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SERIAL POSITION IN AUDITORY VERBAL SHORT-TERM MEMORY AMONG CONDUCTION, BROCA'S AND ANOMIC APHASICS

City University of New York PH.D. 1982

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SERIAL POSITION IN AUDITORY VERBAL SHORT-TERM MEMORY AMONG CONDUCTION, BROCA'S AND ANOMIC APHASICS

by

GALE KAUFMAN

A dissertation submitted to
the Graduate Faculty in
Speech and Hearing Sciences
in partial fulfillment of the
requirements for the degree
of Doctor of Philosophy, the
City University of New York.

1982

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GALE KAUFMAN

1982

This manuscript has been read and accepted for the Graduate Faculty in Speech and Hearing Sciences in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

Serial Position Effect in Auditory Verbal Short-Term Memory In Conduction, Broca's, and Anomic Aphasics

By

Gale Kaufman

Adviser: Professor Louis J. Gerstman

The hallmark of conduction aphasia, marked repetition difficulty, has recently been reinterpreted in single case reports as reflecting an underlying auditory-verbal short-term memory (STM) deficit. A probe type STM experiment was conducted to determine if this deficit could be demonstrated in a group of such patients. Experimental subjects were six conduction, six Broca's, and eight anomic aphasics, all with mild linguistic impairments. Controls were seven right brain damaged (RBD) and seven non brain damaged normal subjects. Aphasic impairment and diagnostic category were determined through administration of the Boston Diagnostic Aphasia Examination (BDAE). The STM test consisted of 28 taped lists of high frequency, low associative words, five per trial, spoken at the rate of one per second. Each list was followed by a probe, one of the list words. Subjects stated the word which followed the probe.

Target items occurred randomly but equally at positions 2, 3, 4, and 5. Subjects responses were categorized by serial position and error type.

Inter and intra group comparisons were made utilizing Mann Whitney U and Wilcoxon T Tests. Significant results indicated conduction aphasics performed poorer on the STM test than the other aphasics, and their serial position curve lacked a primacy and recency effect. Anomic aphasics displayed the expected U shaped serial position curve, while Broca's aphasics displayed a recency but no primacy effect. All contrasts between normal controls and aphasics were significant as were some contrasts between aphasics and RBD controls. It was determined that conduction aphasics are grossly impaired in short-term memory function relative to other aphasics, and this impairment can not be attributed to an underlying linguistic impairment since conduction aphasics performed only slightly below that of the other aphasics on the BDAE. One conduction aphasic lacked the literal paraphasias typical of this syndrome but performed no differently from the five others. It is concluded that the lack of a serial position effect in the presence of fluent speech and good auditory comprehension is a strong diagnostic indicator of conduction aphasia.

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I cannot name all the people who helped this research along, the list is too long. Yet without this help, and from people who had nothing to gain for their trouble, I never would have been able to complete this dissertation.

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Chapter 1

INTRODUCTION

Among the many problems which aphasics of all classifications experience must be included some degree of operational impairment of auditory-verbal short-term memory span. This impairment generally manifests itself as an impairment in the ability to repeat, and receptively, as an inability to retain and to act upon a sentence or word string (whose individual elements can be comprehended). In most forms of aphasia this impairment is considered to be secondary to the existing language and comprehension deficits that the individual may be experiencing, rather than of mnestic origin (e.g., Schuell, Jenkins, and Jimenez-Pabon, 1964, p.5). In the syndrome of conduction aphasia, however, in which impairment of repetition, short-term recall, and short-term recognition is markedly out of proportion to language impairment, this explanation by itself seems insufficient.

Many attempts have been made in the aphasia literature to account for the repetition defect in conduction aphasia. Most well known of these characterizations is Wernicke's concept of conduction aphasia (1908) in which the pathway from the center for speech memory to the center for motor articulation is thought to be disrupted, and Goldstein's central aphasia (1948) in which inner speech is supposedly impaired making it impossible to translate thought into speech adequately, or to call up the specific words necessary for repetition. However, much of the current interest in the disorder has been stimulated by the research of Warrington and her associates who have interpreted the repetition defect in conduction aphasia to be a consequence of an isolated and selective disorder of short-term memory, analogous to the various forms of amnesia, which selectively impairs long-term memory.

Warrington and Shallice (1969) and Shallice and Warrington (1970) performed an extensive clinical and experimental investigation into the memory and language function of a single patient, K.F., and were able to demonstrate that in this patient, other language and memory functions are spared while short-term memory is markedly impaired. These results have been replicated several times with other patients (Warrington, Logue, and Pratt, 1971; Saffran and Marin, 1975; Saffran et al, 1977; Caramazza et al, 1979, 1981) and they have had major implications for the theoretical view of short-term memory and its function in language. They illustrate the seeming independence of long-term memory and language from short-term memory, and they call into question what the function of short-term memory may be if patients are able to function quite adequately (except for repetition) with a severely impaired version of it.

Several authors, while not denying that the patients discussed here display an impaired STM performance, have questioned whether some underlying deficit, other than a truly mnestic one, is responsible for this impairment. Some alternate explanations include the following: (a) the repetition defect occurs because decoding for meaning interferes and competes with the conversion of the understood message into the proper phonemic structure (Strub and Gardner, 1974), (b) conduction aphasia represents a specific deficit in ability to retain and produce sequences (Tzortis and Albert, 1974), and (c) the STM defect in conduction aphasia is no different from that in Broca's aphasia and reflects an inabiity to repeat, and not vice versa (Heilman, Scholes, and Watson, 1976).

The controversy over whether the repetition defect in conduction aphasia has a mnestic or linguistic base, which has come to assume a prominent place in the literature, may be a controversy of terms, however, rather than a controversy of substance. All research in this area tends to confirm that conduction aphasics have impaired auditory-verbal STM performance. Rather than characterizing the syndrome as an isolated STM disorder, it is heuristically more beneficial to identify what it is about the conduction syndrome which causes this impaired performance. By pinpointing the processes or mechanisms which are underlying the mnestic failure, insight can be gained into the nature of the conduction aphasic's speech and language disorder as well as his STM.

In order to go forward in this area, several aspects of the literature dealing with STM and conduction aphasia have to be addressed. Much of the data collected thus far has been the result of investigations detailing the memory functioning of single subjects. Valuable as this data is, it has certain obvious limitations as differences in the memory functioning of individual subjects can be attributed to differences in the symptomatology of the patients. There is considerable need for research investigations which can demonstrate the predictive value of data obtained from single subjects and its implications for a study of STM, conduction aphasia, and aphasia in general. There exists only a few experimental studies which explore the STM function of a group of conduction aphasics as compared with aphasics of other syndromes. What is more, while these studies attempt to fulfill the need discussed above, they fail to respond to other problems inherent in the nature of STM research in aphasia.

Testing the short-term memory of aphasics presents certain problems over and above those encountered when testing memory in normal subjects, and a variety of experimental techniques must be employed which avoid, as much as possible, the possibility of confounding memory impairment with expressive and receptive language impairment. When the experimental aphasic population is chosen from those patients whose impairment is relatively mild, and care is taken to insure that the speech comprehension and expressive aspects of the memory task do not exceed the capabilities of the subjects, this danger can be largely avoided. Similarly, care must also be taken, when comparing sub-groups of aphasic subjects' performance on a memory task, to insure that the subgroups are equivalent in their relative degree of language impairment, lest differences in the respective scores of the groups reflect differences in language capabilities rather than differences in mnestic capabilities. Nevertheless, among the limited number of experimental investigations in short-term memory and aphasia employing groups of subjects (rather than single subject populations) these considerations, with the exception of Saffran et al (1977) are largely overlooked.

It is also extremely important, for similar reasons to those discussed above, to choose an experimental paradigm which will be able to demonstrate the desired memory effects reliably while surmounting the difficulty of testing verbal memory in verbally impaired subjects. An approach to this problem calls for a rather thorough knowlege of the types of difficulties which aphasics typically encounter. Some experimental tasks, while avoiding extensive demands on expressive capabilities, may complicate the testing of STM in aphasia by their inclusion of concurrent and superfluous cognitive tasks which may overtax the ability of the aphasic subjects and artificially depress their memory scores. The substitution of pointing span for repetition (Tzortis and Albert, 1974; Saffran et al, 1977), for example, yields no benefit in avoiding the expressive language demands of repetition, for pointing span may be even more impaired in aphasia than repetition (De Renzi and Nichelli, 1975). It most likely involves covert repetition, it includes the additional tasks of transcoding from auditory to visual, and in the case of Saffran et al (1977), it requires the subjects to search a random array, making the task even more complicated. One would like to see aphasic's best STM performance before making hypotheses about their STM capabilities, and there is a need for research which utilizes an appropriate STM task for aphasics before some of the issues regarding STM and conduction aphasia, and aphasia in general can be resolved.

It is also beneficial, as discussed earlier, to employ an experimental paradigm which may give some indication of which component processes or mechanisms underlying STM may be at fault; attempts at this have been somewhat limited in the study of STM and aphasia and most of the investigation in this area is yet to be accomplished. Such an investigation should seek to determine, as much as possible, if impaired STM performance is the result of coding, storage, retrieval, or rehearsal deficiencies. While no STM paradigm can yield all of this information reliably, there are a variety of tasks which are able to indicate information beyond a test of simple span. These tasks should be the paradigms of choice in the area of STM and aphasia, where there may be differing impairments in underlying mechanisms among the different aphasic populations which may be overlooked in simple tests of STM span.

The present study was designed to investigate the auditory-verbal STM function among a group of conduction aphasics, and to compare their performance with that of a group of Broca's and a group of anomic aphasics, all of whom can be considered mildly impaired aphasics. The data were analyzed in an attempt to answer two basic questions:

1. Are there qualitative as well as quantitative differences in auditory-verbal STM performance among conduction, Broca's and anomic aphasics?

2. What are the underlying mechanisms responsible for these differences, if found?

Chapter 2

REVIEW OF RELATED LITERATURE

In Chapter 2, the literature related to short-term memory, short-term memory and aphasia, and short-term memory and conduction aphasia will be discussed. The following major topics will be included in this discussion: (a) development of the theoretical concept of short-term memory, (b) separable stores theory of memory, sensory and short-term stages, (c) the levels of processing framework for memory research, (d) Baddeley's concept of working memory, (e) short-term memory and aphasia, (f) methodological considerations in short-term memory and aphasia, (g) the syndrome conduction aphasia.

In the recent past, researchers in the experimental study of human memory were in relative agreement that memory can be divided into separable sensory information, short-term, and long-term stores with distinct characteristics, and that information flows or is transferred from store to store. This situation no longer exists; general consensus is lacking about the nature of the broad theoretical framework with which to evaluate the specific results of memory research. There are those who continue to evaluate memory research in terms of a structuralist model, the separable stores theory of human memory. Others, influenced by the framework for memory research proposed by Craik and Lockhart (1972) ascribe to a more functional approach which attempts to integrate memory more fully into information processing. This approach emphasizes the nature of the encoding processes incoming information may receive and posits that the strength of a memory trace is a function of these. Finally, others, especially Baddeley (1978), argue for less ambitious but more specific and testable theoretical underpinnings for memory research, such as his own conceptualization of working memory as comprising a cognitive space served by an articulatory rehearsal loop which has some similar characteristics to the short-term store but with less of a prominent role. In the following REVIEW OF LITERATURE, these theories will be discussed and evaluated, and the research relevant to the topic of this study will be examined.

SHORT-TERM MEMORY

Recent History of a Theory

The modern statement of the separable stores theory of memory is structuralist in nature (Eysenck, 1977, p.6). It was influenced by the advent of information processing systems which, in addition to long-term storage of information, almost always employ temporary storage units to hold incoming information until it can be processed (Norman, 1969, p.87). Information theory researchers such as Miller (1956) and Broadbent (1958) theorized that there is a separable short-term memory within the human information processor to perform a similar function to that in the machine. The characteristic features of short-term memory in Broadbent's (1958) model consist of a mechanism with limited capacity, rapid access and retrieval, and the ability to maintain items in STM through rehearsal, or to transfer them for future and permanent storage into LTM.

Research elaborating the features of STM was considerately stimulated following the publication of results (independently arrived at) by Brown (1958) and Peterson and Peterson (1959) demonstrating that a subject will not be able to retain a three item string over a short period of time measured in seconds if he is prevented from rehearsal by a distractor activity, typically counting backwards by threes. The introduction of the Brown-Peterson paradigm gave impetus to the study of STM. It gave researchers a sensitive tool for exploring the features of STM. Any new models of STM had to incorporate into their construction the rapid forgetting generated by the paradigm. Finally, as Brown (1958) and Peterson and Peterson (1959) both interpreted the results of their experiments in terms of decay theory rather than the interference theory of forgetting held by the associationists employed in the study of memory at the time, a considerably amount of controversy was aroused by this research (Baddeley, 1976, p.101).

Throughout the 1960s there was an enormous increase in the publication of memory studies, and the theory that memory is not a unitary system, and that STM exists as a separate mechanism was developed and extended. In a widely quoted paper, Waugh and Norman (1965) devised a serial digit probe technique which allowed them to extend the model of STM. In Waugh and Norman's (1965) probe digit paradigm, subjects are presented with strings of digits; the last digit of each list serves as a probe. The subjects in the experiment are required to recall the number following the probe in the original list. Waugh and Norman determined that forgetting increases as the number of intervening digits between the target item and the probe increases. Increasing the retention interval itself by slowing up presentation of the stimuli does not have the same effect.

Using the terms primary and secondary memory first proposed by William James (1890), Waugh and

Norman (1965) suggest that the contents of PM and SM need not be mutually exclusive; an item may be stored in both systems at the same time. As entry into SM from PM may be rapid, there is a necessity to determine in any STM experiment whether items in LTM are also making a contribution to the results. Waugh and Norman devised a formula to calculate the capacity of PM freed from any contribution from secondary or long-term memory. They also proposed that items may be transferred from PM to SM by rehearsal, a feature which became a fixture of most current models of memory, and which is still being investigated today in a slightly different form.

Models of Memory. Because of the influence of information processing systems on the study of memory, it became popular beginning with Broadbent (1958) to construct models of memory which conceptualize the flow of information in human memory. Throughout the 1960s and early 1970s, a major part of memory theorizing took the form of the flow-chart or memory model. The Atkinson and Shiffrin (1968) model is generally accepted to be the most influential (Baddeley, 1976, p.151); it divides memory into structural and control processes. The structural features of memory are considered to be the basic components of the memory system, consisting of a sensory register, a short-term store or working memory, and a long-term store. It also includes physical constraints such as the rules governing the decay of information in the different stores, and the route information can travel from store to store. The control processes govern the flow of information in the system and are under the control of the individual. They include such things as scanning, rehearsal, search strategies, and coding procedures.

A major contribution of the Atkinson-Shiffrin (1968) model is that it stresses the influence of voluntary control processes within the confines of psychological structure. It influenced many thinkers to break away from a strict behaviorism which would not allow them to consider such "mentalistic" concepts as "voluntary control over mental events" (Crowder, 1976, p.157). It also equates STM with working memory, so that in this model, the role of STM is expanded beyond that of a static store.

Although the Atkinson-Shiffrin (1968) model of human memory is considered to be a highly explicit and influential one, many memory models are similar, so that it is possible to abstract a "modal model" (Murdock, 1972) which summarizes the features that the various memory models have in common. It is widely accepted by these models that memory can be subdivided into three distinct storage systems: a sensory information store, a short-term store, and a long-term store. The modality specific, sensory information store (similar to the iconic or echoic memory proposed by Neisser, 1967) receives the results of the preattentive initial perceptual encoding of the stimulus (Norman, 1970, p.2). Attended information then enters a limited capacity short-term store which may also be modality specific. There the items are either continually recycled (rehearsed) or displaced by other items. Rehearsal also serves to transfer the items in short-term store into the more permanent long-term store where the capacity is large and unfixed, and forgetting is slow (Murdock, 1972).

The "modal model" summarizes the areas of agreement in the separable stores representation of memory. However, there was and is considerable disagreement about the specific theoretical characteristics of the memory stores. The major issues involved in the study of STM will now be discussed in the following section.

The Characteristics of the Memory Stores: Early Stages

The separable stores theory of memory posits the existence of a sensory information store (SIS) distinct from a short-term store. This store is presumed to hold the results of the early sensory analysis of the stimulus (Norman, 1970, p.2) perhaps for the purpose of enhancing the percept (Baddeley and Patterson, 1971). Information in the SIS is thought to be preattentive and modality specific, somewhat of a literal copy of the original stimulus. It is intrinsic in the model of the SIS that information can be transferred from there to the short-term store, but no information can enter the SIS from either the short-term or long-term stores. The capacity of the SIS is large; retrieval is by "read out." The trace contains more information than the individual can report, and forgetting is extremely rapid, as information cannot be maintained in the SIS. The trace duration of this information is estimated to be from 250 msecs to 2 seconds (Craik and Lockhart, 1972).

The Visual Information Store. It has been observed that a visual image will persist for a short period after the actual image is removed, but it is through experiments initiated by Sperling (1960), chiefly using the tachistoscope, that the salient characteristics of this after-image have been explored (Neisser, 1967, p.15). Sperling attempted to solve the experimental problem that when subjects are asked to recall the stimuli in a briefly presented visual array (typically 200 msecs), the number of items that can be recalled is confounded by the relatively slow speed at which they are able to be identified and reported. The common performance on this task is four or five items, although subjects note that for a brief time after the display is removed, they can visualize more letters than they can report. Sperling (1960) found that subjects can be directed by a probe to report from different locations (rows) in the array, and that using this technique, it can be demonstrated that subjects have a considerable amount of visual information available in excess of the amount they are able to report before it is lost to them.

In addition to location, subjects in this type of experiment are able to identify items in iconic memory (a widely used term for visual sensory information store proposed by Neisser, 1967) by other physical properties such as size or color (von Wright, 1968), and shape (Turvey and Kravetz, 1970). However, when subjects are directed to report out items by more highly encoded characteristics such as whether they are digits or numbers, their performance falls to that on noncued trials (Sperling, 1960). This is taken to indicate that the information in the icon is precategorical, i.e., not yet in contact with a learned name (Crowder, 1976, p.29).

Auditory Sensory Information Store. Although visual sensory information store is the most highly explored of the sensory information stores, there is evidence that a store with similar characteristics exists in the auditory modality as well, and presumably for all modalities such as the kinesthetic, tactile, gustatory, etc. The situation is more complex, however, for auditory rather than visual memory, for there are assumed differences between speech and non speech perception and memory, and one cannot make generalizations about memory for language based on experiments using non speech stimuli. Intuitively, there is a greater need for storage of sensory information in audition than in vision, for auditory stimuli are spread out in time and earlier parts of the signal need to be held until later parts arrive in order to perceive the whole (Crowder, 1976, p.45).

Several experiments have attempted to demonstrate the existence and properties of the auditory SIS using techniques such as forward masking, in which the detection of a target sound becomes impaired because of a louder sound which precedes it (Homick, Elfner, and Bothe, 1969). Efron (1970) trained subjects to adjust a light to coincide with the onset and perceptual offset of a tone in order to measure its perceptual duration. Efron found that tones 30 to 100 msecs in length produced a perceptual duration of approximately 130 msecs, an interval most likely too brief to be of aid for speech.

Most relevant for this report are studies demonstrating the existence of auditory SIS for speech stimuli. Darwin, Turvey, and Crowder (1972) used a partial report paradigm in which digits or consonants were presented to subjects simultaneously from three locations. The subjects were presented with visual probes at one of the locations following delays of from 0 to 4 seconds. Analogous to Sperling's experiments, subjects demonstrated that they were able to retain more information than they were able to report before losing it, and that the physical aspects of the stimuli were much better cues than the categorical aspects (digits vs consonants).

<u>Precategorical Acoustical Store</u>. Crowder and Morton (1969) have attempted to demonstrate the existence of an auditory verbal memory which is pre-attentive and precategorical, and which they call PAS, Precategorical Acoustical Store. In a variety of experiments, they present subjects with heard strings of digits of varying lengths, followed in the experimental condition by a "stimulus suffix", typically the word "zero." The "stimulus suffix" is the

same for each trial that it is present and subjects are instructed that they need not pay attention to it, that it may be used as a cue to commence recall of the list. However, when the suffix is present, it considerably depresses recall of items from the ends of the lists. The effect is most pronounced when the suffix is physically similar to the stimuli. Although the suffix is redundant, subjects are not able to ignore it and it displaces acoustically stored non-redundant information. The suffix is considered to displace precategorical information because its effect is not altered by differing semantic values; the words zero, rosy, and recall yield similar results.

The authors theorize that the PAS provides "extra read out time," as the information in the PAS is tapped in experiments in which subjects demonstrate a recency effect, i.e., enhanced recall of items from the ends of heard lists. The PAS is also thought to be responsible for the modality effect in which recency is exhibited for auditorially presented lists as compared with visually presented ones. The modality effect can be induced by having subjects read aloud while the words are being presented visually. Typically, silent reading will not produce the same effect (Crowder, 1978).

The results of the experiments cited in this section clearly indicate that there is storage of the physical features of auditory verbal information. Nevertheless, it is unclear if, first of all, this information is truly precategorical, and second, whether it is necessary to posit a store wich is separate from the short-term store to hold it. As Crowder (1978) points out, in the precategorical state, auditory stimuli should only be subject to analyses such as spatial location of voice, intensity, quality, sex of speaker, pitch and intonation, etc. Most writers presume that the physical non speech aspects of the signal are encoded at an early stage of feature analysis, and are stored before categorical information is available (Crowder, 1976, p.66). However, Marcel and Patterson (1978) have shown that subjects can be made to indicate that they have some semantic knowledge of words they are not even aware of having perceived. In one of a series of experiments, Marcel and Patterson (1978) present a word briefly to a subject by tachistoscope, followed by a mask of jumbled letters. If the mask is sufficiently close to the word in time, the subject is not able to detect the occurrence of the word. Nevertheless, when subjects are asked to guess what the word might be (even though they are not aware of having perceived a word) they are likely to guess a word semantically related to the target, such as yellow for red, or king for queen.

Although this experiment is visual rather than auditory, it calls into question whether there is any stage of verbal processing which is precategorical, as even at these brief time levels of stimulation, some semantic knowledge is evident. Second, it also makes it seem doubtful if it is necessary to posit a separate sensory storage mechanism, as it casts doubt on the widely held assumption that perception and encoding proceed in a series of stages from early sensory to later semantic (Baddeley, 1978). Finally, if such a mechanism as SIS exists, it should be possible to show that it is governed by unitary rules such as, for example, a uniform level of processing and a uniform decay rate of information. Without this unanimity, the designation of a separate store is quite arbitrary (Shiffrin, 1975). Some recent studies have indicated that contrary to a uniform level of processing, many levels of processing can coexist at a given instant in a modality. In a review of this literature, Shiffrin (1975) has shown that this lack of coding uniformity makes it impossible to determine at which stage or domain the label sensory or short-term can be applied. The theoretical necessity for a separate SIS may not exist if information at various stages of encoding can be held in the short-term store.

Summary. In the preceding section some of the evidence supporting a separate storage mechanism for "early" incoming sensory information was discussed. This hypothetical mechanism of large capacity and rapid retrieval is considered to exist for each modality and to be modality specific, as it holds a literal, preattentive and precategorical record of the original stimulus. The characteristics of the visual SIS have been explored by experiments initiated by Sperling (1960) using a partial report paradigm in which subjects are able to identify items held in VIS by means of probes related to the physical properties of the items. Crowder and Morton (1969) have posited a similar mechanism in the auditory-verbal realm to hold "early" incoming information from the speech signal: the Precategorical Acoustical Store (PAS). The PAS is thought to be the basis for the recency and modality effects typically exhibited in short-term memory experiments.

Recently, some arguments have been raised regarding the necessity of hypothesizing a separate sensory information store distinct from the short-term store. Such a store should be governed by unitary laws as, for example, a uniform code and a uniform decay rate, or else the raison d'etre for the theoretical contruct is eliminated. Shiffrin (1975) in a review of the literature concerning the storage of sensory information, primarily in the visual modality, has demonstrated that there is no such unity. A second objection to the notion of a separable SIS arises from results which indicate that subjects have knowledge of semantic aspects of a stimulus before they have knowledge of its physical aspects (Marcel and Patterson, 1978). If processing proceeds from the "top down," i.e., semantic to physical, rather than from the "bottom up," i.e., physical to semantic (Treisman, 1979) there should be no stage of processing which is precategorical and no need to separately store "early" sensory data.

Although the experimental investigation of memory for the physical-sensory features of a stimulus is a major and vast area, the primary emphasis in the separable stores theory of memory is on the division of memory into short-term and long-term stores. In the following section, the theoretical characteristics features of the short-term store will be discussed.

Characteristics of the Short-Term Memory or Store

Before commencing a discussion of short-term memory or store it is important to distinguish the various terms which have been used to describe the mechanism and whether or not they refer to the same thing. In the early stages of the current era of memory research, the most popular term short-term memory or STM was either rather loosely applied or else operationally defined, as, for example, in Belmont and Butterfield (1969), "how much a person recognizes, recalls or reproduces seconds or minutes after some material is presented." It soon became clear, however, that the term short-term memory was being employed in quite different ways with some resultant confusion: as a theoretically distinct neuropsychological mechanism, and as a description of an experimental situation (as in the above) (Craik, 1971). Following the lead of Atkinson and Shiffrin (1968) most writers employ the terms short-term and long-term stores to signify a specific neuropsychological mechanism, and short-term memory to apply to the experimental situation in which a small amount of material is recalled after a short interval. The other terms which have been used and which are synonomous to short-term store or STS are primary memory and immediate memory, as well as very short-term memory. In this study, as is now the custom, STM or short-term memory will be used when the experimental situation is referred to, and STS or short-term store will be used to designate the neuropsychological mechanism.

Short-term store is considered to be a memory storage system of limited capacity, with relatively easy and rapid storage, retrieval, and forgetting, and no permanent memory trace (Craik, 1971). Although there is relative agreement in the literature supportive of the stores theory of memory about these major characteristics, when an attempt is made to specify clearly the boundaries of each characteristic feature, or how it is achieved from a neuropsychological vantage point, a considerable amount of controversy becomes evident in the following areas.

Capacity of STS. The traditional view of short-term span is that it is limited to 7 plus or minus 2 items or chunks (Miller, 1956). However, Miller's measure is one of STM rather than STS and most likely includes a sizable contribution from long-term memory as well as the results of the utilization of active strategies to facilitate recall, most noticeably, rehearsal. Waugh and Norman (1965) were the first to propose a method of calculating the isolated capacity of STS or primary memory based on a formula which estimates the probability that an item has been retrieved from LTS or secondary memory and then eliminates that amount. Other methods have been proposed as well. This literature has been reviewed by Craik (1971), and Crowder (1976) with all estimates yielding a capacity for STS in the range of 2.5 to 3.6 words, depending upon the method used and the list length in the experiment. This capacity is thought to remain constant even when the syllable length of the words is varied from one to four, indicating it is the word itself which seems to be the unit of storage (Craik, 1968).

The Coding Format in STS. Most of the experiments which investigate the method of coding in the STS agree that phonetic coding is employed in the storage of items in this store, while semantic coding is active in LTS. This dichotomy has been a hallmark of the structural view of memory, so much so that there is sometimes a tendency to oversimplify the issue and ascribe any phonetic effects in memory to the STS. This is clearly absurd since phonemic information about language has to be permanently stored in order to be generated when needed and, by definition, STS cannot perform this function.

To briefly review the literature, the assumption that coding in STS is phonemic is based on studies chiefly performed in the 1960s such as Conrad (1964) which analyzed confusion errors in STM and found that stimuli which are acoustically and phonetically similar produce higher error rates than nonsimilar items. Comparable results were also demonstrated by Wicklegren (1965), Baddeley (1966) as well as by many others. The dichotomy between phonemic coding in STM and semantic coding in LTM was shown strikingly by Kintsch and Bushke (1969) who utilized Waugh and Norman's (1965) probe technique in two experiments comparing memory for lists containing synonyms, homonyms, and unrelated words. The list containing synonyms caused impaired performance in the earlier positions of the lists (as compared to a list of unrelated words). The list containing pairs of words which are homonyms of each other depressed performance for the last few serial positions of the lists, and yielded a reduced recency effect in comparison with performance on lists of unrelated words.

Although the notion that there is differential coding effects in STS and LTS has been well accepted, it is not without challengers. Wicklegren (1975) has argued that coding differences cannot be assumed on the basis of dynamic differences in forgetting rates of the two types of material, phonemic and semantic. He points out that in many memory paradigms, forgetting can be shown to be initially quite rapid, followed by a period characterized by slower forgetting. Therefore, the finding that phonetic effects occur when subjects are given a short time to learn a list is not a reliable basis for the argument that there is a separate STS with a phonetic format.

Shulman (1971), following a different line of reasoning, maintains that most STM experiments in which subjects are expected to remember lists of unrelated words over a short period are not conducive to semantic encoding, but this need not reflect reality when encoding strategies may be more flexible. Using a probe type paradigm in which the probe is a semantically related word to the target, Shulman has been able to demonstrate that semantic effects can be exhibited in STS.

Although Shulman's (1971) results are difficult to accommodate within a stores theory of memory, it was always clear that coding differences in STS and LTS could not be completely dichotomous. As discussed earlier, it is not surprising to find phonetic information stored long term, since the phonology of language has to be stored permanently in order to be generated when needed, and by definition, only LTS can perform this function. Additionally, many tasks such as rhyming, or retrieving alliteratives, etc., could not be accomplished if phonetic information is not available in LTS. It is chiefly on the issue of encoding a theoretical reevaluation of memory in terms of coding processes rather than stores has been set forth by Craik and Lockhart (1972) and the recent experiments in this area are primarily concerned with testing the assumptions of this framework.

The Role of Rehearsal in STS and STM. The role of rehearsal is one of central importance in a study of the functioning of the STS. However, there is much disagreement about the actual definition of what constitutes rehearsal, as well as the extent of its role in maintaining information and perhaps transferring information from STS to LTS. Most theorists agree that rehearsal is a verbal recycling of items in STS (Baddeley and Patterson, 1971); the subjective experience of rehearsal entails covert repetition of the items to be remembered (Craik, 1971). A few researchers have extended the definition of rehearsal beyond rote recycling to include other activities which may enhance recall from STS such as heightened attention to incoming items (Waugh and Norman, 1965), or semantic elaboration of incoming items (Craik and Jacoby, 1975). In current models, rehearsal is differentiated into two types: Type I or

Primary Rehearsal which is a covert reading out of items, and Type II or Secondary Rehearsal which modifies the form of the item through elaboration, and leads to permanent storage (Bjork, 1975). A common assumption in all definitions and explanations of rehearsal, however, is that it applies to verbal material only. Rehearsal seems to play no part as a strategy in any modality other than verbal (Eysenck, 1977).

Most researchers would also agree that rehearsal serves to renew or keep items active in STS, and perhaps, to maintain recent order information, as well (Bjork, 1975). However, if the definition of rehearsal is confined to a rote recirculation of surface information only, several experiments have shown that it does not seem to be the case that it has a role in transferring information to LTS, a major claim of the Atkinson and Shiffrin (1968) model, and of Waugh and Norman (1965). In one of these experiments, Jacoby (1973) presented five word lists to two groups of subjects. One group recalled the lists immediately following presentation, and one group was required to overtly rehearse the lists for 15 second intervals. After all lists were presented, a surprise final free recall test of all words to both groups showed that the words which had been rehearsed were no more likely to be recalled than words which were unrehearsed on the final recall trial. Jacoby concludes that increasing the time that an item spends in STS does not by itself increase the likelihood that the item will enter LTS. In fact, Jacoby speculates that the opposite is true; the requirements of active rehearsal may interfere with more important methods of processing and prevent the permanent storage of items in LTS. This conclusion has intuitive appeal for it seems highly unlikely that rote rehearsal, a relatively inefficient and cumbersome activity, should be the method for entering items into long-term storage. Additionally, as it is quite clear that it is not a factor in other modalities outside of verbal, its role as a means of affecting long-term storage must be negated.

Nevertheless, in some recent experiments such as Glenberg and Adams (1978), Geiselman and Bjork (1980), and Maki and Schuler (1980), it has been shown that long-term recognition memory can be enhanced by overt rehearsal, probably by aiding the subject in learning the physical features of the stimulus. However, since the effect is small it does not invalidate the above conclusion.

The Primacy Effect. The use of rehearsal does tend to increase memory span in characteristic ways in the STM experiment. In free recall paradigms, in which subjects are presented with lists of words which they then recall in the order of their choice, recall is typically enhanced from the initial serial positions of the lists. The effect is also exhibited in probed recall or recognition type paradigms, as well. This effect is called the primacy effect and is thought to result from the tendency of subjects to rehearse initial items more than subsequent ones. In verification of this, Belmont and Butterfield (1969) found that retarded children who failed to rehearse during list learning had a markedly reduced primacy effect, in comparison with normal children. Additionally, in experiments with adults, Fischler, Rundus, and Atkinson (1970) found that when rehearsal is equalized over all positions of lists, the primacy effect is substantially reduced.

The Recency Effect. The other effect typically exhibited in free recall experiments is the recency effect, which has been much more highly investigated than the primacy effect, and is of greater theoretical interest. The recency effect consists of near perfect memory for the last serial item on a list when recall is immediate, and enhanced memory for the last few items of the list (the most recent items) when recall is immediate. The recency effect is highly robust and is vulnerable only in situations when recall is delayed, and some activity such as counting backwards is interpolated between presentation and recall to prevent rehearsal. The recency effect was traditionally thought to reflect the rather pure output of the STS (Baddeley, 1976, pp.103-105) and can be demonstrated even for unattended stimuli such as in experiments in which subjects repeat (shadow) a message to a designated ear, and then are tested on their knowledge of material from their unattended ear (Norman, 1969).

Crowder and Morton (1969), as noted earlier, attribute the recency effect to the availability of acoustic and phonetic information in the PAS, the precategorical acoustical store. Other authors might argue whether the information is stored precategorically, but concur that the recency effect is chiefly the result of acoustic phonetic information stored in the STS. However, several studies now indicate that recency effects can occur in situations in which it is highly unlikely that STS is the contributing source. Tzeng (1973), in results which have been replicated repeatedly, interpolated distractor activity (counting backwards), between every word on a list. This activity should eliminate the recency effect just as distractor activity following the terminal item on a list typically does. Nevertheless, subjects exhibited a marked recency effect, and this recency effect was also exhibited when subjects underwent a final test of all remembered words at the end of the experiment. Even when an extremely demanding distractor activity is interpolated inter item, such as mental arithmetic (Bjork and Whitten, 1974) recency effects are clearly exhibited in both initial and final recall.

It is difficult to see how results such as these can fit into a framework in which recency is the sole result of the output of STS. Craik and Jacoby (1976) suggest that recency effects in LTS may be the result of specific retrieval strategies which subjects may employ. They hypothesize that subjects may either scan backwards over very recent events in episodic memory (a kind of counting backwards by episodes), or reconstruct items using retrieval cues supplied by the task. Baddeley (1976) has also suggested that some recency phenomena unexplainable by recourse to STS may arise from various retrieval strategies. At the very least, these experiments belie the tendency to attribute all recency phenomena to STS. They are a major problem for the stores theory of memory, a hallmark of which is the treatment of the primacy effect as representing the output from LTS and the recency effect as the output from STS.

The Serial Position Effect. The combined effects of primacy and recency displayed in free recall and some probe recognition and recall paradigms is called the serial position effect and is typically characterized as a U-shaped curved response. It refers to the serial position of each word on the list and its chance of being remembered as a function of its position. The normal subject shows enhanced memory for the items at the beginnings and ends of lists, while memory for the middle items, regardless of the length of the list is depressed and relatively flat. As the serial position curve is really a composite of two curves which are the result of the recency and primacy effects, a variety of conditions can independently effect either aspect of the curve and alter its shape. These typically include an increased inter-stimulus interval (the conventional rate is one word/second) which enhances the primacy effect, presumably because the subject is able to devote more time to rehearsing these items, and the inclusion of a distractor activity following presentation of the list. As already discussed, this will virtually eliminate the recency effect, presumably because the distractor activity displaces the items held in the STS (Lindsay and Norman, 1972, pp. 351-354).

The Function of STS. Although the characteristic features of STS such as capacity and format can be investigated more or less directly, the function of STS in language is something that must be guessed at. The most likely contribution of an STS in language is that it increases the opportunity to understand an utterance in situations in which this is unusually difficult. When sentences are long, ambiguous, or intellectually complex, subjects can re-read or rehearse the items stored in STS until the meaning of the utterance becomes clear. Similarly, in situations in which the individual's attention wanders, or in which redundancy is reduced, e.g., when trying to understand a foreign language or listening to speech in low signal to noise ratio, people are aided in decoding speech because the last few words in the utterance are stored in STS.

Some writers have suggested that STS serves to store up incoming words until enough have been presented so that the entire utterance can be understood (Neisser, 1967; Gough, 1972). The logic of this is that since incoming words are spread out in time and the beginnings of utterances must be remembered in order to understand the ends, STS is the likely mechanism to perform this function. Similarly, designers of information processing machines almost always include temporary storage units at lines which communicate with the environment (input-output lines) because the speeds at which information is received or transmitted, and at which information is processed differ (Norman, 1969). This function now seems highly unlikely. The capacity of STS has been shown to be quite limited, approximately 2.5 to 3.5 items (Craik, 1971) to be of much use in containing entire clauses or sentences. Secondly, and more important, several patients have been identified who have pathologically reduced STS or STM capacity and yet are quite capable of understanding sentences (but not of repeating them). In a series of reports, Warrington and her associates (Warrington and Shallice, 1969, 1972; Warrington, Logue and Pratt, 1971; Shallice and Warrington, 1970, 1977; Warrington and Weiskrantz, 1973; Shallice and Butterworth, 1977) extensively tested one patient, and then two similar ones, utilizing tasks involving repetition, pointing, matching, and probed recognition, primarily of digits and letters, and demonstrated quite unequivocally that a patient may have an isolated and severe impairment of STS and yet function quite adequately in other areas of language and memory.

The authors point out, if, as the model predicts, all material must go to STS before it can be coded in LTS, one should never see an individual with an impaired STS and a normal functioning LTS. Input to LTS, learning, recall, and language comprehension should be correspondingly impaired as well. In fact, however, as reported in the literature, the patient with isolated and severely impaired STS does not suffer from any major defect of thought and language other than an inability to perform rote repetition. Clearly then, information need not be stored in STS before entering LTS. Warington and Shallice (1969) hypothesize that entry into STS can occur in parallel with entry into LTS rather than in series as the classic model predicts. This, however, significantly lessens the function that STS can play in language and memory, and eliminates a major tenet of the stores model of memory.

The Warrington et al results have cast some doubt on the adequacy of the stores model, although their research was originally interpreted in terms of it. The clear indication that information is not transferred from store to store in the manner predicted in the "modal" model of memory, as well as the observation of other contradictory STS results, especially the demonstration of recency effects in LTS, has led to a shift of emphasis in the memory literature. There has been a general rejection of the rigid adherence to the notion that memory consists of a series of isolated boxes with inflexible rules regarding storage, retrieval, etc. This is evident even in a statement by Donald Norman (1970) in the Preface to his book Models of Memory which is devoted to model building. He states,

> A few years ago, most of the quantitative models of memory were based upon the formal representation of some learning theory, or some sort of information-processing analysis and storage and retrieval of items in memory. Now, however, we find increasing emphasis on cognitive processes and increasing concern about the rules and strategies used by subjects in storing and retrieving information. More and more, the processes involved in memory are being described in terms very similar to those used to describe the processes of perception, of thinking, and of problem solving. We find the tools from linguistic theories of semantics, from computer studies of list structures, from general considerations of retrieval and organization, and from a sort of systems analysis of the way that the different processes involved in the human memory system interact with one another.

Although the terms STM and LTM still function to describe qualitatively different states, an alternate framework for interpreting the memory literature has become increasingly popular which conceives of memory as being dependent upon the kind of encoding incoming items receive. Memory and other forms of information processing, especially perception, are now envisioned as being closely interfunctionally integrated. In the following section, the levels of processing approach or framework for memory research (Craik and Lockhart, 1972) which is the form this new emphasis in memory research has taken, will be discussed.

Summary. The major dichotomy in the separable stores theory of memory is the STS-LTS distinction. STS is considered to be an identifiable mechanism of quite limited capacity (2.5 to 3.5 items), with easy and rapid storage, retrieval, and forgetting, and no permanent memory trace. The term STM or short-term memory is generally used in the literature to refer to the experimental situation in which subjects are expected to retain information for a short period and there is no attempt to isolate the STS from any contribution from LTS. This has caused some confusion as STS and STM are not always synononous.

In several areas, basic assumptions of the stores theory of memory have met with conflicting evidence. These areas include the following:

(1) Coding differences in STS and LTS are no longer thought to reflect a clear dichotomy between phonetic and semantic. Early research into memory processes indicates that LTS can retain phonetic information. More recently it has been shown

that semantic information is available at an early stage of processing, perhaps even preceding phonetic information in its availability to the subject (Baddeley, 1978).

(2) Recency effects can be demonstrated in paradigms in which the source cannot be STS. A major tool for distinguishing the contribution of STS has been the assumption that all recency effects reflect its contents (Craik and Jacoby, 1975).

(3) Several patients have been identified who seem to exhibit a profound and isolated deficit of STS and yet are able to function quite adequately in other areas of memory and language, aside from rote repetition. The indication that input to LTS is not correspondingly impaired in these patients has led to a reevaluation of the stores theory of memory, for it demonstrates that information need not be stored in STS to enter LTS (Warrington and Shallice, 1969).

The Levels of Processing Framework for Memory Research

Most of the research which regards human memory as an outgrowth of differential coding processes has been stimulated by the framework proposed by Craik and Lockhart (1972). As originally formulated, Craik and Lockhart hypothesize that perceptual analysis encompasses a continuum of levels or stages.

In the early stages of the analysis of stimuli, physical or sensory features are extracted such as light/dark contrast, detection of angles, or auditorially, pitch and loudness. Analysis later proceeds to more abstract levels; the meaning is extracted and the stimulus is matched with past learning. Each stage of analysis from superficial to deep leaves a memory trace and the persistence of that trace, which is a byproduct of the perceptual analysis performed, will vary depending upon the "depth" of that analysis. The memory trace for the more automatic sensory and physical analysis will be fleeting while the trace for deeper, meaningful levels of analysis will be more durable, since the goal of the individual is generally the extraction of meaning from the environment, and it is to the advantage of the individual to store this information over a long time.

The authors claim that trace retention is also a function of the amount of attention a stimulus receives, the amount of time available to process it, and its compatibility with the structures performing the analysis. Stimuli that are highly compatible, such as over-learned sentences, will be processed rapidly so that speed of processing does not necessarily indicate depth of processing taking place.

A major aspect of the conception of the levels of processing approach has been modified in the last few years. The notion that processing proceeds in an "inevitable series of stages" has been rejected. Although it is still acknowledged that the earliest feature extraction is almost certainly sensory in nature, "further processing within a domain may be better characterized as a lateral 'spread' of encoding rather than as a hierarchically organized series of levels" (Craik and Jacoby, 1976).

Many of the questions and controversies surrounding issues raised by the separable stores theory of memory are no longer as relevant when memory is viewed as a trace byproduct of processing. Capacity is not seen as a certain amount of fixed places in a store. The trace results of the currently active perceptual analysis are held "in mind" and the quantity of items held depends somewhat upon the degree of processing each receives (Craik and Jacoby, 1976). The issue of which code is employed for each store is no longer relevant since the code depends upon the type of analysis performed. Likewise, the issue of interstore transfer is bypassed. Long-term storage is achieved by the formation of an elaborative trace; other features of the stimulus may be extracted as well such as physical information, but the information is not transferred in any way (Craik and Jacoby, 1976). Finally, the issue of the role of rehearsal is considerably altered. Craik and Lockhart (1972) distinguish between two types of rehearsal: Type I which consists of the maintenance of information at a constant depth, and Type II in which the information is semantically elaborated. Contrary to the predictions of the stores model, only Type II rehearsal is expected to leave a durable trace.

Much of the research for which the levels of processing framework has served as an impetus has clustered about the demonstration that deeper semantic processing enhances long-term learning and recall, while shallow phonetic or sensory analysis serves only to maintain information at a constant depth. Most experiments in this vein demonstrate that when subjects are given a semantic as compared with a phonetic retrieval cue (Craik and Jacoby, 1976; Cermak and Moreines, 1976) or employ Type II (semantic elaborative) rehearsal rather than Type I (rote) rehearsal (Elmes and Bjork, 1975; Mazuryk, 1974) long-term remembrance of these items is considerably enhanced, while short-term remembrance is not. The emphasis in these experiments has been primarily on the long-term components of coding and is not entirely relevant for this study. In fact, the short-term component of the original framework comes close to being overlooked (Baddeley, 1978).

Some Critical Comments Concerning the Levels of Processing Framework. The major criticism of the levels of processing framework has been that its formulations are vague and untestable (Eysenck, 1978; Baddeley, 1978). Such terms as depth of processing, spread of encoding, elaboration, distinctiveness, do not lend themselves to rigorous definition and investigation. Secondly, as Eysenck (1978) complains, most of the studies which have been generated in this realm concentrate almost exclusively on variations in coding. There is almost no acknowledgement that there can be the same variety and flexibility of retrieval strategies. Furthermore, even within the domain of coding, very little of the research directed towards this issue investigates, or even acknowledges the fact that differential coding strategy may reflect the individual variations of the subjects rather than some universal coding behavior.

When certain issues which can be specifically formulated from the framework have been tested, some of the results have proved difficult to incorporate into the levels of processing approach. The findings that the learning of certain physical features of a stimulus can take place over the long term

(Jacoby, 1975) or that rote rehearsal can facilitate long-term learning (Geiselman and Bjork, 1980; Maki and Schuler, 1980) are difficult to explain within the proposed framework, which predicts that processing of physical features and rote rehearsal should not lead to the formation of a permanent trace. Other results which cause difficulty are those of Marcel and Patterson (1978) indicating that a subject seems to have some semantic knowledge of a word stimulus prior to the formation of a phonetic trace and even prior to his awareness of actually having perceived the stimulus. This research, as Baddeley (1978) points out, flies in the face of the widely held assumption that processing invariably progresses in a series of stages from the abstraction of physical or sensory information to the abstraction of semantic or meaning information. Awareness of the physical features of a stimulus may be a relatively late stage in information processing.

Lockhart and Craik (1978) defend their framework by pointing out that it was never intended to be a completely articulated theory, but is meant to be a conceptual guide for viewing and integrating research in human memory. It has freed memory research, to some extent from the problem of paradigm specificity, in which particular paradigms generated results which could not be demonstrated by other paradigms and thereby replicated (Eysenck, 1979). However, its greatest virtue is considered to be that it has tied memory much more closely to the general realm of information processing (Baddeley, 1976, p. 167).

As a heuristic, the levels of processing framework has proved fruitful for the neuropsychological investigation of human memory pathology for it forces investigators to consider that a memory disorder must always be the result of some impairment in information processing, as well as vice versa. Several studies have been performed which investigate underlying coding deficits in Korsakoff's syndrome as well as other amnesic disorders (Cermak, Butters, and Moreines, 1974; Cermak and Moreines, 1976). However, as the framework has not been concentrated on the short-term component of memory, similar investigations into disorders of STM have yet to be performed.

A Conception of Working Memory

Baddeley (1976) has proposed a conceptualization of working memory which, although much less encompassing than the levels of processing framework, offers the advantages of being specific and testable, while avoiding the rigidity of the stores model. It also elucidates the area most overlooked in the framework, that of information held over the short-term. Arising from an attempt to explicate the function that STS might play in human information processing (since it is quite clear, chiefly from the neuropsychological evidence already cited that STS by itself cannot play a major function in processing) Baddeley (1976, p. 176) suggests that STM constitutes a dual system: (1) a working memory and (2) "an articulatory or verbal loop..., a limited capacity slave system which can be used to supplement the central processor" and which is roughly synonomous with the standard concept of STS. This secondary system provides a valuable temporary store but it is not essential to the function of working memory. In disorders of the type that Warrington has investigated (Warrington and Shallice, 1969) in which STM is thought to be impaired, presumably it is this articulatory loop which is deficient.

Some of the research that is taken to support this conceptualization are the findings that subjects can perform a variety of verbal mental tasks while concurrently holding sets of digits in mind. It seems that it is only when the concurrent memory task begins to exceed the articulatory store or loop that a clear decrement in the subject's performance on the reasoning task begins to appear (Baddeley and

Hitch, 1974). In conditions when subjects are also required to suppress articulation through active rehearsal of the concurrent memory stimuli, a small decrement in reasoning appears when memory load is low, and a marked decrement appears when it is high. The greatest effect occurs when the reasoning task is quite difficult and the memory load is high (Baddeley & Hitch, 1974).

Baddeley and Hitch (1974) take these results to indicate that working memory and STS are not synonomous since subjects are able to perform the tasks even at the highest memory load. They also serve to demonstrate that working memory makes demands on STS or on an articulatory store since filling it causes a decline in performance, especially regarding the amount of time subjects must employ to perform the reasoning tasks.

Summary of Memory Theories

Beginning with the late 1950s, most researchers ascribed to the theoretical view of memory as a series of separate stores with unitary rules providing for retrieval and storage. Human memory was thought to consist of a sensory information store to hold incoming sensory information in a relatively literal format, an acoustic phonetic short-term store of small capacity and rapid retrieval, and a long-term semantically based store with a vast capacity. In time, however, as a result of conflicting findings, as well as because the predictions from the theory were quite limited, the stores model of memory was seen to be somewhat of an oversimplification. The conception of memory as a holder of information only gave way to a more functionally integrated approach in which memory is one aspect of general information processing along with such other tasks as perception and coding. The levels of processing framework proposed by Craik and Lockhart (1972) is the major conceptualization of this functional approach to memory. A more limited but more specific one is that proposed by Baddeley (1976) comprising a working memory with an articulatory loop. One important influence on the recent evolution of memory theory has been the research by Warrington and her associates which has identified a syndrome, thought to be a form of conduction aphasia, in which short-term memory is selectively and markedly impaired, while other functions are spared. This research illustrates the limited function STM must play in language comprehension, speech output, and reasoning, since patients with this syndrome are able to perform quite adequately in these areas. Additionally, it demonstrates that models of memory which predict that information must enter LTM through STM are incorrect, as this model would also predict that a grossly impaired STM should lead to a correspondingly impaired LTM.

Some researchers have attacked the above findings on the grounds that: (1) the impairment is not of memory but of linguistic origin (Strub and Gardner, 1974) and (2) the patients discussed are not true conduction aphasics (Shallice and Warrington, 1977). In the following section, the research regarding STM and aphasia will be discussed in an attempt to resolve these questions as well as to make comprehensive the significance of the short-term memory deficit in conduction aphasia for a study of memory and language.

Short-Term Memory and Aphasia

Aphasics of all classifications commonly have some degree of impairment of auditory-verbal short-term memory span. In general, this is exhibited expressively by difficulty in repetition, and receptively, by difficulty in retaining long and/or complex utterances. Many researchers have considered this impairment to be secondary to the existing overall linguistic deficit present in aphasia (Schuell et al., 1964, pp. 123-124) and it is only within the past ten years that researchers have begun to consider that language and verbal memory can be differentially impaired in aphasia as well as in conjunction with each other.

The initial studies in this area stress localization of STM (Milner, 1962, 1967; Butters et al, 1970; Samuels et al, 1972) employing patients who have undergone lobectomies, and demonstrating differing impairments, depending upon which cortical lobe has been excised. Although there is some disagreement regarding the results of excision in the right temporal and the parietal lobes, perhaps because of different experimental methods, both Milner (1967) and Samuels et al (1972) find that patients with left temporal lesions exhibit reduced verbal STM. Additionally, Butters et al (1970) demonstrated that left frontal patients (all but one of whom are aphasic) perform poorly on a Peterson task even at a zero retention interval, while left parietal patients tend to show impairment only when they are required to retain stimuli over a longer retention interval (up to eight seconds in this experiment). Butters et al (1970) hypothesize that the deficit of the left frontal patients is one of "registration" while the left parietal patients or subjects have a verbal (short-term) memory deficit. These studies have the value of demonstrating qualitatively different STM performances in frontal, temporal, and parietal patients. Additionally, since some of the patients employed in these studies are not aphasic, they also illustrate that auditory verbal STM impairment can exist without consequent auditory comprehension deficit.

Loss of Memory Function and Change of Memory Strategy. When aphasic subjects are compared with normal subjects on short-term memory tasks, they uniformly perform poorer, as can be expected. Additionally, however, some unusual aspects of their short-term memory performance are displayed. Goodglass et al (1974) had subjects (aphasics and normals) study sets of pictures containing two, three, or four cards, and then had the subjects place the face down cards on their match in an array. Unlike the controls, the aphasic subjects did not experience a decrement in performance when the pictures were homophonic (similar in sound). The most likely explanation as Goodglass et al (1974) conclude, is that the aphasic subjects were not troubled by acoustic confusion, because, on this type of task, they do not rely to a large extent on verbal mediation, a poor choice of strategy given their impaired language.

Similarly, Swinney and Taylor (1971) discovered that the aphasic subjects in their experiment adopted a different strategy than the typical one employed by normals in a digit probe reaction time experiment. In this task, subjects were visually presented with a series of three digits, and then were required to indicate whether a probe stimuli was part of the series, for each set of digits, in turn. Aphasics displayed longer latencies and made many more errors than the normal controls. More striking, however, is the finding that aphasics seemed to adopt a self-terminating strategy in which they responded as soon as they discovered a match, rather than the typical exhaustive search strategy (adopted in this experiment by the normal controls) in which the probe is responded to after the entire set is read through. Swinney and Taylor (1971) account for the aphasics' performance by postulating a slower scanning rate for the brain damaged subjects. An alternate possibility is that it is too difficult for aphasics to rehearse the lists quickly, given their language impairment, and they must renew the items one at a time, laboriously matching the probe with each digit on the list.

Inability to rehearse with ease affects the aphasic STM performance in other ways. Locke and Deck (1978) had aphasic subjects name 60 pictures. From these, two lists were drawn for each subject consisting of words the subject could name easily and those he failed to name. Subjects then received a three item probed memory test consisting of pictured stimuli, in which the subject's task was to overturn the duplicate of the probe for each series (pictures were placed face down following presentation). As might be predicted, when the list items were unnameable by the subject they could not be rehearsed, leading to a considerable loss of primacy, as compared with the nameable lists. The recency effect was marked for both conditions and was not reduced by inability to name the target item. However, while rehearsal did enhance memory for the initial position in the nameable lists, there was a corresponding decrement in ability to remember the medial items of those lists so that the aphasic's "net gain from rehearsal is negligible." Apparently, as demonstrated by this experiment, if the aphasic adopts the strategy of active rehearsal, he is not able to perform concurrent memory tasks adequately, most likely because rehearsal requires an abnormal amount of the subject's attention because of his language impairment. For normal subjects, rote rehearsal should require only minimal cognitive capacity (Glenberg, 1978).

Not surprisingly, it has also been found that aphasic subjects are much more susceptible to the effects of an interpolated distractor activity than are nonaphasic subjects (including brain damaged nonaphasics). De Renzi et al (1978) demonstrated that mildly impaired aphasics do not perform significantly worse than nonaphasic brain damaged subjects on three item Token Test commands. However, when a 20 second distractor activity (counting) is interpolated between the command and the response of the subject, aphasics are much more adversely affected by the distractor than are the brain damaged nonaphasics and the normal control subjects. The authors hypothesize that the distractor interferes with the "organization" of the task, i.e., "the ability to relate a word to other related words" and which, they presume, enhances trace strength. The evidence for this explanation, however, is indirect at best, as the authors admit. It seems at least as likely, as discussed above, that aphasic subjects do not have the cognitive space available to perform concurrent language and STM tasks effectively as the verbal demands of the one interfere with the verbal demands of the other. In this case, the counting task probably requires an abnormal amount of attention and language effort, and memory for the Token commands cannot be rehearsed and is lost.

Although aphasia is not considered a memory disorder, per se, there is some evidence that aphasic performance on memory tasks is surprisingly poor even in comparison with that of other disorders in which the decrement in memory is a major feature of the syndrome. Bender (1979) found, for example, that aphasic subjects make more errors in reverse seriation than other brain damaged groups including those with specific memory disorders. Of course, it is necessary in the case of aphasia to discriminate whether what seems to be a poor performance on a memory task merely reflects the subject's linquistic impairment. However, even when the experimental task is designed to minimize the expressive language component so as not to unduly penalize the language impaired subject, aphasics perform poorly on most memory tests.

Cermak et al (1976) reason that since (according to the Craik and Lockhart (1972) levels of processing framework) verbal memory depends upon the ability to analyze the features of words, impairments in analytical ability may result in impairment of memory. When aphasic subjects were required to detect repetitions, rhymes, and semantic associations in lists which were read to them, they performed significantly poorer than Korsakoff's subjects. The aphasic group did especially poorly as the number of intervening words between the target and its repetition, rhyme or category match increased. Interestingly, when the lists were presented relatively slowly, at the rate of one word/three seconds, the aphasic performance improved until they were slightly better than the Korsakoff's group (the Korsakoff's syndrome subjects were not aided by the slower rate).

The authors comment that unlike the Korsakoff subjects "it is the aphasic's speed of processing that seems to be impaired, and not their potential to analyze the semantic properties of words." However, since the aphasic performance was significantly below that of the normal controls, even at the slower rate of presentation, processing time cannot be the only variable required to bring aphasic performance up to normal. In fact, there is some evidence which specifically demonstrates that aphasic subjects have difficulty analyzing the full range of semantic values which a word may carry (Tillman and Gerstman, 1977; Zurif et al, 1979). Finally, it should be pointed out that there is a problem in explaining the STM deficit in aphasia using data which has been obtained from only one aphasic syndrome; in this case Cermak et al (1976) obtained their data almost entirely from a group of Broca's aphasics. It is quite likely that the different aphasic syndromes tend to exhibit differing decrements in STM, and it is also likely that these differing decrements reflect impairments in underlying mechanisms responsible for the decrements which may be specific for each syndrome. Evidence in this regard has been offered by several investigators (Butters et al, 1970; Saffran and Marin, 1977).

Short-Term Memory Impairment and Language Comprehension in Aphasia. Some of the interest in STM and aphasia has been stimulated because it is thought it might shed some light on the function of STM in language and, more specifically, answer the question whether reduced STM leads to reduced language comprehension. Three studies explore this question by comparing aphasics' performance on either digit span (Shewan and Cantor, 1971; Heilman et al, 1976) or pointing span (Goodglass et al, 1970) with their comprehension of sentences. Auditory comprehension for sentences is tested using picture verification (the subject hears a sentence and chooses a corresponding picture from a picture plate containing four choices). Only Heilman et al (1976) found a relationship between reduced STM and impaired auditory comprehension for sentences, perhaps because it is the only study which examined the comprehension of sentences with reversible semantic elements. Heilman et al (1976) demonstrated that when aphasic subjects made comprehension errors, these tended to occur in sentences such as, "The girl is hitting the man" in which the actors can be reversed. The study also claimed that "digit span correlated significantly with total comprehension scores."

There is some indication then that subjects who have impaired STM are at a disadvantage when it is necessary to retain word order in order to comprehend meaning, but in situations in which retention of word order is not strictly necessary, impaired STM in itself does not seem to lead to impaired auditory comprehension. This is nicely illustrated in a study performed by Saffran and Marin (1975), in which a subject, I.L., a conduction aphasic with extremely depressed STM, was asked to repeat a series of sentences immediately upon presentation. I.L. offered paraphrases (he did not repeat a single sentence verbatim) which tended to preserve the meaning of the original. However, when repeating reversible sentences, I.L. was unable to preserve the order of the semantic elements and made some errors of meaning. Additionally, when an introductory clause began a passive sentence so that the information contained in the word order was mid sentence rather than at the beginning where the subject is better at retaining it, I.L. tended to convert the sentence to an active form and to make meaning errors, if it was reversible as well. These findings have since been replicated by Shallice and Butterworth (1977) with a similar patient, J.B.

Summary. In the preceding section, several studies which explore STM impairments in the overall aphasic population were reviewed. There is general agreement in this research, as can be expected, that aphasic subjects have impaired STM in comparison with normals, and even with other brain damaged groups. It is not nearly as clear, however, when an aphasic performed poorly on a STM task, whether the impaired performance is simply a carry over of a language deficit into STM, or whether it reflects actual changes in memory function such as coding and retrieval. In some studies there is an indication that aphasics must rely on a less efficient memory strategy than normals because of the nature of their language difficulties. Inability to rehearse effectively, inability to perform concurrent memory and language tasks, susceptibility to distraction, and problems with retaining sequential information all contribute to failure on STM tasks. Nevertheless, STM deficit in itself does not seem to lead to a corresponding deficit in the ability to comprehend sentences except in the special situation in which retention of word order is essential for comprehension of meaning.

<u>Methodological Considerations: STM and Aphasia</u>. It is quite obvious that there are some special methodological problems in testing STM in language impaired subjects, as one must be confident as much as possible, of not confounding memory impairment with expressive or receptive language impairment. A good part of these problems can be avoided if the subjects chosen are mildly rather than moderately or even severely language impaired, a precaution that was not followed for the most part in the studies just reviewed. It is also necessary when comparing subgroups of aphasics, to insure that one group of aphasics does not have a greater degree of language impairment than another, for degree of severity can easily bias the results of performance on a STM task. Heilman et al (1976) who find no difference in digit span between Broca's aphasics and conduction aphasics give only minimal information regarding whether the two groups were similar in degree of severity. Since Broca's aphasia tends to be a more severe type of aphasia than conduction aphasia, this is particularly important in this case. Finally, it is important in STM research in aphasia to

neither make generalizations from one syndrome nor to ignore differing underlying mechanisms which may yield the same memory score but arise from different sources. Cermak et al (1976), as pointed out earlier, gathered their data primarily from anterior aphasics. Their subjects may have performed poorly because they are slow at encoding the stimuli as the authors hypothesize. However, anomics or conduction aphasics, of whom they did not obtain an adequate sample, may do poorly for other reasons such as retrieval or storage failure.

On the other hand, Heilman et al (1976) employed digit span repetition to compare Broca's and conduction aphasics. Aside from its other problems, which will be discussed shortly, this paradigm gives no indication of the underlying mechanism responsible for reduced digit span, be it expressive language difficulty, STM impairment, or even anxiety, depression (Eysenck, 1977), or intellectual performance (Black and Strub, 1978), all of which can be reflected on occasion in the span. It is preferable, when comparing subgroups of aphasics on STM tasks, or in any STM paradigm, to incorporate a device such as serial position effect, reaction time, or some indication of differential encoding, etc. to yield some knowledge regarding underlying mechanisms involved to attempt to differentiate the groups. A straight measure of span is quite limited in the information it reveals about memory function. In the case of Heilman et al (1976) the assumption is made that conduction and Broca's aphasics have similar repetition deficits based on their digit span repetition, an assumption which is unlikely, given the literature available which documents the special repetition defect which is the hallmark of the conduction aphasia syndrome.

Just as it is extremely important in the area of STM and aphasia to choose a population carefully, both to avoid confounding memory and language problems as well as to avoid ignoring underlying mechanisms, it is also necessary to devise an experimental paradigm with the same care for the same reasons. One of the problems of using digit span, that it yields only a gross measure of span with no information regarding underlying mechanisms, has already been discussed. Additionally, Talland (1968) has shown that normal subjects who do not differ on span can differ on other recall measures. Several studies have shown that digits are not necessarily representative of other types of material in repetition tests with an aphasic population (Geschwind, 1965; De Renzi and Nichelli, 1975; Gardner and Winner, 1978).

The substitution of reverse digit span for forward span, preferred by some, does not seem to be of any benefit in testing the STM capacity of aphasics. Aphasics have been shown to have the highest incidence of errors on this task in comparison with several groups of subjects with other brain pathology (Bender, 1979); it is an extremely difficult task for even a mild aphasic as the subject must rehearse the stimuli forwards and hold them in mind while reciting them backwards. This type of concurrent memory and language activity has been shown to be quite difficult for the aphasic, as already mentioned, and in this case, may complicate STM testing by including superfluous cognitive tasks which overload the aphasic subject's capabilities. Additionally, reverse digit span may even involve a spatial component (Black and Strub, 1978). Taking all this into consideration, it would seem that digits, whether forward or backwards, are an unrepresentative set of stimuli for the purpose of testing STM, especially in aphasia. Furthermore, since it is ultimately the processing and coding of words that is under investigation in most studies of memory and language, there seems little benefit to rely on digits as experimental stimuli.

A second problem with the use of digit repetition or with any repetition task to test STM in aphasia is the problem of utilizing repetition in a population with expressive language impairment. As list length increases and subjects begin to make errors of repetition, it is difficult to determine if the source of the errors is memory impairment or expressive language impairment. This problem is not eliminated by utilizing pointing span as some studies do (Tzortis and Albert, 1974; Saffran et al, 1977), for in this case the solution may be worse than the problem. Pointing span most probably involves covert repetition, and complicates matters by bringing in other cognitive operations such as transcoding from auditory to visual. Additionally, in some experimental designs, subjects are asked to search an array which may also include extraneous stimuli, which, of course, makes the task even more complicated. Pointing span is generally impaired in aphasia, and studies which compare repetition and pointing tasks in a language impaired population indicate that pointing span is either no better than repetition (Saffran and Marin, 1975) or considerably worse (De Renzi and Nichelli, 1975).

Short-Term Memory and Conduction Aphasia

In recent years, much of the current interest in STM and aphasia has been stimulated by the research of Warrington and her associates in conduction aphasia. In most forms of aphasia, it is difficult to rule out the possibility that the linguistic impairment underlies a great deal of the demonstrable verbal STM deficit, for surely if a patient is experiencing receptive and expressive difficulties, he will also be unable to retain items and/or repeat them. However, in the syndrome conduction aphasia, in which verbal STM is markedly impaired out of proportion to the impairment of the other existing language modalities, this explanation by itself seems insufficient. Warrington and her associates have interpreted the repetition defect in conduction aphasia to be a consequence of a selective disturbance in verbal short-term memory, analogous to amnesia, a selective disturbance of long-term memory.

The subject was introduced when Warrington and Shallice (1969) published a clinical study of a patient, K.F., who, following a brain lesion is unable to repeat, but can be shown to possess intact motor speech, auditory comprehension, and long-term memory. On tests of span, K.F. was shown to have a capacity of between one and two items. This article was followed by a neuropsychological study (Shallice and Warrington, 1970) which reported on K.F.'s performance in five STM experiments designed to display his marked impairment of STM. Although all of these experiments demonstrate K.F.'s disability, the most vivid results were obtained from tests of immediate free recall (Experiment I) and probed letter recall (Experiment IV). On tasks of immediate free recall of lists of ten words, K.F.'s serial position curve is almost flat for the middle eight positions of the list. His recency effect is limited to the final position of the list, and his primacy effect is likewise limited to the initial position of the list. As noted earlier, in normal subjects the primacy and recency effect should extend over several positions at the beginning and end of a list, respectively, and only the true middle section of the list in this task should yield a flat curve. Similarly, in probed recall, again it was shown that K.F.'s recency effect is quite limited, to the final position of the list.

As these results or others that are similar have been replicated with other patients by Warrington, Logue, and Pratt (1971) as well as by other authors (Saffran and Marin, 1975; Saffran et al 1977; Caramazza et al, 1979, 1981), there can be little doubt that there are patients who exhibit an isolated inability to repeat or retain items over the short-term. As discussed earlier, the identification of a disorder with impaired STM and unimpaired LTM has had major ramifications for theories of human information processing, because it makes untenable the notion that information mandatorily enters STM before it is encoded in LTM. Additionally, it also brings into question what the function of STM can be in language and thought if these subjects can perform almost all tasks (with the exception of rote repetition) with such a severely limited STM. However, several authors, while conceding that the subjects discussed here perform poorly on STM tests, attribute the defect to mechanisms other than memory, such as a higher level linguistic disorder (Strub and Gardner, 1974) or a specific inability to retain sequences (Tzortis and Albert, 1974).

Some researchers, citing a second major question regarding this literature, have doubted whether K.F., as well as the other patients in this literature, actually exhibit conduction aphasia. Shallice and Warrington (1970) state that the patient K.F. "has a profound repetition defect (in the neurological literature, this deficit is the cardinal feature of 'conduction aphasia')." Nevertheless, since K.F. does not appear to exhibit the paraphasias which are considered typical in the expressive speech of the conduction aphasic (Goodglass and Kaplan, 1972) and other patients, J.B. (Shallice and Butterworth, 1977) and I.L. (Saffran et al, 1977) exhibit almost no expressive impairment of any kind, the results discussed here may have little relevance for the study of aphasia as a whole. In discussing this issue, Shallice and Warrington (1977) propose that there may be two anatomically (rather than functionally) related disorders with "close anatomical relation between the critical site lesions," consisting of typical conduction aphasia with paraphasias, and "pure" conduction aphasia without paraphasias. Shallice and Warrington (1977) then go on to posit two different mechanisms to explain the repetition disorder in the two syndromes: reproduction impairment in the former, and STM impairment in the latter. As both of these issues (the underlying cause of the repetition defect, and its relevance for aphasia) require some knowledge about the syndrome of conduction aphasia in order to be comprehended, information from both clinical and experimental sources will be reviewed in the following section.

The Syndrome Conduction Aphasia

The syndrome conduction aphasia was first described by Wernicke in 1874 (Leitungsaphasie) and was based on prediction rather than clinical experience, as a patient with the syndrome had not at that time been examined (Brown, 1972, p. 76). Wernicke stated that the disorder should occur from a lesion which disrupts the communication between the anterior and posterior speech centers, which should remain intact. He also predicted that in this syndrome comprehension would be preserved, while spontaneous speech and repetition would be paraphasic. In later writings, Wernicke hypothesized that conduction aphasia might occur from a lesion of the arcuate fasciculus, a nerve fiber tract which arises from Wernicke's area at the first temporal convolution (Eggert, 1977). Some researchers accept a modified form of Wernicke's theory regarding conduction aphasia (Geschwind, 1965) but point out that the lesion involved effects "part of the sensory area or posterior superior temporal gyrus itself" in addition to the fiber tract (Green and Howes, 1977, p. 134).

Goldstein (1948) has offered a theoretical view of this syndrome which rejects a conduction or connexionist basis for the disorder. Goldstein renamed it "central" aphasia because of his belief that the syndrome arises from impairment of a central cortical mechanism which relates thought to speech, rather than disruption of a pathway. This view has been taken up and made more specific by Hecaen (1972) who, together with his associates, has studied the speech of conduction aphasics extensively. Hecaen finds that the underlying disturbance in the speech of the conduction aphasic is an inability to grasp and produce the correct structure of an utterance so that it can be articulated.

The lesion which produces the syndrome conduction aphasia is not limited to one specific area, but tends to occur in a variety of posterior perisylvian sites in the left cortical hemisphere. Both Wernicke and Goldstein originally postulated lesions in the insula, but current opinion is against this (Brown, 1972, p. 80). In a survey of neuroanatomic findings in 25 cases of conduction aphasia, including cases of trauma, tumor, and vascular lesions, Green and Howes (1977) found that the damage to the temporoparietal area of the dominant hemisphere consisted of 13 cases with lesions extending from posterior superior temporal gyrus to the supramarginal gyrus, 9 cases with the temporal area spared but the supramarginal gyrus damaged, and 3 cases with the temporal area damaged but the supramarginal gyrus spared. This neuroanatomical information was obtained from records of surgical intervention and post mortem examination. The authors also surveyed the clinical features of the individual cases of conduction aphasia and concluded that there were no subgroups of clinical features that could be identified with a particular lesion. A similar conclusion was reached by Kertesz et al (1979) using CT and RN scans to provide neuroanatomic data, and a popular aphasia battery to provide clinical results of aphasia.

It is generally agreed by a variety of writers (Brown, 1972; Benson et al, 1973; Green and Howes, 1977) that the syndrome conduction aphasia consists of the following constellation of symptoms: fluent, but generally paraphasic speech, good to normal auditory comprehension, and grossly impaired repetition. Reading aloud and writing are impaired in a similar manner to speech, while silent reading for meaning tends to be preserved. Green and Howes (1977) estimate that approximately five to ten percent of the aphasics in their facility, The Boston Veterans Administration Hospital Center, have conduction aphasia, and presumably the incidence in other facilities is similar.

Characteristics of Expressive Speech and Conduction Aphasia. The expressive speech of the conduction aphasic is fluent, but, in many cases, this fluency is interrupted by copious literal, with some verbal paraphasias. A literal paraphasia consists of a speech sound substitution, omission, transposition, or certain types of speech sound distortions (which do not evince problems of production such as slurring). Verbal paraphasias are characterized by the substitution of a semantically related word for the target word (Green and Howes, 1977). The patient is aware of his paraphasic output and struggles with it, attempting repeatedly to produce a correct utterance (Joanette, 1980). Therefore, although the speech of a conduction aphasic does consist of runs of fluent speech, the net effect can be one of haltingness (Goodglass and Kaplan, 1972).

As conduction aphasics have a high level of awareness of their expressive difficulties, it is not unusual for a conduction aphasic to make more than ten attempts to produce a word correctly, Joanette et al (1980) observed, in a study which compares the approximations to target of three subgroups of aphasics: Wernicke's, conduction, and Broca's aphasics. The conduction aphasics were able to produce a continuous progression towards the target utterance for both vowels and consonants (this was also true for the Broca's aphasics for vowel but not consonant production) and the conduction aphasics consistently ended nearer the target than the other groups. As the authors point out, this illustrates that the conduction aphasics have control over their output to some extent and can compare it with a target and improve on it. It also suggests that it is not the internal phonological representation of the utterance which is impaired, but its execution.

Related to this is the apparent ability of the conduction aphasic to exhibit some knowledge of a word even if it cannot be retrieved. Goodglass et al (1976) induced "tip of the tongue" phenomenon in Broca's, Wernicke's, anomic and conduction aphasics. Subjects were instructed to indicate initial letter (displayed on an alphabet card) and number of syllables of unnameable pictures. Conduction aphasics were markedly superior to the other groups of aphasics in their underlying tacit knowledge of unretrieved words indicating, in the author's opinion, a relatively "late" stage of impairment in naming.

In an investigation of the characteristics of literal paraphasias, as well as other sound errors in aphasia, Blumstein et al (1980) has closely measured one dimension of speech, voice onset time (VOT) for initial stop consonants and how it relates to a target in Broca's, Wernicke's and conduction aphasics. In this experiment a response was characterized as being a phonetic error if it fell between the defined ranges of voiced and voiceless stops, and a phonemic error if it fell within the range of the opposing phonetic category. As compared with the other groups, conduction aphasics made more phonetic than phonemic errors, a surprising result, as conduction aphasia is a form of fluent aphasia in which the phonological defect is usually characterized as one in which the sounds are well formed but the wrong choice of phonemes. As can be expected, Broca's aphasics had a large proportion of phonetic errors. Blumstein et al (1980) speculate that since the lesion producing conduction aphasia can vary in location, those patients with lesions above the Sylvian fissure may tend to resemble Broca's aphasics, while those with lesions below the fissure may sound more like the "typical" fluent aphasic in their expressive speech. Benson et al (1973) have also hypothesized that this may be so. Blumstein et al (1980) present two cases with neurological data to support this argument. As discussed above, however, studies which survey large populations of conduction aphasics (Green and Howes, 1977) for lesion location and clinical feature subsets have not corroborated any systematic variation in speech symptom with lesion location.

In the case of Blumstein, et al. (1980), the number of conduction aphasics is small (four), as is the number of errors analyzed, and the subject variability is large, so large in fact, that the authors hypothetically identify two different types of conduction aphasia among their four subjects. Another objection to the findings of this study is that only one dimension of speech production is analyzed, the VOT, which by itself may not be indicative of phonemic and phonetic trends in the speech of the conduction aphasic. Finally, many conduction aphasics do not typically make a high degree of errors on one word repetition tasks. The repetition defect is quite variable in conduction aphasia and many patient's speech impairment becomes pronounced only when they are required to repeat phrases or word strings (Gardner and Winner, 1978). Therefore, taking all these considerations into account, more measurements of the phonology of the expressive deficit in conduction aphasia must be made before its features can be reliably characterized.

In an attempt to clarify the features of conduction aphasia reported in the literature, a major study of speech and auditory comprehension characteristics has been compiled by Green and Howes (1977) with the addition of cases which they themselves have analyzed. When the degree of severity of impairment in spontaneous speech was examined without reference to manner of impairment, out of 51 cases, none were "within normal limits," 26 were "mild," 18 "moderate," and 7 "severe." Of the 24 cases in which the presence or absence of literal paraphasias in spontaneous speech was examined, 5 cases reported "severe" paraphasias, 9 "moderate," 9 "mild," and 1 "scant." Because there was a variety of clinical methods employed by the different examiners, there may be some questions regarding some of the testing performed in some of the cases. However, the large number of cases surveyed, supplemented with cases examined by the authors themselves, contribute to the reliability of the survey which indicates that cases of conduction aphasia without expressive difficulty, particularly the presence of literal paraphasias are unusual.

The two cases in the literature of conduction aphasia that have been highly investigated and who seem to exhibit normal or minimally impaired conversational speech but impaired repetition are I.L. (Saffran and Marin, 1975) and J.B. (Shallice and Butterworth, 1977). A third case, M.C. reported by Caramazza, et al. (1981), is described as lacking literal paraphasias, but his speech is not "normal" as it evinces "moderate word finding difficulties". I.L. suffered a left posterior parietal lesion; he is reported to have good comprehension, minimal expressive difficulty, normal long-term memory, and severely impaired STM. Patient J.B.'s expressive speech has been more extensively investigated. J.B. is reported to have suffered a meningioma attached to the dura in the region of the left angular gyrus, which was removed surgically. Three weeks post operatively she exhibited literal paraphasias and impaired comprehension for complex material. These symptoms cleared for the most part and she is left with a marked repetition defect as her major impairment, as well as some reported comprehension problems which should be mild, as she is employed as a secretary.

In order to demonstrate that J.B.'s speech is normal, a clinical judgment which can obviously suffer from a lack of objectivity, Shallice and Butterworth (1977) analyzed her taped speech with a signal detector to determine pause time and phonation time ratios. The tapes were transcribed, and the number of words was counted, as well as other measures such as omissions, literal and verbal paraphasias, and function word errors. In comparison with a normal control subject, J.B.'s expressive speech on a task describing a recent vacation did not differ on the measures taken except for a small tendency to make function word errors. On a more demanding task describing the nature of her work, however, J.B. did exhibit a slight tendency to pause and to make errors, especially those of function words. She did not exhibit paraphasias.

The importance of this case and of any similar ones is that it suggests at least in this situation, that it is very unlikely that the repetition defect can be attributed to any underlying linguistic impairment, since none seems to exist, or is so minimal that it cannot be the basis for such a severe impairment. Although the case of J.B. is unusual, nevertheless, it illustrates that STM can be selectively and independently impaired, with little likelihood that an alternate mechanism is responsible for the deficit. However, Shallice and Warrington (1977) in discussing the same case, make no claim for its predictive value for other conduction aphasics. In fact, they propose that the hypothesis that a STM deficit underlies the repetition failure of the conduction aphasic is only accurate for those few conduction aphasics whose speech profile resembles J.B.'s. To assess the value of this statement it is necessary to review the repetition defect which exists in conduction aphasia as it is represented in the literature. This will be done in a forthcoming section. It should be stated, however, that Shallice and Warrington (1977), and also Caramazza, et al. (1981), who support this position, make no attempt to prove that the repetition deficit in those conduction aphasics whose speech is paraphasic is based on "reproduction" difficulties, and this aspect of the hypothesis is conjecture.

Summary. In the preceding section, some research investigating the expressive impairment in conduction aphasia is discussed. The impairment which is generally exhibited in both spontaneous speech and even more markedly in repetition is characterized by copious literal paraphasias, and to a lesser extent, verbal paraphasias. In some instances the spontaneous speech is normal, only repetition is impaired, and paraphasias are absent. During speech failure, the conduction aphasic seems to have knowledge of the target (Goodglass et al, 1976) and to be able to guide his utterances to achieve a closer approximation of it (Joanette et al, 1980). A detailed analysis of one dimension of literal paraphasias, voice onset time (VOT) demonstrated surprisingly that conduction aphasics made more phonetic than phonemic errors (Blumstein et al, 1980). However, as there were few subjects and much subject variability, this result is somewhat inconclusive. Because two subjects seemed to exhibit different speech error patterns and to have differing lesions, Blumstein et al (1980) also hypothesize that there may be systematic differences in the symptomatology of conduction aphasia dependent upon the site of lesion. Shallice and Warrington (1977) also favor this explanation to account for the difference between those conduction aphasics who exhibit paraphasias and those who do not. Green and Howes (1977) in a major survey which compared clinical features and neurological and anatomical data from conduction aphasics reported in the literature found, however, that such systematic variation does not exist. A similar conclusion was arrived at by Kertesz et al (1979) who compared the results of CT and RN scans with data from an aphasia battery. Although there is considerable variety in the location of lesion, and some differences in the speech pattern displayed by some conduction aphasics, there is no evidence that these variations in speech are caused by differences in site of lesion.

Auditory Comprehension in Conduction Aphasia. In striking contrast to the copious paraphasias, both literal and verbal, which generally mar the expressive speech of the conduction aphasic, auditory comprehension is ordinarily mildly impaired and sometimes seems to be preserved (Brown, 1972, p. 84). Patients seem able to follow both simple and complex utterances and commands, and of all aphasics, seem to be most intact in social situations in which the ability to understand conversation is needed. Nevertheless, on certain types of auditory language comprehension tasks, the performance of the conduction aphasic typically begins to break down. These tasks include the most difficult portions of The Token Test (Warrington et al, 1971), identifying pictures from among homonymous choices, or in the presence of noise, determining whether a named picture is correctly pronounced or paraphasic (Alajouanine and Llermitte, 1964), and determining if paired spoken words, especially nonsense words and those with reversible syllables are the same (Strub and Gardner, 1974; Basso, Casati and Vignolo, 1977).

It is important to note, however, that there are aspects of language comprehension in which the STM system most likely comes into play because rehearsal, or a second attempt at the stimuli (because of a lack of redundancy) is needed. Such situations might be characterized as those which contain stimuli which are long, ambiguous, lack redundancy, or have low signal to noise ratios. The tasks listed above seem prime examples of the kinds of tasks on which an individual with a STM deficit might have difficulty, which in fact is the case in conduction aphasia.

Likewise, the effect of reduced STM on auditory sentence comprehension has already been discussed. Subjects with reduced STM span seem able to understand auditorially presented sentences, except in the special case when word order retention is essential for comprehension because the semantic elements may be reversed (Saffran and Marin, 1974; Heilman, Scholes and Watson, 1976). It would seem worthwhile then to acknowledge that STM seems to play a part in auditory comprehension in certain specialized situations, and that most of the special auditory comprehension difficulties which conduction aphasics have been shown to exhibit most likely arise from this source.

The Repetition Defect in Conduction Aphasia. The most marked clinical feature of conduction aphasia, in fact its hallmark, is severe inability to repeat. While other aphasic syndromes also show impaired repetition, this impairment tends to be in proportion to other existing deficits. For example, the Broca's aphasic has difficulty in repetition, but unlike the conduction aphasic who is fluent, the repetition difficulty of the Broca's aphasic stems from nonfluent speech and repetition is generally superior to spontaneous speech. On the other hand, the Wernicke's aphasic, who is fluent, also shows impaired repetition, but in this case the defect is the result of grossly impaired comprehension. Only the conduction aphasic can be identified by good comprehension, fluent speech, but extremely impaired repetition (Green and Howes, 1977).

The repetition attempts of the conduction aphasic are marked by literal, and to a lesser extent, verbal paraphasias, as well as complete failure. Although many patients are able to repeat single, high frequency words, as number of syllables, length of utterance, and unfamiliarity increase, performance declines dramatically. This repetition failure is in contrast to conversational speech which is often much superior to repetition, sometimes strikingly so. There is a high awareness of errors, and the patient may make repeated attempts at self correction (Brown, 1972, p. 84).

In a study of repetition employing 60 aphasics of differing syndromes and using many different types of repetition stimuli, Gardner and Winner (1978) found that conduction aphasics were most sensitive to the nature of the stimuli, and showed the greatest range of difficulty. 92% of the responses of the 12 conduction aphasics were correct for the easiest sets of stimuli, single digits and high frequency single syllable concrete nouns, while there was almost total failure for the hardest set of stimuli, repetition of money amounts.

Some of the approaches formulated in the past to the problem of explicating the repetition defect in conduction aphasia were discussed earlier, such as the conduction hypothesis of Wernicke and the theory that repetition failure represents an inability to translate thought into words espoused by Goldstein (1948). Currently, some additional explanations for the same phenomenon have also been proposed for the explicit purpose of disproving the Warrington-Shallice hypothesis.

A study performed by Strub and Gardner (1974) which replicates some of the findings of Warrington and her associates (Warrington, 1971; Warrington, Logue, and Pratt, 1971) with a similar patient, L.S., might be viewed as an outgrowth of the theoretical position of Goldstein (1948). The authors reject a mnestic interpretation for their patient's failure to repeat, and instead, attribute it to the interference and competition which results when meaning is extracted from an utterance, so that the patient is unable to convert the perceived phonetic structure of the utterance into speech. Patient L.S. was tested by different forms of repetition and sequencing, both verbal and nonverbal. Although the patient was significantly impaired on almost all of these tests (he has a repetition capacity of two items) the authors note that his performance improved when he was given additional time between stimuli, when particular attention was paid to the patient's ability to retain the initial item of a sequence, and when sequence information was ignored and only item retention was scored. It should be noted, however, in the first and second examples cited, that these are specific situations in which one might predict that long-term memory is making a significant contribution to the results. Additionally, it also must be pointed out that although L.S. can demonstrate that he can retain item information better than order information, his retention of item information falls far below that expected of an unimpaired subject, and this explanation cannot be the basis for the deficit (Shallice and Warrington, 1977).

Some comments must also be stated criticizing the theoretical assertions of Strub and Gardner (1974). As Shallice and Warrington (1977) point out, they are nearly untestable because of their vagueness and complexity. In fact, Strub and Gardner (1974) offer little to support their hypothesis that subjects fail to repeat because the act of extracting meaning interferes with their ability to do so. They concentrate instead on attempts to disprove the Warrington-Shallice hypothesis that the underlying mechanism at fault in the repetition failure of the conduction aphasic is a STM deficit. Furthermore, in tasks of nonverbal sequencing, in which the subject is required only to point to common objects in the sequence demonstrated to him, and in which there presumably is small need to decode for meaning, L.S. remains impaired in his ability to retain item and order information.

Another hypothetical explanation of the repetition defect in conduction aphasia which has been proposed is that it is a deficiency in memory for the specific sequential order of items to be remembered (Dubois et al, 1971). This issue has been closely investigated by Tzortis and Albert (1974) and Albert (1976) as part of a general investigation of temporal sequencing in aphasia. They point out that if sequencing errors are ignored and only item retention is considered, in a variety of tests, modalities, and responses, conduction aphasics are actually able to recall much more than their initial performance would indicate. Strub and Gardner (1974) also cite the abundance of sequencing errors in their patient's performance, L.S., as an argument against the mnestic interpretation of the repetition defect.

As already noted, however, if conduction aphasia is a disorder of sequencing only, performance should approach normality once sequential errors are ignored. Since none of the results of the conduction aphasics tested by Tzortis and Albert (1974) and Strub and Gardner (1974) would achieve normality if order errors are ignored, there is still a substantial impairment which awaits explanation. Additionally, on several tasks such as free recall, probed recognition (Shallice and Warrington, 1970; Warrington, Logue and Pratt, 1971), and one item Brown-Peterson paradigm (Warrington and Shallice, 1972), the performance of the conduction aphasic continues to be considerably impaired even though order information is irrelevant on these tasks. Finally, it is likely the case that order information is primarily stored in STM and maintained through rehearsal (Bjork, 1975). Impaired ability to store and/or retrieve information from STM should predictably lead to a loss of ability to retain sequential information. Most likely then, any observed difficulty in sequencing in conduction aphasia arises because of a deficit in verbal STM and not vice versa as Dubois et al (1971) and Tzortis and Albert (1974) propose.

In some respects the controversy over whether or not the repetition defect in conduction aphasia has a mnestic basis does not go far enough. All research in this area confirms that the auditory verbal STM performance of conduction aphasics is greatly impaired, whatever the underlying cause. If the issue is left, however, that conduction aphasia represents a selective disturbance of STM without exploring what it is about the conduction syndrome which causes this impaired performance, much of what has been gained from the experimental literature in STM will have been ignored. It is at least as important, and heuristically more beneficial to identify the processes or mechanisms which underlie the mnestic failure. By pinpointing which aspect of STM is impaired in conduction aphasia, insight may be gained into the nature of the conduction aphasic's speech and language, as well as his STM.

Recently, two related issues have been investigated under the general subject STM and conduction aphasia which attempt to go beyond the initial question raised by Warrington and her colleagues. Heilman, Scholes, and Watson (1976) have tried to determine if the STM defect in conduction aphasia is different in degree from that in Broca's aphasia, while Saffran et al (1977) have attempted to investigate if there are different mechanisms at fault in the STM impairment in the two syndromes.

Heilman, Scholes, and Watson (1976) utilize the task digit repetition and digit pointing to demonstrate that there is no significant difference in the repetition and pointing performance of Broca's and conduction aphasics. The problems that this procedure entails have been discussed earlier. They include such objections as the following:

(1) It is unreliable to compare subgroups of aphasics unless care is taken to insure that the degree of impairment in the groups is approximately the same. Broca's aphasia tends to be a more severe impairment of expressive language than conduction aphasia and failure on a repetition task may have more to do with expressive difficulty than STM impairment.

(2) Digit span is a relatively insensitive task for studying STM impairment since it does not reflect underlying mechanisms. Additionally, it has been shown to vary with several non language and non memory variables.

(3) Repetition tasks are a poor choice of experimental paradigm because they may be confounded by the expressive difficulties of the subject, while other problems are entailed by the substitution of the cognitively more complex task of digit pointing.

Saffran et al (1977) also investigate differences in STM impairment among Broca's and conduction aphasics. However, they go further than the study discussed above by attempting to identify specific mechanisms which can be impaired when STM is impaired in aphasia. The authors hypothesize that in conduction aphasia, there is an impairment in the precategorical acoustical store, the PAS (Crowder, 1969), from which articulatory phonetic information is retrieved to yield a recency effect. Therefore, impairment in the PAS should lead to a significant reduction in the recency effect in paradigms which explore the serial position of remembered items. Broca's aphasics, on the other hand, because of their characteristic motor articulation difficulties (Goodglass and Kaplan, 1972) should be impaired in their ability to rehearse, leading in turn to a reduced primacy effect.

Saffran et al (1977) analyzed the serial position curves and error patterns of subjects' responses on a task in which the stimuli were strings of digits, one to five items in length. The subjects were required to press digit keys (arranged in random order and hidden from view during presentation of the stimuli) in the same serial order as the stimuli. It was found that on this task the five Broca's subjects obtained a normal U-shaped serial position curve (but with reduced overall performance in relation to normal subjects) while the two conduction aphasics lacked a recency effect. The Broca's subjects were also impaired in remembering sequences, as an analysis of items correct vs. items-in-order revealed. The authors hypothesize that the impaired performance of the Broca's aphasics is due to an impaired ability to utilize the articulatory mechanism for covert sub-vocal rehearsal, while the impairment of the recency effect in the serial position curve of the conduction aphasics is due to impairment of the acoustic-phonetic store, the PAS. It is difficult to understand, however, why the conduction aphasic should not be at least as deficient as the Broca's aphasic in his ability to rehearse, which is a form of covert repetition, since this is his chief area of deficiency.

The study performed by Saffran et al (1977) is quite valuable because it demonstrates that there exists a STM deficit even among the more common conduction aphasic population who exhibit the typical expressive difficulties of the syndrome. This deficit cannot be attributed to "reproduction" as Shallice and Warrington (1977) suggest, as no reproduction is involved in this task. Secondly, it takes the trouble to equate the error ratio of the Broca's and conduction aphasics so that the comparisons are valid between the groups. However, although the task employed by Saffran et al (1977) avoids the problem of subjects with expressive difficulty having to repeat item strings in order to reproduce the stimuli, subjects must continually search the random keyboard for the correct digit keys, a task even more cognitively complicated than simple pointing span, and which must put an added burden on the STM system. One would like to see aphasics' best STM performance before making hypotheses about impaired mechanisms in STM, and a task which involves several cognitive aspects as this one does (remembering items and sequence, transcoding auditory to visual to motor, search of random sequence of digits) is not the paradigm best designed to display this.

Summary. Several explanations have been proposed to account for the marked repetition deficit of the conduction aphasic. While past explanations of this phenomena include Wernicke's conduction hypothesis and Goldstein's view of conduction aphasia as a central impairment of language, much of the current theorizing has been stimulated by the hypothesis of Warrington and her associates that conduction aphasia represents a selective impairment of verbal STM. Recently, the scope of this hypothesis has been narrowed to apply to only those relatively "pure" conduction aphasics who do not exhibit literal paraphasias in their expressive speech. For those conduction aphasics with paraphasic difficulties, it is proposed that "reproduction" problems underlie the repetition deficit (Shallice and Warrington, 1977; Caramazza, et al, 1981). However, some evidence presented by Saffran et al (1977), seems to contradict this proposal. Other recent alternate explanations of the repetition deficit in conduction aphasia include the higher level language deficit proposed by Strub and Gardner (1974) and the selective deficit in sequencing proposed by Tzortis and Albert (1974). However, these two studies must be criticized because their results fail to support their hypotheses.

All of the results cited here demonstrate that the STM performance of the conduction aphasic is impaired. It is important, however, to identify which memory mechanisms may themselves be impaired and be responsible for the observed performance deficit. Only the study performed by Saffran et al (1977) comes close to addressing this question by hypothesizing that it is the PAS (Crowder, 1969) which is impaired in conduction aphasia. Although this study demonstrates that STM can be implicated even in a population of conduction aphasics with impaired expression, its choice of stimuli (digits) and method of testing have some disadvantages. There is a substantial need for a study which explores the question of the STM deficit in conduction aphasia and which has the advantages of employing an experimental population in larger numbers, and an experimental task which minimizes expressive ability and yet does not add additional cognitive loads to complicate the main investigation.

Overall Summary

In the preceding chapter an attempt was made to present the past and recent theoretical conceptualizations of short-term memory in the human memory literature, to indicate the complexities of the issues involved, and to relate those conceptualizations and issues to a study of aphasia, particularly conduction aphasia. Much of the current interest in the connection between short-term memory and conduction aphasia has been stimulated by the research of Warrington and her associates who hypothesize that the marked repetition defect in conduction aphasia represents an isolated and selective disorder of short-term memory. This review of the related literature tends to support this hypothesis but makes it evident that there is a virtual lack of research which rigorously examines the STM performance of a <u>group</u> of conduction aphasics and compares this performance with that of aphasics of differing syndromes. Therefore, strong support for the hypothesis that conduction aphasia represents a disorder of short-term memory is still lacking. Additionally, the lack of group data leaves a secondary issue unresolved, i.e., whether all conduction aphasics can be considered to have an STM disorder or whether the hypothesis described above applies only to those whose expressive speech is relatively unimpaired. The study described in the following chapter has been designed to address these issues and to fill this need.

Chapter 3

METHODS

SUBJECTS

Aphasics

The experimental aphasic subjects in this experiment consist of 20 adults, 8 females and 12 males, with unilateral left hemisphere brain lesions of vascular origin. They were identified chiefly at various hospitals and clinics in New York City and its environs through the cooperation of speech pathologists employed at these facilities. Table 1 summarizes the number and type of subjects obtained from each of these facilities.

These aphasic subjects were chosen to satisfy the following criteria: (a) pre-mordibly right handed, (b) completion of some high school, (c) at least two months post-onset of symptoms, (d) good facility with the English language, (e) no evidence of hearing loss serious enough to interfere with communication, (f) no frank neurological or behavioral signs of bilaterality of lesion or progressive deterioration, (g) relatively mild linguistic impairment. The age range of the aphasic population varied from 27 to 70 years, mean = 56.5; the amount of time elapsed from onset of symptoms varied from 2 months to 10 years, mean = 2.5 years.

Degree of linguistic impairment. Because of the problems inherent in testing short-term memory in aphasic subjects, it was considered appropriate to select only those aphasics whose degree of severity of expressive and receptive language impairments falls into the range of mild, or mild to moderate. This was determined based on the results of the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1972), Sections I, II, and III, which test expressive speech, language, and auditory comprehension (Sections IV and V which test reading and writing were omitted). The BDAE was administered to every aphasic subject and scored by the examiner in strict adherence to the guidelines set forth in the test manual.

An aphasic was considered to have a relatively mild linguistic impairment if his or her performance on the BDAE met the following criteria:

1. A Rating Score of 3 (out of 5) or better on the Aphasia Severity Rating Scale, i.e. "the patient can discuss almost all every day problems (original emphasis) with little or no assistance. However, reduction of speech and/or comprehension make

Table 1. List of Medical Facilities

From which Subjects were Obtained

Institutions	Sample size/group				Total
	C	B	A	RBD	
Institute for the Crippled and Disabled			1		1
New York Veterans Administration Hospital Center	3		4	4	11
Montefiore Hospital and Medical Center	1	1	1		3
Herbert H. Lehman College Speech and Hearing Center	1	1			2
Kessler Institute for Rehabilitation		3			3
Private Patients			2		2
Goldwater Memorial Hospital	1	1			2
New York University Medical Center, Institute for Rehabilitation Medicine				3	3
Totals	6	6	8	7	27

Key

C	Conduction Aphasics
B	Broca's Aphasics
A	Anomic Aphasics
RBD	Right Brain Damaged Control Subjects

conversation about certain material difficult or impossible."

2. A minimum mean Z score of +0.5 on the Auditory Comprehension Section, II, of the BDAE.

In actuality, only one aphasic subject received an Aphasia Severity Rating Score of 3, while six subject were rated 3.5, six were rated 4, six were rated 4.5, and one received a rating of 5, mean = 4. A rating of 4 indicates "some obvious loss of fluency in speech or facility of comprehension, without significant limitation on ideas expressed of form of expression." A rating score of 5 indicates "minimal discernible speech handicaps, patient may have subjective difficulties which are not apparent to listener."

Aphasic classification of subjects. The aphasic population of this experiment was divided into three subgroups: conduction, Broca's, and anomic aphasics. This classification was based on the subject's Z-Score Profile on the BDAE, as well as by a clinical assessment of speech and language characteristics performed by the examiner. In the following sections, the characteristics of each group will be discussed, and the basis for the classification will be set forth. Table 2 summarizes much of this information.

Conduction Aphasics. The conduction aphasic subgroup consisted of six subjects, five males, and one female. At the time of testing, their ages ranged from 53 to 70, mean = 62.5. All six had incurred left hemisphere CVAs; the length of time post onset varied from one year to ten years, mean = three years. All subjects ambulated freely although two subjects reported mild hemiparesis of the right arm, or right arm and leg.

Diagnosis of conduction aphasia was based on the following speech and language characteristics (Kinsbourne, 1972; Benson et al, 1973; Goodglass and Kaplan, 1972): (a) fluent speech, (b) gross deficit of repetition, (c) good auditory comprehension, (d) (usually but not always) presence of copious paraphasias, especially literal paraphasias. A sample of the typical expressive speech characteristics of the conduction aphasic is presented in Appendix A, Aphasic Responses to the Cookie Theft Picture, Subtest Ie, BDAE.

On the Rating Scale Profile of Speech Characteristics of the BDAE, the conduction aphasic should display good articulation, speech melody, phrase length, variety of grammatical forms, auditory comprehension, and a high rate of paraphasias. On the Z-Score Profile of Aphasia Subscores, the conduction aphasic syndrome is generally characterized by markedly reduced repetition scores, and an elevated rate of occurrence of paraphasias (Goodglass, 1977). The conduction aphasics in this study were readily distinguishable from the other aphasics on the basis of these scores. However, one conduction aphasic subject exhibited no paraphasias and was identified by his markedly reduced repetition scores. This information is presented in detail in Chapter 4 in the section analyzing the results of the BDAE and in Appendix D, Table 9.

Broca's aphasics. The Broca's aphasia subgroup consisted of six subjects, four females and two males; at the time of testing their ages ranged from 27 to 68, mean = 49.66. Of the six subjects, five had incurred left hemisphere CVAs while one subject had a ruptured arterioventricular malformation (left), average time post onset ranged from seven months to ten years, mean = 3.3 years. At the time of testing, all six subjects displayed hemiplegia of the right arm and leg. Two Broca's aphasics were in wheelchairs (the only experimental subjects who were not able to ambulate), three ambulated with the aid of a cane, and one was able to walk without aid.

Diagnosis of Broca's aphasia was based on the following speech and language characteristics

Table 2. Sex, Mean Age, Time Post Onset, and *Aphasia Severity Ratings taken from the Boston Diagnostic Aphasia Examination

	Conduction Aphasics	Broca's Aphasics	Anomic Aphasics	All Aphasics	Right Brain Damaged	Normal Controls
N	6	6	8	20	7	7
Sex M/F	5/1	2/4	5/3	12/8	5/2	5/2
Age (yrs.)	62.5	49.6	57	56.5	59	50.25
TPO (yrs.)	3	3.3	1.6	2.5	.25	--
Severity	3.6	3.9	4.3	4	--	--
Melody	6.8	5.8	7	6.6	--	--
Phrase Length	7	6.3	7	6.8	--	--
Artic.	6.7	5.8	6.9	6.5	--	--
Gram. Form	6.8	5.8	7	6.5	--	--
Paraphasia	3.4	7	6.4	5.6	--	--
Word Finding	3	5.5	3.3	3.6	--	--

* Rating Scale Varies From 1 to 7

(Brown, 1972; Goodglass and Kaplan, 1972): (a) awkward, labored articulation and prosody, (b) impaired fluency, (c) impaired ability to produce syntactically complex and lengthy sentences, (d) relatively preserved auditory comprehension in relation to expressive language.

On the Aphasia Severity Rating Scale of the BDAE, a Broca's aphasic should score at the lower end of the scale (1-7) for speech melody, phrase length, articulation, variety of grammatical forms, and paraphasia, and towards the higher end of the scale for word finding and auditory comprehension. The Z-Score Profile should display auditory comprehension and naming scores which are better than fluency and severity, and relatively few paraphasias, especially of the verbal kind (Goodglass and Kaplan, 1972).

The Broca's aphasics who participated in this experiment did not display every characteristic expected of that syndrome because of the relative mildness of their impairments. For example, the ratings for melodic line, phrase length, articulation, and grammatical form tended to be slightly rather than markedly reduced. Additionally, as these subjects tended to make only scattered errors on the various subtests, and their performance approached the top scores possible on the test, their Z-Score

Profiles did not always display the pattern described above. However, these patients were easily distinguished from the conduction and anomic aphasics, for the ratings for the above characteristics were rarely reduced at all for these subjects. A sample of the typical speech characteristics of the Broca's aphasic is presented in Appendix A, Aphasic Responses to the Cookie Theft Picture, BDAE, Ie.

Anomic aphasics. The anomic aphasic subgroup consisted of eight subjects, five males and three females. At the time of testing, their ages ranged from 50 to 67, mean = 57 years. Seven subjects had incurred left hemisphere CVAs, while the aphasia of the eighth subject is the result of a left hemisphere subarachnoid hemorrhage; the length of time elapsing from onset varied from two months to five years, mean = 1.6 years. All subjects were able to ambulate freely, although three subjects reported mild right sided hemiparesis and two reported "numbness" of the right.

Aphasic subjects were assigned to the classification anomic aphasic if they displayed the following speech and language characteristics (Goodglass and Kaplan, 1972): (a) fluent speech, (b) good auditory comprehension, (c) good repetition, (d) difficulty in word finding. On the Aphasia Severity Rating Scale of the BDAE, the ratings for all of the speech characteristics should fall into the highest range (a rating of 7 for paraphasia signifies no paraphasia in running speech, while a rating of 1 indicates paraphasia occurs in every utterance) with the exception of word finding, which should show scores typically in the range of ratings 1 to 3.

The Z-Score Profile for anomic aphasics should show high fluency ratings, as well as high scores for auditory comprehension and repitition. Visual confrontation naming, i.e., the subject names items which the examiner points to, is generally rated lower than the above scores, and paraphasia scores tend to be low (Goodglass and Kaplan, 1972).

The scores for the anomic aphasic subgroups conformed to the above criteria. However, as the subjects in this group were quite mildly impaired, mean severity rating = 4.3, even for anomic aphasics in general, reduction in confrontation nameing was not evident as many subject performed close to or at ceiling in this area. Word finding difficulty was evident, nevertheless, in the more demanding task of describing the Cookie Theft picture. A typical anomic aphasic response is included in Appendix A.

Control Groups

The control population for this experiment consisted of two groups, a right brain damaged group, and a normal control group. Control subjects met the same criteria as experimental subjects except where these criteria were inappropriate, such as in the case of the non brain damaged subjects for which onset, stability and unilaterality of lesion are not relevant. The ages and educational level of the control subjects are similar to those of the experimental population.

Right brain damaged control group. The right brain damaged control group consisted of seven subjects, five males and two females, with unilateral right hemisphere lesions resultant from CVAs; post onset time varied from 2 to 5 months, mean = .25 years. They were being treated in the same facilities as the aphasic subjects, primarily in the rehabilitation units. The age range of the right brain damaged subjects (RBD) varied from 41 to 70, mean = 59.

All of the seven RBD subjects experienced hemiplegia of the left arm and leg. At the time of testing, five patients came to the testing site in wheelchairs, although one reported he was able to ambulate. The remaining two ambulated, one with the use of a cane. One RBD subject was reported to be incontinent.

The auditory comprehension section of the BDAE was administered by the examiner to the RBD Group to insure that there was no aphasic involvement. Five patients made no errors on the subtests, one patient scored one error, and one patient scored two errors, both in understanding complex material. In general, it is unfortunate that there were some indications that as a group, the RBD subjects seemed to be more impaired than the aphasic subjects, except in language. They were more severely hemiplegic, the amount of time elapsing from onset of symptoms was considerably less, 0.25 years vs. 2.5 years (means) for the aphasics, and they appeared to be less alert. In fact, Costa (1972) has reported that when right and left brain damaged patients are compared in experiments, it can be shown that the RBD subjects have indications of greater severity than the LBD, such as size of lesion, reaction time, and degree of alertness. In this experiment, it was not possible to obtain subjects with right brain damage who were as mildly impaired as the aphasics, as the aphasics were an unusually mildly impaired population.

Normal control group. The normal control group for this experiment consisted of seven subjects, five males and two females, with no known neurological pathology. Their ages ranged from 34 to 64 at the time of testing, mean = 50.25, and their educational level, handedness, etc. conformed to the relevant criteria for the experimental population.

STIMULI

The stimuli for this experiment consist of 28 lists of one syllable words, five words in length. The lists are composed of high frequency nouns, i.e., with a Standard Frequency Index of 55 or more (Carroll, Davies, and Richman, 1971) and were scrutinized to eliminate any strong intralist semantic associations or phonetic similarities. Each list contains a probe word and a target word; the probe word is a repetition of one of the words of the list, and the target word is the word following the probe word on each list. The position of the target word is varied in a random fashion throughout the task, but occurs an equal number of times in list positions two, three, four, and five. Because the target word, by definition, follows the probe word, it cannot appear in the first position of the list.

The word lists for this experiment were recorded in a double walled test suite manufactured by Industrial Acoustics Corporation on a Norelco Cassette Recorder, Model 1420. The words were recorded at the rate of one word/second. A buzzer sound was inserted one second before the presentation of each probe word to help alert the subjects. Following the probe word, the subjects had ten seconds to respond before the next trial began. The length of time for the entire test is appoximately 17 minutes.

Although the experimental task consists of 28 lists of words, four taped practice trials precede the actual task, to familiarize the subjects with the task, and insure that they are able to perform it reliably. The stimuli for this experiment (including practice trials) can be found in Appendix B.

EXPERIMENTAL PROCEDURE

The subjects were tested in speech therapy rooms located in the facilities at which they were being treated. Two patients who were being treated by private speech pathologists were tested in their homes, as well as all of the normal control subjects. Most subjects required between 45 minutes and one hour to complete all testing, including the BDAE. This was accomplished in either one or two sessions, depending upon the scheduling requirements of the patient and the facility.

After being introduced by the referring speech pathologist, the examiner described the test to the subject, including its general purpose and experimental nature. All subjects were then handed the Consent Form and Instructions to Subject (Appendix C) which they read. Additionally, the examiner read the form aloud to each subject to ensure comprehension. This Consent Form describes the subject's role in the experiment, and stresses the voluntary nature of his/her participation. Subjects were also advised that they should guess if they were unable to recall the target word. The subject then signed and dated the form, as did the examiner. The number of forms signed and the presence or absence of a witness's signature varied depending upon the requirements of each facility. A copy of the Consent Form can be found in Appendix C. Because it was found that many potential subjects were unable to perform the experimental task, the STM task was administered before the aphasia test to avoid having to administer the aphasia test to many subjects who ultimately would not be part of the experiment.

Before the experimental task was initiated, the subjects were administered several practice trials, first unrecorded and relatively flexible, and then recorded and formal. After it was clear that the subject understood the task, the examiner initiated the task. All of the responses of the subject's to the task were recorded, whether or not they were correct.

Approximately 60 aphasic subjects attempted to perform the STM test. However, because of the high degree of concentration and language comprehension required on the part of the aphasic subject, and because it was not always possible to reject in advance those aphasic subjects who were completely unable to perform the task, 24 subjects completed the experimental test. Additionally, 10 right brain damaged control subjects attempted the task of whom 7 completed it. All of the normal control subjects, as could be expected, were able to complete the task.

The BDAE

After the experimental STM test was completed, aphasic subject were administered the Boston Diagnostic Aphasia Examination (BDAE) including Sections I, Conversational and Expository Speech; II, Auditory Comprehension; III, Oral Expression (Goodglass and Kaplan, 1972). Right brain damaged control subjects were administered Section II, Auditory Comprehension only. The BDAE was administered according to the guidelines set forth by Goodglass and Kaplan, and was also in accordance with the procedures of the Boston Diagnostic Aphasia Examination Workshop conducted by Nancy Helm-Estabrooks, Chief of Speech Pathology, Boston Veterans Administration Hospital (Helm-Estabrooks, 1981).

Section I of the BDAE which functions to elicit a sample of free conversation was a major source of data for the purpose of classifying the aphasic subjects into subgroups. Subjects were encouraged to discuss (a) the nature of the work they were doing before their illness, and (b) the events surrounding their illness. All responses were tape recorded (as were all other subtests eliciting expressive responses) for later scoring. Additionally, the subject's response to the Cookie Theft picture (subtest I,i) was transcribed for analysis (Appendix A).

Of the 24 aphasic subjects who completed all testing, 4 were eliminated from the final experimental population for the following reasons: 3 subjects could not be clearly classified as to aphasic syndrome and 1 subject was eliminated because he was aphasic as the result of a brain tumor while all others had aphasia associated with vascular disease.

Of the remaining 20 experimental subjects, one conduction aphasic, subject M.R., refused to return for a second session of the BDAE with the result that no data is available for this subject for the Auditory Comprehension, Naming, and Oral reading subtests of the test. Therefore, the subtests from these sections include data from only the other five conduction aphasics. With this exception, all of the data from this experiment is complete. In the following chapter, Chapter 4, the results of this investigation are presented.

CHAPTER 4

RESULTS

SHORT-TERM MEMORY TEST

The data base for this study consists of the responses of the 20 aphasic subjects to the probe type short-term memory test described in the previous chapter. The aphasic subjects were divided into sub-groups on the basis of their diagnostic classifications, conduction, Broca's, and anomic aphasics, and the responses of these groups were compared with each other and with those of the two control groups, the right brain damaged and the normal control groups. In this chapter, these groups will have the alternate designations Groups C, B, A, RBD, and NC, respectively, to facilitate discussion.

Analysis of the data involved many group comparisons. These comparisions include the variables: (a) overall correct scores, (b) correct scores for each serial position, (c) serial position of response regardless of correctness, (d) error analysis. Additionally, to determine serial position effect within each group, both the correct scores and the number of responses regardless of correctness were compared with each other for each serial position. The relevant significant and non significant scores are described below. All of the following comparisions utilized the Mann Whitney U and Wilcoxon Rank Sum W tests.

Overall Correct Scores

Group comparisons of correct scores only, regardless of serial position, revealed, predictably, that the aphasics as a whole achieved short-term memory scores which are significantly below those of the normal controls (NC) (10.55 vs. 23.86) $p < .001$, as well as those of the right brain damaged controls (RBD) (11.85 vs. 20.14) $p < .01$. Additionally, there is a significant difference between the correct scores of the RBD and NC groups (4.07 vs. 10.93) $p < .005$.

When the overall correct scores for the conduction aphasics (C) are compared with those of the other aphasics, Group C's performance is significantly inferior (4.92 vs. 12.89) $p < .005$. Examined individually, the difference between the scores of Group C and A (anomic aphasics) is significant (3.75 vs. 10.31) $p < .005$ while the difference between Groups C and B (Broca's aphasics) approaches significance (4.67 vs. 8.33) $p < .07$. There is no significant difference between the scores of A and B. The preceding information is summarized in Table 3, Serial Position and Total Correct Scores by Groups.

Correct Scores/Serial Position

Serial position 2. Group comparisons of correct scores for serial position 2 are important because they indicate the degree of primacy (recall from the primary position or positions of the list) achieved by each group. As stated earlier, the presence of a primacy effect in a task such as this is thought to indicate the subjects's use of active memory strategies, especially rehearsal. When the aphasics as a whole are compared with their control groups, the difference between all aphasics and NC is significant (11.82 vs. 20.21) $p < .01$, while the difference between all aphasics and RBD is not.

In comparing the primacy rate of the conductives with that of the other aphasics, there is a significant difference with Group A (4.17 vs. 10) $p < .01$ and with A+B (5.83 vs. 12.50) $p < .01$. It should also be noted that the primacy rate of the Broca's group is significantly inferior to that of the Anomic group (5 vs. 9.38) $p < .01$.

Serial position 3. Comparisons of correct scores for position 3, the first middle target position of the list, yield significant differences between all aphasics vs. the NC (10.88 vs. 22.93) $p < .0005$, and the RBD (12.17 vs. 19.21) $p < .05$. The difference between the RBD and NC is also significant

Table 3. Ordinal Contrasts For Correct Scores/Serial Position among 3 Aphasic and 2 Control Groups

	Contrasts													
Serial Position	All Aphasics/ NC	All Aphasics/ RBD	NC/ RBD	N/ A+B	C/B	C/A	C/ A+B	C/RBD	C/NC	B/A	B/RBD	B/NC	A/RBD	A/NC
2 mean ranks	11.82/ 20.21	12.97/ 16.93	9.29/ 5.71	14.50/ 9.25	5.17/ 7.83	4.17/ 10.00	5.83/ 12.50	4.33/ 9.29	3.83/ 9.71	5.00/ 9.38	5.25/ 8.50	4.25/ 9.36	8.75/ 9.14	7.00 9.14
Z scores	** 2.45	1.16	1.64	1.86	1.33	** 2.62	**2.36	** 2.39	** 2.76	*1.98	1.55	** 2.40	.72	.94
3 mean ranks	10.88/ 22.93	12.17/ 19.21	9.51/ 5.43	17.00/ 8.00	6.08/ 6.92	5.67/ 8.88	8.25/ 11.46	4.42/ 9.21	3.58/ 9.93	6.08/ 8.56	4.75/ 8.93	3.75/ 9.79	7.06/ 9.07	5.19/ 11.21
Z scores	** 3.50	* 2.05	*1.89	***3.16	.41	1.46	1.14	*2.25	** 2.96	1.11	* 1.98	** 2.81	.88	** 2.63
4 mean ranks	10.63/ 23.64	13.63/ 15.07	10.43/ 4.57	17.71/ 7.64	6.25/ 6.75	7.58/ 7.44	10.33/ 10.57	6.58/ 7.36	3.58/ 9.93	7.92/ 7.19	6.83/ 7.14	3.67/ 9.86	7.50/ 8.57	4.63/ 11.86
Z scores	*** 3.79	.42	**2.69	***3.55	.24	.06	.08	.36	** 2.98	.33	.14	** 2.91	.47	** 3.17
5 mean ranks	11.22/ 21.93	12.82/ 17.36	9.07/ 5.93	15.93/ 8.54	4.00/ 9.00	4.92/ 9.44	5.42/ 12.68	4.42/ 9.21	3.50/ 10.00	9.25/ 6.19	7.17/ 6.86	5.00/ 8.71	6.88/ 9.29	5.19/ 11.21
Z scores	*** 3.10	1.33	1.46	**2.62	** 2.41	* 2.06	**2.56	* 2.26	** 3.03	1.39	.14	1.77	1.10	** 2.66
Total mean ranks	10.55/ 23.86	11.85/ 20.14	5.86/ 9.14	17.86/ 7.57	4.67/ 8.33	3.75/ 10.31	4.92/ 12.89	3.50/ 10.00	3.50/ 10.00	6.33/ 8.38	5.33/ 8.43	3.58/ 9.93	6.50/ 9.71	4.56/ 11.93
Z scores	**** 3.82	** 2.38	**3.08	*** 3.59	1.77	** 2.91	**2.77	** 3.00	** 3.01	.91	1.43	* 2.94	1.40	*** 3.19

Key * $p < .05$ ** $p < .01$ *** $p < .001$ **** $p < .0001$

(5.43 vs. 9.57) $p < .05$. Additionally, except for the anomics, every contrast between the aphasic subgroups and the controls is significant for this position. However, not surprisingly, since all the aphasics tended to perform at a low level for this position, none of the contrasts between the aphasic subgroups are significantly different.

Serial position 4. Comparisons of correct scores for target position 4, the second middle position of the list, yield results similar to the previous position except that the RBD performed poorer at this point, and none of the mean contrasts between the aphasics and the RBDs achieve significance. The comparison between all aphasics and the NCs is significant (10.63 vs. 23.64) $p < .0001$ as are the aphasic subgroups with the NC group. Contrasts among the subgroups themselves, however, are not significant. As in position 3, there is also a significant finding between the RBD and NC groups (4.57 vs. 10.43) $p < .01$.

Serial position 5. The correct scores for serial position 5 for each subject reflect the magnitude of the recency effect. As these items are stored and retrieved quite effortlessly by most of the subjects (conflicting theories which account for this phenomenon are discussed in Chapter 2) encountered in STM experiments, retrieval is expectedly enhanced for items at the ends of lists. However, in this experiment, while most subjects exhibited this effect, the conduction aphasics did not, yielding a significant difference between the scores of the conduction aphasics with that of every other group: (a) C vs. NC (3.50 vs. 10) $p < .005$; (b) C vs. RBD (4.42 vs. 9.21) $p < .05$; (c) C vs. A (4.92 vs. 9.44) $p < .05$; (d) C vs. B (4 vs. 9) $p < .01$; (e) C vs. A+B (5.42 vs. 12.68) $p < .01$. Unlike at position 2, there is no significant difference between the A and B groups.

In other group comparisons, the scores of the A and B aphasics are significantly inferior to that of the NC but not that of the RBD. Details of these comparisons and summaries of the above information in tabular form can be found in Table 3.

Summary

An investigation of the comparisons between mean correct scores among aphasic subgroups and right brain damaged and normal control groups yielded the results that the conduction aphasics performed at a significantly inferior level to that of the other groups for serial target positions 2 (the primacy position), and 5 (the recency position), and overall correct mean scores. As might be expected, every contrast between all aphasics or aphasic classification subgroups and normal controls is significant. The difference between the right brain damaged controls (who generally performed at a level between that of the aphasics and that of the normals) and the aphasics is sometimes significant and sometimes not.

Subjects' Choice of Response/Serial Position

Although the major source of data for this study consists of the correct responses of the subjects to the STM probe task, the serial positions of every scorable response the subjects made (one of the words from the appropriate list) were also recorded and contrasted in a similar manner to those of the correct responses to yield additional information. It was thought that this method might yield suggestions of a response bias, if any existed, which might influence the scores independent of memory.

When the aphasics as a whole are compared with the NC, the aphasics are significantly more likely to choose position 1 (16.17 vs. 7.79) $p < .01$, while the NC are significantly more likely to choose positions 3 (20.64 vs. 11.67) $p < .01$, and 4 (20.43 vs. 11.75) $p < .01$. None of the comparisons between the aphasics and the TBD are significant. It should be noted that selection of position 1 represents an

Table 4. Ordinal Contrasts For Response Choice/Serial Position

Among 3 Aphasic and 2 Control Groups

Serial Position	All Aphasics/ NC	All Aphasics/ RBD	NC/ RBD	NC/ A+B	C/B	C/A	C/ A+B	C/RBD	C/NC	B/A	B/RBD	B/NC	A/RBD	A/NC
1 mean ranks	16.17/ 7.79	14.95/ 11.29	5.36/ 9.64	13.07/ 6.86	6.08/ 6.92	9.00/ 6.38	11.58/ 10.04	8.25/ 5.93	9.42/ 4.93	9.75/ 5.81	8.92/ 5.36	9.67/ 4.71	8.00/ 8.00	9.36/ 6.16
Z scores	** 2.47	1.07	2.04	*2.24	.40	1.20	.54	1.09	* 2.16	1.81	1.67	** 2.36	.00	1.60
2 mean ranks	12.85/ 17.29	13.20/ 16.29	7.86/ 7.14	10.07/ 12.86	5.83/ 7.17	5.58/ 8.94	7.92/ 11.61	5.42/ 8.36	5.33/ 8.43	4.75/ 9.56	5.17/ 8.57	4.33/ 9.29	8.56/ 7.36	8.38/ 9.57
Z scores	1.28	.89	.32	.98	.65	1.49	1.29	1.36	1.44	* 2.15	1.59	** 2.32	.52	.35
3 mean ranks	11.69/ 20.64	12.63/ 17.93	9.07/ 5.93	8.75/ 15.50	7.33/ 5.67	7.25/ 7.69	11.08/ 10.25	5.92/ 7.93	4.50/ 9.14	6.08/ 8.56	4.83/ 8.80	4.00/ 9.59	7.00/ 9.14	6.31/ 9.93
Z scores	** 2.60	1.53	1.46	**2.37	.81	.19	.29	.95	* 2.26	1.11	*1.88	** 2.65	.93	1.58
4 mean ranks	11.75/ 20.43	13.38/ 15.79	8.07/ 6.93	8.82/ 15.36	5.75/ 7.25	7.33/ 7.63	9.58/ 10.89	6.25/ 7.64	4.58/ 9.07	8.33/ 6.88	6.67/ 7.29	5.17/ 8.57	7.25/ 8.86	5.56/ 10.79
Z scores	** 2.52	.70	.51	* 2.30	.73	.13	.46	.65	* 2.10	.65	.28	1.60	.70	*2.28
5 mean ranks	12.72/ 17.64	13.90/ 14.29	9.07/ 5.93	10.39/ 12.21	4.33/ 8.67	6.92/ 7.94	7.75/ 11.68	5.75/ 8.07	4.17/ 9.43	9.42/ 6.06	8.50/ 5.71	7.67/ 6.43	7.56/ 8.50	6.44/ 9.79
Z scores	1.42	.11	1.43	.63	*2.1[illegible]	.45	1.38	1.13	** 2.47	1.49	1.33	.57	.40	1.46

Key * p< .05 ** p< .01

aberrant response since the target word can appear only in positions 2, 3, 4, or 5.

In contrast to the situation in which only the correct responses/group is examined, when the position of all responses/group is investigated, the only significant contrast between the conduction aphasics and the other aphasic groups occurs at position 5 between the C and B groups (4.33 vs. 8.67) $p < .05$. There is also a difference which approaches significance between the response choice for position 2 of the B and A groups with the anomic aphasics being considerably more likely to choose that position than the Broca's aphasics (5.81 vs. 9.75) $p < .07$. The above information is presented in tabular and complete form in Table 4, Ordinal Contrasts for Response Choice/Serial Position among 3 Aphasic and 2 Control Groups.

Serial Position Effect

To determine the serial position effect for each group, only the correct scores for positions 2, 3, 4, and 5 were compared with each other. These comparisons were achieved in a fashion similar to those in the preceding section utilizing Mann Whitney U and Wilcoxon Rank Sum W Tests, although in this case, it is positions rather than groups which are compared.

Controls. In analyzing the data, it is surprising to note that neither the RBD nor the NC groups displayed the expected U shaped curve typical of correct responses for the probe type STM task employed here. While both groups displayed a significant recency effect, there is little indication, if any, of a primacy effect. This is evident, not only from statistical tests, but also from the graph of the means of the correct scores in Figure 1. For the normal control group, statistical analysis reveals that the subjects scored significantly better at serial position 5 than they did at positions 2, 3, and 4, (3 vs. 0) $p < .05$ for all three contrasts. For the RBD group, although the serial position curve of the mean correct scores in Figure 1 is more like that expected of this task than the curve of the NC group, none of the differences of the correct scores are significant upon comparison.

Aphasics. When the correct scores for each position are compared with each other the results for each aphasic group are quite different from each other. The conduction group exhibited nothing like a U shaped curve, as can be seen in Figure 1. There is no indication of a primacy nor a recency effect, and the only comparison which approaches significance is

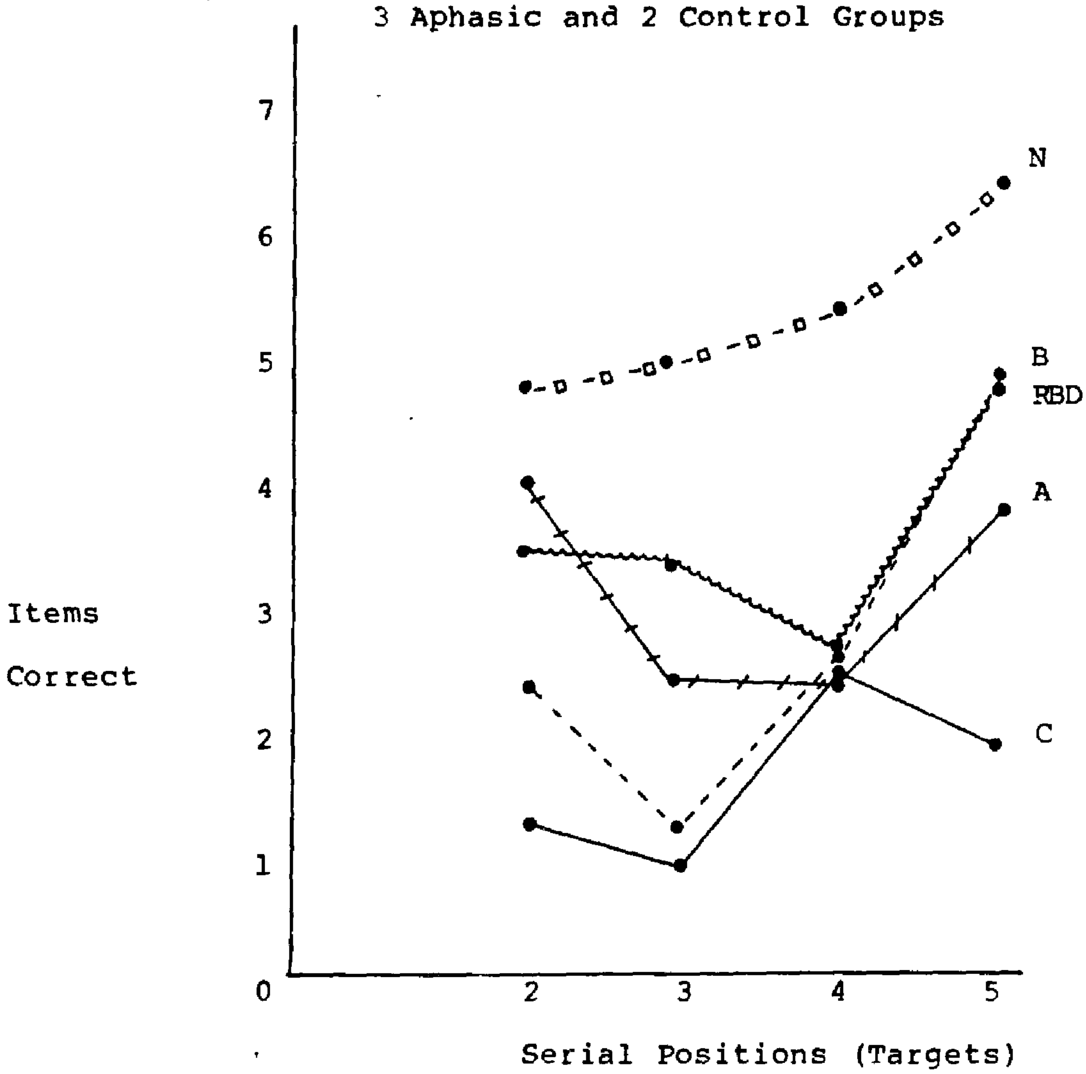
Table 5. Ordinal Contrasts for Serial Position Effect Among 3 Aphasic and 2 Control Groups

Groups	Contrasts 2/3	2/4	2/5	3/4	3/5	4/5
Conduction mean ranks	2.00/2.00	1.50/4.00	4.00/3.25	2.00/3.80	3.50/2.88	2.83/1.50
Z-Scores	.53	1.21	.52	1.78	.28	.20
Broca's mean ranks	3.25/2.00	1.00/2.00	1.50/3.90	1.50/3.38	0.00/3.50	0.00/2.50
Z-Scores	.13	.44	*1.88	1.61	*2.20	1.82
Anomics mean ranks	5.19/2.50	4.25/2.50	4.25/3.67	3.60/6.00	2.33/5.25	0.00/3.00
Z-Scores	1.82	*1.94	.50	.00	1.18	*2.02
Normals mean ranks	1.50/3.50	2.50/3.13	0.00/3.00	2.50/3.33	0.00/3.00	0.00/3.00
Z-Scores	.73	1.34	*2.02	.67	*2.02	*2.02
Right brain damaged mean ranks	2.00/4.00	3.63/3.25	2.50/4.60	4.67/2.33	5.50/3.10	2.00/4.25
Z-Scores	.36	.83	1.52	.73	1.04	1.36

Key

* $p < .05$

Figure 1. Mean Serial Position Curves For
3 Aphasic and 2 Control Groups



KEY

C Conduction Aphasics
B Broca's Aphasics
A Anomic Aphasics
RBD Right Brain Damaged Control Group
N Normal Control Group

the unexplainable difference between positions 3 and 4 (2 vs. 3.80) $p < .07$.

The anomic group, on the other hand, does display a normal type U shaped serial position curve, albeit at an overall reduced level of correctness, with a marked primacy and recency effect. There is a significant difference between positions 2 with 4 (4.25 vs. 3.67) $p < .05$, and the contrast between positions 2 and 3 approaches significance $p < .07$. The recency effect is indicated by the significant difference between positions 4 and 5 (0 vs. 3) $p < .05$.

The Broca's aphasics score somewhat differently as they lack a primacy effect but display a relatively large recency effect (Figure 1). There are significant differences between serial positions 2 with 5 (1.30 vs. 3.90) and 3 with 5 (0 vs. 3.50) $p < .05$, while the difference between positions 4 and 5 approaches significance, $p < .06$. A detailed summary of this information in tabular form is presented in Table 5, Ordinal Contrasts for Serial Position Effect Among 3 Aphasic and 2 Control Groups.

Correct Scores Including Paraphasias

Because of the nature of the expressive speech of the conduction aphasics, it was found that several of the responses of these subjects on the STM task were close literal paraphasic approximations of the target. Since it can be argued that if a subject is able to offer a paraphasia which is closely related to the target utterance, he or she must have the target in memory, it was decided to reanalyze the scores of the STM task counting close paraphasic responses as corrects. A response was considered to be a close approximation if only one consonant sound or cluster was altered. All of the responses of all of the subjects were examined in this fashion and some changes were effected in Total Correct Scores and Correct Scores/Serial Position for four conduction aphasics and four anomic aphasics. The Broca's aphasics and control subjects' scores were unaffected.

Use of the procedure described above had only a small effect on the statistical analysis of the correct scores between the conduction aphasics and the other aphasic groups. For the most part, the recency effect for the conduction aphasics and the primacy effect for the anomic aphasics was slightly enhanced. Because of the improved scores of the C group at position 5, there is no longer a significant difference between the C and A groups at this position. Additionally, for the anomic group only, the correct scores for position 2 are significantly greater than those of position 3 (4.33 vs. 2.00) $p < .05$, $Z = 2.02$. Although some former significant differences are slightly weaker, essentially there are no other differences in the comparisons between the groups, when literal paraphasic approximations of the correct scores are counted as correct. Figure 2 displays the mean serial position curves for the C, B, and A groups for this analysis.

<u>Error Analysis</u>

In order to gain more information regarding the type of error subjects were likely to commit when their response was incorrect, the variety of errors was categorized in the following manner, and the rate at which they occurred was tabulated and contrasted between groups using Mann Whitney U and Wilcoxon Rank Sum W Tests. Most of the errors which the subjects made consisted of list items which were other than the target. For these errors, the serial position of the response was recorded, and along with the correct response, the serial position of all on-list responses by group were analyzed and have been set forth in a previous section (Subjects' Choice of Response/Serial Position). Those errors which were not appropriate trial list items are termed Off Target Errors. These can be categorized in the following way:

1. Zero-no response to the trial.

2. Perseveration-a response from the preceding list.

3. Phonetic-a response which is phonetically similar to a list item (bread for bed).

4. Semantic-a response which is semantically related and similar to a list item (dog for cat).

5. Complex-a response apparently unrelated to any item of the list.

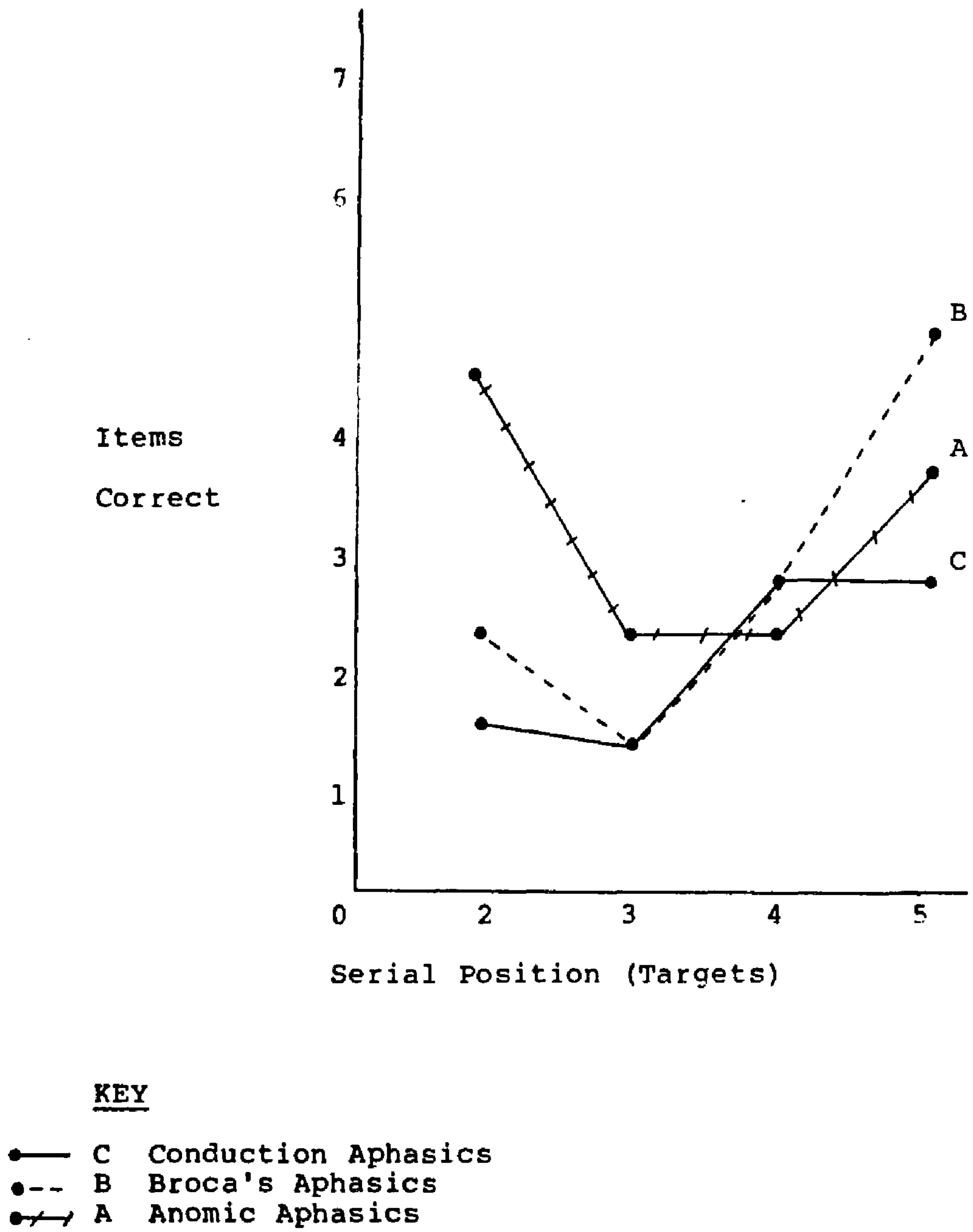
6. Total of off target responses

Total of off target responses. When viewed as a group, not surprisingly, the aphasics are significantly much more likely to commit off target errors than the normal control subjects (16.50 vs. 6.86) $p < .005$. However, there is no significant difference between the aphasics and the right brain damaged control subjects (nor between the RBD and NC).

Of all of the aphasic groups, off target responses were more common among the conduction aphasics. Although the individual comparisons between the C and the other aphasic groups are not significant, the contrast between the C vs. B and A groups combined does reach significance (13.21 vs. 6.57) $p < .05$.

No response. Significant findings for this variable include a significantly greater rate of no response for aphasics vs. normals (16.17 vs. 7.79) $p < .01$ and for conduction aphasics vs. Broca's and

Figure 2. Mean Serial Position Curves For
3 Aphasic Groups (Paraphasias counted as Correct)



anomic aphasics combined (12.89 vs. 7.21) $p < .05$. None of the other contrasts are significant.

Perseveration. In general, the rate of perseveration on this task is not a major differentiator among the groups. Although aphasics tended to perseverate more than normals, and conduction aphasics have a higher rate of perseveration than the other aphasics, only the contrasts between the C and A groups (10.08 vs. 5.56) and the C and RBD (9.08 vs. 5.21) achieve significance $p < .05$.

Phonetically related responses. It was expected that on the experimental task, conduction aphasics would produce a higher rate of responses phonetically related to list items than the other aphasics, as phonetic paraphasia is part of the syndrome of conduction aphasia. In fact, almost all of the comparisons between the conduction and the other aphasic groups are significant, with the exception of the anomic aphasics who also committed phonetic errors, although less than the conduction aphasics. The comparison between the Broca's and conduction aphasics reveals that the C group made a significantly higher rate of phonetic errors (8.50 vs. 4.50) $p < .05$; the contrast between the C vs. B + A approaches significance, $p < .08$. Of course, when the conduc-

Table 6. Ordinal Contrasts For Off-Target Responses Among 3 Aphasic and 2 Control Groups

Off-Target Responses	Contrasts													
	All Aphasics/ NC	All Aphasics/ RBD	NC/ RBD	NC/ A+B	C/B	C/A	C/ A+B	C/RBD	C/NC	B/A	B/RBD	B/NC	A/RBD	A/NC
Zero mean ranks	7.79/ 16.17	15.05/ 11.00	5.86/ 9.14	7.21/ 12.89	6.00/ 7.00	8.58/ 6.69	11.08/ 10.25	8.50/ 5.71	9.83/ 4.57	8.50/ 6.75	8.33/ 5.86	9.00/ 5.29	8.50/ 7.43	9.81/ 5.93
Z scores	** 2.46	1.18	1.57	* 2.06	.48	.87	.29	1.30	** 2.50	.79	1.16	1.86	.47	1.78
Perseveration mean ranks	12.14/ 14.65	14.72/ 11.93	7.57/ 7.43	10.79/ 11.11	8.17/ 4.83	10.08/ 5.56	14.75/ 8.68	9.08/ 5.21	8.92/ 5.36	7.58/ 7.44	7.17/ 6.86	7.08/ 6.93	8.13/ 7.86	8.13/ 7.86
Z scores	.79	.89	.08	.13	1.68	* 2.13	* 2.28	* 1.90	1.74	.07	.17	.08	.13	.13
Phonetic mean ranks	8.50/ 15.92	15.45/ 9.86	7.00/ 8.00	7.86/ 12.57	8.50/ 4.50	8.17/ 7.00	13.17/ 9.36	9.25/ 5.0[illegible]	[illegible].75/ 4.64	5.50/ 9.00	7.50/ 6.57	8.00/ 6.14	9.56/ 6.21	10.00/ 5.71
Z scores	* 2.21	1.67	.52	1.73	* 2.14	.52	1.37	* 2.01	** 2.46	1.61	.47	.96	1.50	* 1.97
Semantic mean ranks	13.36/ 14.22	14.42/ 13.36	7.50/ 7.50	10.50/ 11.25	6.58/ 6.42	7.33/ 7.63	10.42/ 10.54	7.17/ 6.86	7.17/ 6.86	7.17/ 7.75	7.08/ 6.93	7.08/ 6.93	8.38/ 7.57	8.38/ 7.57
Z scores	.36	.36	.00	.38	.12	.18	.05	.22	.22	.36	.11	.11	.50	.50
Complex mean ranks	10.21/ 15.32	13.42/ 15.64	5.43/ 9.57	8.43/ 12.24	7.33/ 5.67	7.75/ 7.31	11.58/ 10.04	7.00/ 7.00	8.42/ 5.79	6.17/ 8.50	5.50/ 8.29	7.67/ 6.43	7.69/ 8.36	9.75/ 6.00
Z scores	1.67	.69	* 2.10	1.11	.90	.20	.58	.00	1.48	1.15	1.43	.78	.32	1.87
Total mean ranks	6.86/ 16.50	15.13/ 10.79	5.43/ 9.57	6.59/ 13.21	8.17/ 4.83	9.25/ 6.19	13.92/ 9.04	9.25/ 5.07	10.17/ 4.29	7.33/ 7.63	7.67/ 6.43	9.00/ 5.29	8.63/ 7.29	10.38/ 5.29
Z Scores	** 2.78	1.25	1.86	* 2.32	1.61	1.36	1.70	* 1.94	** 2.73	.13	.58	1.73	.55	1.60

Key * p< .05 ** p< .01

tion aphasics are compared with the normal subjects, and also with the RBD controls, the results are significant. This information is completely presented in tabular form in Table 6.

Semantically related responses. This category of error failed to distinguish the experimental and the control groups in this study, and none of the group comparisons are significant.

Complex. Complex responses, i.e. responses unrelated to any of the list items of the trial, were most frequently committed by conduction aphasics. These, however, were not highly frequent, and this variable does not strongly differentiate the experimental and control groups. Surprisingly, the comparison between the normal controls and the right brain damaged controls is significant (5.43 vs. 9.57) $p < .05$, and this is the only contrast in this category which reaches significance.

Summary. An analysis of off target errors, i.e., those subject responses which are not appropriate trial list items, reveals that conduction aphasics can be differentiated from the other aphasics on the basis of their tendency to respond with items from subsequent trials, their tendency to make errors which are phonetically related to list items, and their total percentage of off target responses. This data is summarized in Table 6, Ordinal Contrasts for Off Target Responses among 3 Aphasic and 2 Control Groups.

BOSTON DIAGNOSTIC APHASIA EXAMINATION

In addition to an experimental short-term memory test, the aphasic subjects in this experiment received the speech and language sections of the BDAE, Parts I, Conversational and Expository Speech; II, Auditory Comprehension; III, Oral Expression. The subjects' responses to I were primarily used to determine aphasic classification, as discussed in Chapter 3. The data from II and III partly serve this function as well, but also yield a more detailed measure of the degree of language impairment each subject and subgroup of aphasics suffers, and offers a method of comparing these scores. This data was examined in two ways.

The BDAE is a standardized aphasia examination, and includes a Z-Score Profile chart which may be used to determine the range, mean, and standard deviation of the aphasic subject's score on each subtest (Goodglass and Kaplan, 1972, p.14). Mean Z-Scores for each subtest were computed for each aphasic subgroup in this experiment. Group comparisons, as well as comparisons with the standardized ranges of the BDAE were then projected.

Additionally, many group comparisons of subtest scores from the same data base were made (utilizing the Mann Whitney U and Wilcoxon Rank Sum W Tests) in the same manner as the experimental data already discussed. However, this method of analysis, while highly sensitive, occasionally indicates significant differences between group subtest scores whereas the Z Scores and even the raw scores are very similar. Therefore, the information derived from both methods of analysis is presented in the following section, and any major divergence between the two is noted.

Taken as a whole, the subtest scores of all the aphasics in this experiment tend to fall into the milder ranges of aphasic linguistic impairment as provided by the Z-Score Profile. However, the glaring exception to this tendency are the scores of the conduction aphasics on measures of repetition, paraphasia, and reading aloud. No aphasic subtest score is below the range of rating 3 (on a scale of 1 to 5) and the majority of Z-Scores can be included in the range of rating 4 or even 5. When aphasic subgroups are compared, most of the significant divergence between the groups occurs because of the difference be-

Table 7. Ordinal Contrasts for Subtests of the Boston Diagnostic Examination among 3 Aphasic Groups

Subtest	C/A mean ranks	z	C/B mean ranks	z	C/A+B mean ranks	z	B/A mean ranks	z
Articulation Rating	6.83 vs. 8.00	1.15	7.50 vs. 5.50	1.14	10.83 vs. 10.36	.23	5.50 vs. 9.00	*2.15
Word Discrimination	4.20 vs. 8.75	*2.16	3.90 vs. 7.75	*2.02	5.10 vs. 11.75	**2.46	7.58 vs. 7.46	.07
Body Part Identification	4.10 vs. 8.81	*2.17	5.30 vs. 6.58	.64	6.40 vs. 11.29	1.69	6.00 vs. 8.63	1.19
Commands	6.70 vs. 7.19	.22	6.20 vs. 5.83	.19	9.90 vs. 10.04	.04	7.00 vs. 7.88	.40
Complex Material	4.90 vs. 8.91	1.60	5.30 vs. 6.58	.64	7.20 vs. 11.00	1.32	7.08 vs. 7.81	.32
Responsive Naming	4.90 vs. 8.31	1.67	4.70 vs. 7.08	1.21	6.60 vs. 11.21	1.70	6.75 vs. 8.06	.49
Confrontation Naming	3.00 vs. 9.50	***3.33	3.80 vs. 7.83	*2.06	3.80 vs. 12.21	***3.31	6.17 vs. 8.50	1.69
Animal Naming	3.70 vs. 9.06	**2.44	4.50 vs. 7.25	1.37	5.20 vs. 11.71	*2.24	6.58 vs. 8.19	.47
Body Part Naming	4.00 vs. 8.88	*2.20	4.50 vs. 7.25	1.37	5.50 vs. 11.61	*2.09	7.08 vs. 7.81	.32
Word Reading	4.20 vs. 8.75	*2.22	4.20 vs. 7.50	1.68	5.40 vs. 11.64	*2.30	6.42 vs. 8.31	.97
Sentence Reading	3.00 vs. 9.50	**3.00	3.00 vs. 8.50	**2.79	3.00 vs. 12.50	***3.36	7.00 vs. 7.88	.42
Repetition (words)	4.17 vs. 10.00	**3.02	4.33 vs. 8.67	*2.26	5.00 vs. 12.86	***3.37	6.83 vs. 8.00	1.15
Hi Probability (phrases)	3.50 vs. 10.50	***3.32	3.50 vs. 9.50	**2.92	3.50 vs. 13.50	***3.71	5.92 vs. 8.69	1.54
Low Probability (phrases)	3.75 vs. 10.91	**3.04	3.58 vs. 9.42	**2.83	3.83 vs. 13.36	***3.41	5.92 vs. 8.69	1.54
Literal Paraphasia	10.92 vs. 4.94	**2.66	9.50 vs. 3.50	**2.92	16.92 vs. 7.75	***3.23	6.00 vs. 8.63	1.22
Verbal Paraphasia	10.92 vs. 4.94	**2.65	9.08 vs. 3.92	**2.49	16.50 vs. 7.93	**2.98	7.17 vs. 7.75	.26
Mean Auditory Comprehension	3.40 vs. 9.25	**2.64	4.50 vs. 7.25	1.38	4.90 vs. 11.82	**2.37	6.25 vs. 8.44	.97
Mean Naming	3.40 vs. 9.25	**2.64	3.80 vs. 7.83	*2.00	4.20 vs. 12.07	**2.69	6.50 vs. 8.25	.78
Mean Repetition	3.50 vs. 10.50	***3.22	3.50 vs. 9.50	**2.89	3.50 vs. 13.50	***3.58	5.83 vs. 8.75	1.43

Key: * $p < .05$ ** $p < .01$ *** $p < .001$

Table 8. Mean Z-Scores for Subtests of the
Boston Diagnostic Aphasia Examination Among 3 Aphasic Groups

Subtest	C	B	A	A+B
Articulation Rating	+.80	+.40	+.90	not calculated
Word Discrimination	+.75	+.90	+.90	+.90
Body Part Identification	+.40	+.60	+1.00	+.75
Commands	+.75	+.75	+.62	+.70
Complex Material	+.50	+.65	+.80	+.78
Responsive Naming	+.75	+1.00	+1.10	+1.00
Confrontation Naming	+.70	+.80	+1.10	+1.00
Animal Naming	+.25	+.70	+.90	+.85
Body Part Naming	+.33	+.75	+.75	+.75
Word Reading	+.50	+.90	+1.00	+.95
Sentence Reading	-.37	+1.25	+1.25	+1.25
Repetition (words)	+.25	+.75	+.75	+.75
High Probability (phrases)	-.25	+1.10	+1.25	+1.20
Low Probability (phrases)	-.37	+1.25	+1.60	+1.40
Literal Paraphasia	+2.50	-.50	-.25	-.37
Verbal Paraphasia	+1.70	-.70	-.62	-.65
Mean Auditory Conprehension	+.60	+.75	+.85	+.78

tween the conduction and the other aphasics in the area just mentioned. The following section sets forth these differences by subtest. The information can also be found in Table 7, Ordinal Contrasts for Subtests of the Boston Diagnostic Aphasia Examination among 3 Aphasic Groups. A table of the relevant Z-Scores for the BDAE for the same subjects is presented in Table 8, Mean Z-Scores for Subtests of the Boston Diagnostic Aphasia Examination among 3 Aphasic Groups.

Auditory Comprehension, II

The Auditory Comprehension Section of the BDAE consists of four subtests and yields five scores: one for each subtest, plus an overall mean auditory comprehension score. The first auditory comprehension subtest, Word Discrimination (IIa) in which the subject points to pictures named by the examiner and the response is timed, is responsible for almost all of the significant differences in comprehension scores between groups. This subtest also yields a marked divergence between the two methods of analysis employed here. For this subtest, the scores of the conduction aphasics are significantly inferior to those of the anomic aphasics (4.20 vs. 8.75) $p < .05$; the Broca's (3.90 vs. 7.75) $p < .05$; and the A and B groups combined (5.10 vs. 11.75) $p < .01$. The mean Z-Scores, however, for the groups are C = +.75; B = +.90; A+B = +.90, standard deviation = 1.

On only one other comprehension subtest does there occur a significant difference in scores, i.e. Body Part Identification (IIB) in which the subject is required to point to body parts named by the examiner. On this test, the C aphasics are significantly poorer than the A aphasics (4.10 vs. 8.81) $p < .05$. The corresponding Z-Scores are C = +.40; A = +1.00, s.d. = 1, and are less than a standard deviation apart.

For overall auditory comprehension (mean of scores on Auditory Comprehension section) the conduction aphasics are significantly inferior to the anomics (3.40 vs. 9.25) $p < .01$; and the A+B (4.90 vs. 11.82) $p < .01$. The mean Z-Scores for this measure, however, are very similar to each other; C = +.60; B = +.75; A = +.85; A+B = +.80; s.d. =1.

Oral Expression, III

In the Oral Expression section of the BDAE, a marked difference exists between the scores of the conduction aphasics with the other aphasics in the areas which test features which are hallmarks of conduction aphasia, i.e. repetition, and the presence of paraphasias. However, differences between the conduction aphasics and the other aphasic groups were also found among subtests which test the function of naming.

Naming. The ability to name is tested by four subtests on the BDAE: Responsive Naming (IIIG), Confrontation Naming (IIIH), Animal Naming (IIIK), and Body Part Naming (IIIJ). The latter three subtests yield significant results among the groups upon statistical analysis. However, the Z-Scores for every comparison remain within less than a standard deviation of each other (Table 8).

On the subtest Confrontation Naming, in which subjects must name items pointed to by the examiner and the response is timed, statistical analysis reveals that the conduction aphasics are significantly inferior to the anomics, Broca's aphasics, and both groups combined: C vs. A (3 vs. 9.50) $p < .001$; C vs. B (3.80 vs. 7.38) $p < .05$: C vs. A+B (3.80 vs. 12.21) $p < .001$. However, in spite of the high levels of significance, the mean Z-Scores for each group are less than one half of a standard deviation from each other: C = +.70; B = +.80; A = +1.10; A+B = +1.00, s.d. = 1.

The subtest Animal Naming in which a subject names as many animals as possible in a proscribed time, and Body Part Naming, in which the subject names body parts indicated by the tester, also yielded significant differences between conduction aphasics and anomics, and A and B combined, but not between groups C and B. For Animal Naming these results are: C vs. A (3.70 vs. 9.06) $p < .01$; C vs. A+B (5.20 vs. 11.71) $p < .05$. Once again, in contrast to these figures, the Z-Scores for the same subtest are close: C = +.70; B = +.80; A = +.90; A+B = +.85, s.d. = 1.

<u>Oral Reading</u>. Conduction aphasics are known to have difficulty reading aloud; this impairment is similar to that of repetition. On the BDAE, subtest Word Reading, IIIF, and Oral Sentence Reading, IIIL, reflect this deficit. For Word Reading for following results are significant: C vs. A (4.20 vs. 8.75) $p < .05$; C vs. A+B (5.40 vs. 11.64) $p < .05$. The relevant mean Z-Scores are C = +.50; B = +.90; A = +1.00; A+B = +.95; s.d. = 1.

Increasing the length of the item that the conduction aphasic must read aloud accelerates his rate of errors. In the subtest Oral Sentence Reading the conduction aphasics made significantly more errors than the anomics and the Broca's aphasics: C vs. A (3 vs. 12.50) $p < .001$; C vs. B (3 vs. 8.50) $p < .005$; C vs. A+B (3 vs. 12.50) $p < .001$. The mean Z-Scores for this test are C = +.375; B = +1.25; A = +1.25; A+B = +1.25.

Repetition and paraphasia. In terms of differentiating conduction aphasics from other types of aphasics, the BDAE includes two important features, i.e., repetition tests in which the subject is asked to repeat words, high probability phrases, and low probability phrases, and a paraphasia score which is derived from a running record of paraphasias which is built in to several of the Oral Expression subtests. In this experiment, conduction aphasics were significantly poorer in repetition than the other aphasic subjects, and displayed a significantly much greater amount of paraphasias. In fact, it would not be inaccurate to state that the Broca's and anomic aphasics had little difficulty with tasks of repetition, and produced only occasional paraphasic responses. This data is presented in Table 7 and Table 8.

Summary

The responses of the aphasic subjects in this experiment to the Boston Diagnostic Aphasia Examination, Parts I, II and III were analyzed in two ways. Mean Z-Scores (which are provided as part of the examination) for each relevant subtest were computed for each aphasic subgroup. Additionally, many group comparisons of subtest scores from the same data base were made utilizing the Mann Whitney U and Wilcoxon Rank Sum W Tests. An examination of mean

Z-Scores revealed that for almost all subtests, except those of repetition, oral sentence reading, and paraphasia, the aphasic subgroups of conduction, Broca's and anomic aphasics scored less than one half of a standard deviation apart, although the conduction aphasics scored consistently below those of the other aphasic groups. However, when the same scores were submitted to the statistical analysis mentioned above, several significant differences were noted between scores of the conduction aphasics and the other aphasics, especially in tests of word discrimination and naming. This data is presented in Table 7, Ordinal Contrasts for Subtests of the Boston Diagnostic Aphasia Examination among 3 Aphasic Groups, and Table 8, Mean Z-Scores and Standard Deviations for Subtests of the Boston Diagnostic Aphasia Examination Among 3 Aphasic Groups.

CHAPTER 5

DISCUSSION

This investigation explored short-term memory performance among conduction, Broca's and anomic aphasics, and compared and contrasted that performance among the aphasic groups themselves, and with two control groups, a right brain damaged group and a group of normal control subjects, i.e., with no known neuropathology. The discussion of the results obtained from this investigation will be organized to address the questions raised in Chapter 1:

1. Are there qualitative as well as quantitative differences in auditory-verbal STM performance among conduction, Broca's and anomic aphasics?

2. What are the underlying mechanisms responsible for these differences, if found?

The results of this study demonstrate quite clearly that there are major differences in STM ability among mild aphasics of different aphasic classifications, as well as between aphasics and normals. The latter conclusion should come as no surprise; a variety of diverse studies suggest that this should be so (Swimmey and Taylor, 1971; Cermak and Moreines, 1976, etc.). The most striking aspect of the results of this experiment, however, is the major impairment in STM exhibited by the conduction aphasics in comparison with the other experimental and control groups. This impairment is evident in every aspect of their performance on the STM task employed in this investigation. Not only did conduction aphasics display the lowest percentage of correct responses on the STM test, but also they were unable to make use of the common STM strategies and mechanisms which enable subjects, even other aphasic subjects, to enhance recall from the beginnings and ends of lists immediately recalled in serial position. Additionally, an analysis of the types of errors committed by conduction aphasics revealed that their responses to the trials of the task frequently diverged from the appropriate list items to a greater extent than the other subjects in this experiment.

While some similar results have been demonstrated by a few researchers investigating the STM function of single patients (Shallice and Warrington, 1970; Saffran and Marin, 1975; Carramazza et al, 1979, 1981) it is believed that this is the first time such a deficit has been demonstrated in a larger population of conduction aphasics and in comparison with aphasics of differing classifications. In the following sections, the details of these results will be discussed.

Total Correct

If the total number of correct scores by group, ignoring serial position for the moment, can be taken to signify quantitative differences in STM ability among the groups, this variable proved to be a powerful differentiator in almost every comparison among the aphasic and the control groups in this study. Of most interest are the findings of no statistically significant difference between the STM performance capabilities of the Broca's and anomic aphasics, while the Total Correct scores of the conduction aphasics are significantly below those of the other aphasics. On this measure, the total number of correct target items that subjects were able to recall declined by groups in the following order:

1. Normal control subjects.
2. Right brain damaged control subjects.
3. Anomic aphasics.
4. Broca's aphasics.
5. Conduction aphasics.

Although some earlier research in STM and aphasia employ aphasics of differing classifications (Albert, 1976; Cermak and Moreines, 1976; Heilman, Scholes, and Watson, 1976; De Renza and Faglioni, 1978) these studies either fail to organize the aphasics into formal groups, or else fail to find differences in STM among aphasics of different classifications. The findings of the present study illustrate that such differences do exist, i.e., that conduction aphasics have a markedly greater degree of impairment than anomic and Broca's aphasics in STM.

<u>STM impairment of right brain damaged subjects</u>. It is not too surprising that not only are there statistically significant differences between the Total Correct scores of aphasics and their control groups, but between the normal control group and the right brain damaged control group there also exists a difference between the scores which has a level of significance of less than .01. As mentioned earlier, the right brain damaged subjects in this experiment were in some respects more severely, and certainly more recently impaired as a group than the aphasic subjects. It is unclear to what extent these factors influenced the scores of the right brain damaged control groups. It is interesting to note that Flowers (1974) found no significant differences between aphasics and RBD subjects, as well as between the RBD and normal groups on a Brown-Peterson type STM task, with the performance of the RBD group falling midway between the aphasics and the normal subjects. However, in most studies of STM which employ

aphasic, RBD and normal subjects, the RBD subjects perform in a similar manner to the normals (De Renzi and Faglioni, 1978).

Serial Position Effect

While the measure of correct responses/group yields an opportunity to assess quantitative differences between aphasic groups themselves, as well as with their controls in overall STM capability, the results of the analysis of the contrasting serial position curves suggest differences among the groups which go beyond this. As discussed earlier, it is virtually axiomatic that in tests of immediate free recall and probed memory, memory is enhanced for items occurring at the beginnings and ends of lists (primacy and recency effects) while items occurring at midlist are less well remembered (Baddeley, 1976; Waugh and Norman, 1965). The primacy effect is thought to be the result of subject's ability to employ active strategies for remembrance, especially rehearsal, while the recency effect stems from the ease with which items can be retrieved from STS (Craik, 1971). Therefore, the curve generated from the scores of a task such as the one employed in this experiment is expected to be U shaped, and the deviations from this shape reflect the subject's inability to make use of these strategies and mechanisms.

In this investigation, serial position effect was determined both by statistically comparing correct responses for each serial position between groups (Table 3), and each position with each other position within each group (Table 5). Within the aphasic population, the results of these comparisons indicate that the curve of the correct responses of the anomic aphasics is U-shaped, i.e. includes a significant primacy and recency effect, while the Broca's aphasics display a recency effect but lack a primacy effect. Only the conduction aphasics display a flat curve, neither a primacy nor a recency effect. The findings which best illustrate the difference between the conduction aphasics and the other aphasics for serial position effect are the significant decrement ($p < .01$) at position 2 and 5 between the conduction aphasics and the A and B groups combined. It is also interesting to note that because the Broca's aphasics had only a minor primacy effect, their correct scores for position 2 are significantly less than those of the anomics.

These results, derived from the task employed in this investigation can be taken to signify the following impairment among conduction aphasics: (a) a failure to employ rehearsal to enhance recall of items from the first target position of the list,

(b) an inability to store and retrieve items from STS which results in a lack of enhanced recall of the terminal target item from each list. Even when responses which are paraphasic approximations of the target are considered to be correct, a procedure which it was thought might demonstrate that memory for the items exists but is blocked because of the expressive complications of literal paraphasia, the conduction aphasics' recency scores were only slightly enhanced and they continued to display a marked impairment in this aspect of memory. In contrast to this, anomic but not Broca's aphasics were found to employ rehearsal effectively, and both Broca's and anomic aphasic groups were able to make use of items stored in STS to improve recall of target position 5 words.

The finding of a flat serial position curve was consistent for every conduction aphasic in this study. Since this result is strikingly different from the performance of the other aphasics, it is determined that a lack of a serial position effect on a task such as this is a strong diagnostic indicator of conduction aphasia when it occurs in a patient with fluent speech and good auditory comprehension.

While some studies of short list repetition among conduction aphasics result in a serial position curve which displays a flat response for all positions (Shallice and Warrington, 1970; Saffran and Marin, 1974), two studies investigating serial position effect in a probe type STM task such as this indicate that contrary to the findings discussed here, primacy and recency effect do exist, but in a reduced fashion (Shallice and Warrington, 1970; Carramazza et al, 1979). There are several differences, however, between these studies and this one. In both of these probed STM tasks, the conduction aphasic subject (a single subject was examined in each investigation) had only to indicate whether a probe letter (Shallice and Warrington, 1970) or word (Carramazza et al, 1979) was part of the list at each trial. This response, which is a form of matching, is somewhat less taxing than the one employed here, i.e., saying the word which follows the probe word on each trial, and probably accounts for the difference in the results among those studies and the current one. In fact, a pilot investigation preceding the present study indicated that mild aphasics make virtually no errors on a task such as the one employed by Caramazza et al, (1979) other than an occasional response which is falsely positive, thus yielding no basis for investigation.

It would appear that only one previous investigation has compared serial position effect among conduction aphasics and another aphasic group, that of Broca's (Saffran, Marin, and Rubman, 1977). On a task in which two conduction and five Broca's subjects pressed digit keys in serial order following presentation of strings of four or five digits, it was found that conduction aphasics had a primacy, but no recency effect, while Broca's aphasics displayed both effects. Again, the difference in the task and the subject's required response, as well as the fact that the authors employed only two conduction aphasics may account for the difference in the results of that investigation and this. It may also be the case that in this investigation, since the initial position on each list was not a target position, measures of primacy are not directly comparable for the additional reason that this may have effected the subjects' lack of primacy in this paradigm.

Saffran, Marin, and Rubman (1977) interpret their findings to signify that conduction aphasics have an underlying impairment of the precategorical acoustical store (PAS) discussed earlier in this report, a store which is thought to contain acoustic information from the "early" stages of speech decoding (Crowder and Morton, 1969). However, as there are some current questions about the features and psychological reality of this mechanism (for a full discussion of this issue see Chapter 2) and because this investigation included no direct method for determining if a disordered PAS could underlie the conduction aphasics' recency failure, it is not possible to affirm this hypothesis here.

One surprising result which is quite difficult to explain other than as an anomaly is the failure of the normal subjects to display a primacy effect. This is contrary to all expectations and it is tempting to dismiss it since it contradicts quite clearly the findings of Waugh and Norman (1965) who were the first to utilize this task (with digits). Perhaps since two of the seven normal control subjects scored unusually low (three correct out of seven) for target position 2, this depressed the scores in this position, a result which would have had less influence in the larger subject pools of Waugh and Norman It is equally surprising that the RBD subjects showed no significant differences in serial position effect although the shape of their curve roughly conforms to a U shape. This can only be ascribed to the generally poor level of health and alertness exhibited by those subjects.

Serial Position of Response and Analysis of Errors

As the majority of the aphasic subjects' responses to the STM task were errors, a substantial amount of attention was paid to the patterns and types of errors committed by the aphasic groups in this investigation. Most of the errors which the subjects committed consist of appropriate list items other than the target. The serial position of these responses together with the correct responses for each position were recorded and analyzed, and certain patterns emerged.

Aphasics as a whole were far more likely to choose the first serial position of each list than the normals, a response which shows some confusion as, by definition, the target word, which is the word following the probe, can only occur in positions 2 through 5. It was rare for normal subjects to respond to the task with a word from the first position of the list, while right brain damaged subjects chose position 1 at a rate between that of the aphasics and the normals.

In general, when responses from the first serial position are ignored, subjects tended to choose responses in a pattern similar to that of the serial position curve of their correct responses. Anomic aphasics were much more likely than Broca's to respond with an item from position 2, probably because these subjects seemed to employ active rehearsal, and these words were available to them. Broca's aphasics chose words from position 5 much more readily than conduction aphasics, as these words seemed lost to the conduction aphasics, as evidenced by their failure to show a recency effect, the only group in this investigation who did not.

Excluding the conduction aphasics who actually committed more off target than on-list errors, it was far more common for Broca's and anomic aphasics and certainly for control subjects to respond to each trial of the experimental task with an appropriate list item than with one which was not an item from the trial. Nevertheless, the difference between the total of off target errors for the conduction aphasics in contrast to the other aphasics approaches but does not reach significance ($p < .08$), a result influenced by the fact that the highest number of off target errors/subject was obtained by an anomic aphasic (17 errors), fully one third of all of the off target errors of that group. More than likely, the tendency of the conduction aphasics to respond to the task with a high percentage of off target errors is due to their difficulty remembering any of the list items on a particular trial.

This conclusion also contradicts the Tzortzis and Albert (1974) hypothesis that conduction aphasics suffer from a specific sequencing deficit. Although the experimental paradigm employed here does not permit separate calculations of item and order errors, the above hypothesis would predict that subjects with a sequencing deficit would make only on list errors. Since conduction aphasics actually committed more off target than on list errors, it is clear that a sequencing deficit explanation cannot account for the conduction aphasics' poor performance on this STM task.

When the off target errors are divided into different classes (the description of the error classes are presented in Chapter 4, Error Analysis) certain interesting patterns emerge. The following is an analytical discussion of aphasics' error types.

No response. The most common off target error which subjects committed in this investigation was a failure to make any response to the trial. The majority of the Broca's aphasics, right brain damaged, and normal control subjects' off target errors were of this sort. Since subjects were instructed to guess if they were unsure of the correct response to a trial, a no response usually seemed to occur when subjects became momentarily distracted and were aware that they could not recall any of the items on the list. This was the only variety of error in which the conduction aphasics displayed less errors than the other aphasics.

Perseveration. The conduction aphasics were the only group who tended to respond to trials with an item from a directly subsequent trial: this error was committed only three times each by the Broca's and anomic groups. While there were a few instances in which an error of this sort appeared to be an example of true perseveration, these instances might also be regarded as prior list intrusions stemming from proactive interference, i.e., a decrement in memory caused by interference from similar items learned earlier. As this phenomenon is thought to occur primarily in long term memory, results indicating that conduction aphasics display this error significantly more than the Broca's and anomic aphasics may signify that these subjects attempt to make use of LTM in STM tasks, probably as a method of compensation for their inadequate STM ability. Some other studies using different techniques with conduction aphasics have also suggested that this may be so (Shallice and Warrington, 1977).

Phonetically related errors. As the conduction aphasics were the only aphasic group to display frequent and copious literal paraphasias, it was expected that they would make a significantly greater number of this type of error than the other aphasics. This proved to be the case when the C and B groups were compared, but as this error was common among the anomic as well as the conduction aphasics, no other comparison among the aphasics is significant.

Other errors. Responses which were verbal associates of list items proved to be rare, and responses which were entirely unrelated to list items, slightly less so. In both of these categories, however, conduction aphasics accounted for half of all errors made, a result which continues to highlight the difficulty conduction aphasics had in this investigation recalling the appropriate response.

Summary. Although conduction aphasics committed more off target errors than the Broca's and anomic aphasics, and far more than the control groups, the difference among the aphasic groups approaches but does not reach significance. The types of off target errors which conduction aphasics committed in contrast with the other aphasics highlight some aspects of their impaired STM function: they confused items from prior lists, perhaps because of attempts to employ LTM in an STM task, they offered phonetic approximations of list items, and they made some responses which were completely unrelated to list items. However, in the category no response, their performance was similar to that of the other aphasics. The preponderance of off target to on list items among conduction aphasics is taken to contradict the sequencing deficit hypothesis of Tzortzis and Albert (1974) which cannot account for this result. It was thought that these results are a further indication of the real difficulty conduction aphasics experience in recalling items from short term, difficulties which are reflected in their increased rate of errors which are not an appropriate list item.

The Boston Diagnostic Aphasia Examination.

The results of the BDAE, Parts I, II, and III indicate that all of the aphasic subjects in this experiment are mildly impaired in their ability to comprehend speech and language. In expressive speech, however, while Broca's and anomic aphasics are measured as being mildly impaired as well, those aspects of the expressive speech of the conduction aphasics which reflect the nature of that syndrome are markedly impaired, i.e., repetition, oral reading, and the presence of paraphasia. The two methods of analysis which were employed in this investigation, the Z-score analysis supplied by the BDAE and the Mann Whitney U and Rank Sum W tests, reflect this pattern. However, the two methods diverge in some important respects (Tables 7 and 8).

The results of the Mann Whitney U and Rank Sum W tests find some unexpected significant differences between the conduction and the other aphasics in auditory comprehension, especially word discrimination, and in every naming test except responsive naming. While it is true that the conduction aphasics scored less than the other aphasics on these tests, the Z-score method of the BDAE indicates that many of the aphasic groups' mean scores are either close or virtually identical, as in word discrimination. On this subtest, as well as some others, the subject's response is timed and his or her score partially depends upon speed of response. It is believed that the Mann Whitney U method of analysis magnified the small differences in the raw scores caused by the particular problems of the conduction aphasics such as STM impairment and paraphasic expression, while the Z-score method is a more accurate reflection, in this case, of the differing impairments of the aphasic groups. It cannot be denied, however, that conduction aphasics performed slightly but consistently below that of the other aphasics except in their understanding of complex material. It is believed that this difference is too small to account for the differences in STM performance among the groups, and certainly cannot account for the lack of primacy and recency effects among the conduction aphasics.

The contribution of conduction aphasia to a study of memory and aphasia

The interest aroused by the study of the repetition/STM performance deficit in conduction aphasia has focussed chiefly on how it reflects on memory rather than on what it has to say about aphasia. In fact, a study of this sort should make a contribution towards an understanding of both of these areas.

Shallice and Warrington (1970; 1977) and Warrington and Shallice (1969, 1972), as discussed earlier, interpreted the findings of their investigation of patients with a seemingly selective and isolated impairment of STM in terms of the two store model of memory. Their results, however, caused them to make a major alteration in this model, i.e., that items entering LTM need not require preliminary storage in STM but can enter in parallel (rather than serially) with entry into STM. However, although Shallice and Warrington have taken their results to indicate support for the two store model of memory, albeit in altered fashion, it is surely no coincidence that following the publication of their research demonstrating that an individual can function in a relatively unimpaired manner in language and thought with a severely reduced STM capacity, an erosion of support has taken place and few researchers now subscribe to the classic form of the two store model so widely accepted just ten years ago.

It is beneficial, therefore, to interpret the results of this investigative study in the light of some of the new ideas about the nature of memory, although these are somewhat in a state of flux. A paradigm such as the one employed in this investigation, which utilizes serial position effect in STM, is generally considered to yield a measure of a subject's ability to employ strategies such as rehearsal, and to retrieve in a relatively automatic fashion, information in short-term store for late list items.

In this study the serial position curve of the conduction aphasic is flat rather than U-shaped, indicating that these subjects were unable to make use of any of these strategies or mechanisms in order to enhance the recall of early and late list items. This is in contrast to the anomic aphasics who displayed a U-shaped curve, although at a lower overall level than the normal subjects, and to the Broca's aphasics who were not able to use rehearsal to enhance their memory of early list items, but were quite successful in retrieving the most recent list items at position 5.

Much of the recent emphasis in the memory literature has focussed itself upon the evolving levels of processing framework which was first proposed by Craik and Lockhart (1972). This approach emphasizes that an individual memory trace is a reflection of the coding process by which it is formulated, and its strength is a function of the type and amounts of encoding utilized in this formulation. Although memory research in the years preceding Craik and Lockhart also acknowledges that memory is a function of active strategies (Neisser, 1967), the new emphasis enhances this tendency many times over.

Although this investigation was not specifically directed towards a support of the levels of processing framework of memory research, it can lend itself to certain interpretations in that vein. Since it is already well known that conduction aphasics have an impairment in phonetic coding as evidenced by the phonetic paraphasias in their speech, it is not surprising that they are at an extreme disability performing the phonetic coding necessary to replicate the phonetic structure of an utterance for the purpose of storage and rehearsal. According to this interpretation, the STM performance defect in conduction aphasia is a consequence of impaired phonetic coding which results in a defective phonetic trace. However, certain aspects of the performance of conduction aphasics contradict some assumptions of the levels of processing framework as it is commonly formulated.

It seems to be generally held that phonetic coding represents a relatively "early" stage in the decoding of a stimulus, while the decoding of the semantic or meaning attributes of a stimulus occur at a relatively "late" stage (Treisman, 1979). Recently, as discussed in Chapter 2, some evidence has been presented which refutes this position (Marcel and Patterson, 1978; Baddeley, 1978) as it suggests that semantic information may be available to the individual before phonetic coding occurs. Therefore, the entire feature extraction of a stimulus may proceed from a "top down" approach (meaning before physical features) rather than from the "bottom up" approach (physical features before meaning) more commonly accepted (Treisman, 1979). Additionally, since the phonetic coding disability of the conduction aphasic seems to interfere to only a minor degree with the comprehension of the incoming stimulus, it would seem more likely to posit that the formation of the phonetic structure of the incoming stimulus which constitutes the items stored in what is commonly called the STS is a relatively late stage in language processing (Baddeley and Hitch, 1974) and that is why its impairment does not cause extreme disruption of the comprehension of language. The evidence from this investigation demonstrating that the conduction aphasic subjects can sustain a marked disruption in STM functioning with only minor interference with auditory comprehension, especially for meaning, supports this position.

A striking aspect of conduction aphasia is the typical unidimensionality of the language impairment. In most forms of aphasia, many aspects of language are impaired, although the pattern of impairment varies with the classification. In conduction aphasia, most aspects of language are not impaired, and it is chiefly the phonetic structure of language in expression and repetition (sometimes only in repetition) which is disturbed. It also can be stated that this unidimensionality of impairment may also underlie the lack of primacy and recency effects exhibited in this experiment by the conduction aphasics. Both rehearsal, a form of covert repetition, and STS, in which items are coded phonetically, rely upon the ability of the individual to indicate the phonetic structure of the incoming items. This process is precisely that which is impaired in the typical conduction aphasia syndrome in which the patient can neither repeat the phonetic structure of a heard utterance which he/she is able to understand, nor express unique and individual utterances without a copious amount of literal paraphasia.

There is a variant of conduction aphasia, however, in which the expressive speech of the patient is not marred by paraphasia, but only repetition and STM performance are impaired. Shallice and Butterworth (1977; supported by Caramazza, et al., 1981) have hypothesized that it is only in this relatively pure and rare form of conduction aphasia (which they posit is anatomically rather than functionally related to standard conduction aphasia) that a STM failure underlies the repetition failure, while in conduction aphasia with paraphasia, repetition fails because of production difficulties. As already discussed in Chapter 2, a search of the literature investigating anatomical lesion and functional deficit in conduction aphasia yields no supporting evidence for this position. Additionally, as can be seen in the Subject Data Tables, Conduction Aphasics, Appendix D, the one conduction aphasic subject, J.B., in this study who failed to exhibit literal paraphasias is indistinguishable from the other conduction aphasics in every other aspect except paraphasia, a finding which makes it difficult to posit that this patient's impaired STM performance is due to failure of a different mechanism than the other five aphasic subjects in this group.

The hypothesis that the STM failure of the conduction aphasic is the result of an underlying impairment in generating the phonetic structure of incoming and (usually) outgoing utterances entertained in this conclusion is an outgrowth of the results of this experiment in serial position effect, as well as from a review of the relevant literature. This hypothesis is not to be taken, however, as indicating support for the position that the repetition defect in conduction aphasia stems from linguistic rather than mnestic origin, the dichotomy formulated by Strub and Gardner (1974) towards which most of the literature in this area has been directed. While the bulk of research in the field of memory has surely yet to be performed before a clearer understanding of the nature of memory is achieved, the recent advances and alterations in the framework by which memory research is interpreted, with its emphasis on coding and retrieval processes rather than static stores, predicts that it is impairment of these processes which impairs memory. Short term storage of language is now seen to involve the same dynamic processes involved in language itself, and the two are inseparable.

Summary

The results of this study demonstrate that there are significant differences in the short-term memory performance of conduction aphasics, in comparison with Broca's and anomic aphasics. These differences show up not only in the lower over all performance of the conduction aphasics, but in their complete lack of serial position effect. This finding is so striking as to constitute a diagnostic sign of the syndrome, when it occurs in a patient in the presence of good auditory comprehension and fluent speech.

The short-term memory task employed here, a probe type task in which the patient need only respond with a single one syllable word was well within the expressive limitations of the conduction aphasic subjects in this experiment. Therefore, the fact that they performed so poorly can only be attributed to their short-term memory limitations, and not to their linguistic impairment. This was evident in all six conduction aphasic subjects, including the one subject who exhibited little or no paraphasias, as well as the five others who did. It is concluded that the repetition deficit in conduction aphasia constitutes an example of a selective deficit of short-term memory.

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Appendix A

Sample Aphasic Responses to the Cookie Theft Picture, Subtest Ie, Boston Diagnostic Aphasia Examination

Conduction aphasic: Mother. Mother. Mother wa- is washing the incidensal- the plate- the slink- sink is overflowing- kids is looking at the char- kickie jar- falling down over the stool- little girl also bending- she's belding too- the boy- and uh a joor on nice- a jar- a jar- it's a nice day and it's or gas- gas- and a- seems to be sometime- summertime... (Subject L.Z.)

Broca's aphasic: Woman is washing the dishes- A little- a girl and a boy that on the stool falling down- he is in the cookie jar-uh- the uh jar uh the uh uh closet door is opened and- uh ooh uh- water is spilling on the uh floor and uh- green grass is growing- curtains- cups and uh plate-um... (Subject E.F.)

Anomic aphasic: Well- is disaster- kid's falling off the stool and uh- grabbin cookies out of- the uh- container- the can- the si...- her sink is running over- uh- that's about all- that's enough. I can't see anything else unusual. I see trouble. (Subject E.K.)

Appendix B

STIMULUS WORD LISTS

	1	2	3	4	5	PROBE	ANSWER	TARGET
PRACTICE TRIALS								
	ring	can	boat	door	shell	can		3
	watch	fruit	moon	book	car	watch		2
	rain	boy	fish	desk	cup	desk		5
	rose	log	gate	shirt	hand	gate		4
1	nest	corn	suit	pie	truck	pie		5
2	hat	dog	salt	rock	barn	dog		3
3	bell	milk	cat	gun	thread	cat		4
4	sun	bed	ear	fence	check	sun		2
5	pipe	wheel	leaf	tail	cake	tail		5
6	egg	stick	yard	floor	rope	egg		2
7	pen	bird	man	wall	feet	bird		3
8	snake	ship	cage	arm	bus	snake		2
9	bridge	mouse	chain	school	light	chain		4
10	ball	tie	train	jar	girl	jar		5
11	nose	glass	cheese	heart	coat	glass		3
12	knife	roof	chair	duck	mouth	chair		4
13	cake	bell	hat	ship	moon	bell		3
14	check	egg	tie	cat	rose	check		2
15	boat	ear	desk	rope	cage	ear		3
16	milk	shirt	school	ring	log	ring		5
17	boy	car	duck	thread	glass	duck		4
18	tail	chain	girl	stick	roof	stick		5
19	heart	cheese	coat	bus	gun	heart		2
20	chair	gate	nose	truck	leaf	nose		4
21	mouth	snake	can	knife	salt	mouth		2
22	fence	ball	rock	suit	mouse	suit		5
23	feet	sun	corn	bed	pie	feet		2
24	yard	cup	light	fish	wall	fish		5
25	fruit	man	wheel	barn	nest	man		3
26	shell	train	arm	pipe	floor	arm		4
27	jar	door	watch	rain	bird	door		3
28	dog	pen	book	hand	bridge	book		4

Name Date SS#

Appendix C

INFORMATION ABOUT SERIAL POSITION EFFECT IN AUDITORY VERBAL SHORT-TERM MEMORY IN CONDUCTION & BROCA'S APHASIA

I am studying how your speech and your memory are related. Since you had your stroke, or other illness which caused brain injury, you may have found it difficult to speak. I am trying to find out if you are also having certain memory difficulties.

Although this study probably will not be of help to you personally, you may be helping to find out important things about speech and memory. There is absolutely no risk to your health.

I am going to have you listen to a list of words, 5 words long. After each list you will hear a word. Your job will be to think back and tell me which word in the list came after this word.

You do not have to take part in this study if you do not want to. Participation in this will in no way change the therapy you are receiving. If you decide to participate, you can stop at any time and it will not affect any care or treatments you are receiving in this hospital. The confidentiality of your medical records will be respected. If you have any questions I will be pleased to answer them. Your signature below indicates your willingness to participate.

PATIENT'S SIGNATURE | DATE

INVESTIGATOR | WITNESS

Appendix D
Table 9: Subject Data Table:
Conduction Aphasics

	Conduction Aphasics					
	J.B.	W.H.	M.R.	H.S.	C.S.	L.Z.
Sex	M	M	F	M	M	M
Age	61	68	70	60	53	63
TPO (yrs.)	2	9	1	2	1.3	1.5
Correct Scores Position 2	0	3	0	1	1	3
3	2	3	0	1	0	0
4	3	2	3	4	1	2
5	3	1	1	4	2	0
Total	8	9	4	10	4	5
Off Target Responses	12	5	15	3	12	11
BDAE Severity Rating	3.5	3.5	3.5	4	3.5	3.5
Z-Scores Aud. Comp.	.5	.75	Missing	.5	.5	.8
Overall Naming	.7	.5	Missing	.65	.3	.4
Overall Repetition	0	-.5	-1.5	.6	.3	-.75
Literal Paraphasia	-.1	2.5	Missing	2.5	2.5	2.5

Appendix E
Table 10: Subject Data Table:
Broca's Aphasics

	Broca's Aphasics					
	E.F.	K.G.	L.K.	I.M.	G.P.	R.W.
Sex	F	F	M	M	F	F
Age	63	31	68	48	27	61
TPO (yrs.)	10	1	6.5	.58	1	.66
Correct Scores Position 2	3	1	1	2	4	3
3	0	0	1	1	2	4
4	2	4	1	2	4	3
5	2	4	5	6	5	7
Total	7	9	8	11	15	17
Off Target Responses	11	1	5	7	7	1
BDAE Severity Rating	4	4.5	4	4	3	4
Z-Scores Aud. Comp.	.5	1.0	.5	.5	.6	1.0
Overall Naming	1.0	1.25	1.0	.6	.4	1.25
Overall Repetition	.7	.7	1.0	1.1	.8	1.1
Literal Paraphasia	-.5	-.5	-.4	-.4	-.3	-.3

Appendix F
Table 11: Subject Data Table:
Anomic Aphasics

	Anomic Aphasics							
	A.C.	E.K.	J.N.	F.N.	R.R.	D.R.	W.S.	M.T.
Sex	F	M	M	M	M	F	M	F
Age	53	55	50	53	67	55	57	66
TPO (yrs.)	5	.17	.58	1.42	.25	1.25	2	.33
Correct Scores Position 2	3	7	4	5	4	2	4	3
3	2	2	0	3	3	0	5	4
4	0	4	3	2	2	4	1	3
5	4	4	4	2	2	7	3	4
Total	9	17	11	12	11	13	13	14
Off Target Responses	3	5	8	2	16	5	2	6
EDAE Severity Rating	4	4	4.5	4	4.5	5	3.5	4.5
Z-Scores Aud. Comp.	.8	.9	1.0	.5	.7	.9	.9	1.0
Overall Naming	1.2	1.3	1.1	1.0	.45	1.2	1.2	1.2
Overall Repetition	1.1	1.1	1.1	1.1	.7	1.1	1.1	1.1
Literal Paraphasia	1.0	-.5	-.5	0	0	-.5	-.3	-.5