THE INFLUENCE OF THE SYLLABLE ON VERBAL LEARNING BY APHASICS

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ABSTRACT

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By

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This study investigated the effect of syllable versus whole word presentation of bisyllabic nouns presented to aphasic and control subjects in a short-term memory serial recall task. Earlier research had implied that aphasic individuals performed better on various short-term memory tasks involving verbal material when given additional processing time. The syllable has been postulated as the perceptual unit of speech perception (Massaro, 1972), yet there is a dearth of information regarding performance on serial recall when verbal material is presented at a basic perceptual level. The present study dealt with the relative efficiency of processing verbal material at the syllabic level and, more specifically, evaluated the effect of word type of the initial syllable presented apart from the second syllable of bisyllabic nouns. In addition, the effect of inter-word interval was investigated.

Nineteen aphasic individuals were grouped according to performance on the auditory comprehension subtest of the Boston Diagnostic

Aphasia Examination (Goodglass and Kaplan, 1972). Individuals who scored at least one standard deviation below the mean on the Z-score profile on one of the four auditory comprehension subtests constituted Group A, and those whose scores fell above the mean on the auditory comprehension subtests constituted Group B. There were nine aphasics in Group A and ten aphasics in Group B. Each aphasic subject had experienced a cerebral vascular accident and was at least one month post-onset of aphasia and not more than six months post-onset. Subjects had no concommitant neurological disorder. The eighteen control subjects were matched for age, sex, race, hearing acuity and educational background. Mean age for all three groups was sixty-one years.

The stimuli consisted of tape recorded lists of bisyllabic nouns presented in series of two, three, and four words. A program written for a PDP-11/40 computer inserted silences of 0, 250, or 375 msec between syllables, and 0 or 400 msec of silence between words in series. Thus, there was a total of six different temporal conditions of stimuli presentation. Stimuli were of three types. In Type 1 words, the initial syllable presented apart from the second syllable provided acoustic information only, for example, as in /fIŋ/ in the word finger. In Type 2 words, the initial syllable apart from the second syllable provided semantic and potential visual information which was complemented by the addition of the second syllable, for example, shoelace. In Type 3 words, the initial syllable apart from the second syllable provided semantic and potential visual information which was incongruent with the addition of the second syllable. For example, the semantic image created by the word arm does not present the same image as created by the word armchair.

Each subject received all three word types for each of the three series lengths, under each of the three inter-syllable conditions and two inter-word conditions, for a total of 162 responses per subject. The response task was to point to the series of pictures that matched auditory presentation in the order named. There were six pictures arranged in two rows of three pictures each on each of the test plates. Stimuli were presented in a controlled listening situation.

The results of this study indicated that aphasic adults process unrelated items in a short-term memory serial recall task less efficiently, but in the same manner as control subjects for two and three word series. Highest percent correct scores were seen for both aphasic groups for three word series when bisyllabic nouns were presented as entire words, with an inter-word interval of 400 msec between words in series. Presentation of verbal material to aphasics at the syllabic level did not necessarily enhance serial recall performance. Of special interest was the information load of the initial syllable presented apart from the second syllable. Word type was found to have little effect on recall except in the four item series. Group B aphasics and control subjects performed best with Type 1 words in which the initial syllable held acoustic information only, for example, as in the word finger. It was suggested that the initial syllable of Type 1 words more readily fused with the second syllable to create a semantic whole. This suggests that Type 1 words in the four word series created less of a semantic load in short-term memory.

Results of the study were discussed with reference to Paivio's (1971) Dual-coding hypothesis of memory. Paivio's model outlines separate systems for verbal and non-verbal information, but recognizes an interconnectedness of the systems so that a word arouses some corresponding perceptual image. It was suggested that given additional processing time aphasic subjects were able to recircuit auditory information into a visual mode and create a perceptual image in short-term memory. This was the preferred explanation to the more traditional viewpoint of the employment of a rehearsal strategy. Paivio noted that the non-verbal image system is not specialized for sequential processing, which is a function of the verbal representational system located anatomically in the left hemisphere. The Paivio model accounts for the reduced recall of order information as compared to recall of item information.

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INTRODUCTION

Results of formal research and clinical testing indicate that performance by aphasic subjects is deficient when learning verbal material during a short-term memory task, but that performance improves when the material is presented at a slower than normal speaking rate (Cermak and Moreines, 1976). Various studies have questioned whether encoding of verbal material is enhanced by introducing pauses at the phoneme, word, or phrase level in connected speech (Sheehan and Aseltine, 1973; Weidner and Lasky, 1976). The syllable has been postulated as the basic unit of speech perception (Massaro, 1972), yet there is a dearth of information regarding performance on serial recall tasks when verbal material is presented at the syllabic level. Further, the type of coding strategy used by aphasics during short-term memory verbal learning tasks is not well known. It is the purpose of this study to investigate the verbal learning and coding strategies used by aphasic persons on a short-term memory task and, more specifically, to determine the relative efficiency of processing visual or acoustic verbal material presented at the syllabic level.

Models of Perceptual Processing

Numerous models of perceptual processing which discuss the interaction between short-term memory (STM) and long-term memory

(LTM) have been proposed. Most models are similar in that they outline at least two stages of perceptual processing.

Aaronson, Markowitz and Shapiro (1971) designated a low level or sensory stage of processing and a higher level or perceptual stage of processing in which the identification or encoding item and order information takes place. Aaronson et al. suggested that the two stage perceptual processor is differentially affected by the duration of the stimulus and by the pause time between the stimuli. They argued that internal processing may not be carried out effectively while the external auditory stimulus is present. Therefore, you would expect to find improved serial recall performance of order information when longer processing time is available between items. This assumption was upheld in their study of immediate recall of seven-digit sequences in the compressed condition where digits were time compressed by 33%, thereby allowing longer intervals between items.

Norman (1968) outlined two forms of memory storage, primary and secondary, as different aspects of one large storage system. Norman contended that formal distinction between the two storage systems was difficult to determine, yet operational differences were apparent. Primary storage was described as an active system which received sensory input and was continually changing. Primary storage was capable of handling a limited number of items whose trace decayed rapidly after four or five items had been added. Norman described secondary storage as passive and permanent. According to Norman, perceptual processing involved matching sensory items from primary storage to its stored representation in secondary storage.

Current theorists have favored a STM model in which visually presented stimuli are transferred to an auditory store for immediate storage and recall (Conrad, 1964; Sperling, 1963). Such a model has been based upon immediate recall of letter sequences presented visually to normal subjects. Error analyses revealed a greater than chance number of errors which were acoustically rather than visually similar to the target stimuli.

Wallington and Shallice (1972) took issue with the above model and postulated the existance of a separate post-perceptual visual store in STM. Their argument was based upon their case report of a conduction aphasic tested on the letter sequence recall paradigm presented either visually or auditorily. The response task was to recall in writing the exact sequence of letters presented. The Peterson procedure, in which random numbers are read aloud as fast as possible during a delay period between presentation and recall to prevent rehearsal of the test items, was employed. Error analyses of recall performance of visually presented sequences revealed less than chance incidence of acoustic errors and a significantly higher than chance incidence of visual errors, that is, errors that were visually similar to the target stimuli.

Wallington and Shallice noted that their aphasic subject performed better when stimuli were presented visually rather than auditorily. This data conflicted with the performance of normal subjects who demonstrated superior recall of auditory as opposed to visual sequences in STM tasks (Crowder and Morton, 1969; Wallington and Shallice, 1972). Wallington and Shallice suggested that in

normal subjects it was likely that the visual STM system was masked by the superior capacity of the auditory STM system. The authors suggested that, for the conduction aphasic, the visual STM system was operating in relative independence.

Evidence for inter-modality switching from auditory input to a visual code in short-term memory was offered by Posner (1969). He examined reaction times on a matching task for paired letters using normal adults. The first letter was presented either auditorily or visually (always upper-case). Subjects were instructed to imagine an upper-case letter in the auditory presentation condition. The duration of the first letter was approximately .5 sec followed by a delay of about .75 sec. The second letter was always presented visually and was either the upper-case (pure condition) or mixed with respect to case of the initial letter (mixed condition).

Results of the study indicated that reaction time in the mixed condition was faster when matching stimuli on visual features as opposed to a name basis, regardless of whether the initial letter was presented visually or auditorily. Posner suggested that subjects based their matches upon some kind of visual code in the auditory condition rather than matching at the name level.

The Posner experiment was replicated using delay periods of 0, .5, and 1 sec between the first auditory/visual letter and the second visual letter. Results of the study showed that after the 1 sec interval the auditory condition was faster than the visual match at the name level, and at least as fast as the visual identity match. In order to explain the highly efficient visual matches from auditory input, Posner postulated the concept of a "...generation of a visual code" (p. 82). Subjective reports from his subjects indicated that they "expect" or "are looking for," or, more rarely, "see" some specific visual information in the interval following presentation of the letter name.

Studies of Aphasic Performance on Serial Recall Tasks

Goodglass, Gleason and Hyde (1970) included an auditory sequential Pointing-Span Test as part of their auditory language comprehension assessment in aphasics. The performance of aphasics was compared with that of normal adults and children. A series of monosyllable-nouns ranging from two to six items were presented by the examiner at the rate of one word per second. A plate containing pictures of all the test items was held face down until the series was presented. Four different test plates were rotated to avoid the possibility of position expectation. Each word was first presented to the aphasic subjects to make sure that the vocabulary items were known and recognized. Results of the Pointing-Span Test indicated that even the best aphasic performance was below that of the average level of normal six year olds.

Tzortis and Albert (1973) presented an extensive battery of sequential memory tasks to aphasics classified according to the Speech Pathology Section, Aphasia Research Unit, V.A. Hospital in Boston. A repetition measure of primary interest was the auditory input-pointing response task, whereby subjects were asked to point to pictures of words in the order named. Sequences increased from one to four items per sequence. Words were presented at the rate of one word per second orally by the examiner. Results of the study indicated that the aphasic subjects, regardless of clinical type, could frequently recall all of the items in a sequence, but not in the order presented.

Albert (1976) compared aphasic (A+) performance on an auditory verbal short-term memory task with brain-damaged nonaphasic (A-) subjects and normal controls. In Albert's first experiment each subject was asked to point to three or four objects in the order named from a choice of 18 common objects which were placed in front of the subject. Error analyses were computed in terms of omissions (failure to provide an item requested without substitution), substitutions (the subject pointed to an item not requested), or incorrect sequences of correct items. Results indicated that:

> Controls made equal amounts of omissions and sequencing errors (20% of errors were of each type). For each brain-damaged group omission errors were the most prominent type: and there was no significant difference between A+ and A- for this type of error (A+ 54%, A- 56%). Sequencing-type errors, however, in aphasics reached 34%, while in controls and nonaphasic brain-damaged subjects, they accounted for 20% each of all errors. At the level of four-item responses...the difference between A+ and A- for sequencing errors was significant ($z=3.68$, $p<0.05$, z cut-off for significance= 1.64). For responses in which three items were indicated, the difference between A+ and A- for sequencing errors was not significant, but was nearly so ($z=1.31$).

Albert (1976) conducted a second experiment in which the same three experimental groups were required to point to two items in the order named from the choice of 18 items. Results indicated that the aphasics made significantly more errors (omission-type) than did the other groups, but sequencing errors did not reach significant differences between the groups at the two item recall level. Albert concluded from these studies that aphasic individuals have significantly impaired auditory short-term memory both for total item information and for verbal sequence.

Temporal Analysis of Sequence: A Function of the Left Hemisphere

It has been suggested that the left hemisphere is responsible for sequencing acoustic stimuli. Albert and Bear (1974) presented a case study of an aphasic with pure word deafness who was required to report the number of clicks heard in a one second period. A digitimer controlled stimulator generated 200 microsecond pulses which were presented through stereophonic headphones. According to the authors, a range of accurate counting in normals is eight to 11 clicks per second. Their aphasic subject, however, was inaccurate at rates above two clicks per second.

In a second experiment the same aphasic subject was required to report having heard one or two clicks as the interval between onset of two brief binaural pulses was varied. Their subject could distinguish two clicks at 15 msec separation, below which time two stimuli appeared "fused" into one click. Normals could distinguish two clicks at one to two msec separations.

Efron (1963) studied aphasics' ability to distinguish between a high and a low tone of ten msec duration. The tones were pulse frequencies of 250 pps and 2500 pps and subjects were required to report which tone was heard first or if the tones were simultaneous. Efron found that at a 100% correct response threshold, nonaphasic controls required a briefer interstimulus interval, that is, 130 msec, in order to sequence the tones than expressive aphasics who required 575 msec. Receptive aphasics required 235 msec to sequence the tones. Efron noted that every subject with a dominant hemisphere lesion who had difficulty with temporal analysis also had some degree of aphasia. Efron stated:

> Disorders of the central mechanism(s) for sequence analysis and control might thus account for certain essential aspects of the symptoms of aphasias, apraxias, and possibly other disturbances of "higher" functions, particularly memory and consciousness (p. 423).

Ebbin and Edwards (1967) presented pairs of nonsense CVs at 0 and 200 msec intervals. Aphasic and nonaphasic individuals with brain pathologies were required to judge the CV pairs as same or different. Results of the study indicated that the aphasics' performance improved when the stimuli were separated by 200 msec. Ebbin and Edwards suggested that aphasia may be a temporally-based impairment.

Efron (1963) and Albert and Bear (1974) contended that the left hemisphere was dominant for the capacity to sequence acoustic stimuli. When damage occurs to the left hemisphere and produces aphasia, additional processing time is required before decisions relating to temporal sequences of non-meaningful acoustic and verbal stimuli can be made.

Conjectured Role of the Right Hemisphere in Aphasia

Seamon and Gazzaniga (1973) contended that the cognitive system of the right hemisphere was specialized for image processes. This contention was based in part on an earlier study by Seamon (1972).

What was unique about that study was that retrieval processes, as measured by reaction time in STM using a probe-word technique, were dependent upon encoding strategies. Normal adults were instructed to either: 1) rehearse the stimuli subvocally, 2) generate an image for each word, but to keep them separated, or 3) imagine the stimuli as an interactive set. Gazzaniga and Seamon suggested that by manipulating encoding instructions, wholly different brain systems were called upon to process information. Gazzaniga (1973) contended that the visual system of the right hemisphere can function in parallel with the language system to aid the left brain-damaged individual. Gazzaniga suggested that one can "shunt" around a brain lesion by using different cognitive systems of the brain in the solution of a language problem.

Albert and Bear (1974), noting improved comprehension by their aphasic subject with pure word deafness when sopken to in a slowed rate, suggested the possibility that the right hemisphere might be processing linguistic information independently as a result of damage to the left hemisphere. Since linguistic processing, however, is not a natural role of the right hemisphere, Albert and Bear proposed that linguistic inputs must be presented at a slowed rate in left brain-damaged persons.

The Question of the Basic Unit of Speech Perception

Massaro (1972) suggested that the syllable is the perceptual unit of speech perception. Massaro contended that during perceptual processing syllabic information is extracted from the stimulus image and this "synthesized percept enters consciousness or short-term memory as a unit" (p. 140).

Massaro reviewed the study by Liberman, Cooper, Shankweiler and Studdert-Kennedy (1967). They noted that the second formant transition in a CV unit such as /di/ was essential to the perception of the initial consonant. When the initial part of the CV pattern was presented in isolation it was perceived as a nonspeech sound. With the addition of the second formant transition the perception of the unit categorically changed to /di/. Thus, they concluded that the second formant transition was essential to the perception of the initial consonant in CV units.

Massaro (1972) interpreted the results of the Liberman et al. study as convincing evidence that the syllable was the perceptual unit of speech perception.

Not all researchers were in complete agreement with Massaro. Studdert-Kennedy (1976) suggested that the syllable is the basic acoustic unit of speech perception, but not the basic linguistic and perceptual unit as Massaro maintained.

Statement of the Problem

Several investigations have determined that aphasics demonstrate deficient performance for both item and order information on STM serial recall tasks (Goodglass et al., 1970; Tzortis and Albert, 1974; Albert, 1976). It has been repeatedly suggested that processing of verbal material by aphasic individuals improves when presented at a slower rate (Cermak and Moreines, 1976; Weidner and Lasky, 1976; Albert and Bear, 1974; Gardner et al., 1975). Aaronson et al. (1971) postulated that what may be crucial for encoding item order in serial recall tasks is the amount of time available between items. Studies of serial recall with aphasics, however, have not extensively dealt with the manipulation of interstimulus interval. Further, two investigations reviewed in this study dealt with the presentation of stimuli at the rate of one item per second (Goodglass et al., 1972; Tzortis and Albert, 1974). Serial recall position curves for aphasic performance on serial recall tasks have not been studied.

In the Goodglass et al. study, stimulus items were monosyllables. Albert (1976) did not control for stimulus syllable length. The syllable has been postulated as the basic unit of speech perception (Massaro, 1972), yet it is not well know if perceptual processing of verbal material by aphasics improves when presented at the syllabic level.

A post-perceptual visual store has been postualted by Wallington and Shallice (1972). Posner (1969) provided evidence for intermodality switching from auditory input to a visual code in STM. Gazzaniga (1974) suggested that the imagery mechanism associated with language behavior appears to be a right hemisphere process, and he further suggested that the right hemisphere might function in parallel with the left to aid the language processing system following insult to the left hemisphere.

In summary, the purpose of this study was to investigate the verbal learning and coding strategies used by aphasic persons in a STM serial recall task. Specifically, the following questions were investigated:

1. What effect does presenting verbal material at the syllabic level have on serial recall in a pointing-span task presented to aphasic and normal adults? Is there a difference in performance when syllables are separated by an interval of 375 msec as opposed to 250 msec?
2. Do aphasics demonstrate primacy and recency effects in serial recall of four item series? That is, is processing of earlier items in a list of unrelated items superior to processing of later items in the list? Is there improved recall for the last item presented?
3. Is there a positive effect on recall performance when the inital syllable presented apart from the second syllable of a bisyllabic noun lends itself to potential visual storage? Specifically, what effect do complementary images such as those created by the word shoe and by the word lace in the word shoelace have on recall? Is there a difference in recall performance when the potential visual image created by the initial syllable of a bisyllabic noun, presented apart from the second syllable, is incongruent with the image created by the second syllable? For example, the visual image created by the word arm is incongruent with the image of a chair in the word armchair.

4. How does recall performance of bisyllabic nouns in which the initial syllable does not lend itself to visual storage, as in the word finger, compare to recall of bisyllabic nouns in which potential visual storage is available?
5. Aaronson et al. suggested that interstimulus interval is crucial to recall of serial order. Do the results of the present study support this contention?

EXPERIMENTAL PROCEDURES

Subjects

Participants in this study were selected based upon the categories of aphasic versus control subject.

Aphasic group: The nineteen persons selected for inclusion in the aphasic group were diagnosed as aphasic by a neurologist or Speech and Language Pathologist, based upon an etiology of cerebral vascular accident (CVA), in the left hemisphere. All aphasic subjects were right handed prior to their CVA. Persons were at the stage of at least one month post-onset of aphasia and not more than six months post-onset. All subjects were currently enrolled in speech therapy or had received speech therapy following the onset of aphasia. Subjects were tested in Battle Creek, Grand Rapids, Jackson, Lansing, and Royal Oak, Michigan. Persons displaying symptoms of confusion, disorientation, bilateral brain pathology or concommitant neurological disease pathology were not included in this study. One subject reported that he had a right visual field deficit, but that he had learned to compensate for the visual field cut by turning his head to scan for peripheral items in his right visual field.

The aphasic subjects were grouped according to performance on the auditory comprehension subtest of the Boston Diagnostic Aphasia

Examination (Goodglass and Kaplan, 1972). Individuals who scored at least one standard deviation below the mean on the Z-score profile on one of the four auditory comprehension subtests constituted Group A, and those whose scores fell above the mean on the auditory comprehension subtests constituted Group B. There were nine aphasics in Group A and ten aphasics in Group B. All of the aphasics had some degree of expressive impairment.

Control group: The 18 persons selected for inclusion in the control group were non-neurologically impaired adults approximately matched with the aphasic subjects on the basis of chronological age, sex, education, hearing acuity and race. The age range for the control subjects was 37 to 75 years with a mean age of 61 years. The age range for Group A aphasics was 41 to 78 years with a mean age of 61 years. For Group B aphasics, the age range was 46 to 77 years with a mean age of 62 years.

In Group A aphasics eight individuals had a high school education while one individual had one additional year of coursework beyond the high school level. In Group B aphasics eight individuals had a high school education, one indiviudal had two additional years of coursework beyond the high school level, and one individual had earned a Ph.D. In the control group three individuals had four years of college beyond the high school level, while the reamining 15 individuals had a high school education.

The distribution of male and female subjects was as follows. There were four males and five females in Group A aphasics, four males and six females in Group B aphasics, and seven males and 11 females in the control group. Overall, there were eight males and 11 females in the aphasia groups combined and seven males and 11 females in the control group.

All of the subjects in this study were Caucasian.

Hearing screening: Subjects in both groups were screened audiometrically via air conduction at 30 dB at 500, 1000, and 2000 Hz. The pure tone average for these frequences was no greater than 30 dB (re: ISO 1964) for the better ear of each aphasic person accepted as a subject.

Stimuli

The stimulus tapes consisted of sequences of two syllable words which were one of three types (See Table 1):

1) Type 1. In Type 1 words, the initial syllable presented apart from the second syllable provided acoustic information only, for example, as in /fIŋ/ in the word finger. Syllable division was agreed upon by four out of five judges who had taken at least one college level course in phonology.
2) Type 2. In Type 2 words, the initial syllable apart from the second syllable provided semantic and potential visual information which was complemented by the addition of the second syllable, for example, shoelace.
3) Type 3. In Type 3 words, the initial syllable apart from the second syllable provided semantic and potential visual information which was incongruent with the addition of the second syllable. For example, the semantic image created by the word arm does not present the same image as created by the word armchair.

TABLE 1. Test item by type.

Type 1.	The initial syllable presented apart from the second syllable provides acoustic information only.
	finger, cookie, oven, nickel, curtain, sweater, garden, table, sugar, blanket, shampoo, shaver, ruler, razor, saucer, paper, butter
Type 2.	The initial syllable presented apart from the second syllable provides semantic and potential visual information which is complemented by the addition of the second syllable.
	shoelace, bookcase, lampshade, wristwatch, bathtub, doornob, doormat, earring, bedspread, doghouse, inkwell, mousetrap, washcloth, iceberg, matchbook, pinecone, toothbrush
Type 3.	The initial syllable presented apart from the second syllable provides semantic and potential visual information which is incongruent with the addition of the second syllable.
	armchair, cowboy, cupcake, greenhouse, ice cream, housecoat, grapefruit, sheepdog, scotchtape, towtruck, t-shirt, sundae, boxcar, drawbridge, football, manhole, headlight

The majority of the stimulus words were selected from workbooks written for aphasics, including Photo Language Stimulation for Aphasic Patients (Canetta, 1974) and Speech and Language Rehabilitation A Workbook For The Neurologically Impaired (Keith, 1972). Black and white line drawings representing each word were selected from the Places and Things Card Set, Modern Education Corporation. In order to make comparable drawings for words not included in this material, pictures were traced or drawn onto the test plate. Final test plates were xerox copies in order to minimize any distracting differences in ink-type. Each test plate had six items arranged in two rows of three pictures each. Each picture measured approximately 2½ x 2½ inches. (See Appendix A for the test word plates).

Each word type was presented in sequences of two, three, and four items. An inter-syllable interval of 0, 250, or 375 msec was programmed between syllables. Words in sequence were separated by 0 or 400 msec pauses. There were a total of six temporal conditions presented. These conditions were as follows:

1) Condition 1. Stimuli were presented at the syllabic level with 375 msec of silence programmed between the first and second syllable of each word and 400 msec of silence programmed between words in series, thus, $S_1 375 S_2 400 S_{1a} 375 S_{2a}$.
2) Condition 2. Stimuli were presented at the syllabic level with 250 msec of silence programmed between the first and second syllable of each word and 400 msec of silence programmed between words in series, thus, $S_1 250 S_2 400 S_{1a} 250 S_{2a}$.

3) Condition 3. Stimuli were presented at the whole word level with a naturally spoken inter-syllable interval with 400 msec of silence programmed between words in series, thus, $S_1S_2400S_{1a}S_{2a}$.
4) Condition 4. Stimuli were presented at the whole word level with a naturally spoken inter-syllable interval with 0 msec of silence programmed between words in series, thus, $S_1S_2S_{1a}S_{2a}$.
5) Condition 5. Stimuli were presented at the syllabic level with 375 msec of silence programmed between the first and second syllable of each word and 0 msec of silence programmed between words in series, thus $S_1375S_2S_{1a}375S_{2a}$.
6) Condition 6. Stimuli were presented at the syllabic level with 250 msec of silence programmed between the first and second syllable of each word and 0 msec of silence programmed between words in series, thus, $S_1250S_2S_{1a}250S_{2a}$.

These six temporal conditions are summarized in Table 2 (See Table 2).

Two forms of the test were developed, form A and form B, to control for order of presentation of temporal condition. Half of the subjects received form A which followed the temporal order of conditions one through six listed immediately above. For form B, the order of presentation was the reverse of form A. That is, subjects first received the condition in which stimuli were presented at the syllabic level with 250 msec of silence programmed between the first and second syllable of each word and 0 msec of silence programmed between words in series (Condition 6). The last test condition in form B was the condition in which stimuli were presented at the

TABLE 2. Six temporal conditions of stimulus presentation.

1. 375 msec inter-syllable interval (ISI), 400 msec inter-word interval (IWI), thus, $S_1 375 S_2 400 S_{1a} 375 S_{2a}$
2. 250 msec ISI, 400 msec IWI, thus, $S_1 250 S_2 400 S_{1a} 250 S_{2a}$
3. naturally spoken ISI, 400 msec IWI, thus, $S_1 S_2 400 S_{1a} S_{2a}$
4. naturally spoken ISI, 0 msec IWI, thus, $S_1 S_2 S_{1a} S_{2a}$
5. 375 msec ISI, 0 msec IWI, thus, $S_1 375 S_2 S_{1a} 375 S_{2a}$
6. 250 msec ISI, 0 msec IWI, thus, $S_1 250 S_2 S_{1a} 250 S_{2a}$

Where: S_1 = first syllable of the initial bisyllabic noun in the word series

S_2 = second syllable of the initial bisyllabic noun in the word series

S_{1a} = first syllable of the second bisyllabic noun in the word series

S_{2a} = second syllable of the second bisyllabic noun in the word series syllabic level with 375 msec of silence programmed between the first and second syllable of each word and 400 msec of silence programmed between words in series (Condition 1).

Words in sequence were all of one word type and were randomly chosen from each of the three word lists. A test stimulus was not used more than once at any given inter-syllable/inter-word combination for each series length. There were three trials of each word type at each sequence length, at each temporal condition.

Each subject received his first word type at all syllable conditions for two word series followed by three word and four word series. He then received his next word type in the same manner, until he had received all the experimental stimuli for a total of 162 responses.

Preparation of Experimental Tapes

The test words were recorded by a female, General American speaker. The speaker exhibited normal fundamental frequency (f_0= 245 Hz), and speaking rate (171 syllables per minute reading rate). The stimuli were recorded inside a sound chamber onto a MCI tape recorder (Model JH-110) with a frequency response of 50 to 20,000 Hz $\pm$ 2 dB. Recording level was monitored at VU $\pm$ 3 dB reading. Representative samples were played into a PDP 11/40 computer (Digital Equipment Corporation), into the analog to digital converter. The sampling rate was 12,500 samples per second. The numbers from the converter were stored on disc. Each word was recorded once and used repeatedly in different word series. The program inserted the appropriate silence of either 0, 250, or 375 msec between syllables and 0 or 400 msec of silence between words in series.

In order to distinguish between speech and silences, the digital signals were filtered through a second order digital filter. The positions of the pole on the z plane were .9 away from the origin with angles of $\pm$ 100 Hz. Zeros were on the unit circle at $\pm$ 60 Hz creating a high pass filter designed to reject frequencies of 60 Hz or lower.

For each word a procedure involving several steps was used to determine the beginning and end of the syllables. First, the stored signal was partitioned into sections of sound and silence, so that those periods defined as "sound" contained speech energy and those defined as "silence" did not. This partition was made in the following manner. The peak amplitude of the signal during a word was determined. A "silence" was then defined as any period of over five msec during which the absolute value of the signal remained less than 1% of the peak amplitude. In other words, in order for any segment to be considered a "silence" that is, non-speech segment, it had to have a duration of greater than five msec during which the absolute value of the segment remained less than 1% of the peak amplitude for that particular word, which had previously been determined. Each segment of the signal containing speech energy was monitored both aurally and visually on a digital GT-44 graphics system (Digital Equipment Corporation) to determine whether it was part of the first or second syllable. (See Figure 1 for a schematic of this process.)

In some instances, one segment of sound was found to contain portions of both syllables. When this happened, the segment was

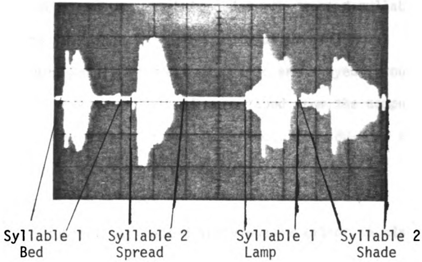


Figure 1. Schematic of segmentation of test stimuli.

divided into two continuous subsegments at a subjectively determined point, so that the first subsegment belonged to the first syllable and the second subsegment belonged to the second syllable. This occured in less than 8% of the stimulus words.

Stimuli were then created on disc and played through a digital to analog converter. Stimuli were taped from the computer onto a Sony Solid State Cassette Recorder (Model TC-180-AV), using high quality recording tape (Memorex ATC).

Presentation Procedures

Each subject was tested individually either in his home or in a rehabilitation unit of a hospital. The tester sat next to the subject to operate the tape recorder and to present the appropriate test plate at the completion of the auditory presentation. The response task was to point to the sequence of pictures that matched auditory presentation in the order named. The order of each subject's responses was noted by the experimenter for later item-order analyses. This was accomplished by marking down the order of pictures chosen from the test plate. The experimenter referred to the top three items in the test plate as items one through three, proceeding in a left to right orientation, and referred to the three items in the bottom row of the test plate as items four through six.

The following instructions were read to each subject by the tester:

> You will hear a series of words. Some will be broken up into two parts. Words will be presented in groups of two's, three's, and four's. Some will be presented more slowly than others. Your task is to listen to each group of words and then point to the picture of the words in the order that you heard them. Do you have any questions?

Questions were entertained and practice items were presented. There were a total of twelve practice items, four items for each of the three series lengths. Half of the practice items were spoken with natural phrasing of syllables and half had silence between syllables in words. If an error was made on a practice item the experimenter demonstrated the correct response. The practice items assured the experimenter that the subject understood the task before actual testing was begun. During actual testing each subject was given as much time as he required to respond.

The tape recorder was placed in front of the subject, approximately 18 inches from the chair of the listener. The signal at the chair of the listener averaged 70-75 dB SPL.

Individual data sheets were completed for each subject listing basic identifying information, experimental condition order, and scores for each experimental condition. (See Appendix B).

The aphasics received eight subtests from the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1972) after completing the experimental tasks. This included the four subtests for the Naming section and the four subtests for Auditory Comprehension. Results were plotted on the Z-Score Profile of Aphasia Subscores and were used to designate two aphasic groups, as noted earlier.

Aphasic individuals were seen on two separate occasions in most instances to avoid fatigue. The time interval between sessions did not exceed ten days.

Error Classification

Following the procedure outlined by Albert (1976), performance was scored in terms of the following paradigm:

1) omission - failure to provide an item requested without substitution.
2) substitution - pointing to items not requested.
3) sequence errors - pointing to all of the items named but not in the correct order.

Error Analysis

Performance for each word type, inter-syllable interval, inter-word interval, and sequence length was analyzed. Comparisons between aphasic and normal persons were made. An analysis of serial order errors was completed.

For primacy and recency effect only those series in which four items were chosen when four items were presented were selected for evaluation.

RESULTS

The results of this study indicated that aphasic adults process unrelated items in a short-term memory serial recall task less efficiently, but in the same manner, as normal adults for two and three item series. Highest percent correct score for serial recall was seen for both aphasic groups on the three item series when bisyllabic verbal material was presented as entire words with an inter-word interval of 400 msec of silence programmed between words in series. These results are shown in Figure 2 and Table 3. Word type had a minor effect on recall in the four item series for conditions in which stimuli were presented at the syllabic level (see Figures 3, 4, 7, 8).

<u>Performance of Group A Aphasics</u>

The performance of Group A aphasics, that is aphasics who scored at least one standard deviation below the mean on at least one of the four auditory comprehension subtests of the Boston Diagnostic Aphasia Examination, on two item serial recall was not strongly influenced by either whole word presentation or inter-word interval (see Figure 2 and Table 3). Four conditions fell within a mean performance range of $\pm$ 5% correct. These conditions were: 1) stimuli presented at the whole word level without a silent pause between words in series ($S_1S_2S_{1a}S_{2a}$, as shown in Figure 2), 2) stimuli

Figure 2. Serial recall performance by group, condition and series length.

Note: Figure 2 was derived from data contained in Table 3.

▲ = Stimuli presented at the whole word level with 400 msec of silence programmed between words in series.

△ = Stimuli presented at the whole word level with 0 msec of silence programmed between words in series.

○ = Stimuli presented at the syllabic level with 375 msec of silence programmed between the first and second syllable of each word and 400 msec of silence programmed between words in series.

● = Stimuli presented at the syllabic level with 250 msec of silence programmed between the first and second syllable of each word and 400 msec of silence programmed between words in series.

□ = Stimuli presented at the syllabic level with 375 msec of silence programmed between the first and second syllable of each word and 0 msec of silence programmed between words in series.

■ = Stimuli presented at the syllabic level with 250 msec of silence programmed between the first and second syllable of each word and 0 msec of silence programmed between words in series.

——— Group A aphasics' performance which includes the cluster of six conditions immediately below.

•••••• Group B aphasics' performance which includes the cluster of six conditions immediately below.

- - - - Control group's performance which includes the cluster of six conditions immediately below.

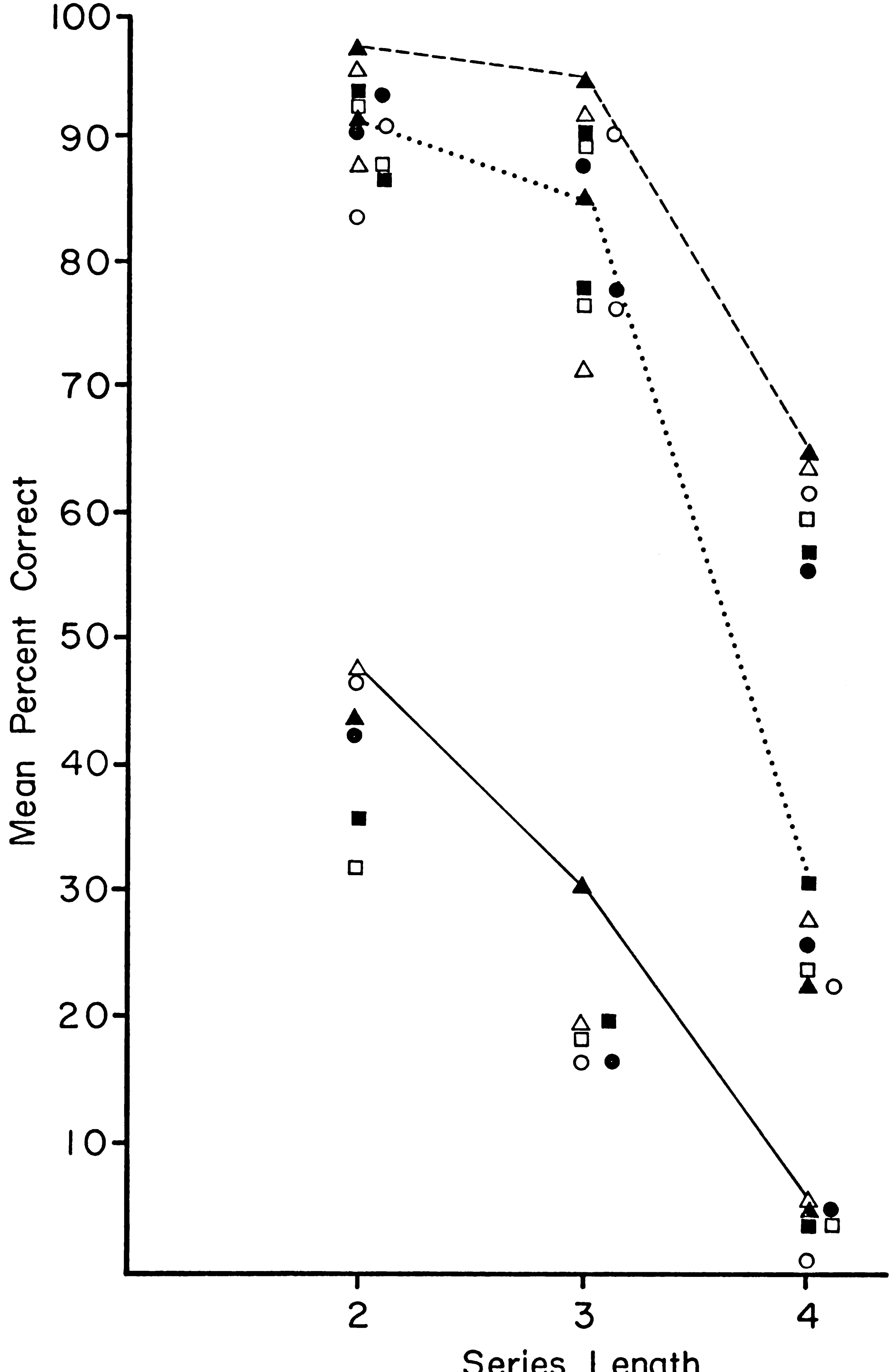

100
90
80
70
60
50
40
30
20
10
Mean Percent Correct
2
3
4
Series Length

Figure 2.

TABLE 3. Mean percentage correct score and range for serial recall by condition, series length, and test group.

$S_1S_2400S_{1a}S_{2a}$: Stimuli presented at the whole word level with 400 msec of silence between words in series

	2 item series	3 item series	4 item series
Group A Aphasics (N=9)			
Mean Percentage	44%	31%	5%
Range	11-89%	0-89%	0-22%
Group B Aphasics (N=10)			
Mean Percentage	92%	86%	23%
Range	67-100%	67-100%	0-67%
Control Subjects (N=18)			
Mean Percentage	97%	95%	65%
Range	56-100%	33-100%	11-100%

$S_1S_2S_{1a}S_{2a}$: Stimuli presented at the whole word level without pauses between words in series

	2 item series	3 item series	4 item series
Group A Aphasics (N=9)			
Mean Percentage	48%	20%	6%
Range	11-100%	0-67%	0-22%
Group B Aphasics (N=10)			
Mean Percentage	88%	72%	28%
Range	56-100%	22-100%	0-67%
Control Subjects (N=18)			
Mean Percentage	96%	92%	64%
Range	44-100%	33-100%	11-100%

$S_1375S_2400S_{1a}375S_{2a}$: Stimuli presented at the syllabic level with 375 msec of silence programmed between syllables in words and 400 msec of silence between words in series

	2 item series	3 item series	4 item series
Group A Aphasics (N=9)			
Mean Percentage	47%	17%	1%
Range	11-77%	0-78%	0-11%
Group B Aphasics (N=10)			
Mean Percentage	84%	77%	23%
Range	56-100%	33-89%	0-67%
Control Subjects (N=18)			
Mean Percentage	91%	91%	62%
Range	0-100%	44-100%	11-100%

TABLE 3. (Continued)

	2 item series	3 item series	4 item series
$S_1 250 S_2 400 S_{1a} 250 S_{2a}$: Stimuli presented at the syllabic level with 250 msec of silence programmed between syllables in words and 400 msec of silence between words in series			
Group A Aphasics (N=9)			
Mean Percentage	43%	17%	5%
Range	0-78%	0-89%	0-22%
Group B Aphasics (N=10)			
Mean Percentage	91%	78%	26%
Range	78-100%	44-89%	0-56%
Control Subjects (N=18)			
Mean Percentage	94%	88%	56%
Range	33-100%	0-100%	11-100%
$S_1 375 S_2 S_{1a} 375 S_{2a}$: Stimuli presented at the syllabic level with 375 msec of silence programmed between syllables and no silence programmed between words in series			
Group A Aphasics (N=9)			
Mean Percentage	32%	19%	4%
Range	11-78%	0-56%	0-11%
Group B Aphasics (N=10)			
Mean Percentage	88%	77%	24%
Range	67-100%	0-100%	11-67%
Control Subjects (N=18)			
Mean Percentage	93%	90%	60%
Range	11-100%	22-100%	0-100%
$S_1 250 S_2 S_{1a} 250 S_{2a}$: Stimuli presented at the syllabic level with 250 msec of silence programmed between syllables in words and no silence programmed between words in series			
Group A Aphasics (N=9)			
Mean Percentage	36%	20%	4%
Range	0-78%	0-67%	0-11%
Group B Aphasics (N=10)			
Mean Percentage	87%	78%	31%
Range	67-100%	33-100%	11-67%
Control Subjects (N=18)			
Mean Percentage	94%	91%	57%
Range	22-100%	11-100%	11-100%

presented at the syllabic level with 375 msec of silence programmed between the first and second syllable of each word and 400 msec of silence between words in series ($S_1375S_2400S_{1a}375S_{2a}$, as shown in Figure 2), 3) stimuli presented at the whole word level with 400 msec of silence programmed between words in series ($S_1S_2400S_{1a}S_{2a}$, as shown in Figure 2), 4) stimuli presented at the syllabic level with 250 msec of silence programmed between the first and second syllable of each word and 400 msec of silence between words in series ($S_1250S_2400S_{1a}250S_{1a}250S_{2a}$, as shown in Figure 2).

The mean percentage correct score and range for each of these four conditions were as follows. For the condition in which words were presented at the whole word level without a silent pause programmed between words in series ($S_1S_2S_{1a}S_{2a}$), the mean percentage correct score was 48% with a range of 11% to 100% correct performance. For the condition in which words were presented at the syllabic level with 375 msec of silence programmed between the first and second syllable of each word and 400 msec of silence programmed between words in series ($S_1375S_2400S_{1a}375S_{2a}$), the mean percentage correct score was 47% with a range of 11% to 77% correct performance. For the condition in which words were presented at the whole word level with 400 msec of silence programmed between words in series, ($S_1S_2400S_{1a}S_{2a}$), the mean percentage correct score was 44% with a range of 11% to 89% correct performance. Finally, for the condition in which words were presented at the syllabic level with 250 msec of silence programmed between the first and second syllable of each word and 400 msec of silence programmed between words in series,

($S_1 250_2 400S_{1a} 250S_{2a}$), the mean percentage correct score was 43% with a range of 0% to 78% correct performance.

The importance of inter-word interval for serial recall for Group A aphasics was most evident in the three item series. Group A aphasics performed maximally when words were presented at the whole word level with 400 msec of silence programmed between words in series. The 400 msec of silence between stimuli may have allowed time for rehearsal of the serial items and/or permitted longer processing time for matching the auditory stimulus with its semantic and/or visual referent in long-term memory.

Performance on four item series was equally difficult in all conditions. Percent correct performance ranged from 1% to 6%. Regardless of condition, four item serial recall was beyond the encoding capabilities of Group A aphasics.

Performance of Group B Aphasics

Group B aphasics, that is, those aphasics whose scores fell above the mean on the auditory comprehension subtests of the Boston Diagnostic Aphasia Examination, achieved within 9% of the highest score of control subjects on two and three item serial recall tasks (see Figure 2 and Table 3). Optimal performance by Group B aphasics for both two and three item serial recall was for the condition in which stimuli were presented at the whole word level with 400 msec of silence programmed between words in series ($S_1 S_2 400S_{1a} S_{2a}$). In the three item series, there was an 8% performance advantage when stimuli were presented at the whole word level with 400 msec of silence programmed between words in series. Group B, like Group A aphasics, were able to benefit from silence programmed between stimuli. Thus, the 400 msec of silence may have allowed subjects to rehearse the stimuli and/or permitted time to match the auditory stimulus with semantic meaning and/or visual imagery in long-term memory.

Comparisons between Group B aphasics and control subjects on four item tasks indicated that aphasic performance fell 34% below the best performance by the control subjects. Optimum performance for Group B aphasics on the four item series was for the condition in which 250 msec of silence was programmed between syllables in words without concurrent silence programmed between words in series ($S_1 250 S_2 S_{1a} 250 S_{2a}$). Despite the fact that this condition demonstrated only a 3% advantage over the next highest condition in the four item series it was an interesting occurance. This was the only time throughout the entire test that the $S_1 250 S_2 S_{1a} 250 S_{2a}$ condition showed any superiority for recall performance. This condition might best be described as the rhythmic condition since the absence of interword interval provided a strange tempo in presentation and suggests that novel, rhythmic stimuli may contribute to the processing capabilities of Group B aphasics.

<u>Performance of Control Subjects</u>

Serial recall (see Figure 2 and Table 3) for all conditions in the two and three item series was met with at least 88% correct performance with a range of 88-97%. Four item series responses ranged from 56% to 65% mean percentage correct. Control subjects demonstrated optimum performance for two, three, and four item series

consistently in two conditions: 1) when stimuli were presented at the whole word level with 400 msec of silence programmed between words in series ($S_1S_2400S_{1a}S_{2a}$), and 2) when stimuli were presented at the whole word level without an inter-word interval ($S_1S_2S_{1a}S_{2a}$). There was less than a 3% difference in serial recall between these two conditions for all three series lengths. These results raise questions pertaining to the validity of the importance of inter-word interval for serial recall for two, three, and four word series in normal adults.

Aaronson et al. (1971) suggested that listeners use pause time between items for identifying them in a particular order. The Aarsonson study involved recall of seven-digit series. It may be that inter-word interval becomes crucial to serial recall for words in series beyond the four word level. Both the Aaronson et al. study and the present study presented tape recorded verbal stimuli. It should be pointed out, however, that the present study differed from the Aaronson et al. study in that the response task was to point to the visual representation of the word instead of requiring a verbal repetition of verbal stimuli. Differences between the two studies can also be attributed to the nature of the stimuli. The Aaronson et al. study used digits whereas in the present study concrete nouns were employed.

The present investigation indicated that serial recall of four word series was a difficult task for normal adults as well as aphasic individuals. Mean percent correct performance was 65% for the condition in which stimuli were presented at the whole word level with

400 msec of silence programmed between items ($S_1S_2400S_{1a}S_{2a}$). This condition showed only a 1% advantage over presentation of stimuli at the whole word level without a silent inter-word interval ($S_1S_2S_{1a}S_{2a}$).

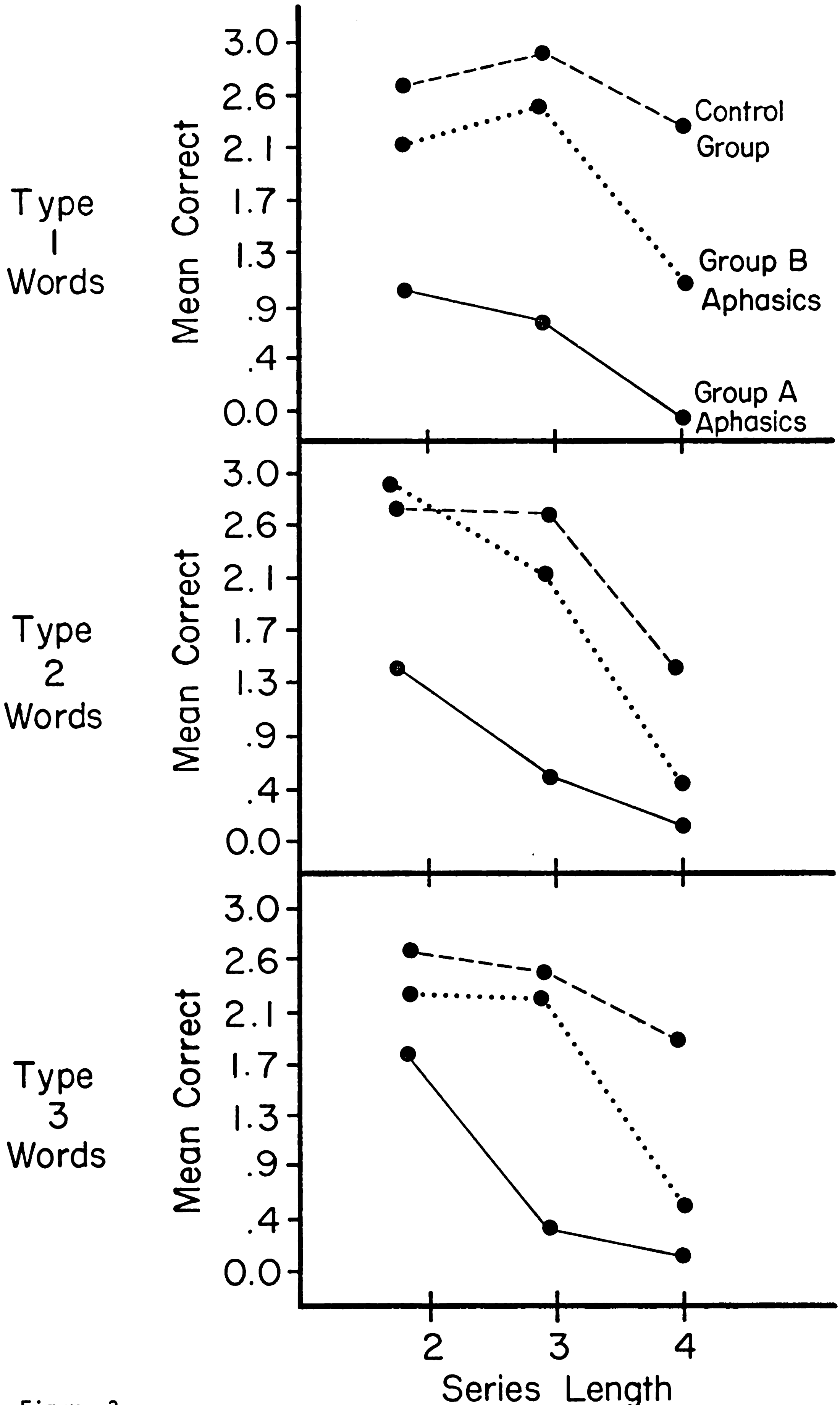
Influence of Word Type on Serial Recall

Word type did not effect recall performance for any test group for two and three item series (see Figures 3 through 8). However, for the four item series in the condition in which stimuli were presented at the syllabic level, results showed that recall of Type 1 words was higher than Type 2 or Type 3 words (see Figures 3, 4, 7, 8). In Type 1 words the initial syllable provided acoustic information without semantic meaning (see Table 1). Both Group B aphasics and control subjects showed higher recall of Type 1 words in the four item series when stimuli were presented at the syllabic level.

These results suggested that semantic interpretation and/or visualization of the inital syllable of bisyllabic stimuli presented in four item series enhanced processing difficulty. That is, syllables separated by silent intervals of 250 or 375 msec may not readily fuse to create a semantic whole. Thus, the individual was left with eight syllables in short-term memory, each with its own semantic and/or visual image, as opposed to four bisyllable units. Type 2 and Type 3 words seemed to exert a greater load on short-term memory serial recall than did Type 1 words. For Type 1 words the acoustic information of the inital syllable was more likely to fuse into a single unit upon presentation of the second syllable.

Figure 3. The effect of word type on stimuli presented at the syllabic level with 375 msec of silence programmed between the first and second syllable of each word and 400 msec of silence programmed between words in series.

Note: Figures 3 through 8 were derived from data contained in Table 3.



Type 1 Words
Type 2 Words
Type 3 Words
Mean Correct
3.0
2.6
2.1
1.7
1.3
.9
.4
0.0
Control Group
Group B Aphasics
Group A Aphasics
2
3
4
Series Length

Figure 3.

Figure 4. The effect of word type on stimuli presented at the syllabic level with 250 msec of silence programmed between the first and second syllable of each word and 400 msec of silence programmed between words in series.

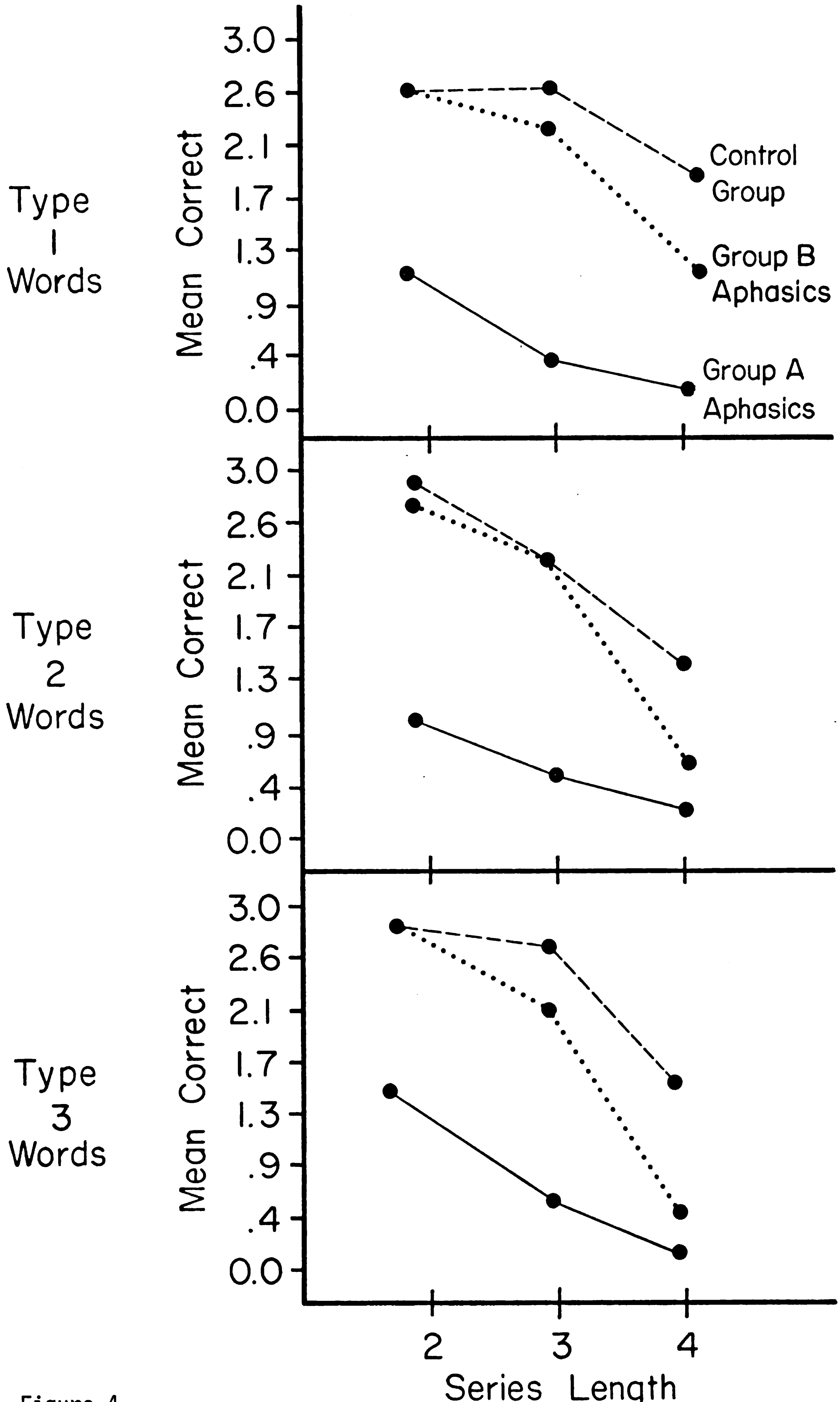

Type
1
Words
Type
2
Words
Type
3
Words
Mean Correct
3.0
2.6
2.1
1.7
1.3
.9
.4
0.0
Control Group
Group B Aphasics
Group A Aphasics
2
3
4
Series Length

Figure 4.

Figure 5. The effect of word type on stimuli presented at the whole word level with 400 msec of silence programmed between words in series.

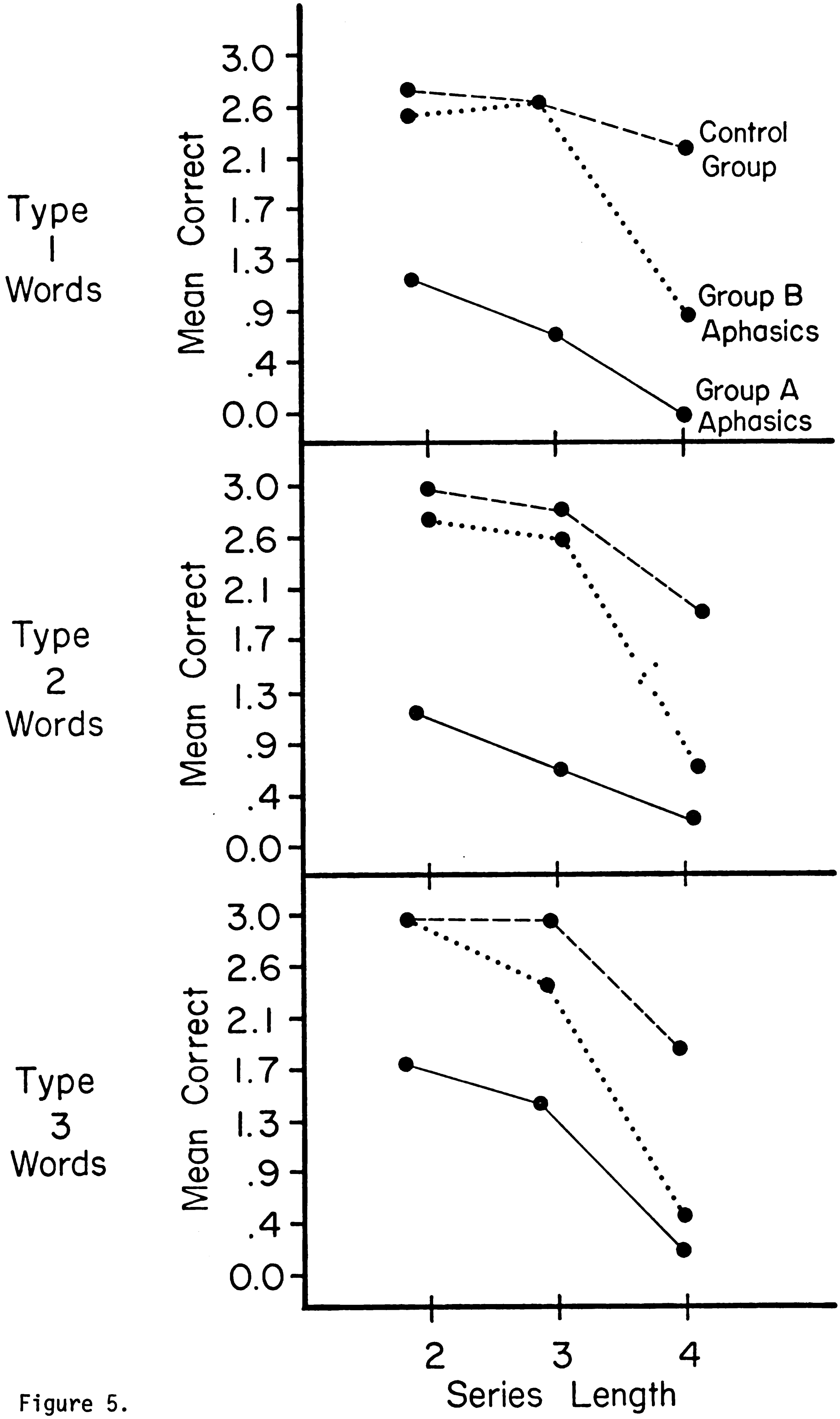
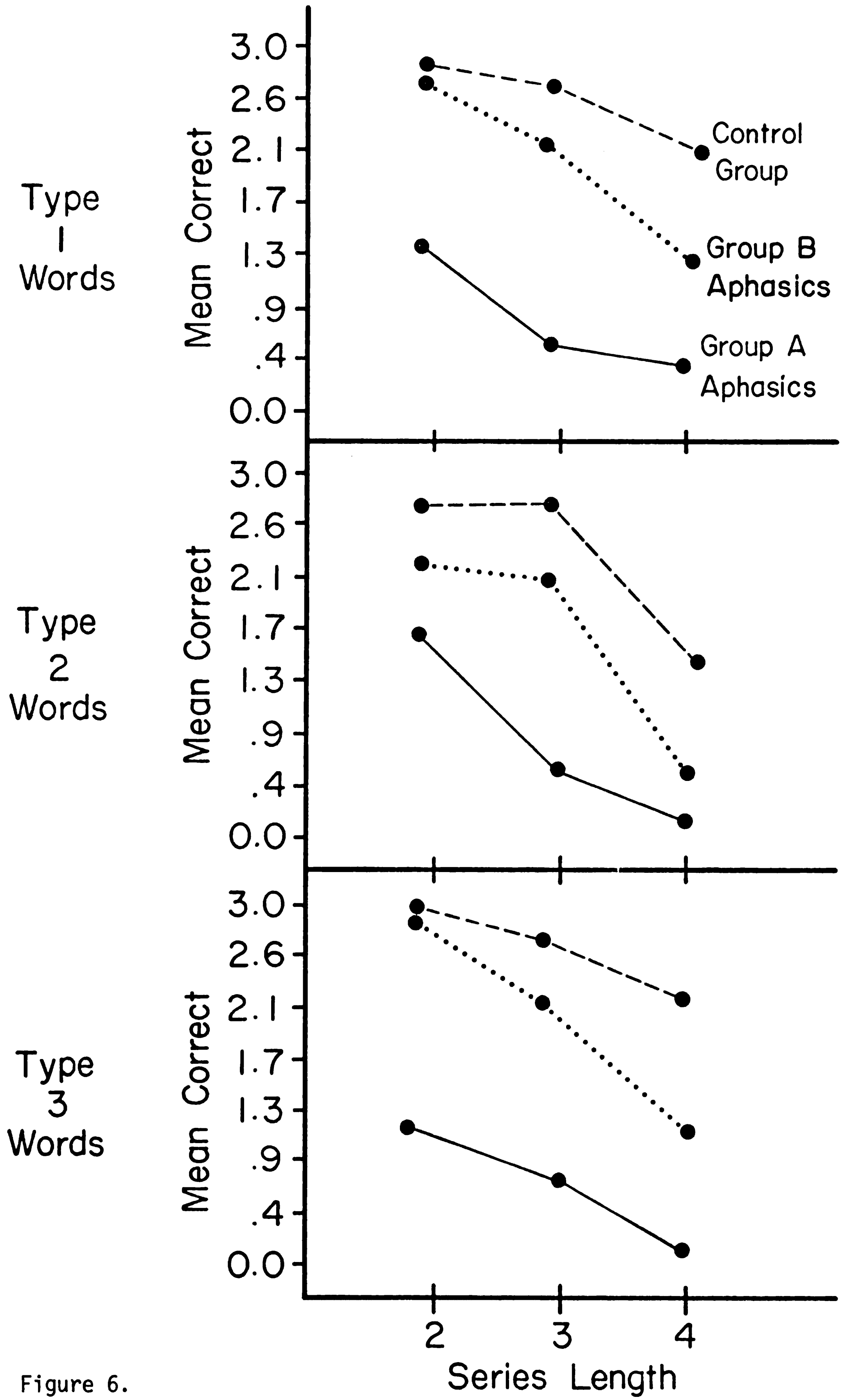

Type
1
Words
Type
2
Words
Type
3
Words
Mean Correct
3.0
2.6
2.1
1.7
1.3
.9
.4
0.0
Control
Group
Group B
Aphasics
Group A
Aphasics
2
3
4
Series Length

Figure 5.

Figure 6. The effect of word type on stimuli presented at the whole word level with 0 msec of silence programmed between words in series.



Type 1 Words
Type 2 Words
Type 3 Words
Mean Correct
3.0
2.6
2.1
1.7
1.3
.9
.4
0.0
Control Group
Group B Aphasics
Group A Aphasics
2
3
4
Series Length

Figure 6.

Figure 7. The effect of word type on stimuli presented at the syllabic level with 375 msec of silence programmed between the first and second syllable of each word and 0 msec of silence programmed between words in series.

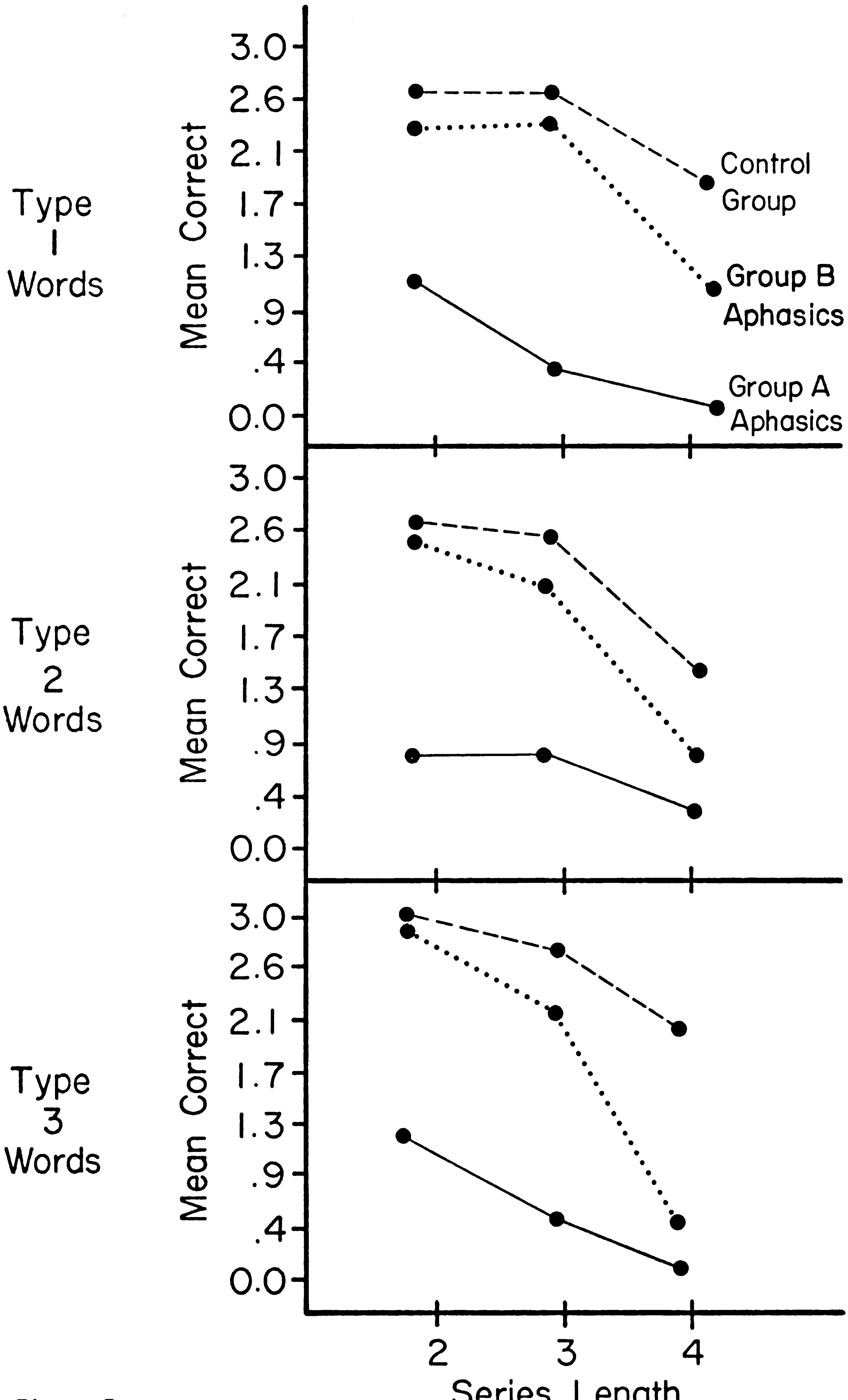
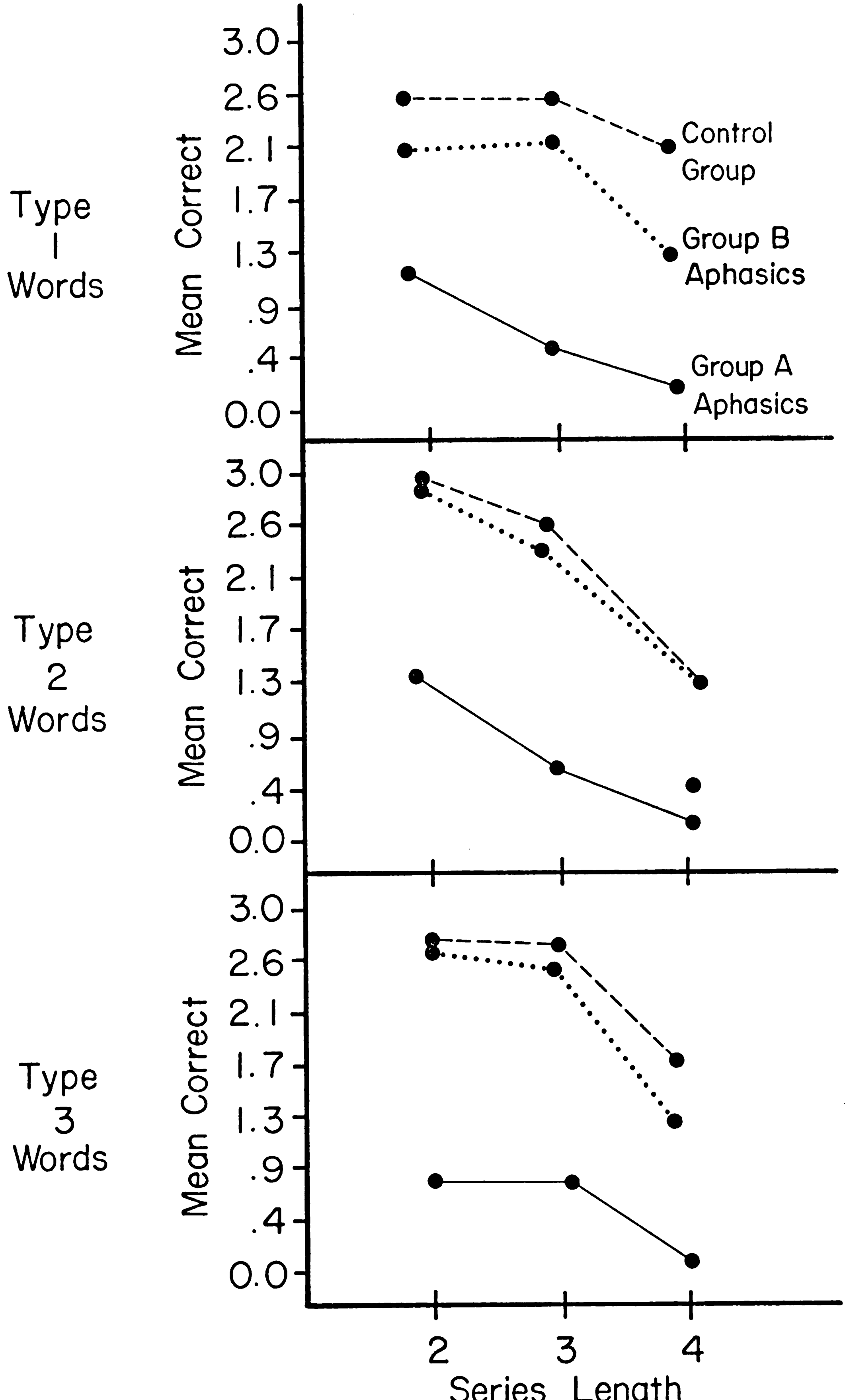

Type
1
Words
Type
2
Words
Type
3
Words
Mean Correct
3.0
2.6
2.1
1.7
1.3
.9
.4
0.0
Control
Group
Group B
Aphasics
Group A
Aphasics
2
3
4
Series Length

Figure 7.

Figure 8. The effect of word type on stimuli presented at the syllabic level with 250 msec of silence programmed between the first and second syllable of each word and 0 msec of silence programmed between words in series.



Type 1 Words
Type 2 Words
Type 3 Words
Mean Correct
3.0
2.6
2.1
1.7
1.3
.9
.4
0.0
Control Group
Group B Aphasics
Group A Aphasics
2
3
4
Series Length

Figure 8.

Primacy and Recency Effects in Four Item Lists

A serial position curve (see Figure 9) was evaluated for each of the three test groups. The control group demonstrated a primacy and recency effect, that is, they showed superior recall for initial and final items as compared to recall of medial items. A comparison of the final item to the initial item indicated that the control group demonstrated a superior recall for the intial item by a 10% margin.

Group B aphasics clearly demonstrated a primacy effect, but a less pronounced recency effect as compared to the control group. Recall of the final item for Group B aphasics was no better than recall of the second item in the list. Group B aphasics demonstrated a 20% mean performance advantage for the initial item as compared to the final item. This suggested that earlier items in the series were more accurately processed than later items in the series.

Serial recall performance of Group A aphasics indicated a definite primacy effect. However, a linear decline in recall was noted for items two through four. Again, recall of the initial item surpassed recall of the final item by a 20% mean performance difference, suggesting that earlier items in the list were more accurately processed than later items in the list.

The results of this study suggested that recall of the initial item in a four word list was superior to recall of later items for both aphasic groups and the control group.

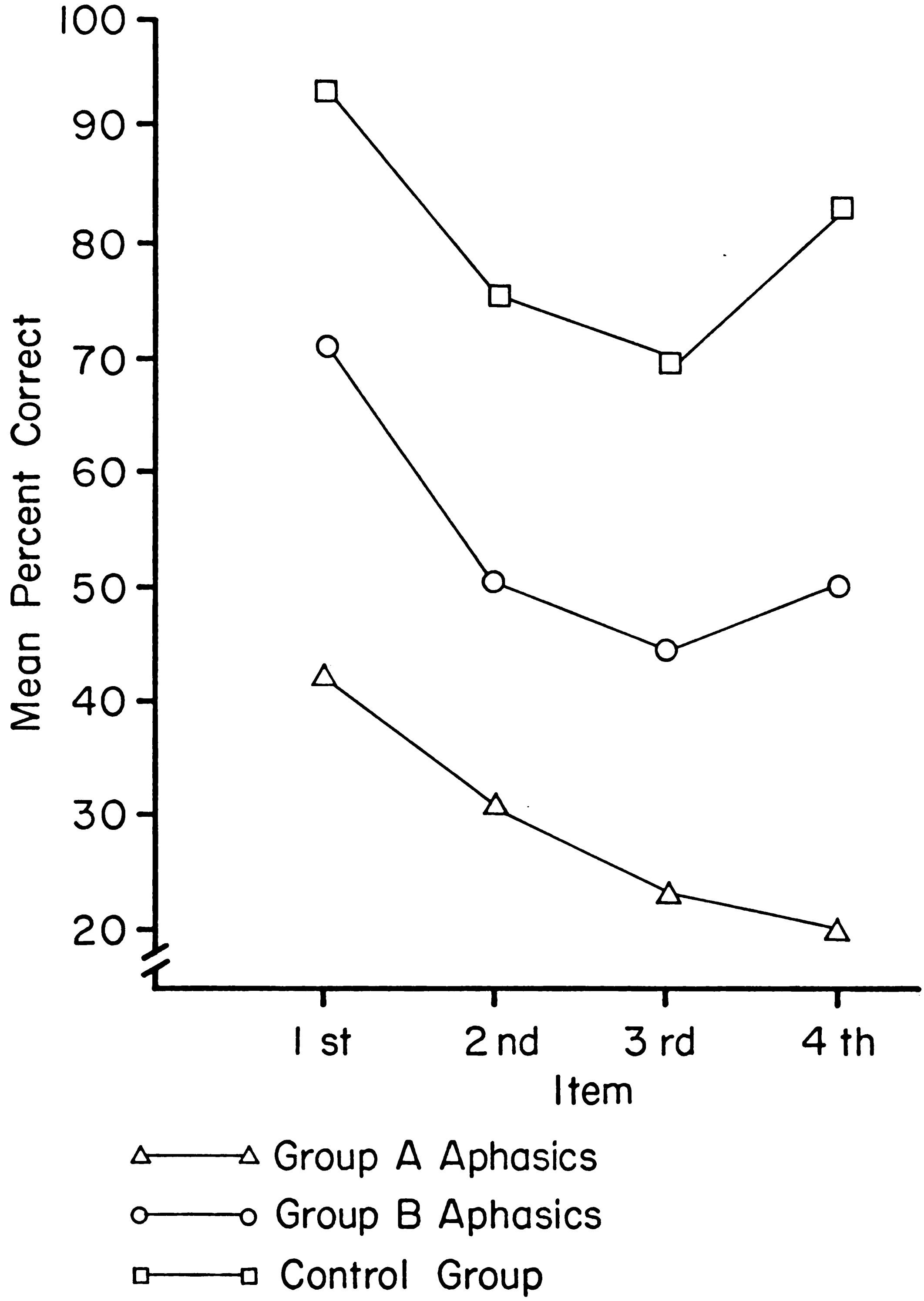


Figure 9. Serial position curve for four item list.

Recall of Item versus Order Information

Albert (1976) raised the question of whether short-term memory for item information was separate from short-term memory for order information. In that study Albert concluded that item and order information were separate capacities of short-term memory. He suggested that aphasic individuals regardless of clinical type demonstrated impairment for both item and order information in short-term memory serial recall tasks.

The results of the present study, in contrast to Albert's conclusion, suggested that for aphasic individuals loss of item information may be a function of degree of comprehension deficit. The present study showed that aphasic individuals without an appreciable comprehension deficit (as measured by scoring above the mean on the auditory comprehension subtest of the Boston Diagnostic Examination for Aphasia) scored above 75% mean correct performance on item information. Short-term memory for two, three, and four word sequences for Group B aphasics was 91%, 93% and 79% respectively (see Figure 10).

Those aphasics who scored below the mean on the auditory comprehension subtest, that is, Group A aphasics, demonstrated both item and order deficits on two, three, and four item tasks. At no time did mean correct performance approach the 75% performance level (see Figure 10).

Control subjects scored above 90% mean correct level for all series lengths for item information and for two and three item series when order information was evaluated. All three test groups

Figure 10. Item and order information of two, three and four word sequences.

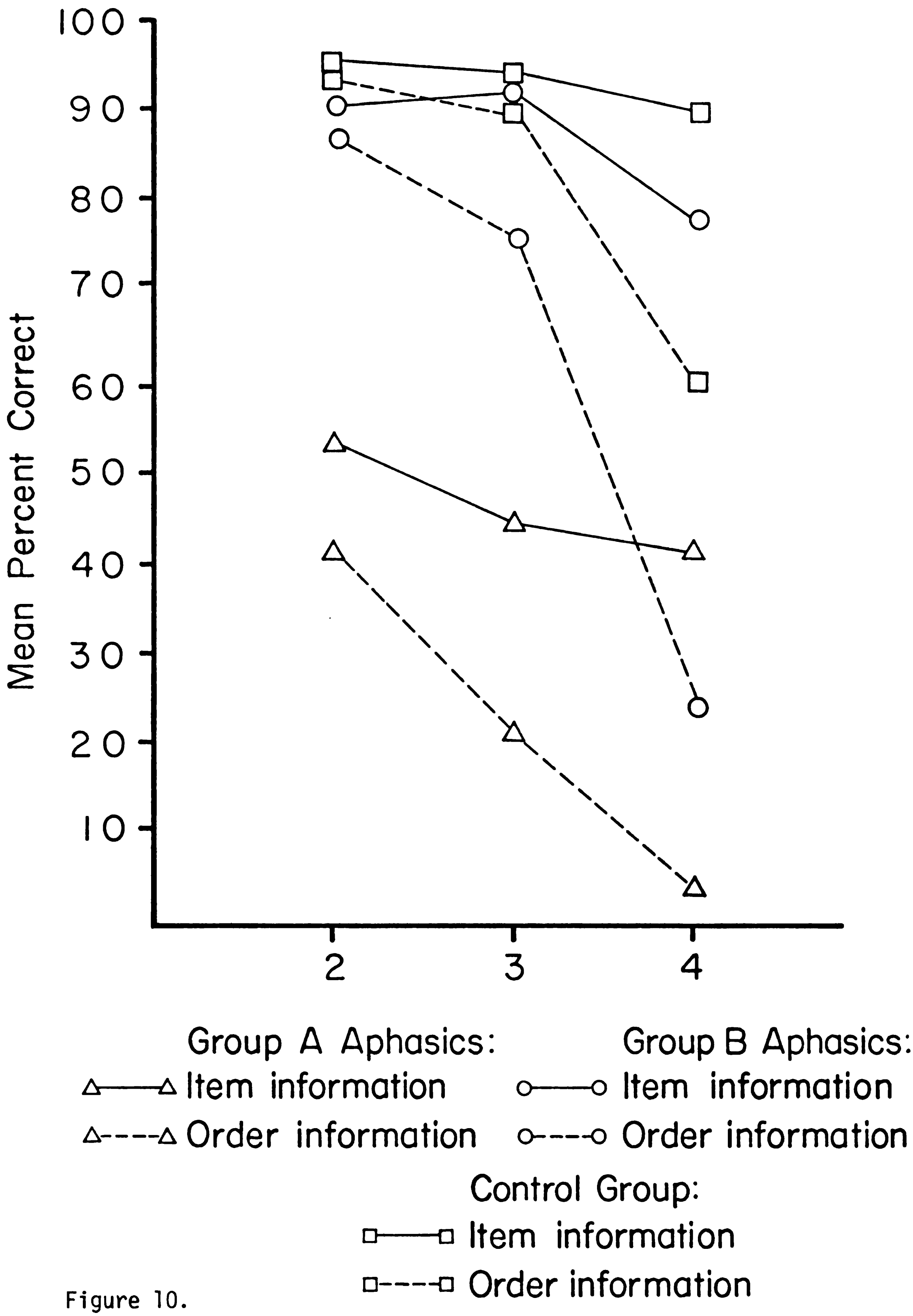

100
90
80
70
60
50
40
30
20
10
Mean Percent Correct
2
3
4
Group A Aphasics:
Item information
Order information
Group B Aphasics:
Item information
Order information
Control Group:
Item information
Order information

Figure 10.

demonstrated a decline in recall of order information as the information load increased, with a substantial decrease in recall performance for four item sequences.

DISCUSSION

The findings of this study were in agreement with aphasia literature which suggests that given additional processing time aphasics' scores improve on various tasks involving verbal material.

Influence of the Syllable on Serial Recall

The results of this study indicated that presenting verbal material to aphasics at the syllabic level does not necessarily enhance serial recall performance. Further, it was hypothesized that aphasics would benefit from syllable presentation of Type 2 words which allowed additional time to process semantic and visual information unique to the initial syllable of the spondee (see Table 1). This did not, however, turn out to be the case.

Results of this study indicated that serial recall was optimal when verbal material was presented as entire word units rather than in syllables, for all word types considered. This suggests that aphasic individuals, including those individuals with a marked auditory comprehension deficit, process bisyllable nouns as whole word units.

Miller (1969) contented that "...language has a hierarchial structure of units--sounds, words, phrases, sentences, narratives--and it is there that one should seek evidence for a similar hierarchy of cognitive units" (p. 12).

The Role of Rehearsal for Serial Recall

The study indicated that aphasics demonstrated highest serial recall performance on three word series when bisyllables were presented with 400 msec of silence programmed between words. This supports the conclusion drawn by Aaronson, Markowitz and Shapiro (1971) that silence periods between items enhanced the processing of order information. Rehearsal is one of four control processes or acquired strategies that an individual can use for retaining information in short-term memory (Chi, 1976). Rehearsal entails subvocal or audible revocalization of verbal units in serial fashion for purpose of serial recall. In order for rehearsal to be an effective strategy there must be time to rehearse between items or between presentation of the test stimuli and actual response. It is highly questionable that Group A aphasics were able to use the additional processing time between items to retain order information.

Evaluation of individual responses indicated that two of the nine aphasics in Group A repeated the words in sequence, but did not point to pictures in the correct order. One other individual typically responded by repeating the first word of the series, but simultaneously pointed to some other picture presented later in the series or one not asked for at all. These results seem to indicate that revocalization of the auditory stimuli did not necessarily assure correct serial identification of pictures in the pointing-span task.

Four of the nine aphasics in Group A did not demonstrate audible rehearsal at any time during testing. This does not discount the possibility, however, that rehearsal was taking place subvocally. Lashley (1951) maintained that "...internal speech may be carried out wholly by processes within the nervous system, with some unessential discharge upon the final common path for vocal movements" (p. 187).

It is highly suspect, however, that rehearsal enhanced serial recall for the majority of Group A aphasics. Rehearsal was certainly a handicap for individuals with aphasia complicated by dyspraxia. In those cases audible revocalization resulted in numerous literal paraphasias where phonemes were substituted for the intended phoneme. Recognition of the error and attempts at correction may have served to distract the individual's attention from the remainder of the serial string.

One individual from Group A who attempted rehearsal ended up producing inappropriate and distracting word series following the first word. For example, when rehearsing the initial word grapefruit the individual continued to name items within the semantic category but not included in the test, for example, "grapefruit, oranges." Rehearsal of the series beginning with the word sundae resulted in the memorized sequence "sundae, Friday, Saturday."

Luria (1972) suggested that selective organization of relevant mental processes is no longer possible for aphasics. "Every stimulus begins to evoke a whole complex of reactions, and weak or unimportant associations are evoked with the same probability as strong or important ones" (p. 38). This was certainly true of the individual just described.

Use of the Visual System in Short-Term Memory Recall

Paivio (1971) presented a Dual-coding hypothesis of memory which outlined separate systems for verbal and non-verbal information. Paivio (1975) stated that the two coding systems were "...functionally independent but partly interconnected cognitive systems for encoding, storing, organizing, transforming, and retrieving stimulus information" (p. 59).

Paivio outlined four levels of his model. Of special interest to the present study is the referential level which referred to "the activation of an established interconnection between images and verbal representations, so that a word arouses some corresponding perceptual image..." (p. 60). Paivio suggested that the term 'referential' recognizes the semantic relation between words and things. The image evoked by a verbal stimulus for each individual is a function of his unique perceptions probably influenced by such factors as past experience and attentional bias. It is not uncommon for discrepancies to result from an image an individual has created upon hearing a word and the intended representation in the mind of the speaker or tester. Comments from the subjects in the present study suggested that they had visually imagined some representation of the test stimuli other than the ones presented on the test plate. For example, one person commented, "Oh, that's your headlight."

Inspection of the item versus order information graphs (see Figure 10) indicated a slight improvement on the three item series for item information as compared to the two item series for Group B aphasics. This unexpected improvement might implicate encoding of bisyllabic nouns in the visual system. Any initial discrepancy between the subject's self generated image of the verbal stimulus and the actual drawing on the test plate may have interfered with ready selection of the intended drawing resulting in error responses in the two item series. A slight improvement by Group B aphasics for three word series is not surprising, then, due to the order of presentation of test stimuli. Two word series preceded three and four word series for each word type. By the time the three word series were presented the individual was familiar with the intended drawing for each stimulus.

One must consider different cognitive systems in order to explain the discrepancy in aphasic performance between retention of item information versus retention of order information. Research involving split brain subjects, individuals with unilateral hemisphere lesions and normal subjects tested with the dichotic listening technique has provided substantial insight into the performance strengths of left versus right cerebral hemisphere. The left hemisphere is specialized for language processes including the sequencing of verbal stimuli (Haggard, 1974; Albert, 1972; Efron, 1963; Lashley, 1951). The right hemisphere is believed to be particularly specialized for the analysis of spatial relationship, part-whole configuration, face recognition, and visual memory (Seamon and Gazzaniga, 1973; Paivio, 1975; Galin, 1974).

In the present study the condition in which stimuli were presented at the whole word level with 400 msec of silence between words allowed optimal recall performance for both aphasic groups.

Given additional processing time between words in series it is possible that the aphasic persons were able to "recircuit" the verbal information contained in the test stimulus to a more operative visual mode and create a visual image of the verbal stimulus (Porch, personal communication, 1977). However, these visual images were not necessarily held sequentially in STM as was evident in the aphasic persons low performance on serial recall.

Seamon (1972) contended that recall performance of noun stimuli depended upon which cognitive system, right or left hemisphere, was dominant in the task. Seamon suggested that instructions to visualize noun stimuli in a short-term memory task, thereby utilizing the right hemisphere, did not eliminate the possibility of concurrent verbal rehearsal. However, if auditorily presented noun stimuli were encoded as a spatial group or as separate visual items without recourse to verbal rehearsal, it was less likely that temporal order of the presented stimuli would be maintained.

The results of the present study were consistent with Paivio's contention that noun stimuli could be held in short-term memory by the visual system without regard to sequential order of presentation.

<u>An Alternative Explanation: Cerebral Dominance as a Decision System</u>

Aphasiologists have been studying the language capacity of the right hemisphere for several years. The assumption that the right hemisphere has certain language capacities that can assist the pathological left hemisphere was favored by Albert and Bear (1974). They maintained, however, that since language processing is not the ordinary function of the right hemisphere, verbal stimuli must be presented at a slowed rate.

Gazzaniga (1974) formulated a hypothesis which suggested that the right hemisphere plays a role in language processing. Gazzaniga maintained that during the early stages of language acquisition the child is exploring his world with both hands laying down perceptions of all kinds in both cerebral hemispheres. This accounts for what Gazzaniga calls bilateral engram formation. Gazzaniga maintained that a "...wide variety of cerebral processes are involved in language and general cognitive behavior and these processes are managed at any of a number of different cerebral cites--both in the left and right hemispheres" (p. 367).

Gazzaniga viewed the phenomenon of cerebral dominance as a decision system. He suggested that this decision system begins to develop around age two, coinciding with the myelination of the corpus callosum. Physiological evidence is cited for the dominance advantage exhibited by the left hemisphere: 1) the planum temporale is enlarged in 67% of the population in the left cerebral hemisphere (Geschwind and Levitsky, 1968); 2) the developing pyramidal tract shows projections from the left hemisphere beginning to cross before those on the right. Based upon these structural-genetic factors, Gazzaniga acknowledges the left hemisphere's predisposition to dominance.

Gazzaniga contended that engrams for language and perceptions of all kinds are established in both cerebral hemispheres up until eight years of age. About this time an "...inhibitory mechanism develops emanating from the dominant language processing systems in the left hemisphere, which limits the cognitive decision capability of the right hemisphere" (p. 368). Gazzaniga described this control system as involved in language activity, but also functioning as a superordinate system to "...institute order in a chaotic cognitive space" (p. 368).

The 400 msec of silence programmed between items in certain conditions in the present study may have allowed the processing time necessary to tap the linguistic capabilities of the right hemisphere.

The Influence of Novel Stimuli on Performance by Group B Aphasics

An unexpected performance by Group B aphasics was observed for the four item series. Optimal recall performance was for the condition in which 250 msec of silence was programmed between the first and second syllable of each word, without concurrent pauses between words in series. This condition was described as "sing-song" by one of the control subjects.

Sokolov (1963) suggested that novelty in the stimulus item results in an orienting reflex, situated in the nuclei of the brain stem reticular formation. (This concept was originally proposed by Pavlov in 1910). According to Sokolov, the orienting reflex is "...a sign that the nervous system has detected a change in the stimulus, that it has differentiated one stimulus from another" (p. 283). It occurs regardless of whether the newly introduced stimulus is weaker, stronger or of different quality from the previously presented stimuli. With repeated application, however, the stimulus which provoked an orienting reflex undergoes extinction.

Sokolov proposed a cortical neuronal model to account for the induction of the orienting reflex by novel stimuli. Incoming stimuli are received in the cortex and compared to the cortical cell assembly that has preserved information about previously presented stimuli. The preserved information includes such features as modality, intensity, duration and order of presentation of earlier stimuli. When a novel stimulus conflicts with the neuronal model a corticifugal discharge to the reticular system occurs.

The effect of reticular activation and consequent reticulo-cortical stimulation is increased sensitivity of the cortex promoting optimal reception of incoming stimuli.

Heilman, Gold, and Tucker (unpublished manuscript) suggested that aphasic performance on comprehension tasks can be influenced by presentation of novel stimuli. They presented commands from the Token Test (DeRenzi and Vignolo, 1962) in two conditions. In the first condition commands were read by one examiner. In the second condition the commands were presented by three different examiners; two male, one female, each one exhibiting different regional dialects. The stimuli in the second condition were presented with varied amplitude, pitch, and stress. The results of their study indicated that mean correct responses in the three voice condition were significantly greater than in the one voice condition.

Heilman et al. employed the concept of the orienting reflex discussed by Sololov to account for the improved performance of the aphasic persons in the novel test condition.

A similar effect may have occured in the present study. Group B aphasics were observed to perform optimally by a 4% margin in the four item series in the condition in which 250 msec of silence was programmed between the first and second syllable of each word without a concurrent interword interval. It may be that the novel rhythmic features of this condition promoted the most favorable attentional state for processing serial items in the four item sequences.

Comments on Normal Adult Performance

The span of immediate memory in adults was studied by Miller (1956). In that classical study, Miller contended that the span of immediate memory was about seven plus or minus two items in length. Chi (1976) discussed the variability in the literature for estimating adult STM capacity:

> Short-term memory span has variously been estimated to be about seven by Miller (1956), six by Spitz (1972), five by Simon (1974), and three to four by Broadbent (1975); (p. 561).

Chi noted that these estimates of STM capacity depended upon the criterion used, the task used to tap this capacity, and the definition of a chunk. Clearly, the question of STM capacity is unresolved.

The present study suggested that short-term memory for serial recall was around three or four items. This estimate was based upon a 75% correct mean performance criterion for serial recall. It appears that short-term memory for item recall is greater than four items. The upper limit of STM capacity for item information was not tapped in the present study.

One observation worth noting of the control group was perseveration for an item presented in the immediately previous four word sequence. This type of error was noticed repeatedly in the responses of the control group. This suggested that the four item series for serial recall was taxing STM capacity.

Rehearsal was a viable strategy for the control subjects. Eleven of the 19 persons rehearsed vocally. Several of the individuals asked if they could say the words out loud, and one individual summarized the situation by commenting, "It's easier if I say them."

Suggestions for Future Research

The results of this study indicated that presentation of unrelated items in two, three, and four word series for serial recall was a difficult task for an aphasic population as well as for control subjects. This suggested that the sentence construction with its inherent redundancy may in fact lend important cues to brain injured aphasics in comprehension of verbal material. One individual, for example, who could not point to nouns spoken in isolation, and therefore did not qualify for the present study, could identify the picture representing the noun when the noun was spoken within a sentence construction. For example, when given the sentence, "The curtain is covering the window," the aphasic individual pointed to a picture of a curtain, but failed to do so upon instruction to "point to curtain" or when the examiner said "curtain" and gestured towards the test plate indicating she desired an identification of the word. It is suggested that future research employ stimuli at the sentence level for evaluating auditory comprehension by aphasic individuals.

Further investigation of word type employed in sentences is indicated. It is not well known if word type enhances comprehension at the sentence level. For example, do bisyllabic nouns in which both syllables lend themselves to semantic interpretation and potential visualization enhance comprehension? Is the sentence, "I bought a bedspread," inherently easier to comprehend than the sentence, "I bought a table." In the second sentence, the noun does not have the redundant semantic and visual properties of the noun bedspread. Paivio (1971) suggested that normal individuals demonstrate varying degrees of ability to visualize verbal stimuli. This ability should be investigated in the aphasic population as a potential therapy aid.

Future research might investigate the complexity of visual stimuli presented for picture identification tasks. It is not well known, for example, if three dimensional drawings are more readily identified by aphasics than more simple line drawings. This, too, might be useful information to employ in the therapy setting.

In evaluating serial recall performance by aphasics, studies to date have not extensively investigated whether aphasics demonstrate serial recall for semantic category information. That is, we do not know if aphasics identify an incorrect item, but one within the same semantic category as the target word, as opposed to random selection of an item in a serial recall task. It has been suggested that a more thorough analysis of recall performance be undertaken accounting for serial recall of words semantically related to the target words (Goodglass, 1977; personal communication).

The use of novel stimuli in alerting the aphasic in auditory tasks should be further investigated. It appears from the results of the present study that certain aphasics can benefit from novel stimuli introduced to the auditory system.

In conclusion, future research with aphasic individuals might investigate such factors as syntactic construction, word type employed in sentences, and the use of novel stimuli for increasing auditory comprehension. In turn, we may broaden our understanding of aphasia as a language disorder and improve our clinical techniques in aphasia rehabilitation.

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APPENDICES

APPENDIX A

TEST WORD PLATES

APPENDIX B

INDIVIDUAL DATA SHEETS

APPENDIX B

INDIVIDUAL DATA SHEETS

Name________________

Date of birth_______

Date of onset_______

Etiology____________

Place Tested________

Paralysis/paresis________

Date therapy began_______

Education_______________

Rehearsal?______________

Hearing screen L		R
____	500	____
____	1000	____
____	2000	____

Form_______

Type ______		Type ______		Type ______	
1.______	28.______	1.______	28.______	1.______	28.______
2.______	29.______	2.______	29.______	2.______	29.______
3.______	30.______	3.______	30.______	3.______	30.______
4.______	31.______	4.______	31.______	4.______	31.______
5.______	32.______	5.______	32.______	5.______	32.______
6.______	33.______	6.______	33.______	6.______	33.______
7.______	34.______	7.______	34.______	7.______	34.______
8.______	35.______	8.______	35.______	8.______	35.______
9.______	36.______	9.______	36.______	9.______	36.______
10.______	37.______	10.______	37.______	10.______	37.______
11.______	38.______	11.______	38.______	11.______	38.______
12.______	39.______	12.______	39.______	12.______	39.______
13.______	40.______	13.______	40.______	13.______	40.______
14.______	41.______	14.______	41.______	14.______	41.______
15.______	42.______	15.______	42.______	15.______	42.______
16.______	43.______	16.______	43.______	16.______	43.______
17.______	44.______	17.______	44.______	17.______	44.______
18.______	45.______	18.______	45.______	18.______	45.______
19.______	46.______	19.______	46.______	19.______	46.______
20.______	47.______	20.______	47.______	20.______	47.______
21.______	48.______	21.______	48.______	21.______	48.______
22.______	49.______	22.______	49.______	22.______	49.______
23.______	50.______	23.______	50.______	23.______	50.______
24.______	51.______	24.______	51.______	24.______	51.______
25.______	52.______	25.______	52.______	25.______	52.______
26.______	53.______	26.______	53.______	26.______	53.______
27.______	54.______	27.______	54.______	27.______	54.______