages of arrival . . . The units of any sensory process (including hearing) are not only acts of reception of individual signals, measurable in terms of thresholds of sensation, but also acts of complex analysis and integration of signals, measurable in units of comparison and discrimination.[2]

The cortical region having to do with the most precise differentiation and the most complex integration of auditory stimuli was part of the "nuclear zone" for audition located in the superior temporal subregion. The "nuclear

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[1]Aleksandor Romanovick Luria, Higher Cortical Functions in Man, trans. by Basil Haigh, (New York: Basic Books, Inc., 1966).

[2]Ibid., p. 97.

zone" was defined as Brodmann's Areas 41, 42 and 22.[1] Injuries to Area 41, the primary area of the analyzer, have produced marked decreases in detection and discrimination of auditory stimuli. However, lesions in the secondary areas (Brodmann's 42 and 22) have resulted in quite different auditory dysfunction, according to Luria. These lesions, in the left hemisphere, have lead to disorganization in the ability to cope with complex groups of stimuli and the relationships among component parts of complex stimuli.

This dysfunction in the "analytic-synthetic" capacity is said to lead to difficulty in the identification of the phonemic signs in the acoustic patterns of the language system.[2] Because the "auditory analyzer" is closely associated with the cortical apparatuses of kinesthetic (articulatory) analysis, the efferent link for the perception of the sounds of speech was not sufficiently activated. These secondary areas possess wider systemic connections with adjacent cortical areas than does the primary auditory area. Direct stimulation of the secondary areas has given rise to potentials detected in the inferior segments of the premotor frontal portions of the cortex--Brodmann's Areas 44, 46 and 10.

There was reason to suspect that the experimental

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[1] _Ibid_., p. 44.

[2] _Ibid_., pp. 102-03.

treatment might activate sufficiently the post-cerebral insult capability of these secondary areas. Luria has cited studies that indicate the induction of potentials in these secondary auditory areas requires more intensive stimulation of the peripheral receptor than is required to induce potentials in the primary auditory area.[1] It seemed the increased durations of the speech stimuli might provide just such an intensification of the phonemic elements. Through the neurophysiological principles of facilitation and summation, this intensification may have improved perception and enabled better recognition and retention of the word stimuli. It was important to recognize that just a moderate increase in the sensory aspect of perception might be sufficient to trigger the efferent (motor) aspect of the perceptual action, hence sharpening the subject's perception of the stimulus to the point where linguistic meaning was aroused.

Subcortical integration.--A second basis for hypothesizing a positive influence from the increased durations of the stimuli on the tasks of this investigation seemed to be found in theories of cerebral function which deemphasized transcortical pathways. Reducing reliance on the extent of post-injury intactness of cortical pathways seemed

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[1] Ibid., p. 99.

to place less demand on the residual, functional adequacy of both the primary cortical areas and the associative cortical areas. It appeared that the intensification or amplification of the phonemic elements would have a greater likelihood of positively influencing performance if the residual adequacy of both primary and associative areas could be maximally integrated without depending heavily on the extent of the intactness of transcortical pathways.

Two theories of functional integration of the cerebral cortex seemed to offer such a basis. They were the theories advanced by Penfield and Roberts and by Pribram.

Penfield and Roberts[1] emphasized cortical-subcortical relationships in the matter of cortical integration. They relegated transcortical connections to a secondary role. They have drawn, as support for this position, evidence derived from the functional adequacy of patients who have experienced radical excision of cortical tissue bordering on primary sensory and primary motor areas. They have named this system the "centrencephalic system" and defined it roughly as a ganglionic area of the higher brain which acts as the central integrating mechanism--the point at which integration of neuronal transactions reaches its peak.[2]

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[1]Wilder Penfield and Lamar Roberts, Speech and Brain Mechanisms (Princeton, N.J.: Princeton University Press, 1959).

[2]*Ibid.*, pp. 21-22.

This postulated interdependency of subcortical centers and cortical centers, they suggested, is a complex one. Impulses triggered in subcortical areas take on the aspects of cortically bound efferent impulses. As efferent impulses aimed at the cortex, they activate one or more cortical areas. The activated cortical areas provide a mediating influence over the impulses having subcortical origin. In this mediating function, certain modifications may be made before the patterned (or repatterned) impulse complex travels along the post-cortical leg of the pathways to the peripheral effector mechanism.

In the view of Penfield and Roberts, subcortical integration functionally unites the two cortical areas they have indicated enable the elaboration of language through speech. The most important of the two areas for language function is the Posterior Speech Cortex, which encompasses Brodmann's Areas 39 and 40. This is the area to which Geschwind attached great significance in terms of intermodal associations. The Posterior Speech Cortex also encompasses most of the classical Wernicke's area. Of secondary importance to language function was the Anterior Speech Cortex situated in the frontal lobe, encompassing Broca's area, Area 44.[1] It will be recalled that Luria reports radiations from secondary acoustic fields reach

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[1] Ibid., pp. 192-204.

Area 44. While these points suggested areas of correspondence in the three rationales, a very important and distinguishing difference rested in the reliance Penfield and Roberts placed on subcortical integration.

Pribram[1] has proposed an alternative to transcortical models of cerebral organization in cognitive processes. He cited evidence from several sources which, he believed, made transcortical models unsatisfactory. One type of evidence indicated the classical dichotomy between motor (efferent) and sensory (afferent) cortical areas was not valid.[2] Secondly, while the first issue might be solved by designating the areas "primary motor (or sensory) projection areas," the functional relationship of these primary projection areas to their association areas was not substantiated by various surgical intervention techniques applied to the cortex. Again, the transcortical model becomes less useful when it was observed that the behavioral changes following such removal, isolation or cross-hatching of the cortex were not those that would be predicted by the transcortical models.[3]

Pribram suggested an alternative model based on

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[1]Karl H. Pribram, "Neocortical Function in Behavior," in Biological and Biochemical Phases of Behavior (Madison: University of Wisconsin Press, 1958), pp. 151-72.

[2]*Ibid.*, pp. 155-158.

[3]*Ibid.*, pp. 159-166.

the thalamocortical connection that the cortical area has with the thalamus. If the thalamic nucleus from which the thalamocortical connection arose received inputs from outside (extrinsic) the thalamus, the cortical area was regarded as an extrinsic sector. Intrinsic sectors of the cortex are those sectors having thalamocortical connections originating in thalamic nuclei which received inputs from within (intrinsic) the thalamus.

Pribram reported the extrinsic sectors correspond to the motor-sensory projection areas, whereas the intrinsic sectors were the classical association areas. With direct functional connections between projection areas and associations being doubtful, the functional significance of the subdivisions of the intrinsic cortex was believed to be the convergence of their output on a common subcortical mechanism. This mechanism also receives output from the extrinsic sectors. The output from the intrinsic system was seen as influencing the output of the extrinsic sectors through this convergence.[1] Without denying the specificity of function associated with certain primary and association areas, a model of cortical function resembling Penfield and Roberts' "centrencephalic system was developed."

In both the Penfield-Roberts and Pribram conceptions, a hypothesized system was seen which seems more

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[1]*Ibid.*, pp. 167-168.

resilient and capable of compensating for injury. Working from these systems, there appeared to be some reason to suppose that speech stimuli, in which phonemic durations were increased, would have some positive consequences on the auditory functions of aphasic subjects. Luria's theoretical views might encompass such an outcome, but a positive influence from the intended stimuli would be somewhat less probable. From Geschwind's point of view, the prediction of no significant effect from the expanded speech stimuli appeared to be the most logical.

Clinical Basis of Investigation

The short history of language therapy for the aphasic dates back to the period immediately after World War I and seemed to have made its most significant advance since World War II in response to the needs of those who sustained brain injury in that war.[1]

From his experiences in treating aphasics during World War II, Wepman reported the major receptive disability of the aphasic adult was in the comprehension of the spoken word. The most common deficit in this modality, which he labeled "auditory verbal agnosia," resembled the sensory aphasia described by Wernicke. However, Wepman reported

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[1] Joseph Wepman, Recovery from Aphasia (New York: Ronald Press Company, 1951), p. 4.

> . . . patients showing this problem have all gradations between comparatively normal speech production and a total lack of that facility, between a total lack of comprehension and a partial lack of the ability to understand spoken words, and between a retained ability to imitate and an apparent total lack of imitative ability.[1]

After necessarily ruling out the influence of impaired hearing acuity and general intellectual impairment, the comprehension loss remains, indicating the cortical disability of integrating aural stimuli, he stated.

Facilitating auditory language function.--The treatment approach recommended by Wepman, and endorsed by others such as Longerich and Bordeaux,[2] is to employ other sensory inputs in combination with auditory stimulation. Wepman notes

> In this area of disturbance more than any other must the total available resources of the patient be utilized. Where auditory stimuli are meaningless, the patient must be approached from the tactile-auditory, the visual-auditory, the kinetic-auditory and the combined visuo-tactile-kinetic-auditory. It should be noted that in each of the proposed approaches the auditory function is an integrated part of the training. The end product is not an ability to develop a substitute for hearing, nor by circuitous methods to hope for a transfer of training, but to redevelop in the patient his use of the disturbed auditory function.[3]

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[1] Ibid., p. 199.

[2] Mary C. Longerich and Jean Bordeaux, Aphasia Therapeutics (New York: Macmillan Co., 1954), pp. 17-18.

[3] Wepman, Recovery from Aphasia, p. 199.

In terms of this objective, increasing the duration of the auditory stimuli was viewed as an attempt to accelerate the redevelopment of the disturbed auditory function by making the auditory stimuli more immediately usable to the patient.

Schuell has maintained that auditory stimulation is the foundation of all aphasia therapy and is essential for all patients.[1] She continues to stress the importance of auditory stimulation, stating in 1965

> All evidence suggests that auditory stimulation is crucial in control of language processes. However, since feedback from more than one sensory modality may contribute to behavior, there is no reason for using this mode exclusively. This suggests that the first principle of treatment for aphasia should be the use of intensive auditory stimulation, although not necessarily stimulation through auditory channels alone.[2]

Nature of aphasic auditory language dysfunction.--In addition to intensifying the stimulus appropriately, Schuell has discussed making the stimulus as adequate as possible for the patient. Many clinicians have heard patients make statements like those which Schuell referred to when she wrote

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[1]Hildred Schuell, "Auditory Impairment in Aphasia: Significance and Retraining Techniques," JSHD, XVIII (1953), pp. 14-21. Hildred Schuell, Virginia Carroll and Barbara Stansell, "Clinical Treatment of Aphasia," JSHD, XX, (1955), pp. 43-53.

[2]Schuell, Jenkins, Jimenez-Pabon, Aphasia in Adults, p. 338.

> People talk too fast and say too much at a time for the aphasic patient to follow. Patients sometimes tell you that people do not seem to be talking right. To some patients it often seems they (people) are not even talking a language he knows.[1]

Luria has made a comment which seemed relevant to this type of aphasic experience. Discussing the role of the "auditory analyzer" in language and speech comprehension, he has written

> It is clear, therefore, that the perception of speech by hearing requires not merely delicate but systematized, hearing. When this selection of the essential, phonemic signs is no longer possible, phonemic hearing is disturbed. This is why the boundary between hearing speech and understanding it loses its sharp distinction. A person ignorant of a foreign language not only does not understand it, but does not even hear it, i.e., he does not distinguish from the flow of sounds the articulated elements of the language and does not systematize the sounds of speech according to its laws. The unfamiliar language is thus perceived by that person as a stream of unarticulated sounds, not only impossible to understand, but inaccessible for accurate auditory analysis.[2]

To the clinician aware of the problems confronting the aphasic patient, this statement must have a familiar ring.

Schuell discussed ways of manipulating the speech stimuli themselves so as to intensify or improve their adequacy for the patient. The objective was to enhance the patient's linguistic perception of the language units. The suggested variables were as follows: the loudness of the stimulus; the meaningfulness of the language units;

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[1] _Ibid._, p. 339.

[2] Luria, _Higher Cortical Functions_, p. 102.

the length of the stimulus; and the duration of the stimulus.[1]

Basing the tasks of this investigation on the theoretical notions of Schuell and her associates, it seemed logical to consider these variables in the design of the investigation. The four variables are given close consideration in the following section.

Experimental Tasks and Associated Variables

In this section the discussion centers on the rationale for selecting the two language tasks employed in this study and the variables considered in structuring the tasks.

Selecting experimental tasks.--The tasks of word recognition and serial retention were employed in this study as procedures for operationalizing the two primary characteristics of aphasia identified by Schuell and Jenkins.[2] They believed the language deficit in aphasia is characterized primarily by a reduction in available vocabulary and an impairment of verbal retention span. Impaired perception and impaired production of messages

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[1] Schuell, Jenkins, Jimenez-Pabon, Aphasia in Adults, pp. 339-40.

[2] Ibid., p. 113.

are additional characteristics which they felt may be secondary to the two primary characteristics. These characteristics of the language deficit are to be found in all language modalities to some extent and may be further impaired by primary disturbances in auditory, visual and sensorimotor processes.

To assess available vocabulary in the auditory modality, the word recognition task used seemed appropriate. Expecting the patient to point to a picture having the most meaningful association with a word spoken by the examiner is a task involving auditory recognition and the gross motor performance of pointing. Auditory recognition for single words might be considered a very low level test of a subject's available vocabulary. Successful performance on this task indicates a capacity to link the auditory representation of the referent with a visual representation of the referent. The recognition of stimulus equivalence attested to the availability of the word meaning in the subject's receptive vocabulary.[1]

In the second task it was necessary for the subject to retain a series of auditorily presented words, and then (maintaining the order of presentation) identify the pictures which had the most meaningful association with the words that had been presented. The period of retention

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[1] Ibid., pp. 149-53.

being on the order of from two to five seconds before the subject could begin his response, this task constituted a minimal test of auditory retention span. However, expecting the subject's reproduction (by pointing) to reflect the order of the auditory stimuli made this a more complex task than it would have been were order not required. It also reduced the likelihood of a subject's guessing a correct response.

The question of the relationship of performance on these tasks to language behavior was answered from the statistical analysis of the tasks comprising the Minnesota Test for Differential Diagnosis of Aphasia. The Minnesota Test included tasks similar to the two tasks employed in this study. In the factor analysis of the battery of tasks, the word recognition task and the serial retention task loaded high on the factor identified as a general dimension of language behavior.[1] The retention task, loading highest on this factor, had its second highest loading on a factor which appeared to represent "visual discrimination, and ensuing recognition and recall of learned visual patterns."[2] The factor on which the word recognition task had its highest loading was a factor involving recognition of

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[1] *Ibid.*, pp. 137-142.

[2] *Ibid.*, p. 143.

stimulus equivalence.[1] Aspects of the factor of general language dimension were identified as: vocabulary, auditory retention span, and the ability to deal with language formulations at various levels of complexity.[2] Therefore, it seemed the two tasks employed in this study were sampling language as it has been identified by these investigators.

The linguistic perception of auditory stimuli by adult aphasics is said to be influenced by four factors.[3] The following is a consideration of these factors.

Loudness of the stimulus.--In addition to being alert to the incidence of moderate to severe hearing losses in aphasic patients,[4] it has been suggested there may be an optimal loudness level for maximum auditory language reception. Except in cases of clearcut perceptual problems, most patients prefer listening at ordinary conversational levels in a free-field.[5]

Meaningfulness of the stimulus.--It is well established that meaningful units of language are recognized

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[1] Ibid., p. 151.

[2] Ibid., p. 153.

[3] Ibid., pp. 338-43.

[4] Barbara Stansell Street, "Hearing Loss in Aphasia," JSHD, XXII (1957), pp. 60-67.

[5] Schuell, Jenkins, Jimenez-Pabon, Aphasia in Adults, p. 340.

more easily than non-meaningful patterns. In the sense that all stimuli used in this study were words in the native language of the subjects, all the stimuli were meaningful.

On the word recognition task, an attempt was made to vary systematically the factor of meaningfulness in the stimulus words of the task. A measure of meaningfulness used in several studies of both normal and aphasic language performance is the frequency with which a given word is used.[1] Aphasic subjects have tended to follow the normal usage patterns but at reduced levels. This indicated that such a measure of meaningfulness was appropriate for the language performance of aphasic adults. The index of usage has generally been determined from word counts of written language,[2] not spoken language.

Another index of meaningfulness was suggested by the Peabody Picture Vocabulary Test.[3] As empirically derived, the test presented a set of words scaled in terms of

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[1]James Deese, "Form Class and the Determinants of Association," Journal of Verbal Learning and Verbal Behavior, I (1962), pp. 70-84. Joseph M. Wepman, *et al.*, "Psycholinguistic Study of Aphasia: A Revision of the Concept of Anomia," JSHD, XXI (1956), pp. 468-77. Hildred Schuell, James Jenkins and Lydia Landis, "Relationship between Auditory Comprehension and Word Frequency in Aphasia," JSHR, IV (1961), pp. 30-36.

[2]Edward L. Thorndike and I. Lorge, Teachers Word Book of 30,000 Words (New York: Bureau of Publications, Columbia University, 1944).

[3]Lloyd Dunn, Peabody Picture Vocabulary Test: Expanded Manual (Minneapolis: American Guidance Service, Inc., 1966), pp. 25-33.

the chronological development of hearing vocabulary. Since, on this task of auditory recognition of words, the factor of meaningfulness was to be varied systematically, this scaled set of words seemed uniquely suited to assessing auditory receptive vocabulary in relation to the other independent variables of the study.

An inspection of the stimulus words of the Peabody Test, in terms of their frequency of usage in written English, revealed those words associated with the period of early auditory language development were very common or highly frequent words in written English. Words associated with later periods of auditory language development were less and less frequent, becoming highly infrequent at the upper levels of the test. As Schuell, Jenkins, and Jimenez-Pabon have stated

> Both from a linguistic and neurophysiological viewpoint, we would expect that more would happen in the brain in response to frequently used words . . . than in response to rarely used words. . . .[1]

On a retention task, since the objective would be to equate the stimuli in terms of meaningfulness, only very common or highly frequent words would be used (e.g., the AA and A words of the Thorndike-Lorge General Count). In addition, on such a task, only one class or form of word might be used, perhaps the most frequent class of words.

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[1]Schuell, Jenkins, Jimenez-Pabon, Aphasia in Adults, p. 399.

Recognizing the semantic-syntactic problems connected with classifying words, it appears that nouns are the most frequently occurring class of words in the language.[1]

Length of the stimulus.--Controlling this variable is, reportedly, related to the reduced auditory retention span always found in aphasia.[2] Control has been suggested by varying the number of syllables per word and the number of words in the stimulus.

In a retention task, the number of words in the stimuli could be varied systematically to create a range of complexity in the task. The discrete words from which the stimuli were created could be controlled in terms of the number of syllables per word.

Duration of the stimulus.--In differentiating this factor from the factor of stimulus length, duration of the stimulus refers to the amount of time given to the utterance of elements in the stimulus, whereas stimulus length refers to the number of elements in the stimulus. Schuell, Jenkins and Jimenez-Pabon have found

> . . . patients with perceptual problems are often able to respond more adequately when a word or phrase is spoken a little more slowly than in ordinary conversational speech. However, inflection should be natural,

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[1]Roger Brown, Words and Things (Glencoe, Ill.: Free Press, 1959), pp. 53-55.

[2]Schuell, Jenkins, Jimenez-Pabon, Aphasia in Adults, p. 340.

> and slowing should not fragment or distort the language unit. Like increasing loudness, slowing down the rate seems to help severely impaired patients initially, then to make no difference.[1]

The above statement implied that the effectiveness of increasing the duration of the stimulus is related to the severity of the auditory language disturbance. Hence, any test of the effectiveness of durational increase should control for this aspect of the language disorder. Control over the severity of auditory language deficit might be achieved through use of a section of the Minnesota Test for Differential Diagnosis of Aphasia.[2]

One study has been found that applied this variable of stimulus duration (as defined here) to the comprehension of language. This investigation, by Luterman, Welsh and Melrose,[3] was designed to determine the effect of stimulus duration on the performance of subjects in responding to recorded phonetically balanced words. The experimental group consisted of aged subjects with sensorineural hearing losses. The experimental conditions included conditions in which the stimulus words were increased in duration

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[1] Ibid., pp. 340-41.

[2] Hildred Schuell, Minnesota Test for Differential Diagnosis of Aphasia: Administrative Manual (Minneapolis: University of Minnesota, 1965).

[3] David M. Luterman, Oliver L. Welsh and Jay Melrose, "Response of Aged Males to Time-Altered Speech Stimuli," JSHR, IX (1966), pp. 226-30.

by a factor of 110% and by a factor of 120%. Other conditions were 10% and 20% time compression of the word durations, as well as the original duration of the stimulus words. The experimental group did not show improved scores under the conditions of increased stimulus duration. The investigators found this outcome surprising, since they had observed, clinically, some advantage in speaking slowly and clearly with aged subjects while engaged with them in speech audiometry.

While investigations of the relationship between rate of speaking (words per minute) and intelligibility or listener preference have been conducted, the study cited above was the only relevant investigation employing the type of increase in stimulus duration used in this study. The relationship between speech compression (decreasing stimulus durations) and comprehension of messages has been investigated with normal subjects and with blind subjects.[1]

Increasing the duration of the auditory stimuli.[2]--Descriptions of two processes for accomplishing the kind

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[1]David B. Orr, Herbert L. Friedman and Jane C. C. Williams, "Trainability of Listening Comprehension of Speeded Discourse," Journal of Educational Psychology, LVI (1965), pp. 148-156. Emerson Foulke, et al., "The Comprehension of Rapid Speech by the Blind," Journal of Exceptional Children, XXIX (1962), pp. 134-141.

[2]Since increases in the duration of the stimuli was the experimental variable of interest in this study, and because the process by which the durational changes

of durational changes of interest in this study have been published. A computer process for compressing and expanding the durational aspects of speech has been reported, but the use of this process was not economically feasible at this time.[1] In 1954, Fairbanks, Everitt and Jaeger[2] published a description of an electromechanical apparatus capable of producing expanded or compressed versions of tape recorded materials. It was an electromechanical device of this nature that was employed in the compressed speech and expanded speech studies previously cited. This type of device was used in this study.[3]

The device operates on a sampling principle. In expanding a previously recorded signal, the device increases the temporal value of segments of the acoustic patterns of the original signal and records a second time some portions

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were produced has had such very limited application, it seems appropriate to provide a general description of the process at this point and a more detailed description which appears in Appendix A.

[1]Emerson Foulke and Thomas Sticht, "A Review of Research on Time Compressed Speech," (from the Proceedings of the Louisville Conference on Time Compressed Speech, University of Louisville, 1967).

[2]Grant Fairbanks, W. L. Everitt and R. P. Jaeger, "Method for Time on Frequency Compression-Expansion of Speech" (1954), in Grant Fairbanks, Experimental Phonetics: Selected Writings (Urbana: University of Illinois Press, 1966), pp. 37-42.

[3]The device used is sold under the name of Eltro Information Rate Changer-Mark II by Infotronic Systems, Inc., 2 West 46 Street, N.Y. 10036.

of the signal. These extra portions (or second samples) appear in the expanded reproduction of the original signal immediately following and adjacent to the first reproduction of the segment. With these "extra samples" of the initial signal added and the temporal value of all samples increased, the expanded reproduction of the signal will have a greater (expanded) duration than the original recording of the signal. When that original signal is speech, the expansion process increases durations of the phonemes in the word, as it reproduces some portions of the initial recording for a second time. This durational increase is accomplished without changing the frequency characteristics of the original signal in any perceptually significant way. This expanded reproduction can be recorded in the standard manner. Depending on the level of expansion, the word, when expanded, will be perceived auditorily as being "stretched out" in comparison to the original version of the word, free of the pitch distortions associated with "slow played" speech which severely reduces its intelligibility.[1] At the upper limits of the device there is a distracting type of distortion in the expanded reproduction which is a function of the temporal values of the repeated segments.[2] The

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[1]William R. Tiffany and Delmond Bennett, "Intelligibility of Slow Played Speech," JSHD, IV (1961), pp. 248-258.

[2]Fairbanks, Everitt, Jaeger, "Compression-Expansion of Speech," p. 41.

upper limit of the device used in this study is 200% expansion (a reproduction having twice the duration of the original signal). There is some indication this distortion has little influence on intelligibility with normal (non-aphasic) listeners.[1]

Summary

This review has indicated that as the study of aphasia has developed during the last one hundred years, it became apparent that the language dysfunction experienced by the aphasic adult involved both the expressive and receptive modalities. It was possible to discern a trend toward conceptualizing the language dysfunction as a unidimensional characteristic, that was operationalized most meaningfully on the basis of observable language performance. It appeared these performances could be analyzed from a linguistic frame of reference. Also, it was possible to take a descriptive approach, based on observations of the aphasic adult's performance of language tasks.

There appeared to be rather authoritative agreement that disturbances in auditory language reception are generally a significant aspect of the total aphasic problem, and are, therefore, very important in the treatment of the

[1]George H. Kurtzrock, "The Effects of Time and Frequency Distortion upon Word Intelligibility," (Ph.D. Dissertation, University of Illinois, 1956).

language dysfunction. In view of this importance, it appeared worthwhile to investigate a means of facilitating auditory language function in aphasic adults. The procedure selected for investigation was increasing the duration of the auditory stimulus.

There seemed to be some neurophysiological support for investigating this dimension of a linguistic stimulus. Several current theories of cerebral function offered a basis for assuming increased stimulus duration would positively influence the performance of aphasic adults on certain language tasks.

In the clinical application of this procedure, several variables have been described that bear on the auditory language reception of aphasic adults. Two of these variables were the subjects' level of auditory language function and the meaningfulness of the stimulus material. These factors were considered in the design of the present experimental investigation.

Two tasks that appeared to have a high degree of relevance to a general dimension of language dysfunction in aphasia were word recognition and retention span. Therefore, auditory tasks involving these capabilities seemed appropriate tasks upon which to test the influence of increased stimulus durations. An electromechanical means of producing temporal expansions in recorded words was available and appeared adequate for an initial experimental investigation of increased stimulus durations on the language receptivity of aphasic adults.

CHAPTER III

EXPERIMENTAL PROCEDURES

This chapter includes a description of the development of the stimulus materials for the word recognition task and the serial retention span task, as well as a discussion of the recording procedures and the manner in which the durational increases were affected in these recordings. The chapter also deals with the selection and grouping of subjects and the procedures followed in presenting the tasks to the subjects. A description of the scoring procedure is given.

Selection and Preparation of Stimulus Materials

Word recognition task materials.--The two forms of the Peabody Picture Vocabulary Test (PPVT)[1] were used as the source of stimulus words and response pictures for the word recognition task. Each form of the test, consisting of 150 words each, was divided into two lists of seventy-five words each. The division was made by assigning the

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[1]Lloyd Dunn, Peabody Picture Vocabulary Test: Expanded Manual, (Minneapolis: American Guidance Service, Inc., 1965).

odd numbered items of the form to list number 1 and the even numbered items to list number 2. Dividing both Form A and Form B of the test in this manner yielded four lists of seventy-five words each, that were designated as A_1, A_2, B_1, and B_2. (See Table 1)

TABLE 1.--Separation of PPVT Forms into Four Lists and Three Hearing Vocabulary Levels.

		PPVT - Form A		PPVT - Form B	
		List A_1	List A_2	List B_1	List B_2
HEARING VOCABULARY LEVELS	I	odd items 1 - 50 1	even items 1 - 50 2	odd items 1 - 50 3	even items 1 - 50 4
	II	odd items 51 - 100 5	even items 51 - 100 6	odd items 51 - 100 7	even items 51 - 100 8
	III	odd items 101 - 150 9	even items 101 - 150 10	odd items 101 - 150 11	even items 101 - 150 12

In terms of hearing vocabulary, as defined earlier, it seemed reasonable to assume the overall difficulty of the four lists would be equivalent. With the two forms of the PPVT being generally equivalent and dividing each form as described, this assumption seemed justified. Perry and Boswell report a correlation of .92 between the two forms when used with aphasic adults.[1]

Each form of the test was regarded as a scaled set of words reflecting the chronological development of hearing vocabulary through the first eighteen to twenty years of life. It is the scaled aspect of the words in each form of the test that permitted the segmentation of each 75 word list into the three Hearing Vocabulary Levels indicated in Table 1. The arbitrary division of each list into three levels provided a means of looking at the available hearing vocabulary of adult aphasics in terms of three developmental levels of hearing vocabulary under the four experimental conditions.

For the purposes of this study, the twenty-five words at Level I of each list were regarded as reflecting the initial phase of the early development of hearing vocabulary. The twenty-five words in the Level II, and Level III segments reflected intermediate and late phases of hearing vocabulary development.

For each of the stimulus words of the PPVT, there was a response plate consisting of four pictures. There were 150 response plates, the same set of 150 plates being used with Form A of the test as were used with Form B. While the stimulus words differ for a given numbered item

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[1]Peter S. Perry and Nathalie S. Boswell, "Adult Aphasic Performance on the Peabody Picture Vocabulary Test," (paper presented at American Speech and Hearing Association Convention, November 3, 1967).

on Form A and Form B, the response plate was the same. One of the four discrete pictures of each plate was the correct picture to associate with a stimulus word on Form A of the test, whereas another picture was the correct picture to associate with the same numbered stimulus word from Form B of the PPVT. The two other pictures were foils.

Thirty-five millimeter slides were prepared of the entire set of 150 response plates. These slides were used to project the response plates in front of the subjects, as will be described later.

Serial retention span materials.--Two basic considerations entered into the development of materials for this task. They were building into the task an adequate range of difficulty and maintaining equivalency of the discrete units of each stimulus.

An adequate range of difficulty was built into this task in order to promote a reasonable range of scores. Only with such a range of scores would it be possible to observe the influence of the experimental treatment. For this study, the series contained two, three, four and five words.

Secondly, it was important to keep the words used in the construction of all series equivalent on certain relevant criteria in order to stay as close to the defined purpose of the task. The three equivalence criteria used in this study were grammatical class, frequency of usage (written English), and hearing vocabulary level.

One grammatical class of words was used. This class was nouns.

Frequency of usage in written English was determined from the Thorndike-Lorge General Count.[1] Schuell, Jenkins and Landis[2] demonstrated the significance of this variable on the ability of aphasic subjects to recognize words presented auditorily. All of the words used in the development of materials for this task had a frequency of usage equal to or greater than 100 times per million. This placed the words among the most frequently used written words of English.

To establish equivalence in terms of hearing vocabulary, the empirically derived scaled word lists of the PPVT were again employed. For this retention span task, only objects pictured in the first fifty plates of the PPVT were used, providing they met the frequency of usage criteria. By empirical determination, the names of the objects pictured in the first fifty plates were within the mean expectation for individuals with a chronological

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[1]Edward L. Thorndike, and I. Lorge. The Teacher's Word Book of 30,000 Words (New York: Bureau of Publications, Teachers College-Columbia University, 1944).

[2]Hildred Schuell, James J. Jenkins, and Lydia Landis, "Relationship Between Auditory Comprehension and Word Frequency in Aphasia," Journal of Speech and Hearing Research IV (1961), pp. 30-36.

age of approximately five years.[1] This provided some additional assurance that the words used were a long standing part of the subject's hearing vocabulary.

It was determined that thirty words met these three criteria. Hence, there were thirty stimulus words and their associated pictures (from the PPVT) available for the development of materials for this task. The thirty picture names are given in Appendix B. The arrangement of these pictures into response plates and the selection of the appropriate number of stimulus words for each plate was accomplished in the following manner.

For this task, thirty-two response plates were required, one for each of the thirty-two stimuli. A series of discrete words was defined as a stimulus. The four duration conditions and the four complexity levels (two, three, four and five word series) created sixteen conditions. Providing two stimuli for each condition resulted in the need for thirty-two stimuli and associated response plates. The pictures for each of the eight-picture response plates were randomly selected, with replacement, from the pool of thirty available pictures. The thirty-two arrangements were photographed on thirty-five millimeter film and processed into slides. Two response plates were then assigned randomly to each of the sixteen conditions. A

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[1]Lloyd Dunn, Peabody Picture Vocabulary Test, p. 12.

plate was designated as either plate A or plate B for a particular cell, indicating the order in which they would be presented to subjects.

With the assignment of plates to conditions completed, the appropriate number of words for each stimulus was selected randomly from each response plate. The number of words selected depended on the complexity level to which the response plate had been assigned. The auditory stimulus consisted of either two, three, four or five picture names with the word "and" inserted before the final word of the series. The inclusion of this conjunction made the stimulus a more complete unit, and enhanced its resemblance to a language unit.

In Appendix B are found the names of the pictures included in each response plate and the stimulus associated with each response plate. The duration conditions to which the materials were assigned are also indicated in this appendix.

The particular stimulus duration-stimulus complexity condition to which the materials were assigned was the same for all subjects. The discrete units of the stimuli were equivalent, and the different random order of conditions was employed for each subject. This randomization procedure will be elaborated in a later section.

Equipment and Materials

The equipment and materials reported below were used in the phases of this experiment to be described in following sections of this chapter.

Equipment.

Tape recorders:

Ampex, Model 350-2
Wollensak, Model T-1500
Sony, Model TC-211TS

Microphone:

Electro-Voice, Model 654

Spectographs:

Voiceprint Laboratories
Kay Sonograph, Model 6061-A

Slide projector, rear projection:

Sonoscope

Amplifier-speaker:

Ampex 620

Power Level recorder:

Bruel-Kjaer Level Recorder, Type 2305

Speech compresser-expander:

Eltro Information Rate Changer-Mark II

Materials.

Kodacolor II, 35 mm.

Scotch Brand Magnetic Recording Tape-111

Recording of Auditory Stimuli

One adult male recorded all the stimulus words for both the word recognition task and the serial retention span task. The use of a single voice eliminated the possible influence of differences in the fundamental pitch of voices and variations in voice quality which would be associated with the use of more than one speaker.

Equipment.--The speaker recorded the material in the sound isolated environment of a prefabricated sound treated booth, using a table mounted microphone. The recorder used was operated at a tape speed of fifteen inches per second. The speaker was able to monitor visually the loudness of his voice by means of the VU meter in the recorder. The speaker was successful in keeping the intensity of the voice signal delivered to the recorder within plus or minus three decibels of the zero decibel reference on the VU meter.

Intelligibility.--An intelligibility check on the recording was made. The recording of the 300 single words and the thirty-two serial retention span items was played to six persons who were not familiar with the Peabody Picture Vocabulary Test. Each person listened to the recording by himself, responding to the recorded words by repeating each word heard. The responses of the six listeners revealed that all but five of the words in the original recording were correctly identified. These five words were re-recorded into the lists. The segments of the lists containing these words were then replayed to the six listeners. On the second presentation the five words were correctly identified, thus making it possible to say that the recorded words were 100% intelligible.

Controlling duration of original stimuli.--It was important to exercise some degree of control over the duration of the words as they were uttered by the speaker in the original recording of the stimulus material. It was felt the durations of the words in the original recording should conform to the expected durations of the words in a connected speech context. In the absence of any relevant previous research, this control was sought in the following manner.

A random sample of one-syllable, two-syllable, three-syllable, four-syllable, and five-syllable words was drawn from the 300 words of the PPVT. The words were drawn so that there were ten words in the first three categories (one, two and three syllable words) and five words in the latter two categories (four and five syllable words). These forty words were then imbedded in syntactically correct paragraph contexts. The speaker rehearsed reading the several paragraphs until the rate of oral reading approximated the rate of 160 words per minute. His oral reading of these paragraphs, at this rate, was then recorded.

This rate of 160 words per minute was an overall rate which includes pauses between sentences. This seemed to be an appropriate rate to use after examining the analysis of measures of speaking and oral reading rate presented by Johnson, Darley and Spriestersbach.[1]

The duration of each of these forty words was determined from spectrograms obtained for each of the words. In converting the linear measurements from the spectrograms to durations in milliseconds, one millimeter was given the value of 7.874 msec. The mean duration in milliseconds and the standard deviation was determined for each group of words, the one, two, three, four and five syllable word groups.

Using the obtained sample means (M) from each of the several groups of words, an estimated range of word durations was determined, such that 95% of the words in that group would be expected to fall within this range. Based on the standard deviation (s.d.) of each sample, the formula used to derive the interval was

$$P\ [M - 1.96\ (s.d.) \leq x \leq M + 1.96\ (s.d.)] = .95$$

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[1]Wendell Johnson, Frederic L. Darley, and Duane C. Spriestersbach, Diagnostic Methods in Speech Pathology, (New York: Harper and Row, Publishers, 1963), pp. 202-04.

Assuming the durations of words within each of these groups is nearly normally distributed, it seemed reasonable to say that additional observations (x) of word durations, which fell within the interval for the word's particular group, were quite probably of a duration to be found in connected speech delivered at a rate of 160 words per minute. A word having a duration which fell outside the interval, for its appropriate group (one syllable, two syllable, etc.), would be regarded as an extremely unlikely event. The results of this analysis of the forty words from context and the intervals computed for each group of words is given in Appendix C. Treating the obtained intervals as acceptance intervals, it was possible to evaluate the recorded single word utterances and the words of the serial retention span stimuli in terms of the extent to which their durations conformed to the durations one would expect in connected speech.

Rather than evaluate all of the recorded words, a random sample of words was drawn from both sets of recorded stimulus materials: thirty words from the 300 single word stimuli and six words from the thirty-two serial retention span stimuli. An *a priori* decision rule was made. This rule was as follows: if more than 90% of the word durations in the sample (thirty-six words) were within the acceptance intervals of their syllable groups, the entire set of recorded stimuli (single words and serial retention items) would be accepted as having durations that would quite likely be found in connected speech uttered at the rate of 160 words per minute. If 10% or more of the words in the sample (four or more words) had durations exceeding the limits of the appropriate interval, the entire set of words was to have been examined spectrographically, in terms of their durations. Recorded stimuli having durations falling outside the established acceptance intervals were to be re-recorded and made to conform to the derived intervals.

The durational measures made on the randomly drawn sample of thirty-six words are given in Appendix C. It will be observed that only two of the thirty-six words had durations falling outside the acceptance interval for their class. The words were: transportation and illumination. They exceed the upper limits of their respective intervals by 261.58 msec. and 65.18 msec.

Based upon the _a priori_ decision rule, the durations of all the recorded words were accepted as being within the expected durational limits for words in connected speech uttered at 160 words per minute. In the sample of thirty-six words, over 91% of the words had durations falling within their appropriate acceptance interval.

Calibration check tone.--To have a means of measuring the precision of the temporal expansions to be made of the stimulus words, a puretone was recorded into the several lists of words. It was felt that a puretone provided a well defined unit upon which to base these measurements. Its onset and termination were better defined than the beginning and ending of a word. Comparing expanded durations of the puretone with the original duration of the tone provided a measure of the durational changes produced in the recorded words by the expansion process.

A 1000 Hz tone was placed at the beginning and end of each of the four lists of seventy-five words, lists A_1, A_2, B_1, and B_2. The tone was also placed at the beginning of the eight stimuli associated with each of the duration conditions for the serial retention span task. The tone had a duration of approximately two seconds.

The outcome of the calibration check is reported in the discussion which follows regarding the expansion of the recorded materials.

Production of increased duration stimuli.--The increased durations of the auditory stimuli - single words and word series - were produced by an electromechanical device, sometimes referred to as a speech compresser-expander. From the original tape recordings of these stimuli, this electromechanical device sampled the stimuli with a degree of temporal expansion that approximated the desired level of durational increase. The product of this processing was reproduced on a second tape at 7.5 inches per second.

As has been previously explained, given the normal duration of the signal or message, the device was able to increase the duration of the signal by a factor of from 1.00 to 2.00. In other words, if the signal at the initial recorded duration (normal) was expanded by a factor of 1.50, it had a duration 50% longer than its initial duration. The signal was now 150% of its original time or duration.

The fixed levels of increased duration selected for this investigation were 125%, 150% and 175%. Adding the normal duration (duration as initially recorded or the 100% level) to the three increased durations provided four levels of the experimental treatment. These levels were selected as representative levels within the expansion capabilities of the electromechanical device.

As previously mentioned, a calibration check tone was used to evaluate the precision of the expansion process. A power level recorder was used to obtain a read-out of the duration of the two second tone (1000 Hz) at the normal duration and at the three expanded durations. Appendix D contains the measurements obtained from this calibration check.

It will be observed in Appendix D that each of the four lists--A_1, A_2, B_1 and B_2--were expanded to the three nominal duration levels. The calibration check tone appeared at the beginning and end of each list. Hence, it was possible to examine the precision of the processing of each list and the constancy of the processing throughout each list.

The measurement of the reference tone (two seconds) was 61 mm., obtained from the read-out of the level recorder. The measured durations (in milliseconds) for the expanded versions of the 1000 Hz tone were compared to this 61 mm. reference. The ratio of the expanded duration to the reference duration was expressed as a percentage of the reference tone. The measurements and percentages are reported in Appendix D.

All obtained expansions were within five percent of the nominal levels of durational increase specified. On the basis of an *a priori* decision, and using the obtained measurements of the calibration check tone, the recorded word stimuli were accepted as being increased in duration to each of the three nominal levels. Before processing, it was decided that deviations of up to five percent from the specified levels of expansion would be accepted under that nominal level.

Each of the four lists--A_1, A_2, B_1, and B_2--was now available at each of the four durations of 100%, 125%, 150% and 175%. Within each version of the four lists, groups of twenty-five words, representing each of the three Hearing Vocabulary Levels were re-recorded, at 3.75 cps on a separate tape. Separately storing each group of twenty-five words at each of the durational levels enabled the type of random presentation procedure to be described in a following section.

Selection and Grouping of Subjects

This section describes the manner in which subjects were identified and selected for participation in the study, as well as the procedure followed in separating the twenty-four subjects into two groups. The subjects were obtained from five treatment centers in Michigan: Constance Brown Hearing and Speech Center, Kalamazoo; Veterans Administration Hospital, Battle Creek; American Legion Hospital, Battle Creek; Rehabilitation Medical Center, Lansing; and Speech Clinic-University of Michigan, Ann Arbor.

Diagnosis.--Each of the subjects in this study had been diagnosed as having some degree of language deficit consequent to a cortical insult of some nature. For all subjects, the aphasia was exhibited at least ninety days following the cortical insult. Delaying the diagnosis until ninety days after the cortical insult generally avoids the period of greatest physiological instability and avoids transient language disturbances that are frequently associated with the immediate post cerebral insult period.

Schuell, Jenkins, and Jimenez-Pabon[1] have indicated the consensus is that most patients reach this stability in about ninety days.

The diagnoses of aphasia were made by several professional speech pathologists. Several examiners were involved as a consequence of having obtained the subjects from several treatment centers. All of the examiners held at least a master's degree in speech pathology and had three or more years of professional experience working with aphasic adults. The speech pathologists based their diagnoses, at least in part, on generally used diagnostic tests such as The Minnesota Test for Differential Diagnosis of Aphasia (MTDDA)[2] and The Language Modalities Test for Aphasia.[3]

All of the subjects had been accepted for treatment in language rehabilitation. This fact is cited as indicating a degree of physiological and psychological stability sufficient to coping with tasks such as those undertaken in this investigation.

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[1]Schuell, Jenkins, and Jimenez-Pabon, Aphasia in Adults, p. 160.

[2]Hildred Schuell, Minnesota Test for Differential Diagnosis of Aphasia: Administrative Manual (Minneapolis: University of Minnesota Press, 1965).

[3]Joseph M. Wepman and Lyle Y. Jones, The Language Modalities Test for Aphasia (Chicago: Education - Industry Service, 1961).

Auditory and visual screening.--It was desired that the auditory sensitivity and visual processes of all subjects be reasonably intact. Primary sensory deficits in these modalities could affect the subjects' performances on the experimental tasks in ways quite independent from the language deficit.

Information was obtained on the auditory sensitivity of all subjects. This information was taken from recent threshold tests or from a screening assessment made at the time the subject was considered for participation in the experiment. The pure tone average, for 500, 1000, and 2000 Hz, by air conduction was no greater than 25 dB (ISO, 1964 Standard) for the better ear of each person accepted as a subject.

In terms of visual function, the medical and clinical records of all potential subjects were examined for indications of visual field problems or uncorrected visual acuity problems which would make the use of the response plates (in experimental tasks) difficult or impossible. Failing to find such evidence, the performance of each person on the first two subtests of the Auditory Disturbance section of the MTDDA was scrutinized for suggestions of interfering visual disturbance. These subtests employ pictured objects in the response plates, as did the tasks of the experiment. All of the persons accepted as subjects made correct responses on 74% or more of the forty-two items on these two subtests. In fact, the median percentage correct for all subjects on these two tasks was 99%. For subjects accustomed to wearing glasses, it was determined if the glasses enabled him to view the response plates better.

On the basis of these outcomes, it seemed reasonable to assume that all subjects were free from primary auditory sensitivity problems and primary visual problems which would impair their performance on the experimental tasks.

Grouping subjects.--After determining that the adult aphasics had met the previously mentioned criteria, five additional subtests of the Auditory Disturbance Section of the MTDDA were administered to them.

These five subtests plus the two previously mentioned subtests constituted the diagnostic tests of this section and are intended to assess impairment in auditory discrimination, reduction of auditory comprehension of vocabulary, and reduction of auditory retention span.[1] The two nondiagnostic subtests omitted from this section of the MTDDA were the test of understanding sentences and the test of understanding a paragraph. The subtests were

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[1]Hildred Schuell, Differential Diagnosis of Aphasia with the Minnesota Test (Minneapolis: University of Minnesota Press, 1965), pp. 26-36.

administered as directed in the manual,[1] with one slight modification. The response plates for three subtests were presented to the subjects by means of the slide projector to be described. This was done to condition the subject for the tasks of the experiment. This modification was made for the following subtests: recognizing common words; recognizing letters; and identifying items named serially. No modification was made in the administration of the other four subtests concerned with discriminating between paired words, following directions, repeating digits, and repeating sentences.

An error score was determined for each subject on the basis of the seven subtests, with the possible range of scores being zero to ninety-six. This score was regarded as a global measure of auditory language disturbance.

Auditory language disturbance was a factor of interest in analyzing the outcomes of this study, as indicated by the hypotheses stated earlier. To control and examine the influence of this variable on the performance of the experimental tasks by the subjects, the sample of twenty-four subjects was separated into two groups on the basis of these error scores.

No attempt was made to control the range of auditory language disturbance scores by selectively accepting

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[1]Hildred Schuell, Minnesota Test, pp. 5-8.

subjects. The division of the total sample was made after all the subjects had been tested.

Subjects with error scores in the lower 50% of the distribution of scores were designated as belonging to the group displaying low auditory language disturbance. Those subjects with error scores in the upper 50% of the distribution were designated as belonging to the high auditory language disturbance group. For the twenty-four subjects, the range of error scores was from four to sixty-five, with the median value being 16.5.

As indicated in Table 2, the distribution of error scores for the low auditory language disturbance group differed from the distribution of scores for the high auditory language disturbance group. The statistical significance of this difference was tested by the Mann-Whitney

TABLE 2. Comparison of Auditory Language Disturbance (ALD) Error Scores of Two Subject Groups.

Group	Median	Range	Mann-Whitney U
Low-ALD	10.5	4-16	
			0.00*
High-ALD	32.0	17-65	

*Probability (one-tail) < 0.00

U Test,[1] as the distributions of scores could not be considered normal. The obtained U was 0. This U had a probability of approximately .00 in testing the hypothesis of no difference between groups against the directional hypothesis that the error scores of the high auditory language disturbance group were in fact higher than the error scores of the low group. Hence, the null hypothesis was rejected in favor of the alternative hypothesis which stated the groups were different in terms of auditory language disturbance.

Other characteristics of the two groups that were examined and tested are given in Table 3. It would have been desirable to have found the two groups similar in terms of these characteristics. The characteristics were quantified in the following manner: age in years to nearest birthday; education in years; and time since onset of aphasia in months. Because the distributions of these measures could not be assumed to be normal, the Mann-Whitney U Test[2] was used to test whether the two groups had been drawn from the same population. Since differences in either direction between the two groups was of interest, a two-tailed test for statistical significance was made, setting the confidence level at .95.

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[1]Sidney Seigel, Nonparametric Statistics for the Behavioral Sciences (New York: McGraw-Hill Book Co., 1956), pp. 111-116.

[2]Ibid.

TABLE 3. Comparison of Age, Educational Level, and Elapsed Time since Onset of Aphasia of Two Subject Groups (Low-ALD and High-ALD).

Characteristic	Low-ALD Group	High-ALD Group	Mann-Whitney U
Age (years)			
Median	41	56	28.0*
Range	21-60	37-72	
Education (years)			
Median	13	12	42.0
Range	12-24	7-17	
Onset (months)			
Median	14	23.5	53.5
Range	3-33	2-50	

*Probability (two-tailed) $< .05$

The hypothesis of no difference between groups was rejected for the age characteristic, with $\alpha = .05$. Interest in the age of the subjects in the two groups stems from the question of the influence of aging on intelligence, more specifically on vocabulary ability. As Wechsler[1] has indicated, vocabulary is less vulnerable to the influences associated with aging than the other capacities assessed by the Wechsler Adult Intelligence Scale. Wechsler indicated little change in the vocabulary scores over the sixteen year period represented in the median age difference between

[1]David Wechsler, The Measurement and Appraisal of Adult Intelligence (Baltimore: Williams & Wilkins Co., 1958), p. 85.

the two groups in this investigation. The vocabulary test of the WAIS is more difficult than the PPVT, in that, on the WAIS the subject must define the word verbally. While the desirability of having greater similarity in the ages of the two groups cannot be denied, the difference was not believed to be critical in terms of the experimental tasks of this investigation.

Educational level showed no statistically significant difference between groups, and only one year of real difference. The median educational level for the low auditory disturbance group was one year beyond high school, while the median level for the other group was high school graduation. This similarity between groups was a most important factor. Lacking information concerning the premorbid intelligence of the subjects, it indicated some degree of equality between groups in terms of premorbid academic achievement. From this similarity, some degree of equality in premorbid vocabulary development was inferred.[1]

The time elapsed since onset of the aphasia was the other group characteristic reported in Table III. On the basis of the statistical test, it was assumed the observed difference was not significant. This factor was seen as reflecting on the degree of motivation subjects had toward participation in the experimental tasks.

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[1] <u>Ibid</u>., p. 84.

Subjects with long standing aphasic conditions might be less motivated to participate in the experimental tasks than an equally impaired subject who had experienced the aphasia more recently.

Presentation of Stimuli to Subjects

Apparatus.--The tapes bearing the recorded auditory stimuli were played on a tape recorder that had a built-in photo-synchronizer circuit, enabling one to synchronize the audio output of the tape recorder with visual stimuli presented on a slide projector. The synchronizing signal from the recorder was delivered to a rear-projection type of slide projection device. The image was projected on a glass screen at the front of the unit. Since the projector itself was behind the screen, touching the screen did not disturb the projected image on the screen. The projector was equipped to handle thirty-five millimeter slides.

The projected image from the slides of the Peabody Test response plates was practically the same size as that of the response plates themselves (6.25 inches x 8.75 inches vs. 6.25 inches x 8.50 inches). The image of the specially constructed response plates for the serial retention span task measured 9.25 inches x 6 inches.

The inaudible signal, which activated the slide changing mechanism of the projector, was placed ahead of the stimuli on the tapes. The signal preceded the stimuli by a period of time sufficient to allow the slide changing mechanism to get the slide into position before its associated word was played. The slide was in position anywhere from two to three seconds before the auditory stimulus was played.

The auditory stimuli were played through an amplifier-speaker rather than through the internal speaker of the tape recorder. The amplifier-speaker was used to provide an auditory stimulus having better fidelity than would have been obtained from the internal speaker of the tape recorder. The amplifier-speaker was placed directly above the projection screen. Hence, the auditory stimuli and the response plate were aligned in the same vertical plane. The output of the speaker was adjusted to a comfortable loudness level, as determined by questioning the subject about the loudness of the signal. In general the level of the auditory stimuli was on the order of 60 to 70 dB SPL (re: .0002 dynes cm^2) at the ear of the subject.

Test conditions.--The conditions under which the testing was done varied as a result of having secured subjects from several different treatment centers. Each subject was tested in the room (or a room quite similar to the room) in which he had previously received therapy. The rooms were reasonably free of visual and auditory distractions and were physically comfortable in terms of temperature and ventilation. Also, these conditions were essentially constant for each subject for each of the three test sessions required for the completion of the tasks in the experiment.

Each of the three test sessions lasted from thirty to sixty minutes. The first session approached sixty minutes for all subjects since the Auditory Disturbance Section of the Minnesota Test for Differential Diagnosis of Aphasia was administered during this session. Testing of a subject was completed within a three day period, with the elapsed time between test sessions being twenty-four hours.

The subjects were seated in front of the projection screen and were assisted in positioning themselves at a comfortable visual distance and angle in relation to the screen. For no subject did this position preclude his being able to touch easily and comfortably the screen of the projector. If the subject was accustomed to wearing glasses, it was determined whether or not his glasses enabled him better to view the visual image on the screen of the projector.

The experimenter was seated to the left of the subject. From this position, the experimenter was able to observe the subjects' pointing responses and still control the tape recorder and record the subjects' responses to the auditory stimuli.

Randomization of stimuli.--The two sets of stimuli--single words and serial items--were randomized independently, with the randomization of the stimuli for each of the tasks being different for each subject. The randomization procedure for the word recognition task is described first, followed by a description of the procedures employed in randomizing the serial retention items.

The twenty-four randomizations, used in presenting the stimuli for the word recognition task to the subjects, were developed by first assigning each of the four lists of seventy-five words, lists A_1, A_2, B_1, and B_2, to one of the four stimulus duration conditions. The assignment was made so as to employ all twenty-four permutations of the four lists. In each of these twenty-four arrangements, the first list was assigned to the 100% stimulus duration; the second list to the 125% duration; the third to the 150% duration; and the fourth list to the 175% stimulus duration. Within each of these lists, the three Hearing Vocabulary Levels were represented. At each level there were twenty-five stimulus words. One such matrix is given in Table 4. Each block of the matrix represents twenty-five stimulus words.

In Appendix E is found the arrangement of lists for each subject. For each of the twenty-four arrangements of the lists, the blocks of twenty-five words were indexed in the same manner. Based on this system of indexing, the

TABLE 4.--Sample Arrangement of Lists with Block Index Numbers.

Hearing Vocabulary Level	Lists: B_1	A_2	A_1	B_2
I	1	2	3	4
II	5	6	7	8
III	9	10	11	12
Stimulus Duration Conditions	1.00	1.25	1.50	1.75

order of presentation for the twelve groups of twenty-five words was randomized for each subject. There were twenty-four such randomly selected block sequences.

The serial retention span stimuli were randomized in a manner similar to the randomization of blocks for the word recognition stimuli. For the serial retention stimuli, each of the four stimulus durations were coupled with four levels of stimulus complexity (two, three, four, and five word series). This resulted in a sixteen block matrix. The auditory stimuli and their associated response plates were not varied across durations for this task, as they were for the word recognition task. Each block contained two serial retention items, the number of words in the auditory stimulus being determined by the complexity level at which the items were placed. The blocks were indexed (in the manner indicated for the word recognition stimuli) with the numbers one through sixteen. One randomization of the sixteen blocks was generated for each subject, for a total of twenty-four block sequences.

One randomization for the word recognition task and for the serial retention span task were paired, and assigned a subject number. The subject was exposed to both of the experimental tasks at each of the three test sessions: four sets of single words with each set containing twenty-five words; and five or six pairs of serial items. The order in which the tasks were presented to a subject varied systematically from test session to test session. If word recognition was the first task of session one, it was the second task of session two, and the first task of session three. The word recognition task was the first task of session one for half of the subjects, while the other half of the subjects began session one with the serial retention span task. This arrangement of tasks within sessions offset possible order effects of one task upon the other.

Instructions to subjects.--Following the administration of the Auditory disturbance section of the MTDDA, either the word recognition task or the serial retention span task was administered to the subjects. At the first test session, the following instructions were given.

For the word recognition task, the instructions were as follows:

> I'm going to show you some pictures like these (pointing to screen with PPVT Example A displayed). You see there are four pictures (pointing to each picture). You will hear a word, then I want you to point to the picture which best tells the meaning of the word. Let's try one. Point to the picture which best tells the meaning of crib. (Get correct response before proceeding.) Fine. (Show PPVT Example B on screen.) Show me fin. (Get correct response.) Good. (Show PPVT Example C on Screen.) Butterfly. Good. Now each time you hear a word point to the picture which best tells the meaning of the word. You may not be sure of the meaning of some words. But look carefully at all the pictures anyway and point to the one you think is right. Do you have any questions? Here's the first one.

Instructions for the serial retention span task were as follows:

> You are going to see pictures like these (pointing to screen on which Sample eight-picture plate is displayed). You see there are eight pictures (pointing to each picture). You will hear several words. There may be two words, or three words, or four words, or five words. The words will name things pictured here. I want you to point to the pictures named. Let's try one. Show me pin and knife. (Get correct response emphasizing order.) Good. Show me duck and pin. (Get correct response emphasizing order.) Fine. Show me duck, pin, and broom. Now each time you hear the words point to the pictures named in the same way you heard the words. Sometimes you may not be sure of all the words. But look carefully at all the pictures anyway and point to the pictures you think are right. Do you understand? Do you have any questions? Here's the first one.

As it was necessary, subjects were encouraged and directed to make the pointing response even though they had to make "a wild guess." A response was obtained from each subject to every stimulus. The subject was given as much time as he took to make his response. The subjects were reminded of the nature of the tasks at the beginning of the second and third sessions.

Scoring responses.--The experimenter recorded the subject's responses by writing down the number or numbers of the picture (or pictures) to which the subject had pointed.

The response record sheet for the word recognition task contained the ordered set of stimulus words as well as the number of the correct picture for each stimulus word. The subject's score was the number of correct responses.

The response record sheets for the serial retention span task provided a space in which the experimenter wrote the sequence of picture numbers pointed to by the subject. A response was scored as correct if, and only if, the subject pointed to all the pictures named in the same order in which they were named. The subject's score on this task was weighted, depending upon the number of words in the stimulus. The scoring procedure for each correct response was as follows: two points for a two word series; three points for a three word series; four points for a four word series; and five points for a five word series.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter presents the results obtained from the procedures described in Chapter III. Twenty-four aphasic adults participated in a word recognition task and a retention span task, in which the stimuli were presented auditorily, under four experimental conditions of stimulus duration. On the word recognition task, the stimuli were associated with one of three levels of hearing vocabulary, as an index of the meaningfulness of the stimuli. On both tasks, subjects were assigned to either the low auditory language disturbance group (hereafter referred to as LALD Group) or the high auditory language disturbance group (hereafter referred to as HALD Group) on the basis of their performance on the Auditory Disturbance Section of the Minnesota Test for the Differential Diagnosis of Aphasia.[1]

Subject performance was measured by the number of correct picture identifications made in response to the auditory presentation of either a single word (recognition

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[1]Hildred Schuell, Minnesota Test for Differential Diagnosis of Aphasia: Administrative Manual (Minneapolis: University of Minnesota, 1965), pp. 5-8.

task) or a series of from two to five words (retention task). The number of correct identifications per condition constituted the subject's score and was considered the dependent variable.

For each of the tasks, there were independent variables that were of interest in terms of assessing the design of the experiment. For the word recognition task, these independent variables were subject groups and levels of hearing vocabulary. The independent (control) variable for the retention task was subject groups. These variables are considered first in the following report of results.

Of major interest, of course, was the influence of stimulus durations, the third independent variable. In addition to examining the independent influence of this variable on performance in both tasks, the interaction of stimulus durations with the other independent variables was of equal interest.

Assumptions underlying statistical tests.--Before proceeding with the several statistical analyses, it was necessary to consider the extent to which the assumptions underlying the use of the statistics had been met. Analysis of variance and a nonparametric correlation were the statistics employed.

The assumptions underlying the use of the analyses of variance were (1) the performance measure was normally distributed in the aphasic adult population, (2) the populations had variances which were homogeneous over the observations to be made, and (3) the performance made by each subject was independent of the performance of every other subject.

Available studies of the performance of aphasic adults on tasks such as those employed in the present study indicated that the distribution of scores was moderately to markedly skewed.[1] The degree of skewedness appeared to depend largely on the range of aphasic disturbance represented in the particular sample of the general population. Allowing that the characteristics may be moderately skewed in the aphasic adult population, it was recognized that the F-test is quite insensitive to the shape of the distribution. Even when a good approximation to a normal distribution fails, Lindquist has stated

> . . . the F-distribution seems so insensitive to the form of the distribution of criterion measures that it hardly seems worthwhile to apply any statistical test to the data to detect non-normality, even though such tests are available. Unless the departure from normality is so extreme that it can easily be detected by mere inspection of the data, the departure from normality will probably have no appreciable effect on the validity of the F-test. . .[2]

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[1]Peter S. Perry, Personal communication, November, 1967. Hildred Schuell, Differential Diagnosis of Aphasia with the Minnesota Test (Minneapolis: University of Minnesota Press, 1965), pp. 27-29, 31.

[2]E. F. Lindquist, Design and Analysis of Experiments in Psychology and Education (Boston: Houghton Mifflin Company, 1953), p. 87.

The above is conditional upon the distribution being homogeneous in both form and variance for the treatment populations.

Regarding the assumption of equal variances across the treatment groups, it is generally recognized that so long as the sample sizes are equal for all conditions of the analysis, violations of the homogeneity assumptions have little effect upon the F-distribution.[1] Sample sizes for all conditions of both analyses were equal.

It seems, therefore, the assumption of normal distribution and homogeneity of variance can be satisfied for this study.

The third major assumption pertains to the independence of the various observations. Only on the auditory language disturbance factor was independence true. The factors of stimulus durations and hearing vocabulary levels were not independent. Each of the twenty-four subjects was observed under all twelve combinations of stimulus durations and hearing vocabulary levels. It was for this reason the three-factor analysis of variance for repeated measures on two factors was selected as the most appropriate statistic to test the null hypotheses derived from the questions concerning word recognition. A two-factor analysis

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[1]William L. Hays, Statistics for Psychologists, (New York: Holt, Rinehart and Winston, 1964), p. 408. Lindquist, Design and Analysis, pp. 33-34.

with repeated measures on one factor was selected for the retention task.

In addition to the assumptions specified above, Winer[1] has listed two additional assumptions that are necessary to repeated measures designs. They are as follows: the order in which the repeated measures are made must be randomized independently for each subject, and the *n* subjects in a group must be a random sample from a specified population. The randomization procedures described in the previous chapter clearly indicate that the first of these special assumptions was satisfied. The second assumption was met in a satisfactory manner by drawing subjects from several clinics in Michigan.

The Spearman rank correlation coefficient was used to assess the degree of association between a subject's performance on the word recognition task and his performance on the retention span task. The use of this statistic requires that both variables me measured in at least an ordinal scale so that the individuals can be ranked in two ordered series.[2] The ordinal level of measurement was achieved on both variables of interest in this comparison:

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[1]B. J. Winer, *Statistical Principles in Experimental Design* (New York: McGraw-Hill Book Company, 1962), pp. 298-301.

[2]Sidney Siegel, *Nonparametric Statistics for the Behavioral Sciences* (New York: McGraw-Hill Company, Inc., 1956), p. 202.

word recognition scores and weighted retention span scores. No further assumptions need be made in the use of this statistic.

The presentation of the results of the statistical treatments is organized on the basis of the two tasks in which the subjects participated, followed by presentation of the inter-task comparisons. A discussion of the obtained results concludes this chapter.

Results from Word Recognition Task

The null hypotheses generated from the three questions concerning the performance of the subjects on the word recognition task were tested by means of three factor analysis of variance for repeated measures.[1] The repeated measures entered the analysis as the factors of stimulus durations (Durations) and hearing vocabulary levels (HVL), the experimental variable and a control variable, respectively. The second control variable was subject groups (Groups): the group of subjects with low auditory language disturbance (LALD); and the group with high auditory language disturbance (HALD). The three factors of the analysis were arranged as a three dimensional table of a 4 x 3 x 2 design. The four columns represented the four Durations,

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[1]Winer, Statistical Principles in Experimental Design, pp. 319-35.

while the three rows represented the three HVL. The third dimension was conceptualized as two slices of the 4 x 3 matrix (Durations x HVL), the slices representing the two subject groups--LALD Group and the HALD Group. The dependent variable (word recognition score) was entered, for each subject, in the appropriate cell of the twelve cell matrix associated with his subject Group.

This analysis of variance was conducted on a Control Data Corporation 3600 Digital Computer (as were all statistical computations in this study).[1] The F-ratio was used in testing the statistical significance of the variance attributable to the three main factors and the several interactions. The .05 level of confidence was established. The summary of this analysis is given in Table 5.

Before considering the influence of the experimental variable, an examination was made of the control variables, auditory language disturbance (Groups) and hearing vocabulary levels (HVL).

The summary table shows the obtained F-statistic for both Groups and HVL is statistically significant. For the Groups, the probability of the F-statistic was approximately 0.002 while for the HVL factor, the probability was less than 0.0005.[2] These outcomes provided

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[1]Agricultural Experiment Station, "STAT Series Description No. 14: Analysis of Variance with Equal Frequency in Each Cell," (East Lansing, Michigan State University, 1968).

[2]*Ibid.*

TABLE 5.--Summary of Analysis of Variance Comparing the Effects of Hearing Vocabulary Levels, Subject Groups, and Stimulus Durations on the Word Recognition Task.

Source of Variance	Sum of Squares	DF	Mean Square	F Statistic
Hear. Vocab. Lev. (A)	8609.424	2	4304.712	168.927#
A x C	104.840	2	52.420	2.057
Z = ACD + AD	1121.236	44	25.483	
Duration (B)	11.347	3	3.782	0.916
B x C	37.514	3	12.504	3.027#
Z = BCD + BD	272.639	66	4.131	
Groups (C)	1144.014	1	1144.014	11.852#
Z = D + CD	2123.472	22	96.521	
A x B	15.632	6	2.605	.706
A x B x C	71.882	6	11.980	3.247#
Z = ABCD + ABD	486.986	132	3.689	
Total	13998.986	287		

#Significant beyond the .05 level

general support for the design of the experiment. Both factors were expected to exert an independent influence on performance of the task, and it was desired to control for their effect in examining the influence of stimulus durations on word recognition.

While the F-statistic indicated the two groups of subjects performed differently, it was noted that the LALD Group made the higher scores. The mean difference, averaged across all twelve duration x hearing vocabulary conditions, was 3.99. In other words, the group with better auditory language function made, on the average, about four more correct responses per treatment condition than did the group of subjects with poorer auditory language function.

Since the F-statistic did not reveal where the significant differences in hearing vocabulary levels lay, a critical difference test[1] was employed to determine if, in fact, the expected differences in hearing vocabulary levels did exist. On the basis of the rationale for structuring these levels, the scores on Level I should have been significantly greater than those at Level II, and Level II scores should have been greater than those of Level III.

In Table 6, the means at each of the hearing vocabulary levels for the two Subject Groups are given, as well

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[1]Lindquist, Design and Analysis, p. 93.

TABLE 6.--Hearing Vocabulary Level Means, and Differences between Means for Each Auditory Language Disturbance Group

	HALD Group	LALD Group
Means		
Level I	21.292	24.542
Level II	16.146	21.833
Level III	8.354	11.375
Difference between Means		
Levels I-II	5.146*	2.709
Levels II-III	7.792*	10.458*
Levels I-III	12.938*	13.375*

*critical difference, .05 level

as the differences between means within groups. It was determined that a difference of more than 4.254 would be significant at the .05 level for differences within the subject groups. As seen in Table 6, one of the differences of interest was not statistically significant: the Level I - Level II differences for the LALD Group. With the exception of this difference, all other differences were statistically significant. It may also be noted, in the analysis of variance summary table, that the interaction of Groups x HVL was not significant, statistically, reflecting the strength of the independent influence of these two factors on the performance of the word recognition task.

The adequacy of the experimental design, with regard to the control exercised over auditory language disturbance, appeared to be substantial. From this same viewpoint, the control of hearing vocabulary appeared to have failed at only one point.

Results of experimental treatment.--Turning to the results of major interest, the null hypotheses derived from the first three questions stated in Chapter I (p. 3) are stated and then evaluated in terms of the outcomes of the statistical analysis.

The general question of the influence of stimulus durations on word recognition lead to the following null hypothesis:

> There is no difference in the mean improvement of auditory recognition under several conditions of stimulus duration on a task involving auditory recognition of single words.

In the summary table (Table 5, page 91) the test of this null hypothesis was found in the main effect for Duration. This main effect was not statistically significant, making it impossible to reject the null hypothesis of no difference from the variations produced in the duration of the stimuli. On the basis of this experiment, increasing the duration of words did not appreciably affect the performance of aphasic adults in recognizing single words presented auditorily. It was noted that the influence of Duration was tested here on the performance of all subjects, ignoring potential differences that may exist between subjects manifesting different degrees of aphasic involvement, an interaction to be considered later.

The question of the interaction of stimulus duration and hearing vocabulary levels generated the following null hypothesis:

> The duration of the stimulus words will not affect mean performance in recognizing single words presented auditorily at several levels of hearing vocabulary.

The Duration x HVL interaction provided the means for testing this null hypothesis. The F-statistic resulted in a ratio that was not significant statistically. This indicated there was a systematic relationship between these two variables. This null hypothesis was not rejected, on the basis of this analysis.

Of the two remaining interactions, both were statistically significant: Duration x Groups, and the triple interaction of HVL x Durations x Groups. The two interactions were of interest to the third question posed in this study. A first approach to an understanding of these interactions was a graphic approach.[1]

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[1] Winer, Statistical Principles in Experimental Design, pp. 178-84.

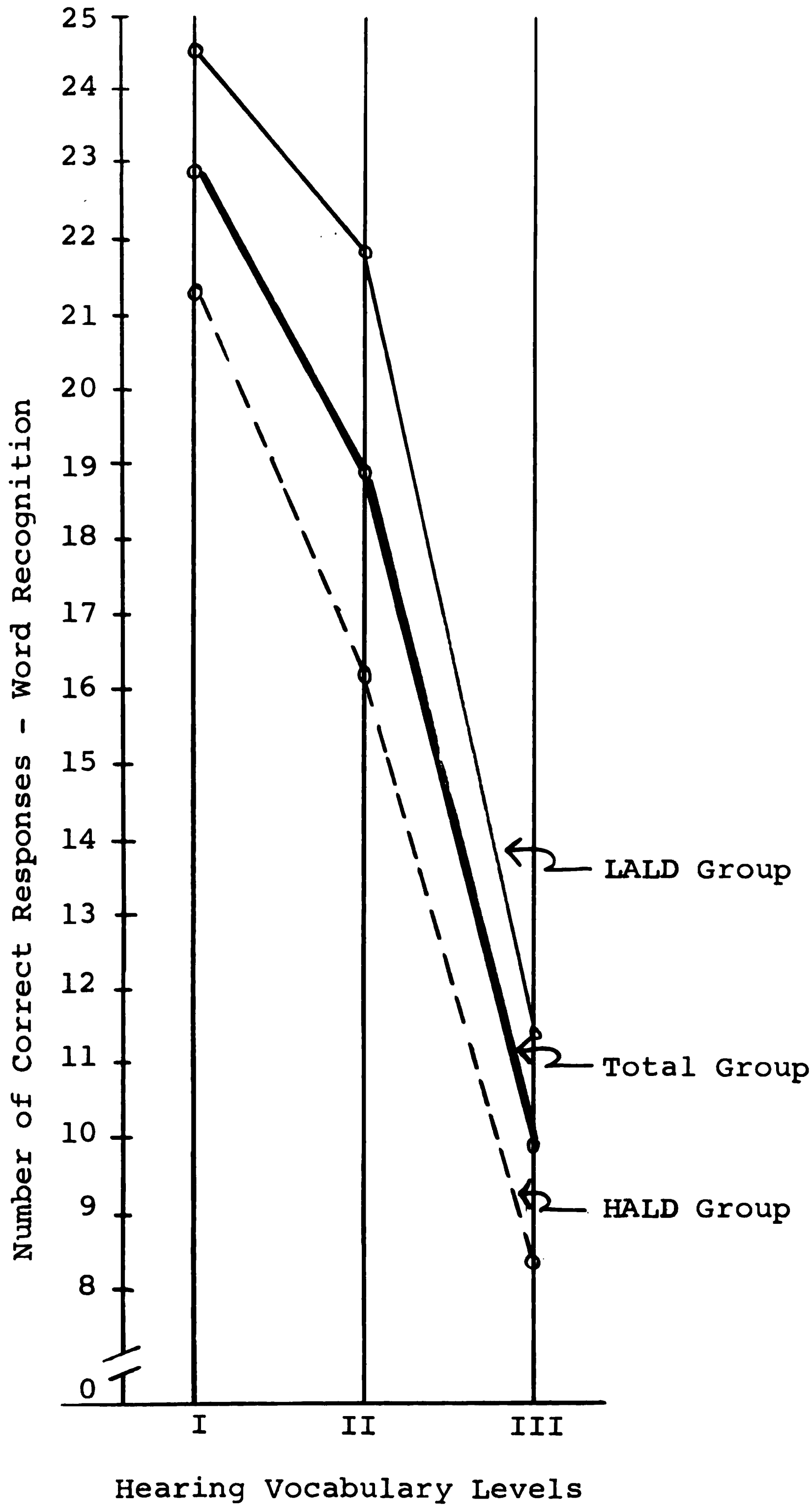
In utilizing this graphic approach, it seemed helpful to examine first an interaction found to be not significant statistically. The Groups x HVL interaction was re-examined for this purpose. The plot of this interaction is given in Figure 1.

In inspecting such plots of data (in this case, means are plotted), it was helpful to remember that interactions not statistically significant reflect a high degree of parallelism between related sets of observations. The plot of the Group x HVL interaction certainly reflected this characteristic. The plot of means for both groups (LALD Group and HALD Group) were quite parallel to each other and parallel to the plot of means for all subjects combined (Total Group). The relationship was quite systematic across all levels of Hearing Vocabulary. As stated previously, this outcome added strength to the experimental design, attesting to the important independent influence of these two variables.

To test the null hypothesis developed from the third question posed in this investigation, the statistical significance of the Groups x Duration interaction was considered. The null hypothesis was:

> Under several conditions of stimulus duration, there will be no difference in the mean performance between subjects identified as having a low degree of auditory language disturbance and those

FIGURE 1.--Graph of Group Means and Total Group Mean at Three HVL



subjects identified as having a high degree of auditory language disturbance, on a task of auditory word recognition.

The real significance of the Groups x Durations interaction was examined in Figure 2, at the heavy lines labelled A, B, and C. At line A, it was seen that the means, at each of the four durations, for the LALD Group arranged themselves in a manner approximating a straight line. The means of the HALD Group (B), on the other hand, did not make as good an approximation to a straight line. This departure of the HALD Group Means from the configuration of the LALD Group Means was sufficient to cause the Groups within Durations interaction to reach statistical significance. Furthermore, since the plot of means for the Total Group (C) reflected a relatively straight line function, it was in the HALD Group (B) that departure from parallelism was to be found.

It appeared that this departure was produced by the observed difference between means at 125% and 175% Stimulus Duration. When, in fact, the differences between means within each of the two groups was tested, the difference between means at 125% and 175% in the HALD Group was the only difference found to be statistically significant at the 5% level of confidence. The test used was the critical difference procedure suggested by Lindquist.[1] The

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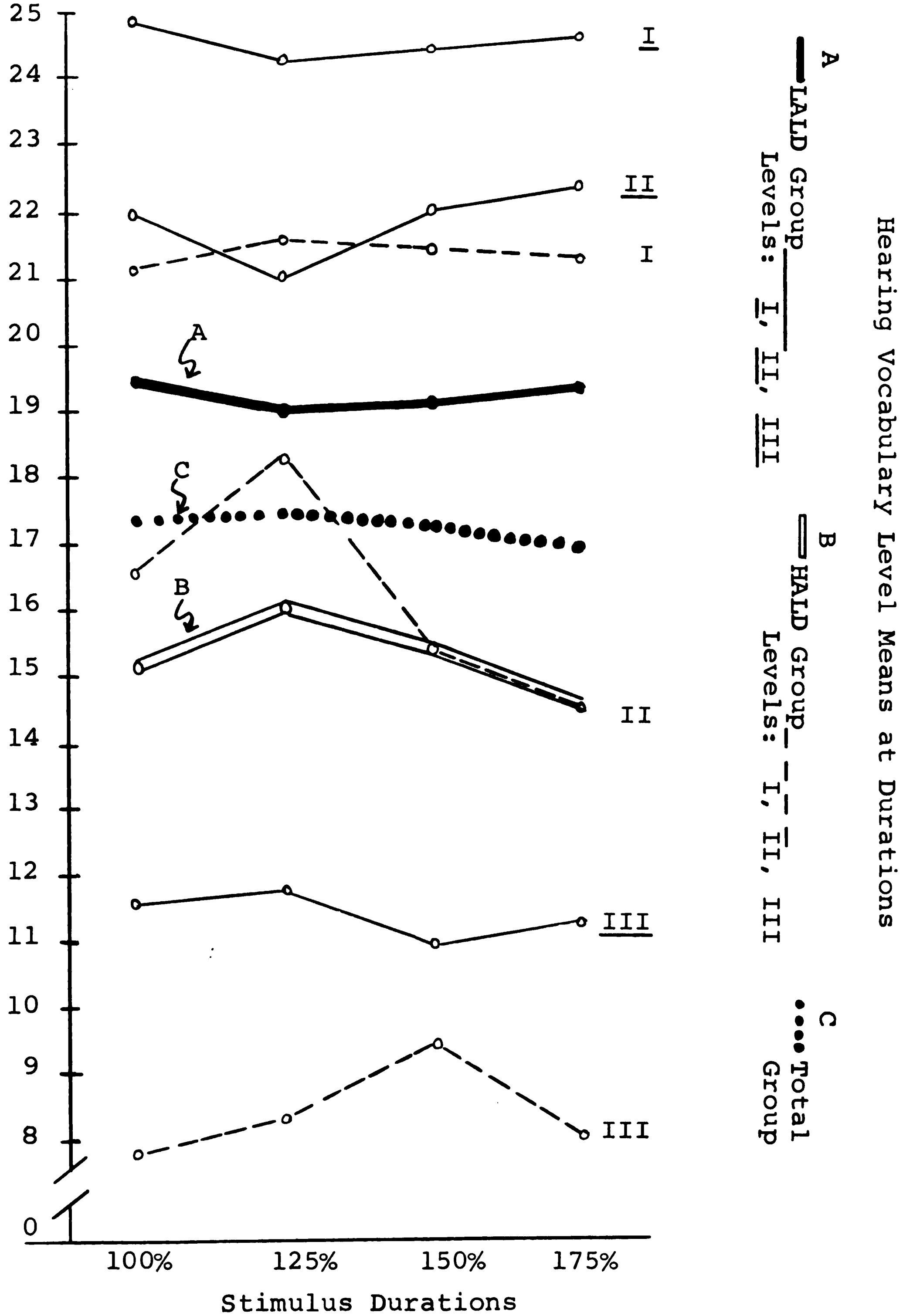
[1]Lindquist, Design and Analysis, pp. 164-66.

FIGURE 2.--Graph of Means for Hearing Vocabulary Levels of Groups at Four Durations.



differences between means within each of the two groups of subjects are reported in Table 7.

TABLE 7.--Mean performance for Each Auditory Language Disturbance Group at Four Stimulus Durations, and Within Group Mean Differences between Duration Conditions

	HALD Group	LALD Group
Duration Means		
100%	15.139	19.472
125%	16.028	19.000
150%	15.389	19.111
175%	14.500	19.417
Difference between Means		
125% - 100%	0.889	-0.472
150% - 100%	0.250	-0.361
175% - 100%	-0.639	-0.055
150% - 125%	-0.639	0.111
175% - 125%	-1.528*	0.417
175% - 150%	-0.889	0.417

*critical difference, .05 level.

The difference in means at 175%-125% in the HALD Group (the only statistically significant difference) was a negative difference. Performance was better at the duration more closely approximating the "normal" duration of 100%, i.e., the 125% duration, than it was at the 175% duration. No real significance was attached to this finding since the performance at 175% duration was not critically different from the performance at 100% duration. The statistical significance of this interaction might lead one to reject the null hypothesis under discussion. However, the interpretation made of this interaction lead to the decision to postpone judgment on this hypothesis.

This decision was influenced by an inspection of the statistically significant triple interaction of HVL x Duration x Groups. This interaction was vividly displayed in Figure 2. While the influence of Durations was negligible, the control variables of Groups and HVL appeared to interact in a highly nonsystematic manner. At both the 125% and 150% Durations, it was possible to observe the between group interaction at II-I, and II-II. While contributing to the statistical significance of the triple interaction, these observations were expected, considering the basis upon which the subjects were grouped. That basis was degree of auditory language disturbance.

Examining the within group differences by levels of hearing vocabulary at the four durations, it was seen that the LALD Group plot of means, at the three HVL, bore a strong resemblance to the LALD Group Means (A). Such was not the case when a similar examination was made within the HALD Group. It was easy to see the dissimilarity in the plot of means for the HALD Group at HVL II and HVL III. The means at these hearing vocabulary levels not only differed from those at HVL I and HALD Group Means (B), but HVL II differed in its configuration from HVL III.

It was undoubtedly in both the between groups interaction and within the HALD Group itself that the statistical significance of the triple interaction was generated. The observed trends within the HALD Group at the three HVL, while not of statistical significance, presented an interesting pattern that is discussed in a later section of this chapter. The interest in this pattern was the basis for postponing a decision on the null hypothesis concerning the influence of the durations on the two groups of subjects.

Results from Retention Span Task

Two of the questions prompting this study concerned the performance of aphasic adults on a retention span task in which the stimuli were presented auditorily at several levels of complexity. The null hypotheses developed from these questions were:

(1) Increasing the duration of the speech stimuli will have no influence on the mean performance of a retention span task in which the words are presented auditorily and in series.

(2) There is no difference in the mean performance of two groups of subjects, identified as having different amounts of auditory language disturbance, at several levels of stimulus duration

on a task requiring the retention of words presented auditorily and in series.

The performance of the subjects was analyzed by a two factor analysis of variance, with repeated measures on one factor.[1] The repeated measure was on stimulus duration (Duration). The second factor was Groups, defined as for the word recognition task. The grouping of subjects was the same as for the word recognition task. The two factors were arranged in a two dimensional table of a 4 x 2 design. The four columns represented stimulus durations, while the two rows represented subject groups (Groups): as before, LALD Group and HALD Group. The dependent variable, weighted retention span score, was entered for each subject in the appropriate cell of the eight cell matrix.

The F-ratio was used in testing the statistical significance of the variance attributable to the two main effects and the two way interaction. The .05 level of confidence was established. The summary of this analysis of variance is given in Table 8.

In this summary table, the only statistically significant F-test obtained was that for Groups. The measured difference in performance between the two groups was 13.61; the mean for the LALD Group was 18.06, while the HALD Group

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[1]Winer, Statistical Principles in Experimental Design, pp. 302-09.

TABLE 8.--Summary of Analysis of Variance Comparing the Effects of Subject Groups and Stimulus Durations on the Retention Span Task.

Source of Variance	Sum of Squares	DF	Mean Square	F Statistic
Duration (A)	36.114	3	12.038	0.797
A x B	10.698	3	3.566	0.236
Z = ABC + AC	996.937	66	15.105	
Group (B)	4441.760	1	4441.760	56.979#
Z = C + BC	1714.979	22	77.953	
Total	7200.489	95		

#significant beyond the .05 level.

had a mean of 4.45. This difference was in the expected direction.

Since the main effect for Duration was not statistically significant, there was no basis for rejecting the first null hypothesis concerned with performance on the retention span task.

The second null hypothesis could not be rejected since the Duration x Groups interaction was not statistically significant.

Under the conditions of this experiment, it must be reported that the duration of the stimulus did not have any important influence on the performance of this retention span task by aphasic adults. Furthermore, the two groups of subjects did not perform differently at any of the four stimulus duration conditions.

Results of Inter-Task Comparison

The final question posed in this investigation dealt with the relationship of subjects' performances on the two tasks employed in the experiment. The question led to the following null hypothesis:

> There is no relationship between performance on a word recognition task and on a retention span task in which the stimuli are presented auditorily.

Since both analyses of variance had indicated that the established grouping of subjects was a significant factor in the performance of both tasks, the measure of association between tasks was applied within groups. The Spearman rank correlation was the measure of association used.[1] The significance of the correlations, as they might reflect on the aphasic adult population, was determined. If, in fact, the two performances were correlated in the population, it seemed reasonable to assume the correlation was positive. This reasoning was based on the previously cited theoretical notions of Jenkins and Schuell.[2] The .05 level of confidence was established. The obtained correlations are presented in Table 9. The only statistically significant correlations were obtained in the group having the poorest auditory language function, the HALD Group.

TABLE 9.--Spearman Rank Correlations of Performance on Word Recognition Task and Retention Span Task for the Two Subject Groups.

	Stimulus	Durations		
Group	100%	125%	150%	175%
LALD	-0.456	-0.144	-0.287	-0.101
HALD	0.599*	0.670*	0.359	0.506*

*significant at .05 level (one-tail)

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[1]Siegel, Nonparametric Statistics for Behavioral Sciences, p. 202.

[2]Hildred Schuell and James J. Jenkins, "The Nature of the Language Deficit in Aphasia," Psychological Review LXVI (1959), pp. 50-51.

It was not possible to reject the null hypothesis at any of the duration conditions for this LALD Group. For the HALD Group, at the three durations, it was possible to reject the hypothesis of no association in favor of a hypothesis stating a positive relationship between performance on the word recognition task and the retention span task. The durations were 100%, 125%, and 175% stimulus duration.

Discussion

Within its limitations, this investigation has demonstrated that increasing the duration of auditory stimuli does not significantly alter the performance of aphasic adults on two tasks which appeared to be highly relevant to the language dysfunction in aphasia. The recognition of words presented auditorily seemed to be related to the reduction in available vocabulary, while the retention span task (for words presented auditorily in series) seemed to be clearly related to the degree of impairment in verbal retention span.[1]

It was entirely possible the increases in stimulus duration, employed in this study, were not great enough to reach an effective level of improvement for the aphasic subjects. This point deserved serious consideration. If

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[1] Ibid.

the clinical modifications made in the duration of auditory language stimuli are, in and of themselves, an effective means of facilitating language reception, then the levels of durational increase may exceed the levels employed in this study. However, this possibility was not fully clarified by this study.

It should be noted that this study was unable to provide information about the possible influence of the "processing noise" resulting from the expansion process. While the lack of statistical significance from the main effect of Duration might lead one to believe the "noise" had no negative influence (as well as no positive influence), it was possible, however, that the "noise" masked some real positive influence due to durational increase.

It was recognized that in both tasks the vocabulary being sampled was more likely a lexical vocabulary, not a linguistic vocabulary. It could be argued that, for this reason, the tasks were assessing only the original vocabulary development of the subjects and not his "available vocabulary." When the general familiarity or meaningfulness of the words within the first two levels of hearing vocabulary are examined, this argument seemed weak. The tasks, as presented, may have been more difficult than typical auditory language reception because of the absence of a linguistic context from which to draw additional meaningful cues.

The hearing vocabulary levels, as defined in this study, certainly did account for a highly significant amount of the variability in the performance of the word recognition task, as was anticipated on the basis of previous research.[1] As indicated by the absence of statistical significance in the Duration x HVL interaction, the influence of Duration was not sufficient to disturb the strong systematic influence of hearing vocabulary levels or the meaningfulness of the stimuli. In fact, the levels of hearing vocabulary, as construed in this experiment, may have been so pervasive as to mask the influence of the experimental treatment, especially in the second and third levels. Both of these levels encompassed an extremely broad range of meaningfulness, in terms of the frequency with which the words within the levels are used. Had levels been defined on more homogeneous groups of words (re: frequency of usage) perhaps the interaction of durations within hearing vocabulary levels would have been significant in more than just statistical sense.

Nevertheless, at the durational increases employed, no significant positive influence on any reduction in available vocabulary or retention span was observed. It was

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[1]Joseph M. Wepman, *et al.*, "Psycholinguistic Study of Aphasia: A Revision of the Concept of Anomia," *JSHD*, XXI (1956), pp. 468-77. Hildred Schuell, James Jenkins and Lydia Landis, "Relationship Between Auditory Comprehension and Word Frequency in Aphasia," *JSHR*, IV (1961), pp. 30-36.

not surprising that durational increases did not affect all subjects,[1] since the level of auditory language function was thought to be a variable affecting any possible positive effect from duration increases. Scores on the Auditory Disturbance Section of the MTDDA did predict those subjects who would do well on the tasks of this study and those who would not. This was indicated in the significant main effects of Groups in both analyses of variance. Of course, test performance and task performance were not totally independent. The MTDDA section used includes tests that reportedly measure the same dimensions of the language deficit as the tasks of this experiment.[2] However, pattern of performance within groups deserved close examination.

Several very interesting observations were made within the group of subjects with high auditory language disturbance at the several durations. There seemed to be little question that their behavior on the tasks was different from the behavior of the other group of subjects. The difference was not just in level of performance but in the kind of performance.

This latter type of difference is especially true of their performance on the word recognition task. It was

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[1] _Ibid_.

[2] Hildred Schuell, James J. Jenkins, Edward Jimenez-Pabon, _Aphasia in Adults: Diagnosis, Prognosis, and Treatment_ (New York: Harper and Row Publishers, 1964), pp. 340-41.

this HALD Group that appeared to generate the statistically significant interactions that were obtained. It was difficult to attach meaning to the interaction of groups within durations. However, a visual inspection of performances of the HALD Group at each of the hearing vocabulary levels across the four durations revealed interesting patterns, even though the magnitude of the variations were small. At HVL II, the positive change associated with the 125% duration was contrasted with the relatively equivalent mean scores the group achieved at HVL I. For less meaningful words a slight increase in duration effected a slight improvement in performance, after which the group performance worsened at the higher levels of duration. In the plot of means for the least meaningful words, HVL III, a slow positive change was observed that reached its peak at 150% duration. Again, for the least meaningful words, a still greater increase in duration was required to make the linguistic significance of the stimulus available to the subject with poor auditory language function. Perhaps these observations do not deserve to be called trends, but at least they were patterns which attracted the attention of the investigator.

When the inter-task relationships were considered, it was again this HALD Group that attracted first attention. All of the significant correlations fell in this group. This significant degree of association may reflect a general low level of language function. The apparent lack of significant association between task performance in the other group of subjects, the LALD Group, provided some support for the notion that reduced available vocabulary and impaired retention span are two basic characteristics of the aphasic language deficit which tend to improve or operate with some degree of independence as auditory language function improves.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study was concerned with an investigation of a clinical procedure used to facilitate the auditory language reception of aphasic adults. The influence of increased stimulus durations was assessed in relation to the meaningfulness of the stimulus and the level of auditory language disturbance manifested by the patient on tasks involving word recognition and retention span for words, with auditory stimuli being presented on both tasks.

Summary

Recognizing the importance of auditory language reception problems in the total rehabilitative effort with the aphasic adult, speech pathologists have sought to develop modifications of the auditory language stimulus that will make the stimulus more meaningful and more adequate for the aphasic adult. One modification that has been recommended, and appeared to have rather widespread clinical application, was increasing the duration of the words spoken to the aphasic adult by increasing the temporal value of the phonemes within the word. Clinical observation has indicated that some aphasic adults profit from this procedure at certain points in the recovery process.

The purpose of this investigation was to assess the effectiveness of such temporal expansions in relation to other variables known to influence the reception of auditory language by aphasic adults. Two language related tasks were selected and developed for the purpose of testing the independent influence of the experimental variable and its interaction with the selected control variables.

Control was exerted over the range of auditory language disturbance represented in the sample of twenty-four aphasic adults by separating the subjects into two groups on the basis of their performance on the subtests of the MTDDA that are intended to assess auditory disturbances in language. One group of twelve subjects was then regarded as having a low degree of auditory language disturbance, while the other group of subjects was regarded as manifesting a high degree of auditory language disturbance. The groups were similar in educational achievement and elapsed time since onset of aphasia but did show a statistically significant difference in age, with the high disturbance group having the higher median age.

A standardized picture vocabulary test (PPVT) provided a means of controlling a second variable known to influence auditory language reception, in addition to providing one of the two language tasks used in the study. The word stimuli within this test were divided in a manner providing four lists of seventy-five words each that were regarded as equivalent in terms of the chronological development of early hearing vocabulary. Within each list, three levels of hearing vocabulary were defined arbitrarily and were regarded as reflecting decreasing levels of meaningfulness. Hence, the independent influence of the meaningfulness of the stimulus word was assessed in its interaction with the two groups of subjects and with the experimental variable of increased stimulus duration on this word recognition task.

As a second task upon which to test the influence of the experimental variable, a retention span task was developed. As this task was structured, a series of discrete words were presented auditorily, and the subjects responded by pointing to pictures of objects named. The pictured objects were equated in terms of meaningfulness and grammatical class (nouns). The auditory stimuli varied in complexity as the stimuli varied in length from two to five words, with all complexity levels represented equally at all four levels of stimulus duration.

The tape recorded auditory stimuli associated with both tasks were assessed to determine if their recorded durations approximated a duration that would be expected in connected speech and to determine if they were intelligible to listeners. Satisfying these criteria, the tape recorded stimuli were submitted to an electromechanical processing that increased their duration to specified nominal levels. The nominal levels of increased duration were 125%, 150%, and 175%. These temporally expanded recorded words, plus the recorded words of normal duration (100%), provided four levels of the experimental variable--stimulus duration.

On a subject by subject basis, the stimuli for the word recognition task and the retention span task were systematically randomized across the four stimulus duration conditions, and presented to the subjects under conditions resembling an average clinical environment.

The dependent variable was the number of correct identifications made by the subjects on each of the two tasks. The data from the word recognition task were treated by a three factor analysis of variance in which the factors were (1) hearing vocabulary levels, (2) subject groups, and (3) stimulus duration. A two factor analysis of variance was used to evaluate the data from the retention span task, the factors being (1) subject groups, and (2) stimulus duration. An inter-task performance comparison was made using a Spearman rank correlation coefficient.

Conclusions

Within the limitations of this study, the investigator believes there are certain conclusions that can be drawn tentatively from the hypotheses tested in this investigation and from observations made of other outcomes of this research.

1. In general, increasing the duration of spoken single words does not improve their recognition or retention by aphasic adults.

2. However, 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.

3. Within groups of words having considerable variation in their meaningfulness (re: development of auditory receptive vocabulary or frequency of usage), increasing the duration of the words is not likely to cause any general improvement in the aphasic adult's ability to recognize the words.

4. Word recognition performance and retention span performance appear to function with a greater degree of independence as the auditory language ability of the aphasic adult improves. These performances seem to reflect on the constructs of reduced available vocabulary and impaired verbal retention span, two disabilities reported to be primary characteristics of the aphasic language deficit.

5. The language deficit in aphasia manifests a very systematic reduction in word recognition performance (available vocabulary) as observations are made across groups of subjects that manifest different degrees of

auditory language disturbance. A major factor in the systematic nature of the reduction is the meaningfulness of the stimulus.

6. In investigations such as the present study, it is imperative that the investigator quantify and control for the expected variations in language deficit to be found within any sample of aphasic adults. Research that ignores such variations, especially variations in the language modalities being studied, will fall far short of providing the better understandings of aphasic language problems that need to be attained.

Suggestions for Future Research

From the observed performance patterns of aphasic adults on the tasks of this study under conditions of increased stimulus duration, several lines of investigation can be suggested.

It appears that a study quite similar to the present study could be meaningfully replicated with a group of aphasic adults manifesting moderate to severe reductions in auditory language function. Selecting more homogeneous groups of subjects within the lower range of auditory language function would provide a clearer analysis of the influence of increased stimulus duration on auditory language reception.

In addition to employing more homogeneous samples of aphasic subjects, any repetition of a study like this should narrow the range of meaningfulness within the arbitrarily defined levels of meaningfulness.

A more linguistically oriented approach employing increased stimulus durations or expanded speech might be considered. It would be interesting to study the influence of temporally expanded speech on the performance of aphasic adults in comprehending linguistic constructions of varied complexity.

It would be reasonable, if it is established that expanded speech does have a positive influence on some aphasic adults, to examine the influence of expanded speech input on the speech output of aphasic adults. The working hypothesis in an investigation of this type would be that improved speech comprehension should lead to improved speech expression. Perhaps, in this area, a means could be developed to test the effectiveness of expanded speech as a procedure for improving the self-monitoring of speech output in aphasic adults.

A word of caution is in order regarding the use of the expansion process employed in this study. It is strongly recommended that investigators check the actual level of expansion achieved by the processing. The nature of the process is going to produce variations in the levels of expansion actually achieved. It is important to know what this variance is with reference to the nominal levels of expansion being sought.

It is this investigator's opinion that this line of research is one that needs, and is deserving of, further investigation. At best, this study has taken but a glimpse of an important aspect of treatment for the aphasic adult. Additional experimental efforts are needed to discover the clinical significance of changes in stimulus duration on the auditory reception of language by aphasic adults.

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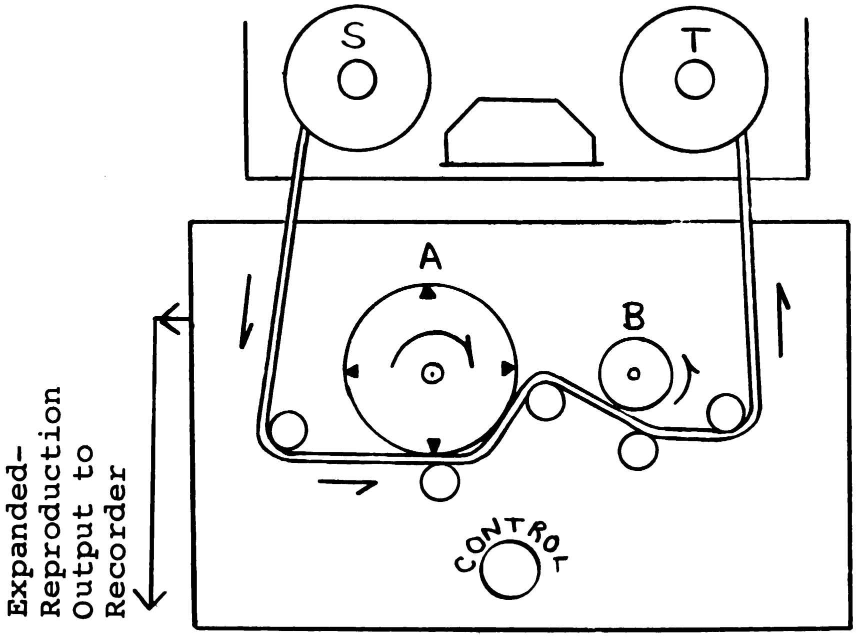
APPENDICES

APPENDIX A

FURTHER DESCRIPTION OF PROCESS BY WHICH STIMULUS DURATIONS WERE INCREASED

This description will begin with a general discussion of the mechanical process, followed by a discussion of the electromechanical aspects of the process that account for the temporal expansions. In Figure 3 is a schematic of the device.

FIGURE 3.--Schematic of Speech Expansion Device.



The tape is directed to the surface of the cylinder (A) in such a manner as to make contact with one-quarter of the cylinder. The tape is driven by the roller and capstan (B). The tape supply and take-up mechanism, an independent unit, are represented at (S) and (T).

When the device is activated for some level of expansion, the tape is advanced in the direction indicated.

The cylinder rotates in a clockwise direction. The relative velocity of the tape transport and the effective linear velocity of the head rotation is maintained at 15 ips--the speed at which the signal on the tape had been recorded. As the tape transport speed is reduced for greater levels of expansion, the rotational speed of the cylinder is increased. Hence the speed of the tape relative to the surface of the cylinder (and reproduce heads) is held constant at 15 ips.

From the schematic diagram, it can be imagined that each of the heads, in turn, makes contact with the tape and that only one head is in contact with the tape at any moment. A single control knob regulates the tape speed and head speed synchronously to maintain the relative speed of 15 ips. The calibration of the control knob is in percentage of original time expansion or compression. The frequency response is reported to be essentially flat to 15000 Hz at all four reproduce heads.

The increases in duration can be produced over a range extending up to approximately 200% of the duration of the original signal. If a word had an initial duration of 500 msec., expanded version of the word could be produced which would have durations ranging up to 1000 msec. In the sampling process associated with the production of the expansions, several aspects of the samples themselves need to be understood.

First, the temporal value of the acoustic patterns within each sampled segment of the original signal or word is increased as the percentage of desired expansion is increased. If a segment of the original recording had a duration in real time of 30 msec., and the signal was being processed for 150% expansion, this segment would have a duration of 45 msec. in the expanded reproduction. Its temporal value now equals 150% of its temporal value in the original recording. The increase in the temporal value of the acoustic patterns in each segment is a function of the reduction in the tape transport velocity. It is necessary to make such reductions as greater expansion levels are sought. Where one inch of the recorded word represented 1/15 of a second at its recorded velocity of 15 ips, one inch of the tape recorded signal transported at a reproduction velocity of 7.5 ips now represents 1/7.5 of a second, or just twice its temporal value in the original recording. This reduction in transport velocity during expansion processing would result in the frequency distortion and intelligibility loss (associated with "slow played" recordings of speech) were it not for the compensatory effect of the rotating reproduce heads. This compensatory effect of the rotating reproduce heads restores the reproduction velocity to the level of the recording velocity.

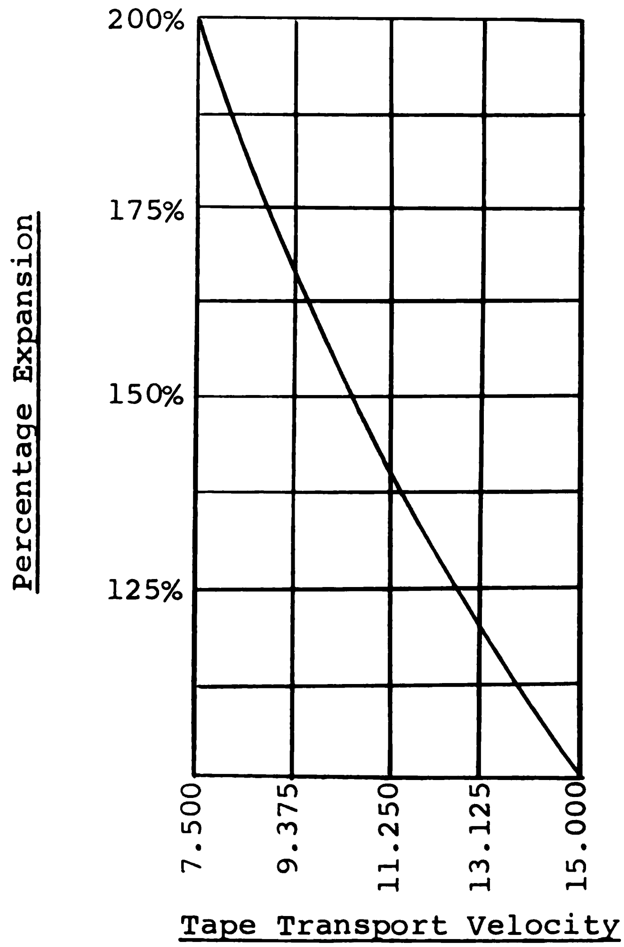
This restoration comes from developing a relative velocity between tape surface and the gap of each reproduce head which is equal to the 15 ips at which the word was originally recorded. Since the tape is being transported in a direction opposite to the linear direction of the head rotation, the relative velocity of the reproduction process (rV) is the sum of the transport velocity (V_T) and the effective linear velocity of the rotating heads (V_R), i.e. $rV = V_T + V_R$. In the example given, reducing transport velocity from 15 ips to 7.5 ips would require a compensatory velocity of head rotation equivalent to 7.5 ips. Achieving this relative velocity would give to the expanded reproduction the frequency characteristics of the original signal. It is necessary to observe, however, that as rotational velocity increases, the number of samples taken per unit of time increases. Each of the rotating heads is scanning a segment of the recorded tape in less time, hence more samples are taken per unit of time. This results in portions of the original signal being sampled a second time as the sampling produced by a given head overlaps a portion of the tape already sampled. But, because the relative velocity with which this scanning occurs is equivalent to the velocity of the original recording, each segment of tape sampled is "treated" as though it were being transported across a stationary reproduce head at a velocity of 15 ips, when in fact it is not. In the example being used, the segment being scanned represents 1/30 of a second of the original recording, since the transport velocity has been reduced by 50% from 15 ips to 7.5 ips. However, with the relative velocity of the reproduction process functioning at 15 ips, that segment is given a temporal value of 1/15 of a second. In the expanded reproduction, the acoustical patterns in that segment of the original recording now have a temporal value which is twice that of their original temporal value. The temporal value of the segment has been increased by 200%.

Repeating this sampling process throughout the original duration of a word would result in an increase in the duration of the word equivalent to 200% of its original duration. It should be recognized that with this type of expansion processing it is highly unlikely that any two expansions of a recorded word will result in exactly the same expansion of the acoustical patterns of that word. This variability results from the differences that will arise in the definition of segments from successive processing of the same utterance. The linear value of each segment is invariant and is determined by the distance (on the circumference of the cylinder containing the reproduce heads) between the reproduce heads. This linear distance on the Eltro Information Rate Changer - Mark II is 13. However, in successive expansions of the same recorded utterance, it is highly unlikely the beginning of that utterance will fall at exactly the same point in the space between any two of the four reproduce heads. Hence, segments will be mapped on the word differently from one reproduction to the next. The influence of such variations on perception are unknown at present.

To illustrate expansion processing, the example used has been that of 200% expansion because it provides the clearest case. The assumption has been that the relationship between reductions in transport velocity and effective velocity of head rotation is relatively linear through the expansion capability of the Eltro device, the three expansion levels used in this investigation could be analyzed as the 200% expansion level has been analyzed. However, the relationship is not exactly linear as indicated in Figure 4. Calculations based on the assumption of linearity from such calculations will not be precisely the expansion levels sought.

From the experience in this study, it is necessary to refer to the obtained levels as nominal levels and specify the observed variation from the stated value of the level which has been allowed. As reported, in this study, a 5% variation from the stated nomial value was allowed. Without knowing the exact values for the transport velocity and the rotational velocity at the three expansion levels employed in this study, the calculations could not be meaningfully made.

FIGURE 4.--Expansion Process: Tape Transport Velocity vs. Percentage of Expansion.*



*from Allen, "Eltro Rate Changer," p. 9.

APPENDIX B
SPAN OF RETENTION RESPONSE PLATES AND ASSOCIATED STIMULUS

Plates developed from the following 30 pictures obtained from the Peabody Picture Vocabulary Test first 50 plates using only pictures whose names had Thorndike-Lorge ratings of AA and limiting selections to noun words. Number in parenthesis indicates PPVT plate in which picture was found.

car (1)	shoe (5)	river (22)
table (1)	finger (6)	mountain (22)
cow (2)	boat (7)	glass (30)
baby (3)	children (8)	nest (31)
horse (3)	bell (9)	saw (33)
tree (3)	can (9)	teacher (26)
dog (4)	bear (10)	soldier (38)
girl (4)	ring (16)	queen (38)
ball (5)	fence (19)	captain (42)
cup (5)	bee (21)	island (49)

Duration: 1.0

		Plate				Stimulus
2-item	(A)	soldier	children	ring	captain	children & tree
		bee	bear	tree	can	
	(B)	dog	mountain	children	soldier	saw & cup
		glass	saw	cup	fence	
3-item	(A)	tree	children	island	bear	shoe, tree & children
		saw	shoe	bee	queen	

APPENDIX B (cont.)

		Plate				Stimulus
	(B)	teacher	bear	soldier	ball	teacher, glass & table
		can	ring	glass	table	
	(A)	glass	mountain	cup	captain	captain, fence, glass & cup
		finger	fence	children	boat	
4-item						
	(B)	saw	bell	glass	nest	nest, glass, saw & queen
		car	queen	boat	island	
	(A)	car	dog	can	ring	ball, teacher, horse, car & can
		ball	teacher	island	horse	
5-item						
	(B)	horse	girl	nest	ball	nest, ball, horse, car & cup
		car	cup	soldier	glass	
Duration: 1.25	(A)	mountain	soldier	glass	horse	nest & queen
		queen	shoe	nest	cup	
2-item						

APPENDIX B (cont.)

		Plate				Stimulus
	(B)	children	finger	mountain	horse	table & children
		dog	boat	ring	table	
	(A)	island	shoe	cup	table	queen, fence & table
		queen	bell	fence	mountain	
3-item						
	(B)	bear	river	boat	table	bear, bee & mountain
		captain	bee	mountain	saw	
	(A)	captain	cow	bear	bee	bee, river, cow & captain
		island	queen	river	teacher	
4-item						
	(B)	table	boat	saw	horse	horse, saw, tree & table
		river	cow	tree	cup	
	(A)	finger	tree	shoe	mountain	fence, cup, girl, finger & tree
		horse	fence	girl	cup	
5-item						

APPENDIX B (cont.)

		Plate				Stimulus
	(B)	bear	bee	horse	cow	bear, island, fence, horse & shoe
		shoe	island	glass	fence	
Duration: 1.50						
2-item	(A)	boat	teacher	finger	soldier	river & bear
		bear	ring	can	river	
	(B)	bee	car	baby	ring	bee & queen
		queen	saw	boat	tree	
3-item	(A)	ring	captain	mountain	dog	ring, horse, & mountain
		shoe	soldier	horse	baby	
	(B)	boat	can	table	bee	finger, horse & shoe
		shoe	finger	teacher	horse	
4-item	(A)	fence	queen	tree	cow	fence, cow, captain & tree
		bell	cup	captain	horse	

APPENDIX B (cont.)

		Plate				Stimulus
	(B)	boat	can	girl	ball	can, girl, bell & ball
		fence	glass	cup	bell	
	(A)	river	ball	queen	finger	boat, ball, cow, finger & bell
		cow	boat	bell	glass	
5-item						
	(B)	ball	queen	island	dog	queen, fence, dog, island & ring
		children	horse	ring	fence	
Duration: 1.75	(A)	boat	horse	shoe	soldier	island & horse
		river	island	girl	finger	
2-item						
	(B)	ball	bear	table	shoe	cow & shoe
		river	can	cow	mountain	
	(A)	mountain	fence	ring	horse	mountain, fence & bell
		captain	glass	bell	finger	
3-item						

APPENDIX B (cont.)

		Plate				Stimulus
	(B)	bee	river	dog	nest	dog,ring & bee
		table	island	teacher	ring	
	(A)	glass	tree	bear	nest	nest,baby,ring, & bear
		shoe	boat	ring	baby	
4-item	(B)	bell	bee	table	girl	bee,children,bell, & table
		river	mountain	dog	children	
	(A)	girl	captain	shoe	tree	ring,fence,shoe, captain & girl
		ring	cup	teacher	fence	
5-item	(B)	bee	nest	queen	glass	queen,glass,nest, horse & table
		ball	horse	dog	table	

APPENDIX C

DATA USED TO ESTABLISH ACCEPTANCE INTERVALS FOR DURATIONS OF WORDS IN ORIGINAL RECORDING

One Syllable Words

Durations obtained from context			Duration of single words		
Word	Measured Length (mm.)	Duration (msec.)	Word	Measured Length (mm.)	Duration (msec.)
nest	47	370.1	trunk	62	488.2
nail	28	220.5	lamp	51	401.6
badge	66	519.7	nest	68	535.4
clown	43	338.6	pod	68	535.4
coast	86	677.2	coast	67	527.5
pod	50	393.7	drum	62	488.2
leaf	44	346.4	bat	53	417.3
car	61	480.3	bear*	69	511.8
girl	56	440.9	nest*	71	559.1
bush	64	503.9	car*	67	527.5

Mean: 439.13 S.D.: 104.24 Interval limits: (234.82, 643.44).
All single words within above interval

*Indicates words sampled from retention task items.

APPENDIX C (cont.)

Two Syllable Words

Durations obtained from context			Duration of single words		
Word	Measured Length (mm.)	Duration (msec.)	Word	Measured Length (mm.)	Duration (msec.)
shining	50	393.7	ringing	70	551.2
baby	66	519.7	horror	80	629.9
pouring	45	354.3	rodent	70	551.2
wiener	55	433.1	casement	87	685.0
canine	62	488.2	hitting	62	488.2
gable	59	464.6	gable	62	488.2
kayack	80	629.9	baby	51	401.6
counter	87	685.0	peacock	80	629.9
meringue	90	708.7	hassock	78	614.2
eagle	34	267.7	cravat	82	645.7
			baby*	64	503.9
			finger*	76	598.4
			captain	84	661.4

Mean 494.49 S.D.: 136.78 Interval limits: (226.40, 762.58).
All single words within above interval

*Indicates words sampled from retention task items.

APPENDIX C (cont.)

Three Syllable Words

Durations obtained from context			Duration of single words		
Word	Measured Length (mm.)	Duration (msec.)	Word	Measured Length (mm.)	Duration (msec.)
kangaroo	82	645.7	bannister	93	732.3
envelope	88	692.9	renovate	89	700.8
confining	79	622.1	assaulting	98	771.6
destruction	81	637.8	kangaroo	98	771.6
directing	72	566.9	prodigy	99	779.5
projector	107	842.5	pedagogue	92	724.4
submarine	83	653.5	carrion	97	673.8
bereavement	80	629.9	immense	87	685.0
accident	89	700.8	hovering	79	662.0
excavate	90	708.7	inclement	100	787.4

Mean: 670.08 S.D.: 70.11 Interval limits: (532.67, 807.49).
All single words within above interval

APPENDIX C (cont.)

Four Syllable Words

Durations obtained from context			Duration of single words		
Word	Measured Length (mm.)	Duration (msec.)	Word	Measured Length (mm.)	Duration (msec.)
graduated	98	771.6	transportation	156	1117.0
coniferous	82	645.7	predatory	105	787.5
obliterate	85	669.3			
ambulation	114	897.6			
transportation	107	842.5			

Mean: 765.34 S.D.: 96.98 Interval limits: (575.26, 955.42).
"transportation" exceeded the interval in duration

APPENDIX C (cont.)

Five Syllable Words

Durations obtained from context			Duration of Single words		
Word	Measured Length (mm.)	Duration (msec.)	Word	Measured Length (mm.)	Duration (msec.)
illumination	105	826.8	illumination	138	1035.0
geneologist	122	960.6			
deleterious	124	976.4			
precipitation	103	811.0			
dissatisfaction	110	866.1			

Mean: 888.18 S.D.: 68.17 Interval limits: (754.57, 1021.79).
"illumination" exceeded the interval in duration

APPENDIX D

CALIBRATION CHECK OF EXPANDED TAPES

The 1000 Hz tone at the beginning (I) and the end (F) of each tape (A_1, A_2, B_1, and B_2) had a measured length of 61 mm. in the original tape. The tone was of the same length on the Retention Span tape (RT), but the tone appeared only at the beginning of tape.

Hence, the length of the 1000 Hz tone as reproduced in the expanded version of each tape provided an estimate of the extent to which the stimulus material on that tape had been expanded. The percentage of expansion was given by the formula

$$\text{Expansion} = \frac{\text{Expanded mm.}}{\text{61 mm.}} \times 100\%$$

The data below are the measured lengths of the 1000 Hz tone for each of the tapes at the nominal levels of expansion. Data obtained from read-out of power level recorder operating at paper speed of 30 mm./sec.

APPENDIX D (cont.)

Tapes		EXPANSIONS					
		125%		150%		175%	
		mm.	expns.	mm.	expns.	mm.	expns.
A_1	I	75	122.9%	90	147.5%	108	177.0%
	F	75	122.9%	89	145.9%	108	177.0%
A_2	I	75	122.9%	90	147.5%	108	177.0%
	F	74	121.3%	89	145.9%	108	177.0%
B_1	I	74	121.3%	90	147.5%	108	177.0%
	F	74	121.3%	90	147.5%	108	177.0%
B_2	I	75	122.9%	90	147.5%	109	178.7%
	F	75	122.9%	90	147.5%	109	178.7%
RT		75	122.9%	90	147.5%	109	178.7%

APPENDIX E

SCORES OF SUBJECTS ON RECOGNITION AND RETENTION TASKS

		WORD RECOGNITION SCORES												RETENTION SCORE DURATIONS (%)			
	LISTS AT	100%			125%			150%			175%						
Ss	DURATIONS	I	II	III	I	II	III	I	II	III	I	II	III	100	125	150	175
LALD																	
1	B1A1B2A2	25	23	12	24	23	06	25	23	07	25	23	06	14	28	28	28
2	A1B1A2B2	25	25	22	25	24	13	25	25	15	25	25	18	14	14	14	14
3	A1B2B1A2	24	20	09	25	18	10	25	21	08	25	22	07	19	14	23	14
4	B2A1B1A2	25	23	09	24	23	13	24	22	10	25	24	10	19	18	23	28
5	B2B1A1A2	24	11	05	21	12	06	22	15	06	22	16	07	14	11	18	07
6	A2B1B2A1	25	22	03	24	18	08	24	18	06	25	19	05	24	18	11	23
7	B2A2B1A1	25	24	11	24	24	15	24	23	13	25	22	14	10	28	23	28
8	A2A1B2B1	25	24	17	25	24	16	25	24	15	25	25	13	05	10	09	10
9	B1A1A2B2	25	23	12	25	22	12	25	22	10	25	22	09	25	23	28	23
10	A2B1A1B2	25	21	05	25	19	08	25	22	08	25	22	11	24	28	14	18
11	B2A1A2B1	25	23	14	24	23	13	24	24	12	24	23	13	19	14	23	23
12	B2B1A2A1	25	25	20	25	22	21	25	25	21	25	25	22	14	15	04	11
HALD																	
1	B1A2A1B2	21	14	05	21	16	01	22	06	07	23	12	10	04	04	02	04
2	B1A2B2A1	24	23	09	23	24	14	25	20	09	25	15	08	05	12	14	10
3	A2B2A1B1	25	21	04	25	20	07	25	21	10	25	17	09	04	06	08	05
4	A1B1B2A2	21	10	04	21	10	08	21	08	09	16	08	06	04	02	04	04
5	B2A2A1B1	24	18	07	22	21	08	24	16	07	23	17	08	05	07	05	03
6	B1B2A1A2	23	20	10	23	21	09	22	11	05	23	16	09	09	14	09	09
7	A1A2B2B1	20	15	07	22	15	03	21	21	09	24	13	04	01	04	02	01
8	A1A2B1B2	23	16	09	21	19	07	19	16	06	24	12	05	05	03	04	01
9	A2B2B1A1	24	18	15	24	24	16	22	23	19	24	21	09	04	05	07	07
10	B1B2A2A1	23	15	06	22	20	09	24	17	10	22	18	10	01	01	02	03
11	A2A1B1B2	19	18	09	21	18	08	21	20	13	18	17	14	01	02	01	02
12	A1B2A2B1	07	10	08	14	11	09	11	05	09	05	08	04	01	01	01	01