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THE EFFECTS OF MEANINGFULNESS AND PRONUNCIABILITY ON SHORT-TERM MEMORY

by

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ABSTRACT

The relative effectiveness of meaningfulness and pronounceability as dimensions for chunking verbal items in STM was studied using a modified Peterson and Peterson paradigm as a test for retention. Sequences of 12 letter strings were used which could be chunked into 4 meaningful but unpronounceable units ($M-\overline{P}$) 4 pronounceable but meaningless units ($\overline{M}-P$) or 4 meaningless and unpronounceable units ($\overline{M}-\overline{P}$). The letters were presented tachistoscopically in accordance with a pilot study designed to equate level of learning at immediate recall. These times were 3.1, 3.8, and 17.5 seconds for the $\overline{M}-P$, $M-\overline{P}$ and $\overline{M}-\overline{P}$ groups, respectively.

The hypothesis that the $M-\overline{P}$ groups would exhibit superior performance after filled retention intervals of 5 and 10 seconds was tested. Results indicated that meaningfulness was a better predictor of performance than pronounceability. These results were discussed in the light of a two process theory of memory with implications for a theory of forgetting.

INTRODUCTION

The subject for investigation in this research is the facilitative effects of encoding in single letter strings. More specifically the concern is with chunking as a means of encoding. Within this framework the research is aimed at determining whether meaningfulness or pronunciability forms a more efficient basis for chunking in short-term memory. By chunking is meant any cognitive unit devised by the subject himself and is a direct result of the subject's perceptual coding processes. This is similar to the notion of mnemonics (and will be used synonymously) which refers to any attempts on the part of the subject to reorganize, segment, or elaborate upon the nominal stimuli or to develop associative bonds between elements of the stimuli (or the stimuli themselves) on the basis of semantic or syntactical relations. The nature of the mnemonic that best facilitates learning in short-term memory has not been well documented. Early research (Underwood and Schulz, 1960; Laughery and Pinkus, 1968; Stark and Calfee, 1969) indicates pronunciability is the key factor in ease of learning since among other things, it allows more time for rehearsal. More recently Boroskin and Lindley (1970) and Bower and Springton (1970) have shown meaningfulness to be a more viable attribute of memory. The contention is that chunking on the basis of meaningfulness permits a greater reduction in the information load.

The question is, does pronunciability affect acquisition, retention or both? And what of the role of meaningfulness with respect to these measures? Pinkus and Laughery (1970) claim that pronunciability reflects the integration of the material wherein a series of items can be chunked and given a new name. They further maintain that letter strings consisting of abbreviations are merely grouped and that the new chunk is not given a new name as a pronounceable item is. Thus a 12 letter string can be rehearsed more per unit time in the former condition since it calls for the repetition of 4 chunks whereas in the latter case to rehearse means to repeat each of the 12 letters, e.g., IBM, RKO,... etc. Clearly these authors are unable to make the claim that prounciability facilitates retention since level of learning was not equated for across groups. Recall was immediate and reflects only level of acquisition.

This research is directed at determining the effects of meaningfulness and pronunciability on the retention of verbal material up to 20 seconds after presentation. Preliminary consideration will be given to recent developments in the field concerning a model for human memory. Discussion will be extended to include the general notions of short-term memory as advanced by Peterson and Peterson (1959), Waugh and Norman (1965), and Norman (1970). This will be followed by a consideration of the nature of encoding and the mechanics that have been shown to apply to short-term memory research. Here distinctions will be made between the variables that affect acquisition and those that affect retention. Some attempt will be made at formulating a theoretical explanation for the differential effects of these variables on learning and retention. Finally, the actual research proposal will be laid out with an adequate rationale for its relevance and importance for the general topic of encoding in short-term memory.

A MODEL FOR HUMAN MEMORY

During the last decade a general consensus of opinion as to the nature of human memory has evolved. Consequently, a number of models have been proposed to explain the way in which information is processed. A great deal of support has been forthcoming for models that make assumptions about three different types of storage systems: a memory storage system, a short-term store and a long-term store. Justification for this comes from a number of sources (Atkinson and Shiffrin, 1968; Conrad, 1962, 1964; Waugh and Norman, 1965; Neisser, 1967). First newly presented information enters through the senses and is represented in the sensory system for a very brief period of time. The information may either be transferred onto the next process or lost through rapid decay. Following this sensory storage the presented material is identified and enters a short-term store where it is retained temporarily. Transfer here does not imply that the sensory image is unaffected by the transfer or that the information is placed in the short-term store unaltered. In most cases information is altered radically by the system; for example, visual information is often altered into auditory information in the process of entering short-term memory (Conrad, 1964). The capacity of short-term memory is limited (Miller, 1956). If, however, information residing in this storage system is rehearsed or reorganized according to certain encoding strategies, it will be transferred to a more permanent form of storage with a certain probability. This store is usually referred to as long-term memory.

Short-term Memory

The central concern in this paper is with short-term memory and specifically the independent variables that affect short-term retention. Short-term memory might be defined as relating to the interval between presentation and recall, i.e., the retention of encoded information over relatively brief periods of time--up to a minute (Melton, 1963). Generally, short-term memory has been thought to involve the storage of auditory information almost exclusively (Conrad, 1962, 1964). This appears to happen independently of the manner of presentation, i.e., even under normal visual conditions short-term memory storage appears to be auditory (Conrad, 1964). Information in this store is lost rapidly if unrehearsed but rehearsal can maintain information here indefinitely. It has been termed the subjects working memory since information transfer to and from other systems takes place through it. It is the conscious part of human memory.

It is not the purpose of this section to review the extensive literature on short-term memory, but rather to describe a few of the mechanisms that have been postulated in short-term memory and to consider one or two models which have been important in providing the theoretical framework for this study. The stimulus for these models was provided by a rather ingenious technique for investigating short-term retention devised by Peterson and Peterson (1959). These experimenters determined the recallability of single trigrams such as KLM after intervals of 3, 6, 9, 12, 15, and 18 seconds. The trigrams were presented auditorily for 1 second, a 3 digit number occurred during the next second, and S counted backwards by 3s and 4s from that number until, after the appropriate interval, he received a signal to recall the trigram. The S was given up to 14 seconds for recall thus avoiding time pressure in the retrieval process. This paradigm has remained the most popular way of studying retention over short periods of time. Variations on this method are related to modality and rate of presentation of the stimulus item(s), the duration of the rentention interval, and the difficulty of the task set for the S during the interval, (Posner, 1966). The universal finding has been that recall decreases monotonically with the length of the retention interval.

It is generally thought that the subject has a limited opportunity to rehearse during the retention interval and this accounts in part for the sharp decline in performance over lengthening retention intervals. It is not surprising, therefore, that the concept of rehearsal plays an important role in the maintenance and consolidation of information in short-term memory. According to Waugh and Norman's (1965) model, every item perceived enters into a primary memory state, (which is here called short-term store) where it can be displaced by the succeeding items unless it is rehearsed. Displaced items are permanently lost. When an item is rehearsed, however, it remains in primary memory and will enter secondary (long-term) memory with a certain probability. Recall is determined by the probability that it is in primary memory, secondary memory or both. In fact Waugh and Norman contend "that most of the published data on short-term retention actually reflect the properties of both memory systems (p. 101)." Atkinson and Shiffrin (1968) propose a somewhat similar model as it relates to short-term memory. They suggest that retrieval in typical short-term memory experiments involves both short-term store and long-term store. Accordingly, they regard short-term memory as being operationally defined as that memory examined in experiments with short-durations or single trials, while the terms short-term store and long-term store refer to theoretical constructs. It is assumed that a trace in the short-term store dissipates fairly rapidly in the absence of rehearsal. The amount of information transferred from short-term store to long-term store is primarily a function of control processes that depend on such factors as instructional set, the experimental task and the past history of the subject. These subject-controlled memory processes include any strategies, coding techniques, or mnemonic techniques used by the subject in his efforts to remember.

Rehearsal

Rehearsal whether immediate or delayed, silent or overt, deliberate or involuntary, is one of the most important factors in human memory. In addition to lengthening the time period information stays in short-term store, it involves encoding and other storage processes which facilitate transfer to long-term memory. It would be desirable to measure short-term memory when rehearsal is completely eliminated. This has proven to be a very difficult task. It could even be argued that the initial perception and "naming" of an item constitutes a rehearsal. Difficulties also arise in attempting to establish how much rehearsal takes place during the retention interval. As indicated earlier the amount and quality of the rehearsal is heavily dependent on the nature of the intervening task, and the length of the retention interval. Neimark, Greenhouse, Law, and Weinheimer (1965) investigated the effects of varying the difficulty of the intervening tasks. They used trigrams of either high or low association value with retention intervals of 0, 3, 9, and 18 seconds. During the retention intervals Ss spelled aloud at a rapid pace nonsense syllables of either high, medium or low association value, or three-digit numbers. The noteworthy result is for low association syllables where recall was best when the intervening task involved the most dissimilar materials (numbers and high association CVCs). This is in accordance with interference theory (Adams, 1967) but an interesting alternative explanation presents itself. The critical factor could be difficulty of the interpolated task. As Kintsch (1970) points out, the difficult tasks severely restrict the opportunity for rehearsal activities since more demands are made upon the subject's central processing capabilities. Consequently, less remain for the task of transferring the to-be-remembered items to a more permanent store.

Data to support this notion are provided by Posner and Rossman (1965) where Ss were presented with an eight digit series and were required to perform a transformation task before attempting to recall the series. The transformations involved either reversal (writing down a pair of digits in the opposite order from presentation), addition (two adjacent digits are added and the sum is written down), 2-bit classification (classifying each pair of numbers into above or below 50), or 1-bit classification (the subject records A if the pair is high and odd or low and even, B for the reverse). It can be seen that the tasks are graded with respect to their difficulty. These transformations utilized either 0, 1, 2, or 3 digit pairs from the eight-digit series, but never the first two digits. Results show that both the nature and number of transformations performed during the retention interval strongly affected recall. The more transformations and the more difficult the task the poorer was recall, suggesting the importance of rehearsal opportunity in the maintenance of information in STM.

Similar problems arise when attempts are made to control rehearsal during actual presentation of the stimulus material. Increasing the rate of presentation only partially solves the problem since even at the fastest conceivable rates Ss can rehearse during presentation if they attend to only a portion of the incoming items. When rehearsal is measured, rate is found to vary from 3 items/second (Landauer, 1962) to 10 items/second (Sperling, 1963) with the former typical for new material. Landauer had Ss think to themselves the numbers from 1-10, 11-20, etc., attempting to go as fast as possible without skipping. Ss indicated the beginning and the end of each set by depressing and releasing a handswitch controlling a Standard Electric timer.

This brings us to a logical distinction which should be made between rehearsal that consists solely of mere repetitions and that which entails more elaborate forms of encoding of the stimulus material. In a study attempting to control the type of rehearsal activity engaged in by the subjects, Glanzer and Meinzer (1967) presented items every 3.2 second followed by free recall. In one condition subjects were instructed to give the just presented word six vocal repetitions whereas, in another condition subjects were allowed to rehearse in any manner that they wished. The latter condition provided for better recall for words occurring at the beginning and middle of the list than did the former condition. There was, however, no difference in recall of items presented at the end of the list. It appears that free rehearsal enables more elaborate forms of encoding to occur. This finding is supported by Glanzer and Cunitz (1966) and points up the possibility that recall of the earlier presented items is from both long- and short-term stores whereas recall for items presented last is almost entirely from short-term store.

Bjork (1970) found that a 12 second free rehearsal period prior to test for recall made items more resistant to retention interval activity before a second recall test. Specifically he tested recall of five 2-digit numbers under four different conditions as indicated in Figure 1. After presentation of the digits Ss had an opportunity to rehearse for 12 or 24 seconds (except Cond. II, which served as a Control), then they were engaged in a counting task (except Cond. I, where Ss were allowed an initial 12 second recall period before counting). Finally, all conditions received a 12 second recall period. The strengthening effects of rehearsal can be seen by comparing performance on the final recall between Conditions I and III and also between Conditons II and IV. It can be argued that the superior performance for Ss who had a rehearsal period was due to the transfer of items to long-term memory, i.e., the rehearsal periods

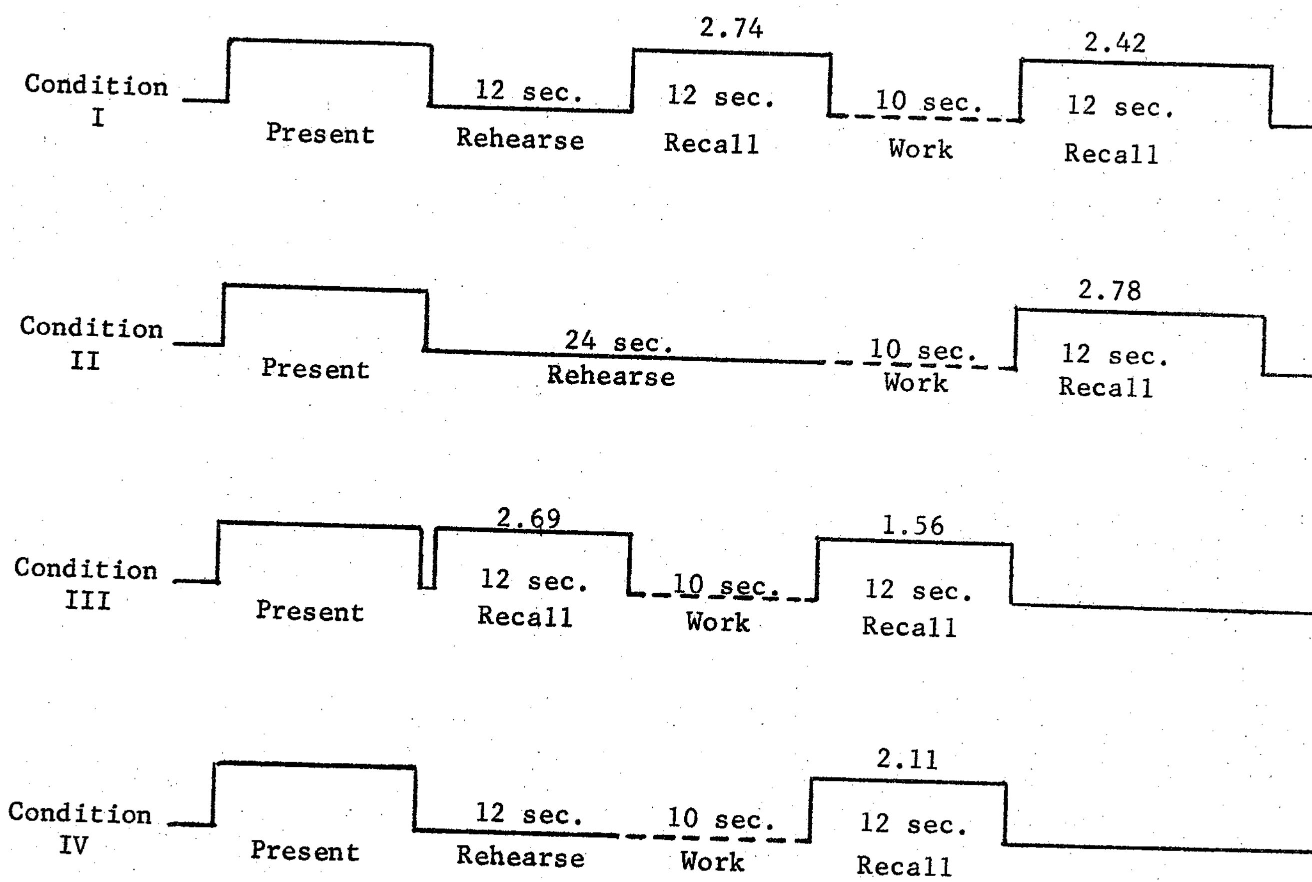

Fig. 1. Mean number of two-digit items recalled correctly in the correct position out of five possible (After Bjork 1970)

permits more freedom for the subject to achieve a long-term encoding of some kind. More importantly, it seems safe to assume that the subjects in Bjork's experiment were in fact engaged in more sophisticated activities than mere repetition.

Bjork (1970) cites an experiment by Pollatsek who gave Ss a single presentation of a word trigram followed by rehearsal periods of 0, 3, 6, or 9 seconds and tested recall after an intervening activity (counting backwards) of 0, 3, 6, 9, 15, or 21 seconds. His results are shown in Figure 2. The retention curves flatten markedly with increased opportunity for rehearsal, and provide substance for the notion that rehearsal benefits memory by increasing the probability that the item is processed into a more permenent store. Additional evidence is forthcoming from experiments by Stanners and Meunier (1969) and Stanners, Meunier and Headley (1969). The latter group of investigators used reaction time as an indicant of rehearsal in short-term memory. They presented three sets of trigrams that were either easy to pronounce (E-Pr) or difficult to pronounce (D-Pr) according to a pool scaled by Underwood and Schulz (1960). Following a procedure whereby the two groups (E-Pr and D-Pr) were equated for learning (six to eight letters in correct position) a 7-second rehearsal period was allowed before recall. At either 1, 2, 4, or 6 seconds into the rehearsal period a buzzer was sounded to which the subject had to respond as quickly as possible by moving a toggle switch. The mean reaction time for the D-Pr group was markedly slower than for the E-Pr group. Of concern for the present paper is the finding that recall scores after the rehearsal period were signific-

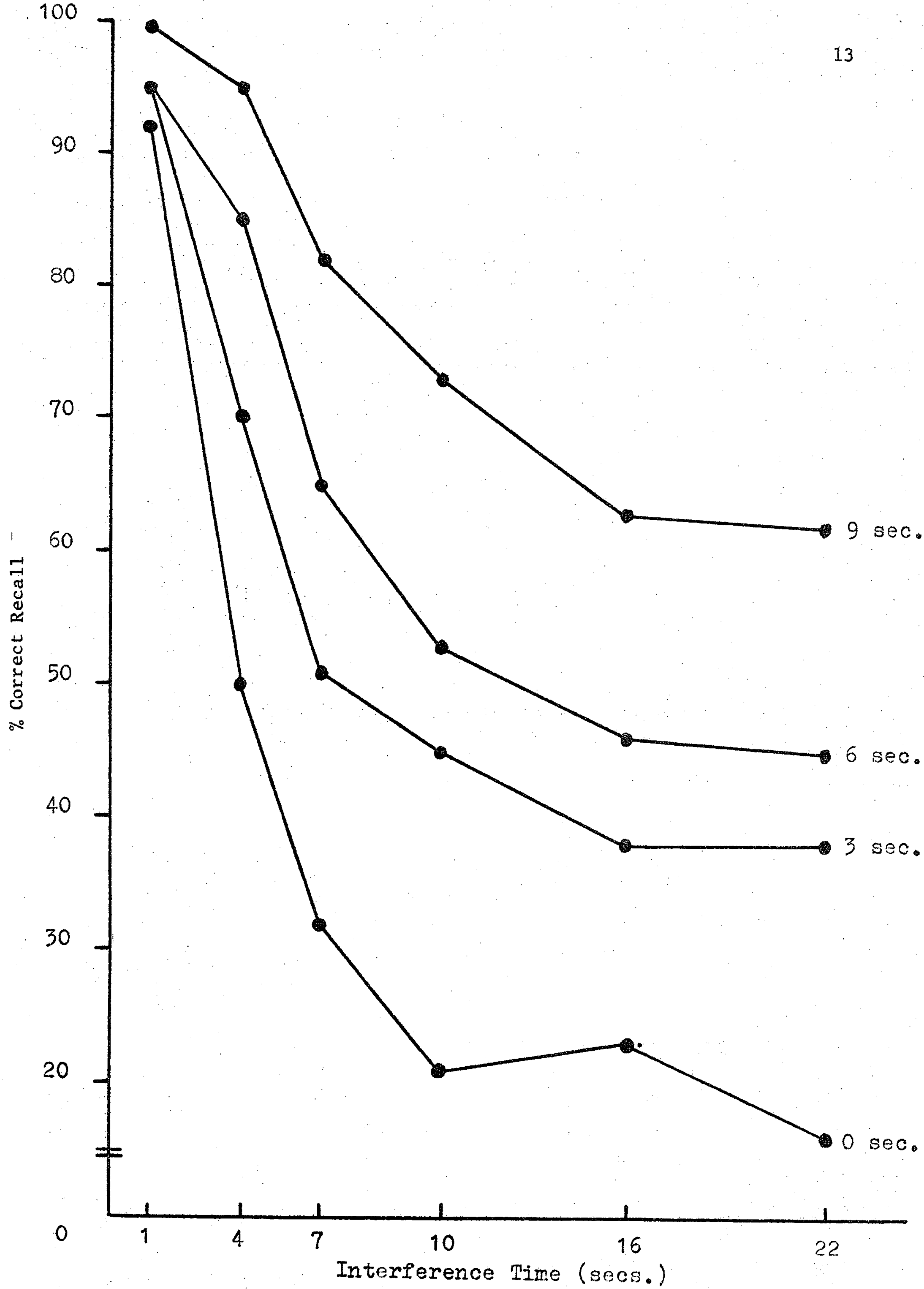

Fig. 2. Proportions of word trigrams recalled completely correctly as a function of rehearsal time.
(After Pollatsek 1969)

antly higher for the E-Pr group, constituting a performance change during the rehearsal period for one or both groups. The contention is that the rehearsal process was more efficient with the E-Pr group and hence more information was transferred from the short- to the long-term store.

The question of the mechanism of rehearsal and how it relates to encoding remains open. Some investigators (Brown, 1958; Waugh and Norman (1965) advance the notion that rote rehearsal actively reinstated the to-be-remembered items. This does not appear to be as efficient , however, as more elaborate techniques that can occur in free rehearsal situations. Here subjects are able to covertly distribute their rehearsal time, i.e., subjects can differentially rehearse items according to their difficulty. What I am suggesting is that the subject is free to spend less time with items that are easily encoded (for him) and a proportionately greater amount of time developing an encoding device for storing the more difficult items.

Capacity

Evidence has been brought forward to suggest that the short-term store has a limited capacity (Miller, 1956). Often, as has been already suggested, subject strategies determine how items will be stored and therefore what will be remembered. Since this limited capacity and these strategies interact, it is considered useful to study them simultaneously to shed further light on the structure of the memory system and its processes. The span of immediate memory is about 7, plus or minus 2, chunks and appears to be quite independent of the size or nature of the chunks (Miller, 1956; Woodworth, 1938, Ch. 27; Averbach, 1963; Murdock, 1961; Pollack and Johnson, 1965). Often the chunks which the subject processes for recall are not those which were presented. Incoming information, verbal or otherwise, may be segmented, grouped, or recoded depending on the nature of stimuli, the ingenuity of the subject, the instructions of the experimenter or any combination of these three. A systematic investigation into the nature of these chunks will hopefully indicate a greater lawfulness and regularity in the way memory operates.

Miller (1956) demonstrates that one can hold in short-term memory only a few chunks, but the chunks themselves may be very rich in information. Short-term memory is by no means constant if measured in terms of amount of information. Miller, in his article, distinguishes between "bits" of information and "chunks" of information. Drawing on the analogy of the Morse Code operator he reasons that a man just beginning to learn, hears each 'dit' and 'dah' separately. After a while he is able to group these sounds into letters. Then the letters are organized into words, which are still larger chunks and finally he begins to segment whole phrases. In this way the amount of information the operator can retain increases or, in Miller's terms, the operator learns to increase the "bits" of information per "chunk". Miller cites an experiment by Smith (pp. 93-95) involving binary digits that adds substance to the above analogy. Preliminary training that consisted of teaching the subject a code name for each possible quadruplet of binary digits (e.g., 0000 = 0, 0001 = 1, 0010 = 2). When the binary digits were presented in a memory span experiment, S recoded the digits according to the previously learned code; at recall S decoded the code names back into the correct sequence of binary digits. In this way the length of memory span was increased from about 10 to about 40 digits.

An important experiment by Tulving and Patkau (1962) provides further support for the notion that chunking can increase the amount of information to be retained. They analyzed the classic result reported by Miller and Selfridge (1950), to the effect that subjects recall more words from strings which approximate more and more closely the word order of grammatical English text. The number of words correctly recalled in an unbroken rote sequence was used as a measure of a size of a chunk. With this criterion in mind, they found very little change in the number of chunks recalled as the order of approximation increased. For zero, second, fourth, and sixth order approximations, and real English text, subjects recalled from 5-6 chunks for each order. What did change was the size of the adopted chunk and the mean number of words recalled increased with approximation to English.

As indicated at the beginning of this section the capacity of the short-term store interacts with the subject's encoding strategies to determine what will be recalled. If the memory span is limited to seven chunks, then whenever more than seven items are recalled after a single presentation, it is because there is enough internal structure among the stimulus items to allow mnemonic devices to operate.

ENCODING MECHANISMS

There is reason to believe that incoming information is reformulated as it is stored and this is often carried out according to some encoding or recoding technique. These techniques may involve any elaboration, reorganization or regrouping of the nominal stimulus that aids recall. Duffy (1969) in discussing types of encoding sees "the problem to be resolved as determining those aspects of natural language habits which lead to facilitation" (p. 19) of the learning process. This could be extended to include those aspects affecting retention, since many studies concerned with short-term memory utilize delayed recall of some kind. It is during this period (i.e., between presentation and recall separated by some interval, filled or unfilled) that the subject has an opportunity to encode newly acquired information.

Elaborative Devices

Bower (1968) has pointed out a variety of ways in which subjects can employ mnemonic techniques to impose some structure on unrelated units. For example, he taught subjects to elaborate upon consonant trigrams until they were proficient in this type of encoding. For example 'TZN' might be elaborated upon to produce 'TARZAN' or similarly 'CLR' could be recalled by remembering 'cats like rodents'. Following this subjects showed very little forgetting (90% recall) after a retention interval of 16 seconds compared to a Control group (55%) that had no mnemonic training. This kind of mnemonic technique has also been found to facilitate recall in other studies involving short-term memory (Montague, Adams, and Kiess, 1966; Groninger, 1966; Stark and Calfee, 1969).

Lindley (1963, 1966), Lindley and Nedler (1965), and Schaub and Lindley (1964) have demonstrated the importance of mnemonics that are elaborative in nature in short-term memory experiments. Lindley (1963) found that low meaningful trigrams were forgotten more slowly when embedded in a real word provided by the experimenter, e.g., ABLe, aCQUire. The contention is that the mnemonic assists the subject in encoding the item into a meaningful chunk of information. The implicit suggestion here, of course, is that meaningfulness itself aids learning, recall, or both. This issue is of central concern to this paper and will be considered more fully later. Lindley and Nedler (1965) and Lindley (1965) demonstrated the importance of the complexity of encoding. In the former study it was found that a mnemonic aided recall if it involved presenting the trigram as the first three letters of a word. Lindley (1965) went a step further and varied the complexity of cue provided for encoding. A trigram was presented either twice or was followed by an easy to encode cue (e.g., CAG-CAGE) or by a difficult to encode cue (e.g., CAG-CAUGHT). Recall was tested after retention intervals of 0, 8, 20, and 32 seconds. Superior performance at recall was found for these trigrams accompanied by an easy to encode cue. An encoding cue at the time of presentation regardless of whether it was easy or difficult to encode provided for better recall than merely presenting the item twice. Additional support for this finding comes from Wike and Wike (1970) and Thomson and Tulving (1970).

Grouping

Bowater (1968) defines grouping as "the classification or segmentation of individual units into larger sets, chunks, or clusters, which have some kind of functional unity" (p. 3). Grouping phenomena are quite common in short-term memory studies and frequently are dependent on perceptual characteristics, temporal rhythms, verbal associations or syntactic rules. One of the distinctions between short and long-term memory might be made on the basis of the way in which information is encoded for storage. Chunks are stored in both memory stores but in short-term memory it is thought they often result from superficial perceptual processing while units of long-term memory are based on more elaborative recoding strategies adopted by the subject. The controlling factor is the amount of time that is available for processing. Full discussion of this type of grouping phenomena is reserved for later.

Even items such as ordinary digits are subject to grouping operations that can be either rhythmical or temporal in nature. These operations can be carried out by the experimenter during presentation or by the subject before recall via rehearsal. This suggests that "rehearsal" includes "grouping" or "recoding" strategies. In fact Wickelgren (1964) asserts "Whatever else a grouping method is, it is a method of rehearsal (p. 414)." In a study designed to investigate the effects of temporal grouping, Ryan (1969) presented 9 items auditorily in the space of 5 seconds. The sequences were grouped temporally by slight pauses into 3 groups of 3 items. Results show superior recall for grouped presentation. Ryan offers the conclusion that the temporal grouping improves recall because of the presence of the unfilled interval between groups rather than simply because of the division of the sequences. In other words, more processing via rehearsal can occur during the unfilled interval. Bower and Springston (1970) adduce further evidence for these findings, as does a study by Pinkus and Laughery (1970).

In addition to grouping on the basis of temporal or spatial structure Ss may group items on the basis of semantic structure (meaning) or on the basis of phonological structure (pronunciability). The latter two methods of grouping constitute the main domain of enquiry in this paper and accordingly I shall discuss each in somewhat greater detail than those variables mentioned above.

Pronunciability. Efforts to pronounce a series of letters can be seen as an attempt to mark off subgroups of the letters in such a way that the chunks obey the same phonological rules as do common words. These "words" may or may not have any set meaning but they do become pronounceable units. Underwood and Schulz (1960) presented evidence that rate of learning is a function of trigram pronunciability. A syllable that is clearly pronounceable can be represented by one response (eg., TAV) whereas one that is not (e.g., XQL) must be represented by three separate responses. So ease of pronouncing a trigram is one measure of the degree of integration of the letters. Since a pronounceable item is more integrated to begin with, it can be argued that less of the learning process must be devoted to the integration of the letters.

The level of integration of a three letter verbal unit in terms of pronunciability has been scaled by Underwood and Schulz (1960 - Appendix E). Capitalizing on Underwood and Schulz's finding that pronunciability and ease of learning are highly correlated, Stark and Calfee (1969) showed that subjects recalled consonant strings (presented at one-half second per letter) better when instructed to insert vowels to make a string of pronounceable units than a group instructed to develop a string of verbs, each one beginning with a letter in the string. Recall comparable to the vowel insertion group was reported for a third group where the consonant string was replaced by a string of words forming a meaningful sentence or phrase. Instructions to form a pronounceable unit of the string may have facilitated rehearsal since the encoding latency (measured between onset of the recall signal and Ss' response) for this group was significantly lower than the other two groups.

Other researchers (Pinkus and Laughery, 1967; Stanners and Meunier, 1968; Laughery and Pinkus, 1968) have also ascribed the facilitative effect of pronunciability to the greater efficiency of rehearsal with easily pronounceable items, i.e., the easier the item is to pronounce, the faster the item can be pronounced and the more material can be rehearsed per unit time. With respect to this, Gibson, Bishop, Schiff and Smith (1964) found that the tachistoscopic thresholds for unmeaningful but pronounceable items (e.g., TAV) were lower than for meaningful but unpronounceable items (e.g., FBI). This suggests that a label or a coding is more easily provided for pronounceable items. Gorfein and Stone (1967) provide additional support to the idea that pronunciability is the key factor in ease of learning because it allows more time for rehearsal. In a short-term memory task difficult to pronounce items (D-Pr) were presented for intervals corresponding to their individual pronounciation latencies. In another condition the same D-Pr items were all exposed for the same interval corresponding to the mean pronounciation latency. Recall was found to be superior in the former condition.

The question is, does pronunciability affect acquisition, retention or both? In order to examine this, it is necessary to standardize the levels of performance for the different groups before the retention interval is introduced (Underwood, 1964). Stanners and Meunier (1969) performed a study that required recall of 3-trigram sets. A pretesting session was used to establish an exposure interval that would place each S at a standard level of performance (six to eight correct letters in correct positions) for a 0-second retention interval, for E-Pr and D-Pr groups. In addition, Ss received a rehearsal period of 0, 5, or 10 seconds, and a retention interval of 0, 5, or 10 seconds. No instructions were given during the rehearsal period and backward counting was employed during the retention period. Their results show a much greater increase in overall level of recall for the E-Pr material than for the D-Pr material after the 5 and 10 second rehearsal periods. Immediate recall, however, favored slightly the D-Pr group and there was a divergence of retention functions over lengthening activity intervals with the D-Pr group continuing to show better recall. This can be accounted for if it is remembered that a much longer exposure interval for the D-Pr material (in order to equate learning) might have allowed some of the material to be transferred to a long-term store. Once an opportunity to rehearse was provided for the E-Pr group, however, there was a definite improvement in their recall pattern.

Laughery and Pinkus (1968) have investigated the meaningfulness and its relation to pronunciability, and report that pronunciability is a more effective dimension for chunking in short-term memory than meaningfulness. Their stimulus materials consisted of 12 letters in which each sequence was composed of four three-letter units where meaningfulness and pronunciability were manipulated as follows:

a) 3 letter words meaningful-pronounceable (M-P, e.g., BIN REDGETSOD

b) 3 letter abbreviations (M-$\overline{\text{P}}$), e.g., NFLCBSAMATNT)

c) 3 letter CVCs ($\overline{\text{M}}$-P), e.g., GOCDERTEGDOS

d) 3 letter units ($\overline{\text{M}}$-$\overline{\text{P}}$), e.g., OUBJOBAIRGFT

Subjects were instructed as to the nature of the material. Thus the first group was informed that the 12-item sequence could be grouped into four three-letter words. The second group was told that the sequence could be divided into three-letter abbreviations, while the third group was told that the sequence could be broken up into pronounceable but meaningless syllables. The group given the meaningless and unpronounceable items was told only that the sequences would contain 12 items.

The investigators were also interested in the effect of presentation rate on these variables; thus each letter of the string was presented for .3, .6, 1.0, 2.0, or 3.0 seconds. Except for the .3

second rate, the letters appeared on the screen for .5 seconds and the screen was blank for the interval prior to recall. Immediately following, subjects recorded their responses on answer sheets. The mean number of letters correct per sequence for the different experimental conditions are depicted in Figure 3. The results were clear across all rates of presentation. Consistently superior performance was found for words and CVCs. Words, however, were still better retained. Performance was inferior in the other sequences but was still better for abbreviations than for letters presented in random order. The authors contend that the subjects use the inter-item intervals to rehearse those items that have already been presented and since the time required to pronounce the CVC syllable is less than the time needed to pronounce the individual letters, rehearsal is maximized for the meaningless-pronounceable ($\overline{M}$-P) condition. It is curious to note, however, that changing the presentation rate (i.e., increasing the time available for rehearsal) had more of a facilitative effect on recall for the M-$\overline{P}$ items than the $\overline{M}$-P items (Fig. 3).

In a follow-up study Pinkus and Laughery (1970) provide added support to the above findings. They found that when the S was permitted to pace the stimulus items in a memory span experiment he pauses at logical organizational/rehearsal points in the sequence, namely at the serial positions 3, 6, and 9. The magnitude of the inter-item times at the three critical points as well as the latency for the entire sequence was found to be the least for words, then CVCs, followed by abbreviations and random letters. Immediate recall again indicated that performance increases in the order--random

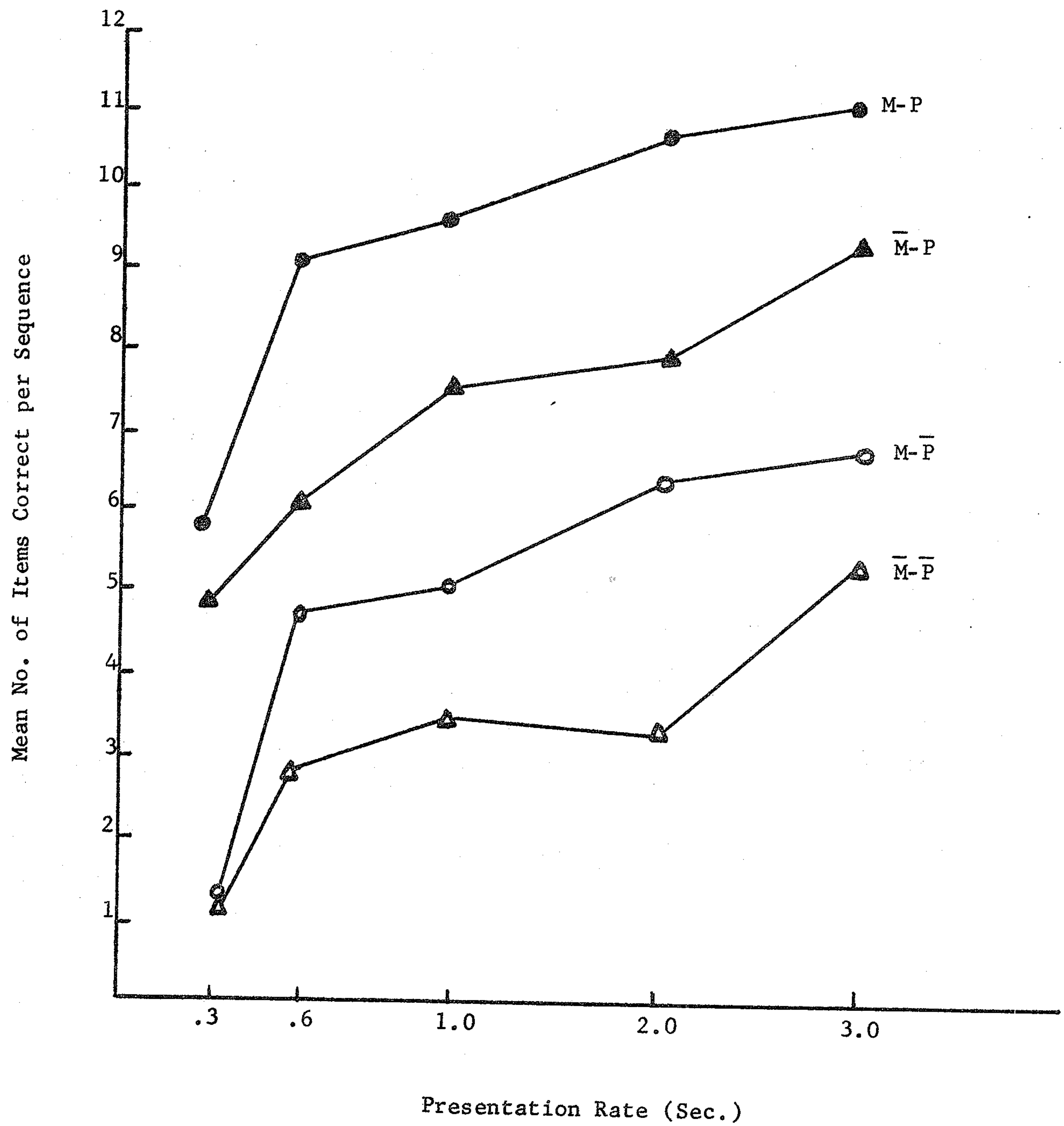

Fig. 3. Mean number of items correct for various experimental conditions. (After Laughery and Pinkus, 1968).

letters, abbreviations, CVCs and words.

The overall effect of pronunciability appears to be a facilitative one when there is limited time available for rehearsal and when recall is immediate. There is no evidence to suggest that pronunciability is a more effective dimension for encoding for a longer period of time. The distinction that has to be made here is between learning and memory. Tulving (1968) maintains that the operations involved in measuring learning and perceiving a trigram are identical. Consequently, items correctly perceived (i.e., reported accurately at immediate recall) will be said to reflect learning. Memory is measured by the amount of material retained after some retention interval, filled or unfilled.

Meaningfulness. Since meaningfulness has been demonstrated to play an important role in multiple trial learning of verbal material, it is not surprising that a number of aspects of this variable (e.g., association value, word frequency, abstractness, etc.) have been investigated using the short-term memory paradigm. When attempting to study the question of how pronunciability and meaningfulness affect short-term retention there is a real problem agreeing on a satisfactory definition of meaningfulness, and selecting items that load highly on one dimension and not on the other. As Gibson et al. (1964) correctly point out, all real words, however meaningful, are by definition pronounceable. In addition, nonsense syllables can be rated on both meaningfulness and pronunciability. In other words, pronunciability is itself a kind of meaning. An item may be pronounceable (e.g., TAQ) but lack semantic reference. Fortunately, the experiments of Underwood and Schulz (1960) have suggested a way of separating meaning in the sense of semantic reference from pronunciability and this method has been widely adopted in attempting to measure the importance of these variables in short-term memory (Laughery and Pinkus, 1968; 1970; Gibson, Bishop, Schiff, and Smith, 1964; Cimbalo and Mahoney, 1970; Boroskin and Lindley, 1970). This method involves generated values. This is a way of indexing integration of the trigram unit by tabulating the strength of association habits leading from the first letter to the second letter and from the first two to the third. In this way generated values of the trigrams can be obtained (see Underwood and Schulz - Appendix F). Generated values have a greater generality than do pronunciability ratings according to Underwood and Schulz, because, although pronounceable items are indexed, they include certain integrative habits which the pronunciability ratings do not, e.g., BVD is not highly pronounceable but it is a highly integrated unit in terms of generated values, since it has a consistent semantic reference. The question of concern in the present paper is how meaningfulness and pronunciability relate to learning and retention.

Lindley (1966) postulated meaningfulness as the dominant factor in short-term memory performance. Invoking the assumption of Miller's chunking notion he hypothesized that when recoding cues are used as mnemonic devices, the degree of recall depends upon the number of chunks of information. Thus, if S is presented with ZERO-ZER, the mnemonic ZERO integrates the three letters contained in ZER into a unitary chunk. Lindley (1966) had Ss either spell or pronounce the TBR item or he paired it with a word where the first three letters of the cue were the three letters of the TBR item, e.g., CAG-CAGE. There was no difference in recall between spelling and pronouncing the items but the mnemonic aid greatly improved recall.

Exploring further the dimension of meaningfulness, Boroskin and Lindley (1970) challenged the conclusions drawn by Laughery and Pinkus (1968) where pronounceable items proved easier to recall. They noted that for Laughery and Pinkus' meaningless-pronounceable trigrams each trigram obeyed the same rule with respect to consonant and letter placement, since all were of the form CVC, whereas the meaningful-unpronounceable trigrams obeyed no such set rule. Boroskin and Lindley changed the form of the $\overline{M}$-P item from CVC to a more random ordering of consonants and vowels in order to equate for this letter sequence difference. Their trigram sequences were as follows:

a) M-P BOYSPYANDILL

b) M-$\overline{P}$ TVATKOVHFDNA

c) $\overline{M}$-P BLEALKIBAUNS

d) $\overline{M}$-$\overline{P}$ GYOBFAYBOUXM

A letter was presented every two seconds and immediate serial recall was required. The more letters were recalled in condition M-$\overline{P}$ than in condition $\overline{M}$-P. Boroskin and Lindley correctly point out, however, that their Meaningless-Pronounceable dichotomies are merely descriptive and that the two attributes should be treated as a continuum. These findings are supported by Cimbalo and Mahoney (1970) and

Gibson et al. (1964). The latter investigators showed that retention, measured by both recognition and free recall, was better for meaningful items (M-$\overline{P}$) than pronounceable items ($\overline{M}$-P), despite the fact that pronunciability was more conducive to creating an integrated unit as indicated by the lower obtained perceptual thresholds. Recall, however, was superior for the M-$\overline{P}$ items. The authors reasoned that the class of "well known initials" provides for a relatively exhaustible category for grouping items in storage. The category of pronounceable trigrams on the other hand is so large as to be of minimal help at recall.

Bower and Springston (1970) investigated further the chunking of letter sequences in terms of pronounciability and meaningfulness. Speculating on the mechanisms of encoding they introduced a temporal pause during the auditory presentation of a twelve letter string. The nature of the pause was such that it came at the end of each trigram which was either M-$\overline{P}$ or $\overline{M}$-P. Hence an allowance is made for the rehearsal of the most recently presented trigram. The authors refer to this as an opportunity for S to conduct a "dictionary look-up". In the case of $\overline{M}$-P items S searches grapheme-phoneme correspondence rules for a usable pronunciation, naming the trigram. The trigram is then replaced in short-term memory by a shorter code which permits faster more efficient rehearsal. For M-$\overline{P}$ (e.g., FBI or NHL) items, "dictionary look-up" results in a shorter code which is more meaningful and recall is facilitated by a word such as "feds" or "hockey". In Experiment I twelve letters were presented in ten seconds with a one second pause between the trigrams. Recall for the $\overline{M}$-P and M-$\overline{P}$ groups was 9.2 and 9.7, respectively, which conflicts with Laughery and Pinkus (1968) and Pinkus and Laughery (1970). There were, however, some differences in design. Laughery and Pinkus used a between-S design and informed their Ss about the possibility of chunking the letters whereas Bower and Springston used a within-S design and their subjects were uninformed as to the chunkability of the letter sequences and different sample items. It is interesting to note that in one condition when the letters were presented at a rate of 1 per second, with no pauses, Ss recalled the M-$\overline{P}$ sequences slightly better than $\overline{M}$-P sequences, but the authors declined from speculating on the possible cause(s) of this finding.

It appears from the research considered, that for meaningfulness to be fully operative as a dimension for chunking in STM sufficient time must be available to S to either conduct a search of the long-term store or at least transfer some information about the stimulus items to long-term store via the mechanism of rehearsal. The implication is that an opportunity to rehearse allows S time to store information in more easily retrievable chunks.

STATEMENT OF THE RESEARCH PROBLEM

It has been shown that subjects typically adopt a variety of encoding strategies when attempting to process a sequence of items that is above the memory span. It appears that chunking operations help reduce the information load (Wood, 1967) by increasing the amount of information stored in each chunk. The literature reviewed has been concerned mainly with establishing whether pronunciability or meaningfulness is the more effective dimension for chunking in short-term memory. None of the studies cited, however, have studied the effects of these variables on retention over time. For the most part, recall was immediate, and reflected only the level of acquisition.

Keppel (1965) cites a study by Peterson, Peterson and Miller to illustrate the problem. These authors reported higher recall for words than low meaningful nonsense syllables 6 seconds after presentation. It is not possible to attribute differences in recall to the effect of meaningfulness on either learning or retention unless immediate recall has shown both the groups to be at the same level. In this case differences in the delayed retention test would reflect differential rates of forgetting. One solution to the problem of differences in immediate retention has been proposed by Underwood (1964). Basically it involves setting presentation rate in such a way for each group that immediate recall is less than perfect (to avoid a ceiling effect) but at the same time equal across groups for the different types of materials. These equations would be determined ahead of time by a pilot study. Now any differences in the retention functions for the different kinds of material can be attributed to the effect of the variable over the retention interval.

With this in mind the research will address itself to the problem of determining whether pronunciability or meaningfulness is the more viable attribute of memory. Memory for an item or an event can be thought of as a collection of attributes (Underwood, 1969). During encoding certain attributes of memory are established and once learning has occurred these attributes are forgotten at different rates. It is postulated here that meaningfulness is a more reliable attribute in short-term retention than pronunciability. In other words, once encoded, a sequence of letters that can be chunked into meaningful but unpronounceable trigrams will prove more resistant to forgetting over short intervals, than a sequence of letters that can be grouped into pronounceable but meaningless trigrams. The rationale behind this hypothesis is based on the notions advanced earlier in support of a multiprocess memory system.

In the case of M-$\overline{P}$ trigrams (e.g., DDT) it is assumed that relevant information concerning these items already resides in long-term storage. If sufficient time is available for the *S*s to gain access to this information or as Bower and Springston (1970) nicely put it, to conduct a "dictionary look-up", then at recall the *S* will be recalling from both memory stores. With $\overline{M}$-P trigrams, however, (e.g., TEV), it is assumed that no information is available *a priori* from the long-term store. Recall for the most part will be from the short-term store only.

The stipulation here, of course, is that S has to have sufficient opportunity to conduct a search of the long-term store to label the meaningful items. Accordingly, in the present study it is intended to introduce a rehearsal period into the design in order to allow for this search. As previously mentioned (Bjork, 1970; Stanners and Meunier, 1969) a rehearsal period has the effect of strengthening the memory trace.

General Expectations

Learning rate in acquisition. It is expected that the exposure time needed to achieve the criterion level of performance and then subsequently used in the experiment proper will be shortest for pronounceable strings, followed by meaningful strings and then the random letter strings. According to Gibson et al. (1964) pronunciability is more powerful as a means of chunking.

Retention effects as a function of rehearsal periods. It is hypothesized that recall will increase with lengthening periods of unfilled activity. With 5 seconds of unfilled retention interval followed by immediate recall it is expected that the recall will be best for the $M\text{-}\overline{P}$ group, followed by the $\overline{M}\text{-}\overline{P}$ and $\overline{M}\text{-}P$ groups, respectively. This can be explained in part by the fact that with the anticipated longer exposure time required for the $M\text{-}\overline{P}$ and $\overline{M}\text{-}\overline{P}$ groups to attain the criterion level, more of the string will have had an opportunity to enter long-term storage. Hence there will be fewer letters left in short-term storage for S to rehearse. At the 10 second unfilled retention interval it is assumed that the recall for the M-$\overline{P}$ will improve little whereas substantial gains are expected from the $\overline{M}$-P group as the effects of rehearsal begin to show more. Little improvement is to be expected from the $\overline{M}$-$\overline{P}$ group and in fact recall will perhaps drop off with the lengthening rehearsal periods since most of the string will have been encoded during presentation.

Retention effects as a function of filled retention interval. It is hypothesized that at the 0 second rehearsal period the meaningful strings will be most resistant to increasing amounts of filled retention interval activity, followed by random strings and poorest for the pronounceable. With the expected long exposure time that will be required for the $\overline{M}$-$\overline{P}$ group to reach the criterion level of 6-9 letters correct it must be assumed that covert rehearsal will be responsible for a good deal of information being transferred to the long-term store. Hence recall will be from both stores after 5 seconds of interpolated activity but decreasingly from the short-term store especially after 10 seconds of color naming. In the case of the pronounceable strings where the rate of presentation is expected to be quite fast little transfer to long-term storage is anticipated. Consequently, recall will be mostly from the short-term store from which information is rapidly lost unless rehearsed.

After 5 seconds of rehearsal period the same general pattern is expected to emerge with respect to the M-$\overline{P}$, $\overline{M}$-P and $\overline{M}$-$\overline{P}$ groups as the duration of color naming increases, i.e., they will become more resistant to forgetting. As stated earlier *S* is in a position to utilize more effective rehearsal strategies in the M-$\overline{P}$ strings since supposedly information about the stimulus items already resides in long-term storage. Comparing the recall of the $\overline{M}$-P and $\overline{M}$-$\overline{P}$ groups a reversal in the retention curves is hypothesized after 5 seconds of rehearsal period. Given an opportunity to chunk the letters of the string into pronounceable units thus allowing more rehearsal per unit time the pronounceable string should prove to be more resistant as the duration of the filled retention interval increases. The same overall pattern is expected after 10 seconds of rehearsal period prior to the introduction of the filled retention interval.

METHOD

Experimental Design

For the experiment there was a 3 x 3 x 3 x 2 mixed model factorial design with three factors being manipulated between subjects and one factor within subjects. The major experimental variables were string type, unfilled retention interval and filled retention interval. This latter variable was manipulated within subjects and orthogonal to the other factors which were manipulated between subjects. Experimenter was also made a between factor since two *E*s were used.

There were three levels of string type that can be classified as meaningful-unpronounceable (e.g., consonant strings that can be grouped into 4 meaningful trigrams--NHLWPGMTCLTD and herein after labelled as M-$\bar{P}$ strings), meaningless-pronounceable (e.g., consonant and vowel strings that can be grouped into 4 pronounceable trigrams--BLIVEASLEORC and herein after labelled as $\bar{M}$-P strings), and meaningless-unpronounceable (e.g., consonant strings that cannot be chunked in terms of meaningfulness or pronunciability--LPGWTHMDLTCN and herein after labelled as $\bar{M}$-$\bar{P}$ strings). There was a departure that was made from previous studies in the material for the M-$\bar{P}$ group. In the sequences used by Laughery and Pinkus (1968), e.g., NFLCBSAMATNT, parts of the string could be grouped into pronounceable chunks, e.g., SAMAT. Consequently, it was not safe to assume that *S*s were in fact encoding completely via meaningfulness. It was, therefore, decided to use consonant trigrams of the type mentioned above when constructing the M-$\bar{P}$ strings.

It is realized that despite a refinement in procedure regarding the selection of the meaningless-pronounceable and meaningful-unpronounceable strings, these labels are not categorically pure and therefore are meant to be descriptive in nature only.

There were three levels of unfilled retention interval or rehearsal period (0, 5, or 10 seconds), and each S received only one string type--rehearsal period combination. The third factor (duration of filled retention interval) was varied within subjects and was designed to prevent or at least severely restrict any rehearsal on the part of S. The unfilled retention intervals were 0, 5, or 10 seconds duration and consisted of color naming (Stroop test--see Wickens, Born and Allen, 1963). Although Ss were not paced during this task they were encouraged to perform as quickly as possible. There were three trials at each level of filled retention interval. Each subject was randomly assigned to one of the 9 groups with the restriction that the Nth subject was not assigned to a given group until N-1 Ss had been assigned to all other groups.

Care was taken to ensure that the string types and filled retention intervals were properly counterbalanced across Ss such that a particular instance of string type occurred with each duration of filled retention interval an equal number of times. In addition, for each subject, the sequence of retention intervals (involving the Stroop test) was randomly ordered.

Materials

Examples of the materials used are detailed in Appendix A.

Nine lists of each string type were constructed, each sequence being 12 letters in length. The stimuli were arranged so that a space of 1/4 inches occurred between each group of three letters and 1/8 inches between letters within a group. Following Boroskin and Lindley's notion that the $\overline{M}$-P string should not be exclusively of the form CVC, it was decided to use their items from that group since they have already been calibrated with respect to meaningfulness and pronunciability. These items had a mean rating of 3.61 on the 9 point pronunciability scale used by Underwood and Schulz (1960). Concomitant meaningfulness ratings of the same items showed a mean of 2.4 on a 5 point scale (Boroskin and Lindley, 1970). The M-$\overline{P}$ strings were constructed from a pool of acronyms found to be generally meaningful for students of this University (e.g., WPG-Winnipeg). The $\overline{M}$-$\overline{P}$ strings were devised by randomly rearranging the letters in the M-$\overline{P}$ strings. The only restriction concerning the construction of each string type from the pool of trigrams was that no string contained more than three occurrences of the same letter.

<u>Procedures</u>

<u>Establishing presentation time</u>. Prior to the experiment proper a session was required to establish the rate of presentation for each string type to be used, in such a way as to equate for initial learning across all groups. The purpose of this procedure was to determine a rate that would permit each <u>S</u> to recall 6-9 correct letters in correct positions at immediate recall. In this pilot study the letters were presented visually on a 3-channel Scientific Prototype tachistoscope.

Lighting was provided by General Electric Cool White fluorescent tubes (No. F8.T5. CW/HH). The visual angle subtended by a stimulus letter was 45^{o} (see Appendix B). In establishing the presentation time needed to equate level of immediate recall each string type group began trial one with a presentation time which preliminary work indicated would yield approximately 50% recall. These times were 3.5 sec., 3.0 sec., and 15.0 sec. for conditions M-$\bar{P}$, $\bar{M}$-P, and $\bar{M}$-$\bar{P}$, respectively. On the basis of the actual recall performance presentation time for an *S* was adjusted by a fixed interval on successive trials so as to focus in on a performance level of 6-9 letters correct. The interval of adjustment was .2 secs. for conditions M-$\bar{P}$ and M-P and 2.0 secs. for condition $\overline{\text{M-P}}$. Each *S* received 9 trials of only one string type. The *S*'s mean presentation time over those trials where recall fell in the criterion range, was treated as his score and the presentation time for the experiment proper was obtained by averaging scores across *S*s.

Subjects were instructed as to the nature of the letter strings and were told to recall as many letters as possible in their proper sequence as soon as presentation ended. On each trial the sequence was as follows. After a verbal "Ready" signal, 3 sec. prior presentation, the string was exposed for the necessary time. Following this *S* was given a sheet of paper with 12 spaces on it and told to write in the 12 letters. Thirty seconds was allowed for recall and there was a 20 sec. intertrial interval before the next "Ready" signal.

Experiment proper. Each subject was instructed as to the nature of the particular string type to be presented, i.e., they were told that the sequences contained 12 letters and could be organized into either 4 meaningless but pronounceable trigrams, 4 meaningful but unpronounceable trigrams, or 4 trigrams in the case of the meaningless-unpronounceable items. They were further told that recall could be aided by chunking the sequences into 4 units rather than trying to remember the individual letters (see Experimental Instructions - Appendix C). Again, presentation of the letter string was signalled by the S saying "Ready"! 3 seconds prior to the onset of the visual stimulus. As in the pilot study the strings were presented tachistoscopically, followed immediately by a rehearsal or unfilled retention interval of 0, 5, or 10 seconds. Ss were uninstructed regarding the rehearsal period. Three strings were presented at each of the three levels of filled retention interval which again consisted of color naming. The purpose of this was to prevent or severely hamper attempts by S to rehearse the string. Thirty-five seconds were allowed for free recall which the S recorded on sheets as in the pilot study. There was an intertrial interval of 20 seconds before the onset of the next "Ready"! signal. The number of correct positions was scored on each of the three retention intervals for each string type. In addition, the number of chunks correctly reported, irrespective of position was tabulated. At the end of the session all Ss were asked to provide a protocol indicating any techniques used in trying to remember the items.

Subjects

One hundred and fifty-two students enrolled in Psychology courses at the University of Manitoba summer session served as subjects. Twenty-four Ss took part in the pilot study and 128 in the experiment proper--14 per condition. The data of 2 of the pilot study Ss were discarded since they failed to reach the criterion level of 3 scores in the 6-9 range within the 9 experimental trials. In the main study, data of 2 Ss were excluded from analysis since one S erroneously ran twice and the other, a recently arrived Chinese student, had a limited facility with the English language. As an inducement to participate most Ss received credit towards their final course grade. Approximately 40% of the Ss served on a volunteer basis due to the acute shortage in the regular summer pool. In all cases volunteer Ss were currently enrolled in higher-level psychology courses where experimental participation is not normally required. Care was taken to ensure that the same number of volunteer Ss were tested in each experimental condition.

RESULTS

Learning Rate in Acquisition

The initial study involved establishing a presentation time for each of the groups that placed the number of letters correct per string between 6 and 9 at immediate recall. On the basis of the results of this study the following times were adopted for the main experiment: $\overline{M}$-P - 3.1 seconds; M-$\overline{P}$ - 3.8 seconds; $\overline{M}$-$\overline{P}$ - 17.5 seconds. As can be seen in Appendix D the time required to achieve the criterion performance was the shortest for the pronounceable strings, followed by the meaningful strings, and longest for the random letter strings. A two-tailed t-test revealed that the difference between the performance of the M-$\overline{P}$ and $\overline{M}$-P groups was highly significant ($t = 5.29$, $df = 26$, $p < .002$). Of practical significance is the finding that even the slowest of the subjects in the $\overline{M}$-P group was faster than the fastest of the M-$\overline{P}$ subjects (see Appendix D). Clearly the differences between both the M-$\overline{P}$ and $\overline{M}$-P and the $\overline{M}$-$\overline{P}$ are significant.

Retention Effects - Experiment Proper

Two criteria were employed in analyzing the data: the number of letters correct in their proper positions and the number of chunks recalled intact irrespective of position.

Letters. The mean number of letters correctly recalled as a function of string type, rehearsal period, and retention interval collapsed across Experimenters, is depicted in Figure 4. An initial question of concern, one that is of major theoretical importance, was

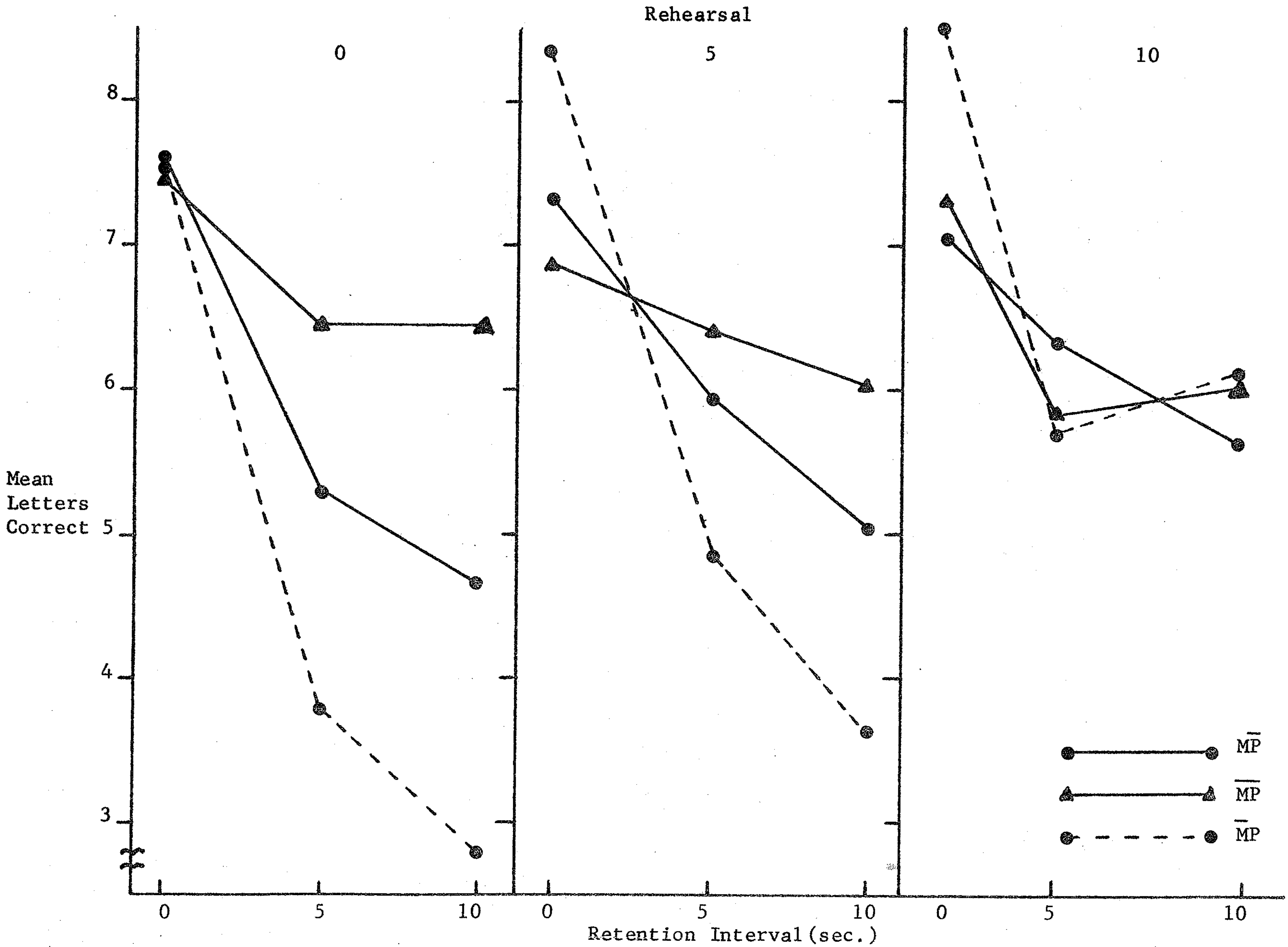

Fig. 4. Mean number of letters correct as a function of string type, rehearsal and retention interval.

whether the presentation times were successful in placing each of the groups at the same level of learning at 0-second rehearsal in terms of number of letters correctly recalled. The obtained means were: $M\text{-}\overline{P}$ - 7.6; $\overline{M}\text{-}P$ - 7.5; and $\overline{M}\text{-}\overline{P}$ - 7.4. A simple analysis of variance on the immediate recall scores indicated no differences ($F < 1$). Hence it can be assumed that level of learning was equated for at immediate recall.

The main analysis was a four-factor analysis of variance performed on the recall scores with string type, rehearsal and experimenter as between-subject variables and retention interval as a withing-subject variable (see Table 1). As can be seen none of the Experimenter effects were significant. The significant effects were Retention ($F = 85.7$; $df = 2, 216$; $p < .001$) and String x Retention ($F = 11.577$; $df = 4, 216$; $p < .01$). Retention losses were approximately 20% from a mean of 7.5 letters correct down to 5.2 letters per string. The significant String x Retention interaction is depicted in Figure 5 where it is apparent that most of the decrease in retention is due to losses incurred by the $\overline{M}\text{-}P$ group (34% vs 8% and 18.4% by the $\overline{M}\text{-}\overline{P}$ and M-P groups, respectively). It should be noted that Figure 4 indicates that the String x Retention interaction was particularly strong at 0-second rehearsal. Recall decreased markedly in the order meaningless-unpronounceable, meaningful-unpronounceable, and meaningless-pronounceable. The import of this effect is reserved for the discussion section.

While not significant at .05 level the effects of String and

TABLE 1

Analysis of Variance of Mean Number of Letters Correct for each S as a Function of String Type, Rehearsal, and Retention Intervals

Source	df	Mean Square	F
String type	2	186.66	2.50
Rehearsal	2	172.51	2.32
String x Rehearsal	4	151.83	2.04
Experimenter	1	4.73	0.06
String x Experimenter	2	74.06	0.99
Rehearsal x Experimenter	2	158.42	2.12
String x Rehearsal x Exp.	4	68.12	0.91
Error (Between)	108	74.56	
Retention	2	1847.81	85.73*
String x Retention	4	249.55	11.58*
Rehearsal x Retention	4	37.39	1.74
String x Rehearsal x Exp.	8	24.53	1.14
Experimenter x Retention	2	34.56	1.60
String x Exp. x Retention	4	26.31	1.22
Rehearsal x Exp. x Retention	4	51.37	2.38
String x Rehearsal X Exp. x Retention	8	19.38	0.89
Error (Within)	216	21.55	

*$p < .001$.

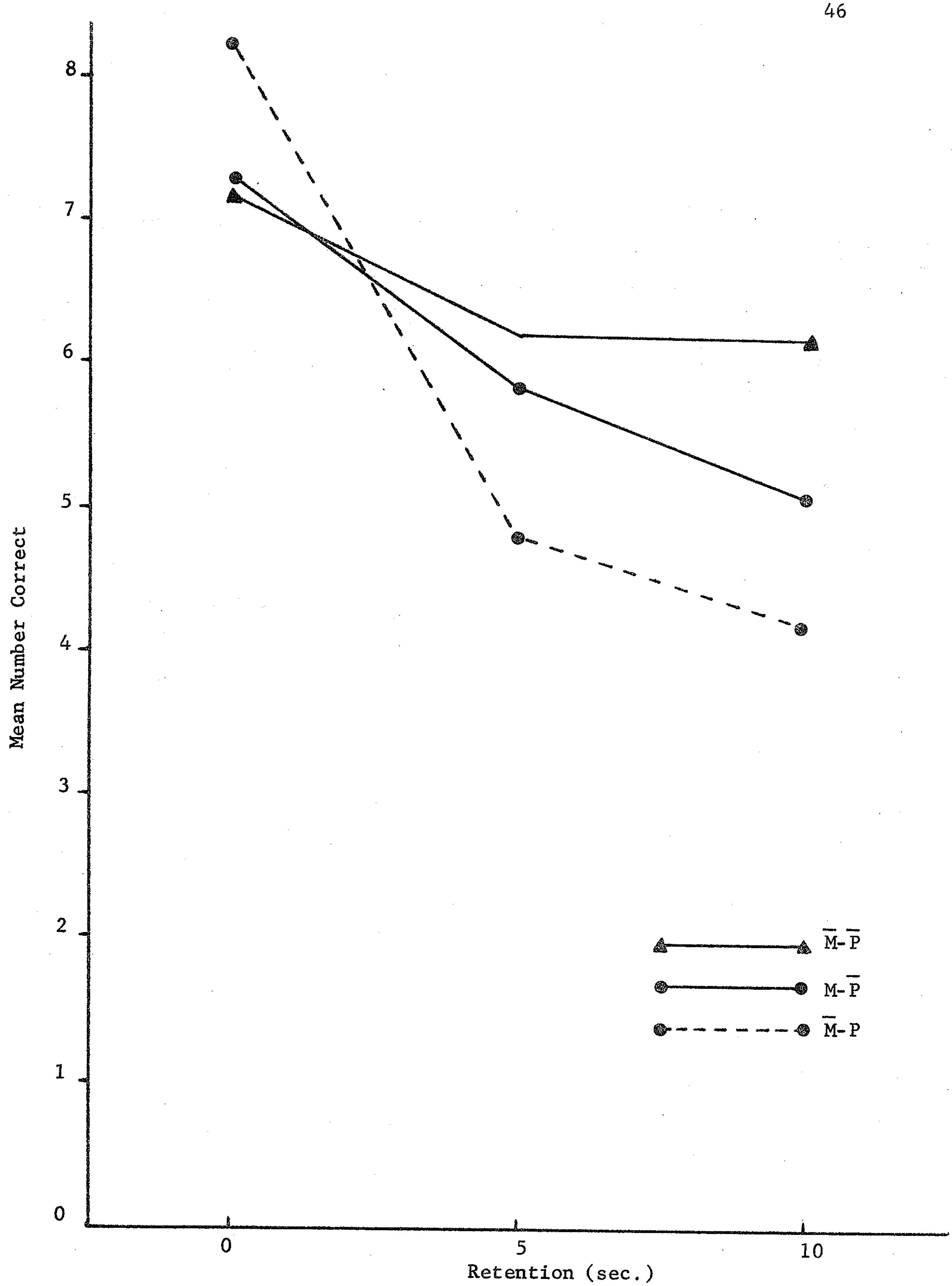

Fig. 5. Mean number of letters recalled for each String type as a function of filled retention interval

String x Rehearsal were in the direction predicted (String: $F = 2.50$; $df = 2, 108$; $p < .09$; String x Rehearsal: $F = 2.04$; $df = 4, 108$; $p < .08$). Part of the weak effects obtained for these factors might be attributed to a reduced *n* per cell for the main experiment. This accommodation took place due to the acute shortage of subjects from the regular summer school pool. In terms of the effects of rehearsal Figure 6 shows the retention curves for each of the string types over each of the free rehearsal periods. The obtained weak effect is almost entirely due to increased recall as a function of rehearsal for the $\overline{M}$-P group (18% vs 2.6% and 4% for the $\overline{M}$-$\overline{P}$ and M-$\overline{P}$ groups, respectively).

Chunks. Table 2 presents analysis of variance on the number of chunks recalled irrespective of position as a function of the string type, rehearsal period, and retention interval. Significant main effects were found for String type ($F = 6.73$; $df = 2, 108$; $p < .01$) and Retention ($F = 43.59$; $df = 2, 216$; $p < .001$). Figure 7 shows the mean number of chunks correct for each string type. Recall was best for M-$\overline{P}$ chunks followed by $\overline{M}$-$\overline{P}$ chunks and worst for $\overline{M}$-P chunks. Tukey's HSD test (see Kirk, 1968, Chapter 3) revealed that for the present *S*s, differences between M-$\overline{P}$ and $\overline{M}$-$\overline{P}$ means and between $\overline{M}$-$\overline{P}$ and $\overline{M}$-P means were statistically significant ($p < .01$). This finding contradicts Gibson et al. (1964) and more recently Laughery and Pinkus (1968) who claim that "pronunciability is a more effective dimension for chunking in STM than meaningfulness" (Laughery and Pinkus, 1968, p. 640).

The opportunity to rehearse was most beneficial for the $\overline{M}$-P

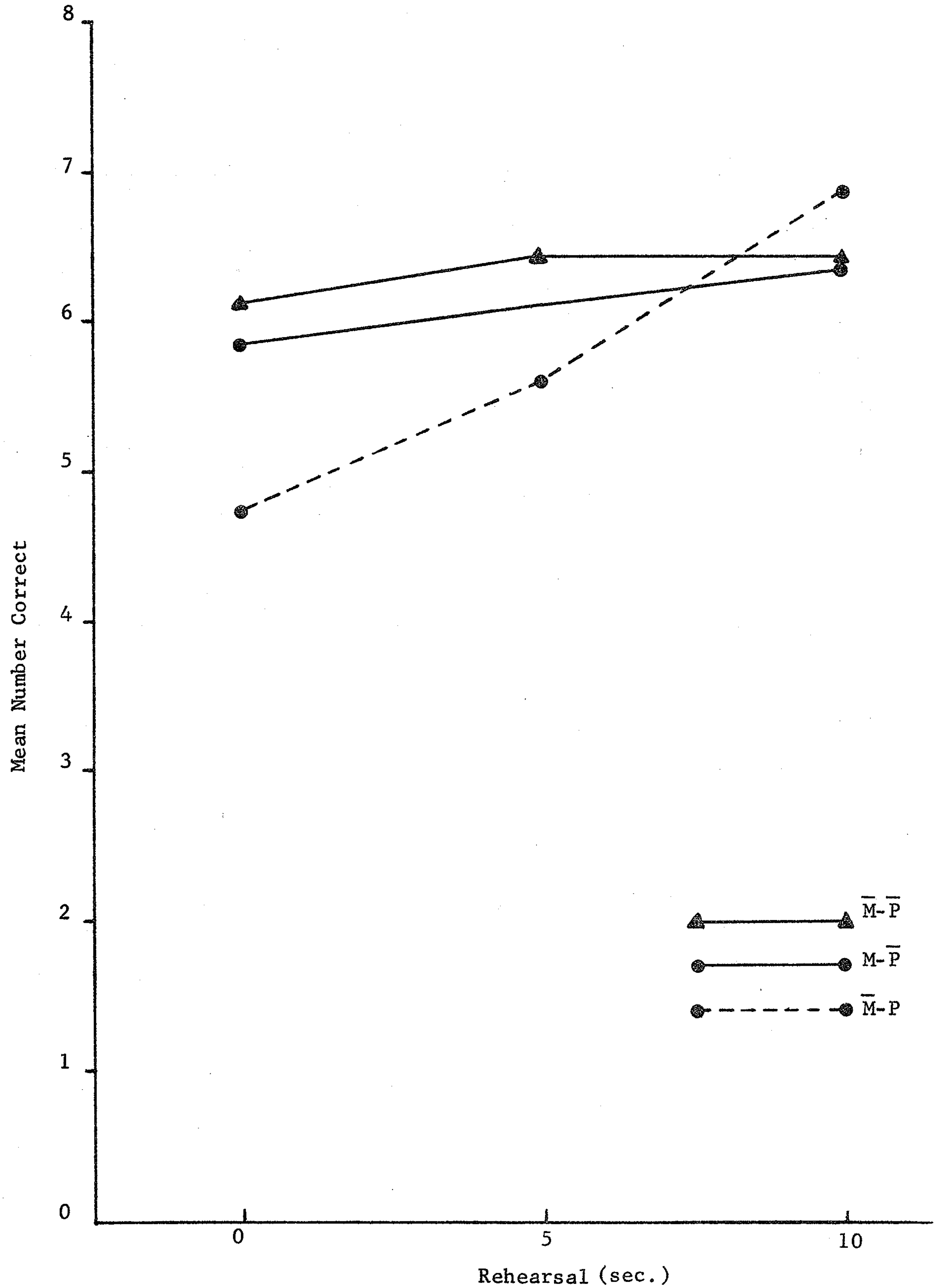

Fig. 6. Mean number of letters recalled for each string type as a function of rehearsal.

TABLE 2

Analysis of Variance of Mean Number of Chunks Correctly Recalled For Each S as a Function of String Type, Rehearsal, and Retention Intervals

Source	df	Mean Square	F
String	2	54.21	6.73**
Rehearsal	2	8.6458	1.07
String x Rehearsal	4	20.96	2.60*
Rehearsal x Experimenter	2	27.75	3.44*
Experimenter	1	1.65	0.20
String x Experimenter	2	11.31	1.40
Rehearsal x Experimenter	2	27.75	3.44*
Str. x Reh. x Exp.	4	8.69	1.07
Error (Between)	108	8.05	
Retention	2	126.87	43.586***
String x Retention	4	13.66	4.69**
Rehearsal x Retention	4	2.33	0.80
Str. x Reh. x Ret.	8	1.66	0.57
Experimenter x Retention	2	1.83	0.63
Str. x Exp. Ret.	4	1.51	0.52
Reh. x Exp. x Ret.	4	5.87	2.01
Str. x Reh. x Exp. x Ret.	88	2.62	0.90
Error (Within)	216	2.91	

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

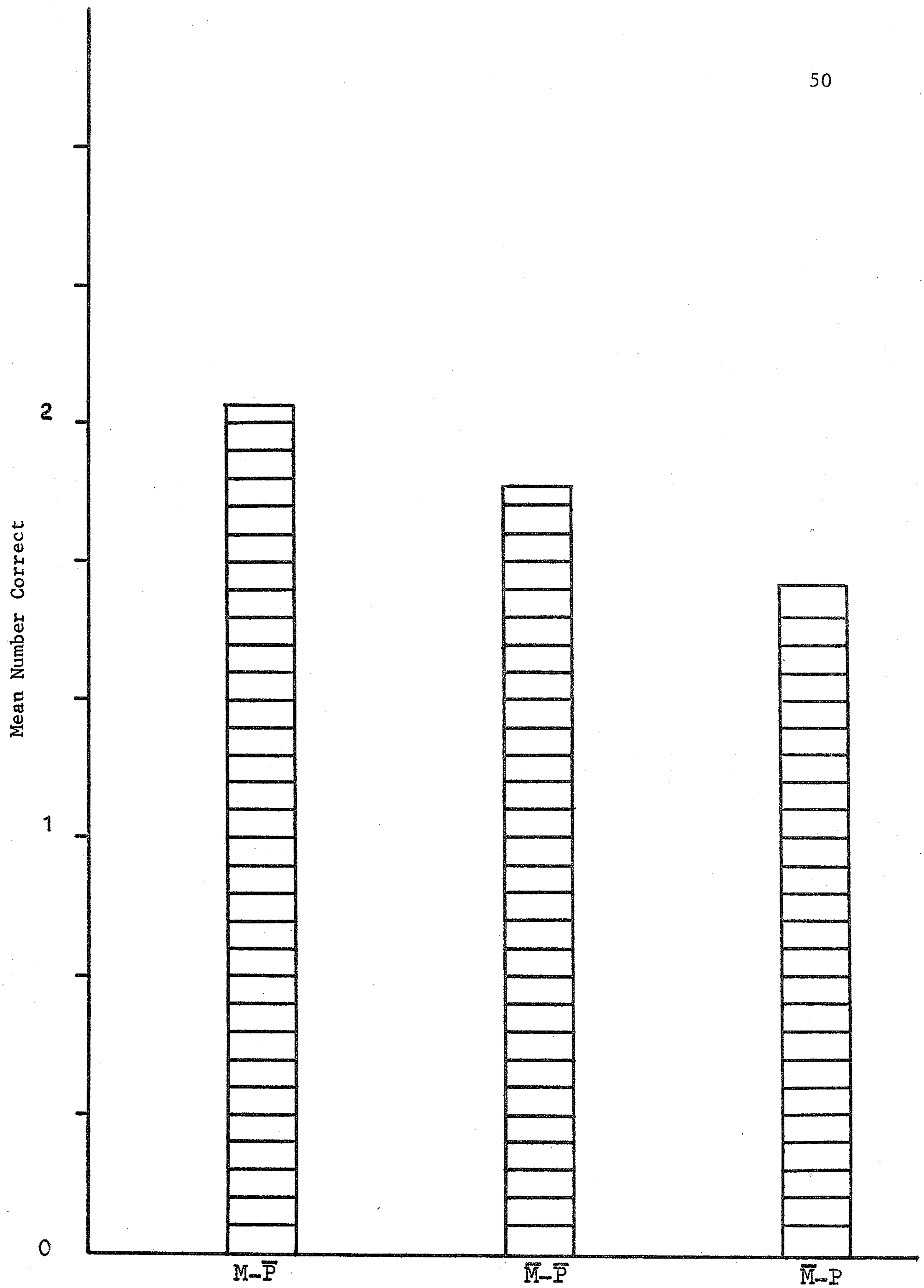

Fig. 7. Mean number of chunks recalled for each string type.

group and this resulted in a significant String x Rehearsal interaction ($F = 2.6$; df = 4, 108; $p < .05$). Figure 8 shows the mean number of chunks recalled over the varying rehearsal periods. While rehearsal had no facilitative effect on either the M-$\overline{P}$ or $\overline{M}$-$\overline{P}$ items the number of chunks recalled for the $\overline{M}$-P group rose from 1.28 to 1.97 after 10 seconds of rehearsal, representing an increase of 17%.

An obtained Experimenter x Rehearsal effect, significant at .05 level ($F = 3.4$; df = 2, 108) cannot be accounted for in any systematic manner. It appears to be due to differential effects with the M-$\overline{P}$ and $\overline{M}$-$\overline{P}$ strings.

A further outcome of the analysis of variance was a significant String x Retention effect ($F = 4.69$; df = 2, 216; $p < .01$). Figure 9 illustrates the retention curves for each of the string types. Although no direct comparison can be made between the retention of $\overline{M}$-P vs M-$\overline{P}$ chunks since they were not equated for at 0 seconds it is interesting to note that the pronounceable items were retained more poorly than the meaningless-unpronounceable items after 10- seconds of filled retention interval activity despite the fact that the $\overline{M}$-P items showed slightly better recall at 0-second retention interval. In addition, it appears that superior chunking ability was evidenced by the meaningful over the pronounceable group at 0-second rehearsal. The mean number of chunks recalled at 0-second rehearsal for each of the string types were M-$\overline{P}$ - 2.44, $\overline{M}$-$\overline{P}$ - 2.09, $\overline{M}$-P - 1.92. A test for the differences between these means using Tukey's HSD test revealed the following: M-$\overline{P}$ > $\overline{M}$-$\overline{P}$ and $\overline{M}$-P ($p < .01$). Although the $\overline{M}$-$\overline{P}$ group

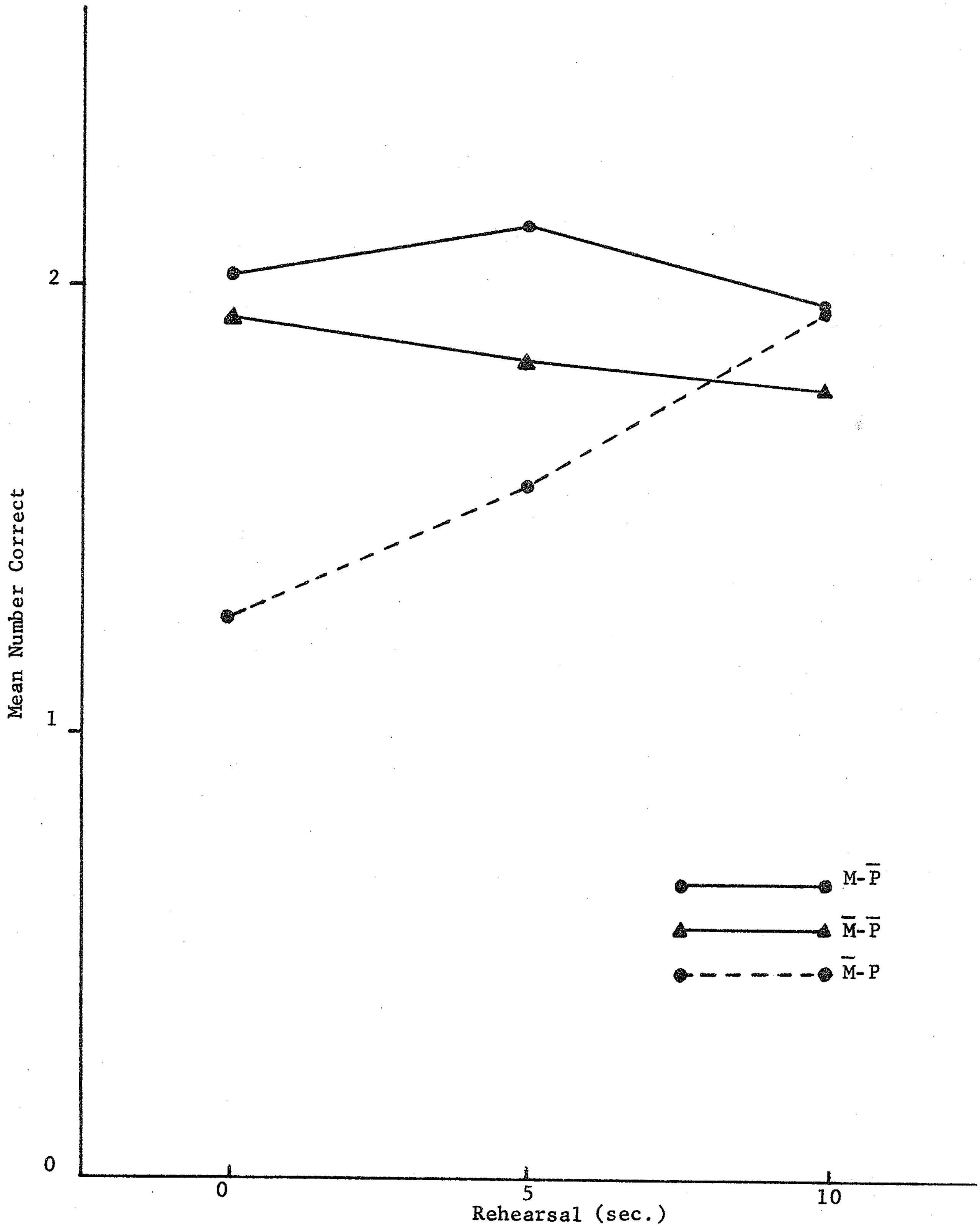

Fig. 8. Mean number of chunks recalled for each string type as a function of rehearsal period.

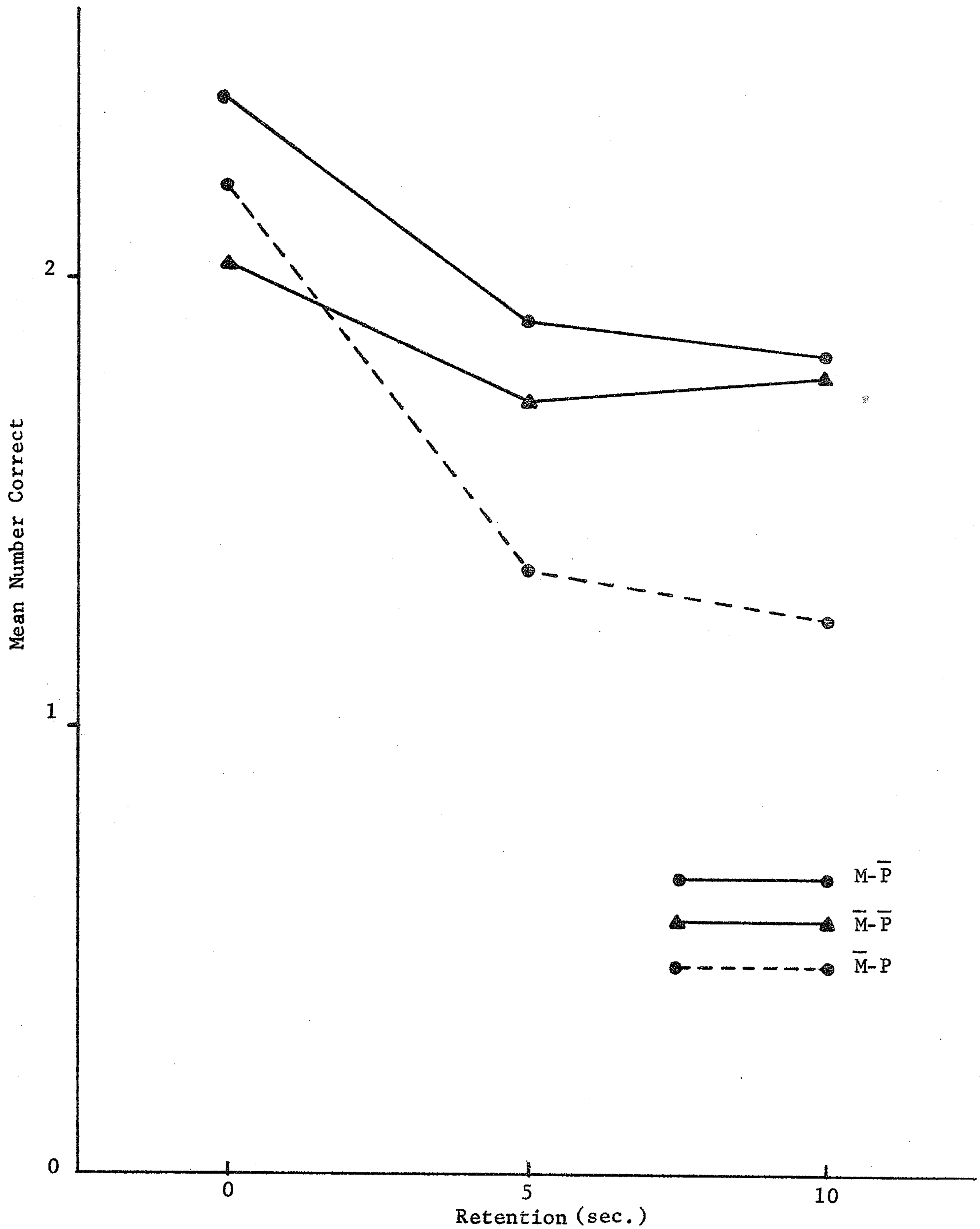

Fig. 9. Mean number of chunks recalled for each string type as a function of filled retention interval.

recalled more chunks than the $\overline{M}$-P group this was not statistically significant.

Recall may have been even better for the M-$\overline{P}$ strings had more of the acronyms been recognized. After the experimental session subjects in the meaningful group were asked to indicate all items not known during presentation. Some items (e.g., BVD, HFC, ZBT) were not known by more than half the Ss (see Appendix E). An analysis of the data revealed that for those trigrams not recognized by all M-$\overline{P}$ Ss (216) errors in recall were subsequently made on 176 of the trigrams indicating that unless information already existed in the long-term store about those items there was very little chance of the items going into long-term store due to the relatively fast presentation time.

DISCUSSION

Retention Effects

Previous research (e.g., Laughery and Pinkus, 1968) investigated immediate recall for sequence of pronounceable CVCs, familiar initials or the same letters in a randomly rearranged manner. Recall varied from best to worst in this order and it was concluded pronunciability led to superior performance in STM. Although the present findings would seem to support this notion in that the time required by the $\bar{M}$-P groups was significantly less than for the other two string types the conclusions drawn by Laughery and Pinkus (1968) and also Gibson et al. (1969) are in doubt. From these results Laughery and Pinkus argue for the superior effectiveness of pronunciability as a strategy for storing items in memory. Again, however, it is stressed that these authors were dealing with STM in only a limited manner since there was no retention interval filled or unfilled prior to recall. It is suggested that the introduction of varying retention intervals can be used to explain the discrepant findings reported here. Hence present results indicate that pronunciability is a relatively poor method of processing information for storage, compared to items that are encoded along a meaninful dimension. It was found that meaningfulness provides a better dimension for retaining and retrieving verbal information (once level of learning had been equated across conditions at immediate recall). In addition, overall retention effects continued to favor the M-$\bar{P}$ and $\bar{M}$-$\bar{P}$ strings even when the opportunity to rehearse was introduced.

Further, these authors claim that pronunciability lends itself better to chunking and the fact that in the present study, the $\bar{M}$-P group required a shorter period of time to achieve the criterion level of 6-9 letters correct seems to support this notion. An analysis of the chunks correctly reported at 0-second rehearsal, however, suggests that meaningfulness is a more powerful means of chunking than pronunciability i.e., despite the fact that both groups were equal in terms of number of letters correct the M-$\bar{P}$ groups had chunked more of these letters.

The assumption here, of course, is that S-determined chunks were the same as the E-provided chunks. Ordinarily it is not possible to define the unit of organization independently of the learner (Miller, 1956b). The findings of Bower and Springston (1970), however, lend support for the claim that providing the Ss with cues (verbal instructions and actual grouping of items during presentation) as to how to encode the letter strings will result in Ss incorporating these cues in their encoding strategies.

An interesting, but not entirely unexpected finding is the relatively high recall in terms of letters found for the $\bar{M}$-$\bar{P}$ groups. The following remarks are applicable specifically to the immediate recall data for the letters so that the retention functions can be looked at without the confounding effect of rehearsal (to be discussed below). Due to the long presentation time experienced by the $\bar{M}$-$\bar{P}$ group it is postulated that Ss were able to impose their own meaning on the string. By developing efficient encoding techniques a substantial proportion of each string is perhaps transferred to the long-term store during presentation. If so, we would expect little deterioration during the filled retention interval. This is in fact what happened. Letter recall decreased by only 7.7% after 10 seconds of filled retention interval (at 0-second rehearsal) compared to a loss of 39% for the pronounceable items. Support for the claim that $\overline{\text{M}}$-$\overline{\text{P}}$ *S*s for the most part used elaborate devices is provided by post-experimental questioning. More than 75% of the $\overline{\text{M}}$-$\overline{\text{P}}$ *S*s reported attempting to develop a mnemonic for a portion of the string, on at least 5 of the 9 trials. Examples of reported mnemonics are presented in Appendix F.

In the case of meaningful strings a good proportion of the strings contain information that already resides in long-term storage. Known trigrams are transferred to a more permanent form of storage which is more resistant to forgetting. As has already been established not all the meaningful trigrams were recognized. Consequently, it is assumed that some portion of each string remained in the short-term store and was subsequently lost when the retention interval was introduced.. Hence some loss over the retention interval was to be expected (24% vs 39% and 7% for the $\overline{\text{M}}$-P and $\overline{\text{M}}$-$\overline{\text{P}}$ strings, respectively),

Turning to a consideration of the $\overline{\text{M}}$-P group it is contended that the relatively fast presentation time for the pronounceable strings effectively restricted the amount of time available to *S*s for rehearsal. Further since these items had no representation in long-term store the majority of items remained in the short-term store from which they were rapidly lost as the duration of the filled retention interval increased.

The above findings are of considerable interest especially in the light of Underwood's (1964) claim that the rate of forgetting is no higher for items of low meaningfulness than it is for highly meaningful materials, provided they are learned equally well in the first place. In the present study differential forgetting occurred in spite of care taken to equate the level of learning across experimental conditions. One explanation, and one that lends support to the theories concerning a multi-memory system is that unless all of the letters recalled at 0-second retention are in the long-term store then some portion of each string is in short-term store and, therefore, subject to fairly rapid forgetting. Now if each string type contains differing proportions of items in short and long-term store then the differential forgetting rates can be accounted for. For purposes of illustration hypothetical proportions have been schematized in Figure 10.

For the meaningful strings only those trigrams not known or not rehearsed should remain in short-term memory and become susceptible to rapid memory loss during the retention interval. Proportionately more of the $\overline{M}$-$\overline{P}$ strings should be transferred to the long-term store during the relatively long presentation and hence few items remain behind in short-term store. With the pronounceable strings there is little chance of more than an item or two getting into long-term store due to the fast presentation time that affords little opportunity to rehearse. Consequently, much of the string remains in

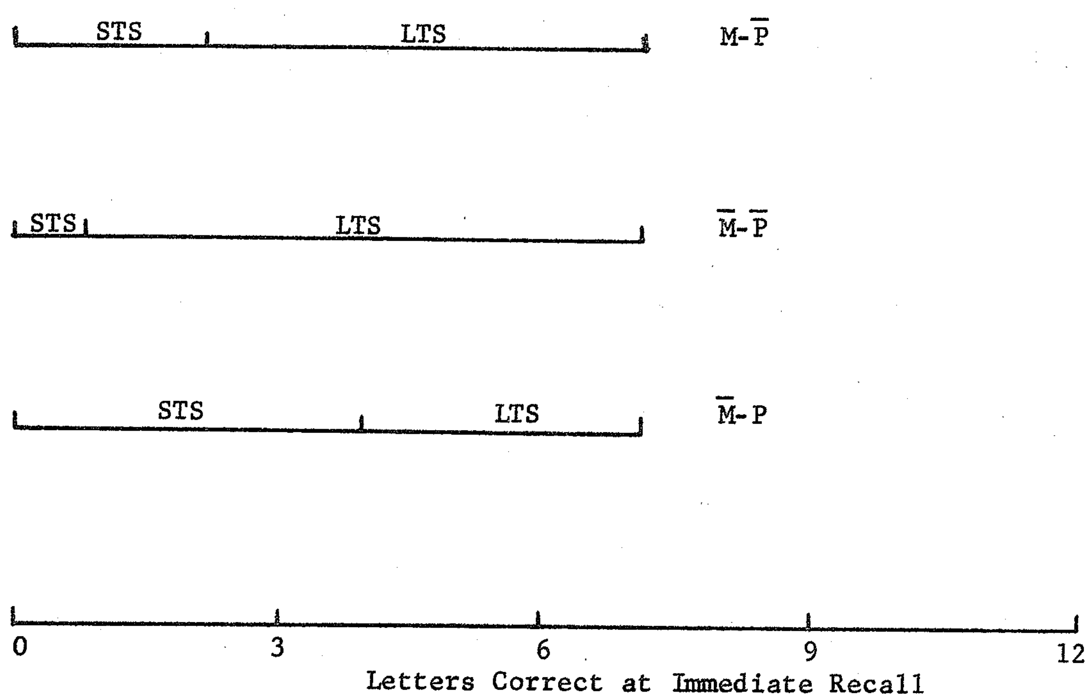

Fig. 10. Hypothetical proportions of the relative amounts of items in each string type in long- and short-term store at immediate recall (for letters).

short-term store and is lost during the filled retention interval.

Rehearsal Effects

It was noted that the main effect of rehearsal, contrary to expectations, was not significant. As indicated in Figure 6, however, rehearsal seemed to have a facilitative effect on the $\bar{M}$-P strings. Moreover, an analysis of the data relating to the number of chunks recalled showed a significant String x Rehearsal interaction with the $\bar{M}$-P again benefitting most by the opportunity to rehearse. Similar results were obtained for letters correct with the interaction approaching statistical significance. These findings can be accounted for by the assumptions underlying the model proposed above. Since a greater portion of the $\bar{M}$-P string is thought to be in short-term store at immediate recall it follows that the Ss experiencing these strings should be able to capitalize most on the availability of a rehearsal period. A disconcerting aspect is the apparent increase in the number of letters correctly recalled for these strings over the varying rehearsal periods prior to color naming (e.g., recall for $\bar{M}$-P groups increased from 62.5% to 73.3% after 10 seconds of free rehearsal). A number of explanations are suggested. To begin with it could be maintained that the opportunity to rehearse enables the Ss to organize the material more efficiently. I suspect that this is only partially true. More likely what is happening is that items are being lost during recall at the 0-second rehearsal period since they are for the most part in STS. Once an opportunity to rehearse is provided a good proportion of the items are transferred to long-term store where they are more resistant to forgetting during recall. This explanation is somewhat similar to Tulving and Arbuckle's (1963) notion of output interference. Added support is forthcoming from the data where there is a general flattening of the retention functions for each of the string types over the varying rehearsal periods (see Figure 4). Again the contention is that rehearsal facilitates transfer of material to the long-term store where the rate of forgetting is less steep.

CONCLUSION

The results of the STM study show the beneficial effects of meaningfulness on recall. In a free serial recall situation *S*s were presented with 12 letter strings at a rate determined previously by a pilot study that equated for levels of learning across groups at immediate recall. *S*s were instructed to group the strings into 4 trigrams that were either meaningless-pronounceable, meaningful-unpronounceable, or meaningless-unpronounceable. Recall was seen to increase in this order following filled and/or unfilled retention intervals. The opportunity to rehearse greatly facilitated the recall of the pronounceable strings and with little or no advantage afforded the meaningless-unpronounceable strings. This is interpreted as general support for a dual process theory of memory since it is contended that at immediate recall most of the pronounceable strings are in the short-term store. This is due to the relatively fast presentation rate for groups receiving the $\overline{M}$-P strings. On the other hand, the $\overline{M}$-$\overline{P}$ groups presumably have ample opportunity to rehearse with the longer presentation rate. It is thought that the major portion of the strings are in the long-term store. Consequently, a further opportunity to rehearse is of little benefit. In the case of the M-$\overline{P}$ strings the increase in recall with lengthening periods of rehearsal is slight. Presumably those trigrams recognized as being meaningful make the transfer directly to the long-term store. Increasing opportunity to rehearse would appear to be of minimal value for those items not known.

The fact that the strings are forgotten at differential rates after being equated for at immediate recall suggests perhaps that Underwood's (1964) theory of forgetting is viable only when all or most of the items are in the long-term store at recall. This aspect of the present findings, however, bears further investigation before any strong conclusions can be drawn. At this point it can only be stated that rehearsal facilitates chunking of items in STM and hence subsequent recall.

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APPENDIX A

$M-\overline{P}$	$\overline{M}-P$	$\overline{M}-\overline{P}$
NHLRFKCBWMTS	BLICIBSKAUNS	NLBCWMRTHFKS
LSDNBCPHDLBJ	MOYIRDVEAFRO	SNCHDJLBPLDB
WPGTNTRPMCNR	IBEGLEACKIRB	PTRMCPGWTNRN
FLQSTPCPRBSC	PLOURAULKJAD	FSPRBQLTCSPC
MTCLTDNFLCBC	IBASLECAYWHA	CLDTMNBFCTLC
GMCDDTHFCGTX	BREAIBDOKILF	MDHTCXGTFDCG
FDSMPHCBSBVD	BUVELBORCTOZ	VFSPCBHSDBMD
CFLBBCHMSJFK	AROBLESNAMEF	CFJCBFKLHMBS
MRSCTVNDPZBT	ENSFICDROPEX	ZMBPRTCNVDST

APPENDIX B

The angle subtended by the stimulus letters was calculated as follows:

$$\underset{\text{(angle)}}{0} = \frac{57.3e}{R}$$

where e = height of letters

R = distance from S to the stimuli

$$0 = \frac{57.3\ (.375\ \text{in.})}{48\ \text{in.}}$$

$$= .447^{\circ}$$

APPENDIX C

EXPERIMENTAL INSTRUCTIONS

"This is the procedure; I'm going to show you twelve letters on a card that will look like this. You'll notice that there are four groups of three and they have been divided up this way in order to help you learn the string more efficiently. The sequence will be this. I'll put these cards one at a time at the back of the tachistoscope and you will see the card light up for a brief period of time a short while after I say "ready". During the time that the stimulus card is alight I want you to learn as many of the letters as you can.* Now after the light goes out I might say "recall" in which case I want you to begin writing as many of the letters as you can remember in the spaces provided. Sometimes, however, I won't say "recall" immediately, I will say "read" instead, and in this case I want you to read this card (shows and explains nature of Stroop test). After you have been reading for a while I will then say "recall" and again I want you to write out as many of the letters as you can remember. Okay, now let's go through the sequence once more. (Goes through sequence again). Okay, now are there any questions? When I say "ready" thats your cue to look right into the tachistoscope.

*<u>For Rehearsal Conditions</u>:

Now after the stimulus light goes out you will have a period of time in which to think about the letters that you've seen. You can use this time in any manner that you wish to try and remember the letters. At the end of the silent period I will say to you either "read" or "recall".

Now I am going to give you a few practice trials using digits so you can get used to the sequence of events and also a chance to see just how long the strings will be exposed.

(Gives 3 practice trials.)

Okay, now we are going to switch over to the letters. Now there's something special I want you to notice about the strings you will see. Each string will be grouped into 4 trigrams as I've already told you. In your case each of these trigrams will

M-$\bar{P}$ Groups

a) hopefully mean something to you, i.e., they will be the initials of some well known person or place or the abbreviation of a company or a product e.g., there is a European Airline KLM. All the trigrams will consist of just consonants.

$\bar{M}$-P Groups

b) from pronounceable units e.g., TAV or YOS. You will find it helpful to read each one as a single unit as you go across the strings.

$\bar{M}$-$\bar{P}$ Groups

c) be grouped into 4 units in order to help you remember them better.

Now we're ready to begin. Are there any questions?"

APPENDIX D

Mean presentation for each S required to establish a criterion of 6-9 correct letters in correct positions (based on at least 3 scores for each S in the criterion range).

	$M-\overline{P}$		$\overline{M}-P$		$\overline{M}-\overline{P}$	
	Letters	Time	Letters	Time	Letters	Time
S1	8.6	3.9	7.2	2.8	7.8	26.5
S2	7.1	4.0	7.2	2.9	7.1	9.0
S3	6.9	3.6	7.8	2.8	8.1	16.8
S4	6.8	3.7	6.7	3.1	7.2	25.2
S5	7.3	3.5	7.5	3.3	7.4	29.4
S6	7.2	3.5	6.5	3.5	8.2	15.9
S7	8.1	3.8	7.7	3.1	7.2	18.6
S8	7.5	4.2	7.6	3.2	7.1	8.1
	7.4	3.8	7.3	3.1	7.3	17.5

APPENDIX E

Meaningful items indicated by Ss as being unknown and known in terms of their semantic reference.

ITEMS NOT RECOGNIZED

ITEM	FREQUENCY
BVD	22
ZBT	21
HFC	19
HMS	18
GTX	16
BSC	15
RFK	15
RPM	14
GMC	12
BBC	11
MRS	9
FDS	7
MTC	7
MPH	5
CFL	4
LTD	3
NBC	3
CBW	2
MTS	2
PHD	2
LBJ	2
TNT	2
NHL	1
CNR	1
NFL	1
CBS	1
JFK	1
TOTAL	216

ITEMS ALWAYS RECOGNIZED

LSD
WPG
STP
CPR
CBC
DDT
CTV
NDP
FLQ

APPENDIX F

Examples of Mnemonics reported by the meaningless-unpronounceable group.

Portion of string for which mnemonic was reported	Mnemonic
PTR -	Peter
CLD -	cold
RTH	Ruth
TMN	Timmins
PRT	part
DST	distance, dust, daylight saving time
VFS	very fine street
DCG	dog
SPC	society for prevention of cruelty to animals
GTF DCG -	go to find dogs, cats and giraffes
LDB	lead bottom
MDH	my dear Horace