ON THE DETERMINANTS OF THE MONOTONIC AND NONMONOTONIC LAG EFFECTS

by

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THESIS

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ABSTRACT

The capability of Glenberg's (1976) version of encoding variability as well as the study-phase retrieval hypothesis in explaining the lag effect was explored in four experiments. Experiment I replicated Glenberg's findings in a modified paired-associate paradigm. Each pair formed the subject and object nouns of a sentence. The subject nouns were used as cues for recall of the object nouns. At the short retention interval (6 events) the lag function was nonmonotonic. At the longer retention interval (final cued recall) the lag function increased monotonically. Glenberg's version of encoding variability theory was refuted in Experiment II using the modified paired-associate technique. In order to induce variable encodings, each experimental pair was connected by different verbs. Ss were given either the subject phrase at P1 or the subject phrase at P2 or both together as cues to recall the object noun. The results showed that the lag effect was not eliminated even though recall was cued by both of the cues at P1 and P2. However, the lag effect was eliminated in a final recall cued by both of the cues at P1 and P2. In Experiment III, the same design and materials in Experiment I were used. In addition, Ss were required to indicate on each presentation whether the sentence had

occurred before or not. Thus, retrieval of P1 information was required at P2. It was argued that the shift from nonmonotonic to monotonic lag functions as the retention interval increased was a consequence of successful study-phase retrieval. Contrary to prediction, the lag effect for items with successful study-phase retrieval was a monotonic function at both short and long retention intervals. However, using a Brown-Peterson free recall paradigm, it was revealed in Experiment IV that items repeated at short lags were readily more retrievable at short retention intervals than items repeated at long lags, but at long retention intervals the opposite was true. Hence, it was concluded that the change from nonmonotonic to monotonic lag function as retention interval increased was caused by a differential optimal recallability associated with items of different values of lag.

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INTRODUCTION

One of the most ubiquitous phenomena in memory literature that has stimulated a tremendous amount of research resulting in confliction theories is the spacing effect. It has been shown that when a to-be-remembered item is presented for study twice (the first and second presentations will be referred to as P1 and P2, respectively), the spacing between the two study presentations affects performance on the test. When the spacing interval is short, retention is poorer than when the spacing interval is long. This seems to be true regardless of what kind of activity fills the spacing interval. For instance, in free recall and paired-associate learning experiments, the spacing interval is filled with presentations of other to-be-remembered items; while in Brown-Peterson short-term retention experiment, it is filled with a distractor task such as counting backward by threes for each number given.

The law that spaced practice is more effective than massed has been widely confirmed since its formulation in 1885 by Ebbinghaus and by Jost in 1897 (McGeoch, 1942, p. 140-142). The facilitative effect of the spacing of repetition is most noticeable, and the number of different conditions under which it occurs is remarkable. It has been demonstrated in free recall (Melton, 1967, 1970); in recognition memory (Kintsch, 1966; Hintzman and Block, 1970); in paired-associate learning (Peterson, Wampler, Kirkpatrick and Saltzman, 1963; Greeno, 1964); in Brown-Peterson short-term retention task (Peterson 1963; Underwood, Kapelak and Malmi, 1976, Exp. II); and with materials such as words (Melton, 1967); pictures (Hintzman and Rogers, 1973); nonsense syllables (Kintsch, 1966); sentences (Underwood, 1970); phrases (D'Agostino and DeRemer, 1972, 1973) and letters (Underwood, et al., 1976). It has also been found with both visual and auditory input modes and with a wide range of presentation rates (Melton, 1970) and where spacing is either within list or between lists (Roediger and Crowder, 1975).

Despite its general characteristics, the magnitude of the spacing effect varies with different tasks. In continuous paired-associate learning, the maximum improvement due to spacing is about 25% relative to massed practice; 15%-20% in Brown-Peterson short-term retention tasks and almost 50% in free recall (cf. Melton, 1970). Hintzman (1974) pointed out that in situations other than recall, the maximum facilitative effect of spacing seems to occur where there are around 15 seconds between the first and the second presentation. More specifically, performance on the test improves as the spacing interval increases from 0 to about 15 seconds, while increases in spacing beyond 15 seconds have little effect. With respect to recall, however, performance is a monotonically increasing function of spacing. For instance, Melton (1967) discovered that different values of lag* were associated with different levels of performance and as the lag increased, performance also increased.

It is important to methodologically differentiate between the terms 'lag effect' and 'massed-distributed practice (MP-DP) effect' which are both aspects of the term 'spacing effect'. The lag effect, also called the Melton effect, compares various values of lag. For instance, Melton (1967) found that recall for repeated items increased monotonically as a function of lag. Hence, different values of lag were associated with different levels of performance. The MP-DP effect contrasts only spacings of zero (massed practice) with all spacings greater than zero (distributed practice). D'Agostino and DeRemer (1972) have shown that DP items are recalled better than MP items, and, moreover, there is no difference in performance with spacings greater than zero.

To complicate matters more, a decrease in performance over P1-P2 intervals** beyond 15 seconds was found in continuous paired-associate learning by Peterson, Wampler, Kirkpatrick, and Saltzman (1963); Young (1971); Glenberg (1976); and Hintzman, et al. (1973) using a frequency-judgement task. This decrease in performance over P1-P2

* When the spacing interval is expressed in terms of number of intervening items between P1 and P2, it will be referred to as lag (e.g., lag 4, lag 10, etc.).

** When the spacing interval is expressed in terms of time unit, it will be referred to as the P1-P2 interval.

intervals beyond 15 seconds is termed the nonmonotonic lag effect to distinguish it from Melton's monotonic lag effect. This paper deals mainly with theories that explain the lag effect and investigates variables which might contribute to the changes in the lag function from nonmonotonic to monotonic as retention interval increases.

As Hintzman (1974) pointed out, the lag effect is an anomaly in at least two respects. First, it violates the law of recency which states that recent items are recalled better than remote items. Since retention increases as the interval between P1 and P2 increases, the lag effect thus works against the law of recency because retention decreases as P1 becomes more recent (i.e. as the interval between P1 and P2 decreases). Second, despite the fact that the amount of time for which an item is presented is the same regardless of spacing, the occurrence of the lag effect violates the total-time law, which states that the level of retention depends only on study time and not on how that time is distributed. These anomalous aspects of the lag effect are worth looking into. The discovery of the mechanism responsible for these properties might contribute to greater understanding of how humans learn.

Three theories have been advanced to explain the lag effect, namely, the consolidation theory, the encoding variability theory and the study-phase retrieval hypothesis. First, the consolidation theory (Landauer, 1969) maintains that superior performance occurs with spaced presentation of repeated items because spacing allows consolidation of information during the interval between presentations and thus leads to more effective utilization of P2. According to Atkinson and Shiffrin (1968), consolidation may occur by means of a psychological mechanism such as the rehearsal buffer. In their model, each item presented enters a rehearsal buffer for a period of time while information regarding the item is transferred to long-term memory. If a second presentation is made while the first presentation is still in the rehearsal buffer, P2 is essentially ignored or a process referred to as the 'cancellation of duplicates' in short-term memory will occur (Glanzer and Duarte, 1971). Therefore P2 is effective only if it is presented after some delay. The lag effect is no longer paradoxical according to the consolidation-rehearsal theory for, although the recallability of a repeated item may be declining after P1, the strength of a long-term trace is growing as a result of rehearsal within the interval separating P1 and P2. Hence as the interval between P1 and P2 increases, more time will be devoted to studying the repeated item via rehearsal. At the time when P2 is presented, it triggers off more rehearsal and consolidation which enhance the strength of the long-term trace. Direct support for the rehearsal hypothesis comes from the experiments of Rundus (1971). He studied the rehearsal patterns of subjects who were instructed to rehearse aloud during presentation of a free recall list. Less overt rehearsal was observed of words that were given massed presentations. Rundus's (cf. Hintzman and Rogers, 1973) data indicated, in addition, that differential rehearsal took place entirely during the spacing interval. The number of rehearsals following P2 did not depend on the length of P1-P2 interval. Rundus concluded that longer P1-P2 intervals led to better long-term retention simply because subjects were given more opportunities to rehearse P1 before P2 occurred.

In accordance with Rundus's observation, one would expect that by using materials that render rehearsal difficult, for instance, scenic pictures (Shaffer and Shiffrin, 1972), one could eliminate the differential rehearsal and thus the lag effect. The results reported by Hintzman and Rogers (1973) showed that despite the elimination of differential rehearsal, the lag effect still occurred. They concluded that the rehearsal explanation of the lag effect was either incorrect or of limited generality. Craik and Watkins (1973) have shown that rehearsal may not enhance long-term retention at all.

An ingenious experiment designed by Bjork and Allen (1970) completely rejected the consolidation-rehearsal theory. A modified Brown-Peterson short-term retention task was used. Either an easy or difficult task intervened between P1 and P2. It was shown that recall after a difficult intervening task was superior to recall after an easy intervening task. The consolidation-rehearsal theory would predict exactly the opposite because the easy intervening task should permit more consolidation or rehearsal than should the difficult task. Several experiments with essentially the same design have also been reported to rule out the consolidation-rehearsal theory (e.g., Robbins and Wise, 1972; Tzeng, 1973).

A second explanation for the lag effect is the encoding variability theory, first formulated by Estes (1955) and later adopted and modified by Melton (1967, 1970); Martin (1968); Anderson and Bower (1971) and D'Agostino and DeRemer (1972, 1973) to explain the MP-DP effect and the lag effect. The theory generally maintains that the encoding of a verbal unit may differ on successive presentations of that unit. Encoding of information is more variable when the interval separating P1 and P2 is large than when it is small since the context of P2 is more likely to be changed in the former than in the latter case (Melton, 1970; Anderson and Bower, 1972). Besides, as the interval between P1 and P2 increases, the encoding at P1 is less likely to be remembered at P2 and therefore a new encoding is more likely to occur (cf. Martin, 1968). There seems to be two rather different ways of conceptualizing encoding variability. Maki and Hasher (1975) referred to the first one as contextual variability which states that the probability of having more sets of contextual cues available for retrieval is a function of spacing. As the interval separating P1 and P2 increases, the context at P2 is likely to be different from the context at P1. Encoding at P2 may differ from encoding at P1 because context affects encoding. As a result of variation in encoding, more than one set of contextual cues are available for retrieval. The second interpretation was referred to as referential variability which occurs when two different semantic interpretations of a word are stored after successive presentations. Again, the probability of having different semantic encodings increases with longer spacing intervals. It has been conceived that the encoding at P1 will probably be forgotten at P2 when the P1-P2 interval is long. Consequently, an encoding which is different from P1 is likely to be generated at P2. For instance, subject may encode the word 'jam' as 'traffic jam' at P1 and perhaps 'strawberry jam' at P2. Therefore, two different semantic encodings have been laid down in memory for a single word. The major difference between these types of encoding variability is that with contextual variability, one semantic representation of a word is stored in different memory contexts;

whereas with referential variability, the semantic representation itself varies across presentations.

Tzeng (1973) suggested that only when memory for P1 is unavailable at P2 could the subject encode P2 differently with a high probability. Thus long-term memory for that item is enhanced as a consequence of variable encoding. Tzeng's notion suggests that for materials that are easy to recognize, such as scenic pictures, the lag effect will be eliminated because the P1 and P2 encodings would be identical. Exactly the reverse was found by Hintzman and Rogers(1973), and Hintzman, Summers, Eki and Moore (1975) using scenic pictures as stimuli. Similar results were also found by Bellezza, Winkler and Andrasik (1975) using high- and low-meaningful trigrams (Exp. I)and words (Exp. II). Although Bellezza, et al. found that recognition at P2 declined as a function of lag, recall increased with lag only with those items recognized as old at P2. These findings are consistent with Nelson's (1971) conclusion that in order for a repetition to be effective, it must be a repetition of remembered information. The lag effect with respect to judgement of spacing (how many items intervene between P1 and P2) (Hintzman and Block, 1973) and judgement of frequency (how many times the same item has occurred) (Hintzman and Block, 1970; Hintzman, Summers and Block, 1975 (a)) parallels Nelson's data and supports his conclusion because only when subjects could identify P2 as old would a correct judgement of spacing or frequency be available. Therefore, Tzeng's attempt to explain the lag effect is counterintuitive and subject to disproof by data from judgement of spacing and judgement of frequency experiments.

The aforementioned conclusions arrived at by Bjork and Allen (1970) and Robins and Wise (1972) also favored the referential variability explanation. They argued that the more difficult the intervening task between P1 and P2 the more likely a new encoding was formed at P2 and therefore more retrieval cues were associated with items repeated after a difficult task intervened between P1 and P2. If this line of reasoning is correct, one should be able to eliminate the facilitative effect of spacing when a different encoding is insured at P2 at all spacing intervals. Maki and Hasher (1975, Exp. II) presented homographs with the same or different associates at P1 and P2 for each word on every trial. For example, subjects were presented with 'traffic jam' at P1 and 'strawberry jam' at P2 for the different-associate condition and either 'traffic jam' or 'strawberry jam' at both P1 and P2 for the same-associate condition. Their results failed to reveal any beneficial effect of different-associate condition over the same-associate condition. Referential variability in encoding did not give rise to any observable facilitative effect in remembering. The conceptualization of referential variability, as I perceive it, is vague since it is only when P1 is forgotten that P2 is given a new encoding (otherwise subjects need not encode P2 differently), there will be only one encoding available at test. If referential variability is to be effective, then it should not lead to a second novel encoding for the item but should lead, perhaps, to an elaboration of encoding for the first code. In this way, the repetition serves to elaborate the code generated at P1 by means of, perhaps, forming an image, a picture or even constructing a sentence so that the code so formed is more resistent to decay and interference.

Contextual variability has been supported by several experiments. For instance, D'Agostino and DeRemer (1973) varied the subject phrase of a sentence for each repetition while keeping the object phrase unchanged. When subjects were asked to free recall the object phrase of each sentence, the lag effect was eliminated. However, quite contrary to D'Agostino and DeRemers' study, Maki and Hasher (1975, Exp. I) did not find any beneficial effect of a varied context over an unvaried one when they manipulated the context with respect to each target word. Similarly, Maskarinec and Thompson (1976, Exp. I) found no significant difference in recall for the same and different context conditions. These conflicting data accruing to the encoding variability theory casts some doubts upon its adequacy in accounting for the lag effect.

A third interpretation of the lag effect is the study-phase retrieval hypothesis suggested by Hintzman and Block (1973). It states that the typical effect of P2 is to retrieve the trace of P1 such that the second occurrence of the word during the study phase enhances the trace. The way I understand the concept of study-phase retrieval is that it need not be a voluntary act. It can occur quite unconsciously. Very often a sense of familiarity arises when we encounter something we have seen before. This sense of familiarity does not arise automatically, it comes as a consequence of our perceptual encoding of that 'something' which triggers recognition. This feeling of recognition is important because it refreshes the memory for its occurrence. From this it seems reasonable to assert that in order for a repetition to be effective, it must be a repetition of remembered information.

Thios and D'Agostino (1976) postulated that depending on the demands of the retrieval operation at P2 (i.e. whether the interval between P1 and P2 is long or short), retrieval of P1 information entails more elaborate encoding at P2 which enhances the trace. At short P1-P2 interval, according to

Jacoby (1974), the retrieval operation can be based on sensory features extracted from superficial processing of P2. However, as the P1-P2 interval increases, judgement of whether a repetition has occurred on the basis of sensory features is more difficult and in order to retrieve P1 information P2 must be given a more extensive or deeper level of analysis (cf. Craik and Tulving, 1975) through the process of reconstruction (Lockhart, Jacoby, and Craik, 1975). Consequently, items repeated at long P1-P2 intervals are more resistant to decay or interference than items repeated at short P1-P2 intervals because of the more elaborate processing afforded P2. Support for this line of reasoning comes from Thios and D'Agostino (1976) who found that the lag effect was significant only in situations where study-phase retrieval was successful.

However, as Glenberg (1976) noted any theory capable of explaining the monotonic lag effect should also be capable of explaining the nonmonotonic lag effect which occurs with short retention intervals (approximately 6-24 seconds) in a paired-associate learning paradigm. He discovered a shift from a nonmonotonic to a monotonic lag function as retention interval (the period from P2 to recall) increased. He found that when the retention intervals were within 6 to 24 seconds, items repeated after a moderate P1-P2 interval (12-24 seconds) were recalled better than items repeated after either short (0 to 3 seconds) or long P1-P2 interval (beyond 24 seconds). Hence, the lag function was a nonmonotonic one. But when the retention interval was very long (beyond 96 seconds), items repeated after a long P1-P2 interval (120 seconds) were recalled better than those repeated after a moderate P1-P2 interval. Whereas items repeated after a short P1-P2 interval were recalled the least. Hence, the lag function was a monotonically increasing one.

On the basis of these findings, Glenberg offered his version of the encoding variability theory to explain the results. He suggested that the amount of change in the context of P1 and P2 is positively correlated with the amount of change in the functional stimulus*. At very short P1-P2 intervals, the context remains fairly constant and no change occurs in the encoding. Hence only one code is available for retrieval. However, as the P1-P2 interval increases, there will be corresponding changes in context which introduce changes in the functional stimulus itself. During the test after a short retention interval the testing context will be very similar to the context at P2. If the context at P2 is very different from the context at P1, then the representation stored at P1

*This is the stimulus term of a paired-associates given during the test trial. This stimulus term is capable of eliciting the response term depending on how it is encoded during the test trial.

will play a minor role in recall. Whereas, the P2 and test context will be very similar so that P2 plays a major role. Hence, items presented at long P1-P2 intervals will be functionally similar to items repeated at short P1-P2 intervals in that only a single stored representation is likely to be elicited by the test stimulus. However, the items repeated at moderate intervals will have two representations that are similar to each other, and also similar to the functional stimulus on the test. These items should be recalled more often than those items repeated after either a short or long P1-P2 interval. Hence a nonmonotonic lag effect results when retention interval is short. As retention interval increases, items repeated at long P1-P2 interval are more likely to have dissimilar encodings. In this case, recall is a monotonic function of P1-P2 interval because, on the average, the encoding at the test is likely to be similar to some prior input encoding when the input encodings are as dissimilar as possible.

The entire approach formulated by Glenberg relies heavily on the assumption that two codes (which provide two retrieval routes) are better than a single code (which provides a single retrieval route). As mentioned already, double codings are not any better than single coding (Maki and Hasher, 1976; Maskarinec and Thompson, 1976). Glenberg's formulation needs further verification preferably from a direct manipulation of the coding strategy.

With an additional assumption of the author that will be subsequently elaborated, the study-phase retrieval hypothesis can also predict the shift from a nonmonotonic to a monotonic function of P1-P2 interval as retention interval increases. The additional assumption is that whenever a repetition of an item is detected (i.e., for every successful study-phase retrieval) a 'repetition unit' results. This unit is more resistant to decay and interference than items which have not been repeated or items repeated but not detected of their repetition. The presence of repetition units highly facilitates mnemonic work. The monotonic and nonmonotonic lag effect can be considered a function of the joint effect of two rather independent factors —— the trace strength and the numerosity of each type of repetition unit. Consider the factor of strength first. At short P1-P2 intervals when P1 is no longer being processed as P2 occurs, the retrieval operation can be based upon superficial processing of P2 information. This can be done by a scanning process (cf. Lockhart, et al., 1975) to detect a repetition and consequently the formation of a repetition unit (call it W-type) results. According to Lackhart, et al., a mental scanning process for a match is most efficient when two occurrences of the same item are in close proximity. Since only little effort is required in the scanning process, the strength of W-type repetition units is weak and subject to loss through rapid decay and interference. Therefore information in W-type repetition units can be retrieved only at very short retention intervals.

At moderate P1-P2 intervals, more effort is needed to achieve successful study-phase retrieval at P2. A deeper level of analysis (Craik and Tulving, 1975) is required to reconstruct the encoding at P1 for successful study-phase retrieval at P2. Because of the deeper level of analysis afforded P2 if retrieval of P1 is successful, the repetition unit (call it M-type) so formed is more resistant to decay and interference than the W-type where little effort is required. Therefore, information in M-type repetition units can readily be retrieved after a moderate retention interval.

Finally, as the interval between P1 and P2 further increases, more extensive and elaborative analysis of P2 is needed in order to detect a repetition. As a result, the type of repetition unit (call it S-type) so formed is by far the strongest and most resistant over longer retention intervals. To summarize, as the P1-P2 interval increases, the strength of the repetition unit so formed increases.

With regard to the factor of numerosity, the focus of concern is the number of each type of repetition unit in the total experiment. Since it will be harder to recognize P2 as a repetition when the P1-P2 interval becomes longer, therefore, the number of successful study-phase retrievals decrease as the interval separating P1 and P2 increases. Consequently repetition units of the W-type are greater in number than the M-type which in turn are more numerous than the S-type. By now, it is clear that in a spacing experiment, although the S-type are fewer in number, they are by far the strongest. Conversely, although the W-type are greater in number, they are the weakest in strength.

With these different types of repetition units, the memory for repeated items can be considered as a function of both the strength of these repetition units and the retention interval. At very short retention intervals, items repeated at short P1-P2 intervals (short-lag items) are recalled better than items repeated at both moderate and long P1-P2 intervals (they will be referred to as moderate-lag and long-lag items, respectively). This is due to the larger number of W-type repetition units which are not yet subject to decay and interference. Therefore, the lag function is monotonically decreasing (see Fig. I).

As the retention interval increases, moderate-lag items are recalled better than both short-lag and long-lag items. In the former case, it is due to the fact that the W-type

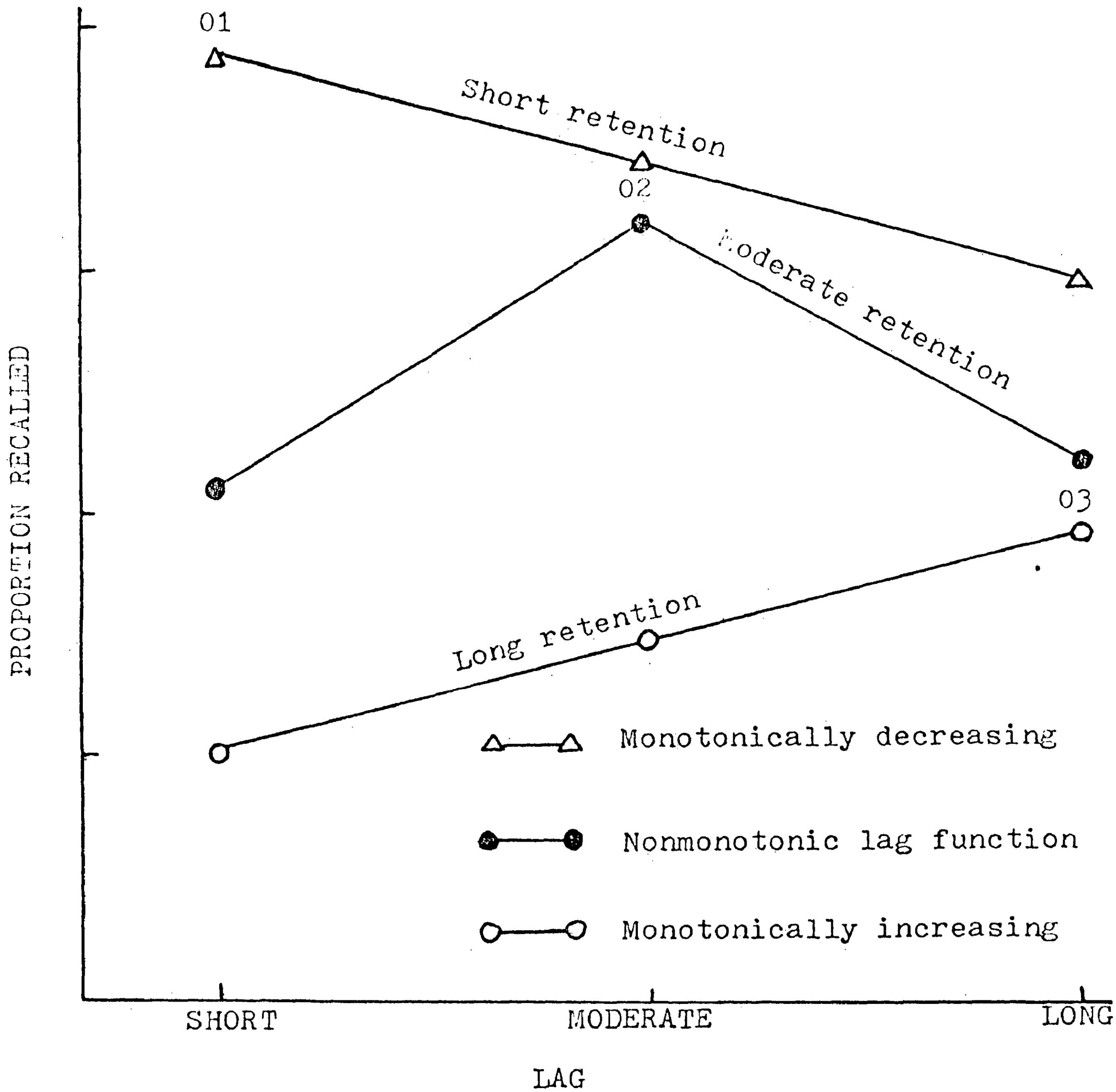

Figure I.
An illustration of the shift in the lag function as a result of the shift in the optimal recallability from short-lag items (01) to moderate- and long-lag items (02, 03, respectively) as retention interval increases.

repetition units are subject to loss through rapid decay and interference. In the latter case, it is because the M-type repetition units outnumber the S-type and therefore, by virtue of their resistance to decay and interference at moderate retention intervals, more of them are recalled. The shape of the lag function is nonmonotonically increasing (see Fig. I). Hence, a moderate retention interval is an important factor in generating a nonmonotonic lag function. Finally, at long retention intervals, long-lag items are recalled the best because repetition units of the S-type are most resistant to decay and interference. At this point, the lag function has shifted from nonmonotonic to monotonically increasing with increases in P1-P2 interval (see Fig. I).

The argument presented so far suggests that as retention interval increases, there is a shift in the optimal recall-ability from short-lag items (O1 in Fig. I) to items repeated at longer P1-P2 intervals (O2, O3 in Fig. I). This shift in the optimal recallability of items repeated at different P1-P2 intervals might explain the shift from nonmonotonic to monotonic lag function as retention interval increases. Furthermore, it maintains that the facilitative effect of repetition for short-lag items is accessible only on condition that the retention intervals are short enough. This line of reasoning is in complete accord with Madigan's (1969) conclusion that the lag effect cannot be attributed to rehearsal or storage failures, but instead to differences in the accessibility of items presented at different lags (p. 835).

There are several advantages that the modified version of study-phase retrieval hypothesis has over the encoding variability theory:-

1. The controversial issues of whether variable encodings are better than invariable encoding can be avoided.
2. The lag effect obtained in judgement of spacing and judgement of frequency experiments can readily be explained.
3. The fact that MP items are recalled better than items that are not repeated can be explained by the notion of repetition unit. However, encoding variability theory is not capable of explaining this fact.

On the basis of these arguments, the following experiments were designed to test Glenberg's (1976) version of encoding variability theory as well as the study-phase retrieval hypothesis developed thus far. The first three experiments employed a modified paired-associate paradigm: Each paired-associate was embedded in a sentence and underlined. The purpose of this modified paired-associate paradigm was to exert more control on the encoding phase. It was conceived that embedding the paired-associate in a sentence and instructing the subjects to use imagery would eliminate much uncontrolled idiosyncratic encoding. Besides, it provided a means by which the context of a paired-associate could be varied by altering only the verb of the sentence.

Experimental sentences were repeated immediately following the first presentation (lag 0), or after 10 events (lag 10) or after 30 events (lag 30). Each was tested 6 events following P2. An 'event' could be either a test trial or a presentation of a sentence. During test trial, subjects were given the subject noun (in Exp. I & III) or the subject phrase (in Exp. II) as a cue to recall the object noun.

Experiment I examined the lag function using the modified paired-associate paradigm. The results were expected to be in accordance with those obtained from paired-associate paradigm. A nonmonotonic lag function was expected for short retention interval and a monotonically increasing lag function was expected for the final cued recall. Experiment II examined Glenberg's notion of encoding variability. Variable encodings of P1 and P2 were induced by altering the verb connecting the pair. During test trials, either the verb at P1, or P2, or both of the verbs at P1 and P2 accompanied the stimulus term. According to Glenberg's theory, recall with two retrieval cues should surpass recall with only one retrieval cue. Moreover, the lag effect should be eliminated in conditions where both of the verbs at P1 and P2 accompained the stimulus term.

Experiment III and IV examined the study-phase retrieval hypothesis. For each presentation of a sentence in Experiment III subjects had to decide whether the sentence had appeared before or not. Thus retrieval of repeated information was required. It was predicted that the lag effect would be a function of successful study-phase retrieval. A nonmonotonic lag function at short retention intervals and a monotonic one at long retention intervals were expected. In Experiment IV, the shift of the lag function as retention interval changed was examined. A Brown-Peterson distractor technique was used. Recall of repeated items was required after short, moderate or long period of intervening activities. It was predicted according to the study-phase retrieval hypothesis that a shift from nonmonotonic to monotonic lag function should result as the retention interval increased. Furthermore, the optimal recallability across the lag values should be a function of retention interval such that the beneficial effect of repetition can be evaluated within a certain range of repetition interval.

It should be pointed out that these experiments were not designed to verify the existence of repetition units, but rather, they were designed to verify some of the predictions generated by the assumption of the existence of repetition units.

EXPERIMENT I

Experiment I examined the lag effect using the modified paired-associate paradigm. The purpose of this experiment was to determine whether the modified paired-associate paradigm would yield the same pattern of results as a paired-associate paradigm. If the same pattern of results occurred, subsequent use of this paradigm would be justified. Experimental pairs were repeated twice with 0, 10 or 30 events intervening between the two presentations. Retention interval was held constant with 6 events separating P2 and recall. This moderate level of retention interval, as indicated before, was an important factor in generating the nonmonotonic lag function. It was anticipated that a nonmonotonic lag effect would result at the 6-event recall. When a final unexpected cued recall was then required of all subjects, it was predicted that a monotonic lag effect would result.

METHOD

Design and Materials. Fifty four paired-associates embedded in 54 different sentences comprised the target items. Each sentence was presented a second time after lags of 0, 10 or 30 events intervened from the first presentation. Due to the difficulty in formulating the overall schedule of events, the repetition lag was allowed to vary ± 1 event for the lag-10 pairs, and 3 events for the lag-30 pairs. The interval from P2 to test was held constant at 6 events following P2. However, there were two instances where retention intervals for the lag-0 and the lag-10 pairs were allowed to vary ± 1 event and three instances where retention interval for the lag-30 pairs was allowed to vary ± 2 events. The sentences were simple declarative article-subject-verb-article-adjective-object in design with the subject and object nouns acting as paired associates and underlined. The subjects and objects were common nouns ranging from 10-100 on the Thorndike and Lorge (1944) word count. The pairs were constructed to avoid common preexperimental associations, rhymes, and orthographic similarities. Each pair served only in one sentence, for instance, 'The butcher visited the new chapel'. Twenty-eight similarly constructed sentences with subject nouns and object nouns underlined were used as fillers and buffers. These sentences were presented only once and were not tested. The first eight sentences in a presentation sequence were buffers used to absorb any effects due to the buildup of proactive interference.

There were 18 pairs at each of lag 0, 10, and 30 such that there were (18 + 18 + 18) x 2 (repetition) learning events plus (18 + 18 + 18) test events plus the 28 fillers and buffers for a total of 190 events in each presentation sequence. Three formats of presentation sequence were constructed such that each of the 54 target sentences appeared equally often at all lag values.

Each event was printed in the center of an index card measuring $2\frac{1}{2}$" x 4". A test event was indicated to the subjects by the appearance of a card with a subject noun accompanied by a question mark. For instance, 'The butcher .....?'. Subjects were required to write down only the object noun.

Procedure. Subjects were tested in groups of 2 to 20 as available. Each subject was given an instruction sheet to read and was encouraged to ask any questions he or she might have about the procedure. Subjects were instructed to learn each sentence by imaging the action suggested by the sentence and pay particular attention to the underlined subject and object nouns because recall of object nouns was cued by subject nouns. Each subject was then given a deck of cards which they were required to turn over at 4-second intervals indicated to them by a sequence of tones previously tape-recorded. Without exception, each test event had to be completed in 4 seconds. The experiment began after 10 practice trials. When the subjects had finished the 190 events, they were given a sheet containing all the 54 subject nouns as cues to recall the subject nouns. The sheets were distributed to the subjects with the blank side up so that all the subjects could turn over the sheet and begin the final cued recall test together following a lapse of approximately three minutes. Ten minutes were allotted for this test.

Subjects. Thirty undergraduate students at Lakehead University were given credits for their participation in the experiment. Ten subjects were randomly assigned to each of the three formats of presentation.

RESULTS AND DISCUSSION

The results of object-noun recall are summarized in Table I and graphically shown in Fig. II. The recall of the repeated words was analyzed in a 3 (presentation formats) x 2 (retention intervals) x 3 (lag values) split-plot analysis of variance, with the last two factors being within-subject factors.

This experiment replicated Glenberg's findings. The effect of retention intervals was significant, $F(1, 27) \doteq 67.88$, $P < .001$, as was the effect of lag, $F(2, 54) = 15.58$, $P < .01$. The lag by retention intervals interaction was significant, $F(2, 54) = 6.09$, $P < .01$. This indicates that the shapes of the lag functions change with changes in the retention interval. The trend analysis performed on the three lag values in the 6-event recall revealed that the quadratic component was significant, $F(1, 87) = 8.22$, $P < .01$. This indicates that the shape of the lag function at the 6-event recall is nonmonotonic. The optimal performance occurred at lag 30. Fig. II shows

TABLE I

Mean proportion recall of repeated items in Experiment I

	Number of events between P1 and P2		
Retention interval	0	10	30
6 - event	0.41	0.58	0.54
Final	0.32	0.43	0.43

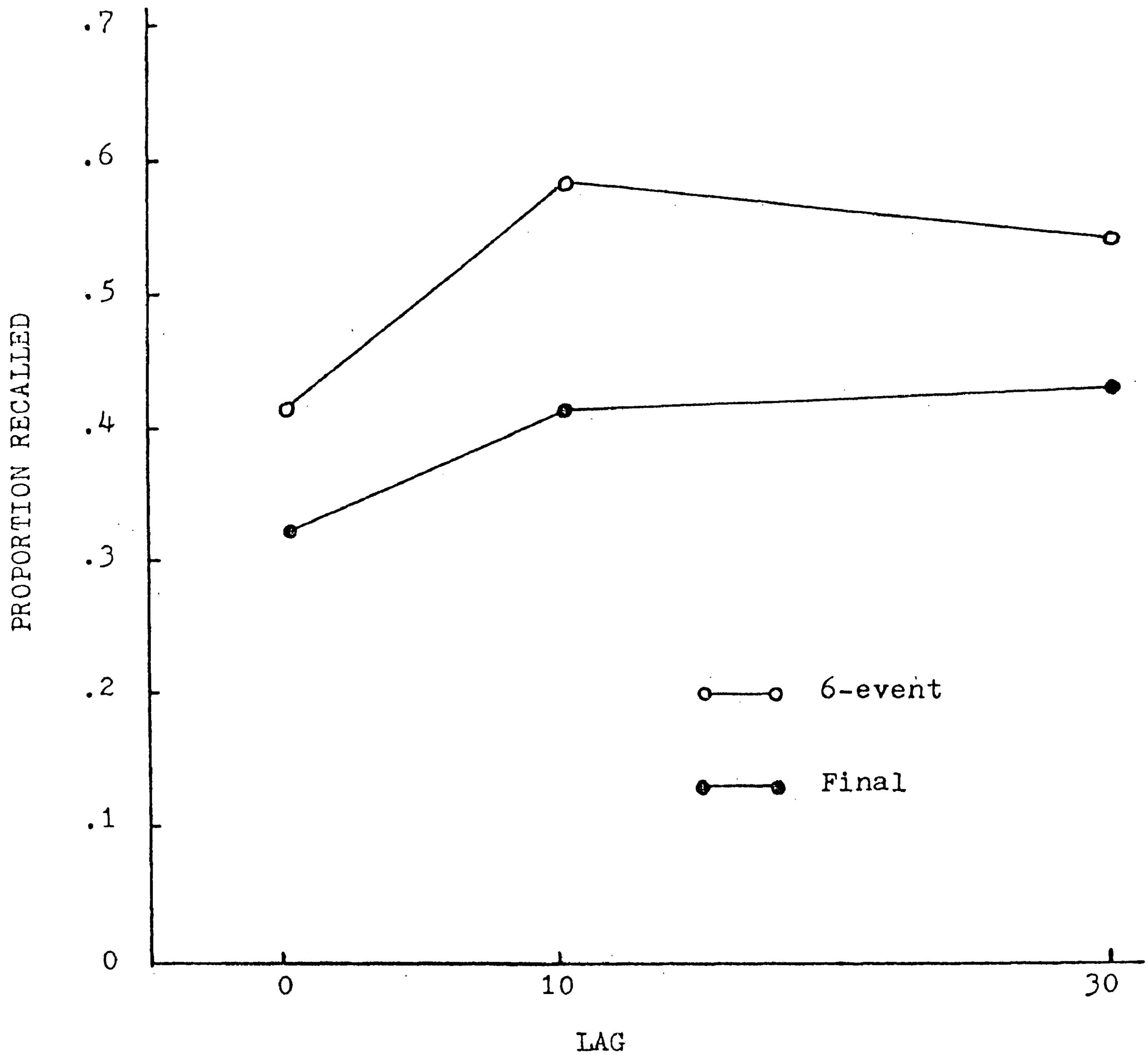

Figure II.
The proportion recalled of the response terms (object nouns), as a function of lag and retention interval in Experiment I.

that the lag function changes from nonmonotonic to monotonic as the retention interval increases.

Experiment I thus replicated Glenberg's findings in yet quite a different experimental setting. The nonmonotonic lag function was obtained when a short retention interval separated P2 and recall. But when the retention interval increased, the nonmonotonic lag effect gave way to a monotonically increasing one.

EXPERIMENT II

According to Glenberg (1976), the above results could be accounted for by his version of encoding variability theory. Experiment II examined the lag function under conditions where variable encoding at P1 and P2 was ensured. The same modified paired-associate paradigm as in experiment I was employed. However, each object noun was connected to the subject noun by different verbs at P1 and P2. This manipulation provided a means by which the encoding of the same pair could be varied at P1 and P2. Recall of each pair was cued by the subject phrase at P1, or the subject phrase at P2, or both of the subject phrases at P1 and P2. On the basis of Glenberg's claim a significant main effect of cue type was expected. Recall cued by both of the subject phrases at P1 and P2 was expected to surpass recall cued by either the subject phrase at P1 or P2 alone. The lag effect should also be eliminated in conditions where recall was cued by both of the subject phrase at P1 and P2.

METHOD

Design and Materials. The 54 declarative sentences in Experiment I were used and for each sentence, a new sentence was constructed such that the subject and object nouns remained unchanged while the verb was replaced by another verb. For instance, 'The giant saved the poor miner.' and 'The giant attacked the poor miner.' Each pair of sentences were presented 0, 10, or 30 events apart and recall of the object noun was tested 6 events after its last presentation and was cued by the subject phrase at P1(C1) or the subject phrase at P2(C2) or both cues together (C1 + C2). The 28 filler sentences were unchanged. Nine formats of presentation were constructed such that, C1, C2 and C1 + C2 as cue(s) for each object noun occurred equally often and each pair of sentences appeared equally often at each lag value. Each format was composed of 190 events including presentations and tests. The first eight sentences were buffers used to absorb any effects due to the build-up of proactive interference.

Procedure. Each subject was given an instruction sheet to read and was encouraged to ask any questions concerning the procedure. All subjects were informed that during the test trial, they would be given either C1 or C2 or both C1 and C2 as cue(s) to recall the object noun. They were also instructed to learn each sentence by imaging the action suggested by the sentence and pay particular attention to the underlined subject and object nouns. Subjects were then given a deck of cards which they were required to turn over at 4-second intervals indicated to them by a sequence of tones previously tape-recorded. A test event was indicated to the subjects by the appearance of subject phrase(s) accompanied by a question mark. Subjects were then required to write down the object noun. Approximately three minutes after the subjects had finished, the final recall sheetswere distributed. Final recall of the object nouns was cued by both C1 and C2. 10 minutes were alotted for this test.

Subjects. Fifty four undergraduate students who had not participated in Experiment I were given credits for their participation in this experiment. Six subjects were assigned randomly to each of the nine formats. Subjects were run in groups of 4 to 20 as available.

RESULTS AND DISCUSSION

The proportion of the object nouns recalled is shown in Fig. III. The results were analysed in a 9 (presentation formats) x 2 (retention intervals) x 3 (lag values) x 3 (cue-types)

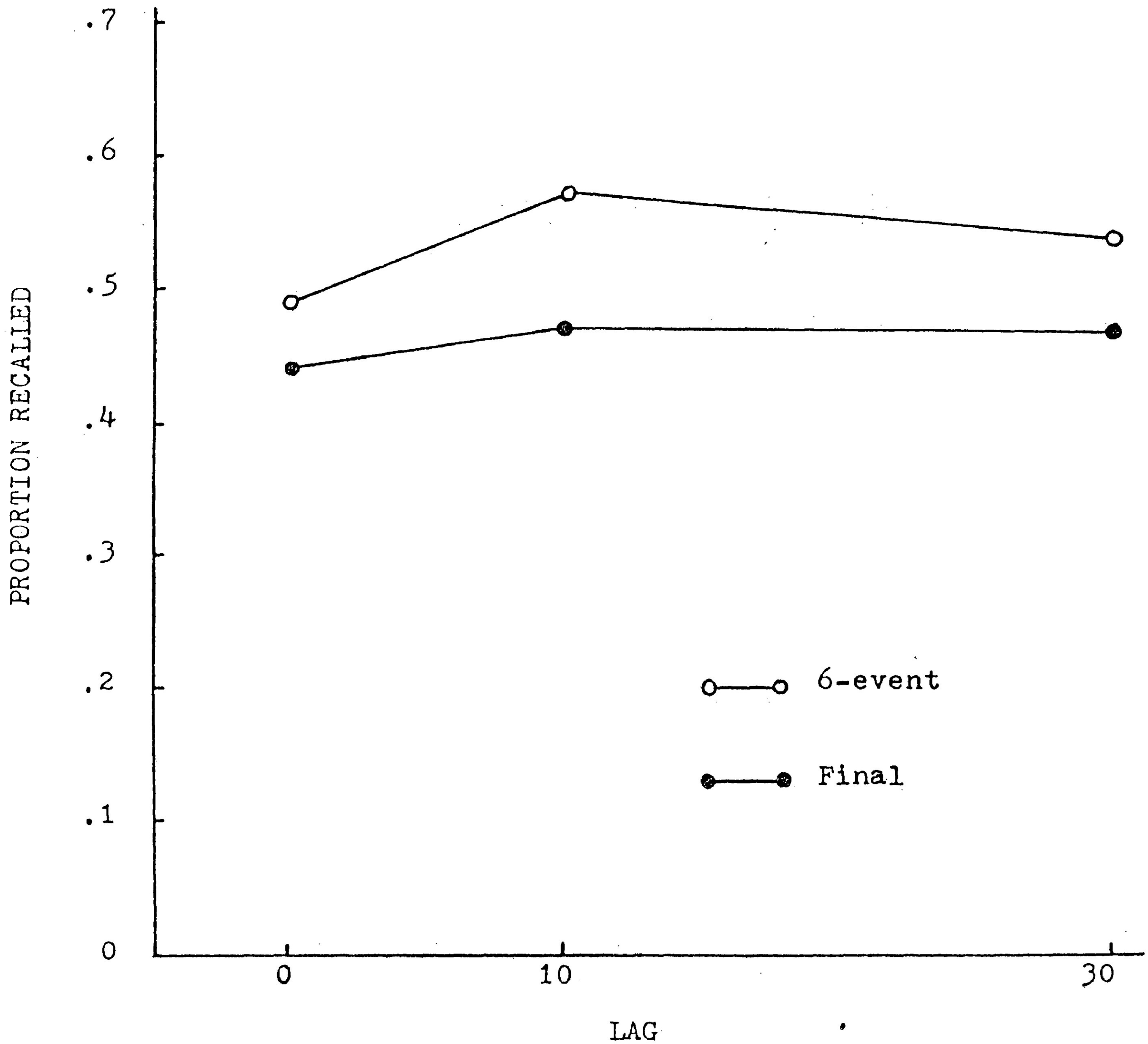

Figure III.
The proportion recalled of the response terms (object nouns), as a function of lag and retention interval in Experiment II.

split-plot analysis of variance with the last three factors being the within-subject factors. Consider the 6-event recall first.

The proportion recalled when cued by C1, C2, and C1 + C2 was 0.52, 0.55 and 0.53, respectively. Quite contrary to Glenberg's claim, the main effect of cue-type was not significant, $F(2, 90) = 0.59$, $P > .25$; nor did it interact with retention intervals (since the final recall was cued by both C1 and C2). This indicates that two cues need not be any better than one cue in recalling the object nouns in the modified paired-associate paradigm. Besides, despite the fact that variable encodings were induced in the input phase, the lag effect still occurred, $F(2,90) = 3.53$, $P < .05$. This lag effect was affected by retention interval which was significant, $F(1,45) = 73.46$, $P < .001$. Fig. III shows that the lag function changes with changes in the retention interval. This was confirmed by the analysis of variance which revealed that the critical interaction of lag by retention interval was significant, $F(2,90) = 4.75$, $P < .05$. A trend analysis performed on the lag values at the 6-event retention interval showed that the quadratic function was significant, $F(1,424) = 10.75$, $P < .01$. This means that at the 6-event retention interval, moderate-lag items were recalled the best.

The fact that double cueing did not change the shape of the lag function is shown in Fig. IV. At the 6-event retention interval, recall under the C1+C2 condition was 0.50, 0.56, 0.53 for lag 0, lag 10 and lag 30 respectively. The sensitive orthogonal comparisions showed that lag 10 items were recalled better than lag 0 and lag 30 items under the C1+C2 condition, $t_{106} = 2.41$, $P < .05$ (2-tailed). The nonmonotonic lag function occurred even when C1 and C2 were available as cues. These findings are in sharp contradiction to Glenberg's version of encoding variability theory which predicts a flat lag function. However, the lag function obtained in the final cued recall where both C1 and C2 were present seemed to give support to Glenberg's theory. A one-way analysis of variance of the three lag values did not show a significant lag effect. The lag effect had been eliminated by the presence of C1 and C2. This indicates that cued recall following variable encodings eliminated much of the lag effect at long retention interval (cf. Madigan, 1969).

The only other significant effects are the effect of format, $F(8,45) = 2.25$, $P < .05$ and the triple interaction of retention interval by lag by cue-type, $F(4,180) = 2.58$, $P < .05$. The effect of format indicates that subjects in one of the 9 formats recalled significantly less than the others. The triple interaction reveals that at the 6-event retention interval and under C2 condition, lag 10 items were recalled more often than

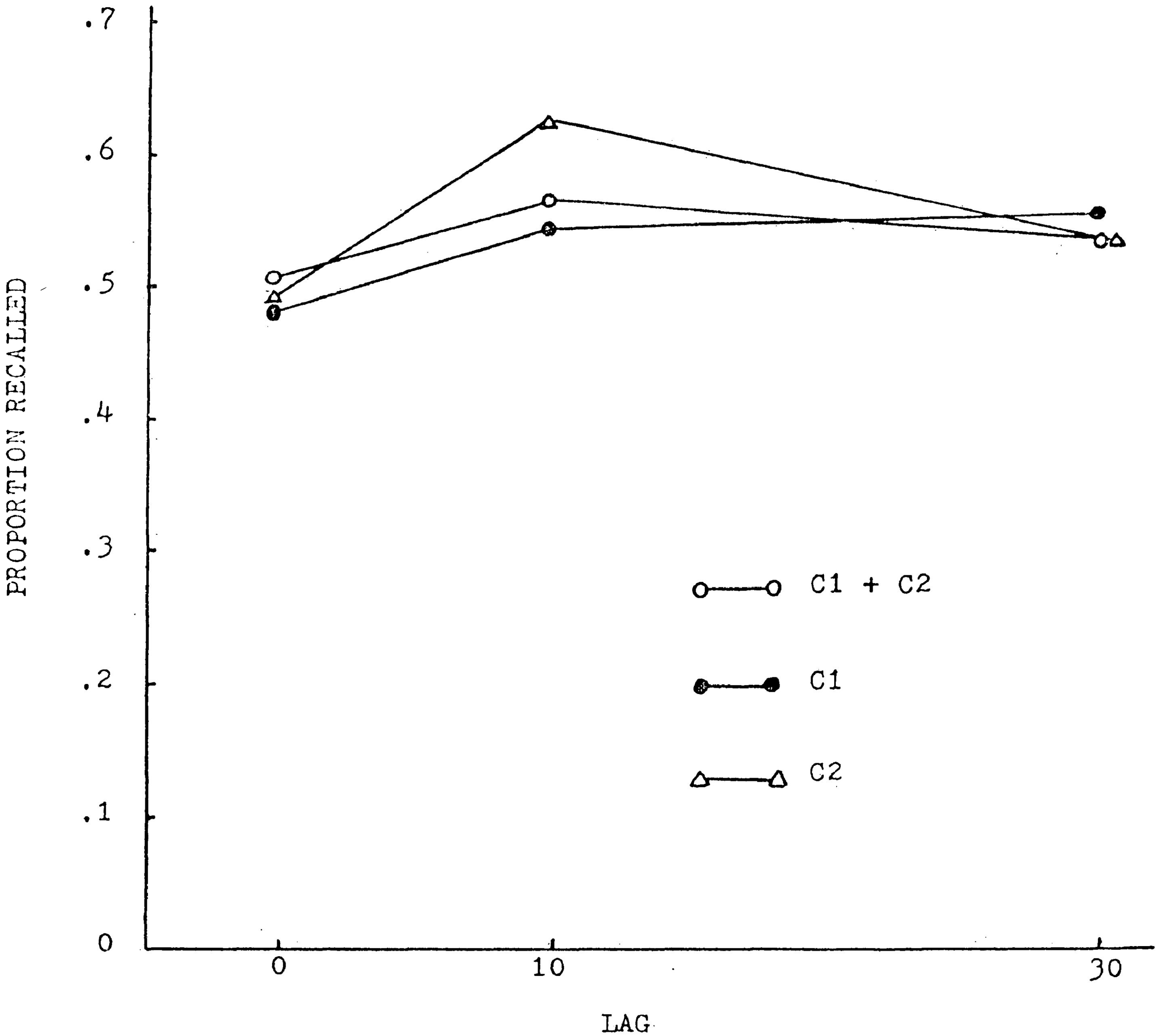

Figure IV.
The proportion recalled of the response terms (object nouns), as a function of lag and cue-type in Experiment II.

the others.

To summarize, the variable encoding thoery definitely is not in a position to account for a shift in the lag function from nonmonotonic to monotonic when the retention interval increases. However, it cannot be totally disregarded. It remains the only theory to predict the elimination of the lag effect in cued recall where variable encodings are ensured and where retention interval is rather long.

Another alternative to encoding variability theory that can explain a shift in the lag function as retention interval increases is the study-phase retrieval hypothesis. It claims that every successful study-phase retrieval at P2 entails the formation of repetition unit. The strength of a repetition unit is a function of the length of P1-P2 interval. Since more effort is required to detect a repetition when the P1-P2 interval is long, the repetition unit so formed is strong in the sense that it can withstand decay and interference for a period of time. On the other hand, the repetition unit is weak when the P1-P2 interval is short because less effort is required to detect a repetition. The shift in the lag function as the retention interval increases can be understood as a consequence of differential rates of forgetting associated with items repeated at different lags. Experiment III examined the lag function under the condition where retrieval of P1 information was required at P2. In Experiment IV, the cause of the shift in the lag function as retention interval increased was investigated.

EXPERIMENT III

The lag function under the condition where retrieval of P1 information was required at P2 was examined. The same design and materials in Experiment I were used. Subjects in this experiment were required to check, on each presentation, whether the sentence had occurred before or not. This provided a means by which successful study-phase retrieval could be measured. It was predicted that the lag effect was a function of successful study-phase retrieval.

METHOD

Design and Materials. The same design and materials as in Experiment I were used. On top of each sentence were printed a 'N' and an 'O' which represented 'NEW' and 'OLD', respectively. Subjects were required to check, on each presentation, whether the sentence was 'N' or 'O'. For each repeated item, if subject checked 'O' at P2, successful study-phase retrieval was assumed to have taken place; otherwise, unsuccessful study-phase retrieval was assumed. If subject checked 'O' at P1, it was regarded as a false alarm and was not scored.

Procedure. The subjects in this experiment received the same kind of instructions as the subjects in Experiment I.

In addition, they were required to check, on each presentation, whether the sentence had appeared before or not. They were given a deck of cards which they were required to turn over at 4-second intervals indicated to them by a sequence of tones previously tape-recorded. Test events were indicated to the subjects by the appearance of a subject noun accompained by a question mark. Subjects were then required to write down the object noun.

Subjects. Thirty undergraduate students who had not participated in Experiment I and II were given credits for their participation in this experiment. Ten subjects were randomly assigned to each of the three presentation formats. Subjects were run in groups of 15.

RESULTS AND DISCUSSION

The proportion of unsuccessful study-phase retrieval associated with lag 0, lag 10 and lag 30 items was 0.01, 0.09, and 0.18, respectively. These data suggested that the number of repetition units formed decreased as the value of lag increased. Proportion recall without study-phase retrieval was 0.002, 0.02 and 0.04 at lag 0, lag 10 and lag 30, respectively, at the 6-event recall; and 0.002, 0.01 and 0.02, respectively, at the final recall. Hence recall without study-phase retrieval was so minimal that an analysis of variance on this condition was meaningless. Therefore only the results of recall with successful study-phase retrieval were analyzed in a 3 (presentation formats) x 2 (retention intervals) x 3 (lag values) analysis of variance. The last two factors were within-subjects factors.

The results of the experiment are summarized in Table II and graphically shown in Fig. V. The main effects of retention interval and lag were significant, $F(1,27) = 62.13$; $F(2,54) = 32.38$, $Ps < .001$. The critical lag by retention interval interaction was significant, $F(2,54) = 4.99$, $P < .01$. Contrary to expectation, the lag function at the 6-event retention interval was monotonically increasing. It resembled the shape of the lag function obtained in final recall of Experiment I. A one-way analysis of variance on the three lag values for the 6-event recall showed that the effect of lag was significant, $F(2,87) = 8.50$, $P < .001$. Both the linear and quadratic components were significant, $F(1,87) = 14.17$, 17.08, $Ps < .001$. For the final recall, the effect of lag was significant $F(2,87) = 3.75$, $P < .05$. Both the linear and quadratic components were significant, $F(1,87) = 4.97$, $P < .05$ and $F(1,87) = 7.6$, $P < .01$, respectively. These results indicate that the shape of the lag function was almost identical for both of the 6-event recall and the final recall. The nonmonotonic lag function was not obtained in the 6-event recall. This was contrary to the prediction generated by the

TABLE II

Mean proportion recall of repeated items with auccessful study-phase retrieval in Experiment III.

	Number of events between P1 and P2		
Retention interval	0	10	30
6 - event	0.33	0.47	0.51
Final	0.26	0.38	0.39

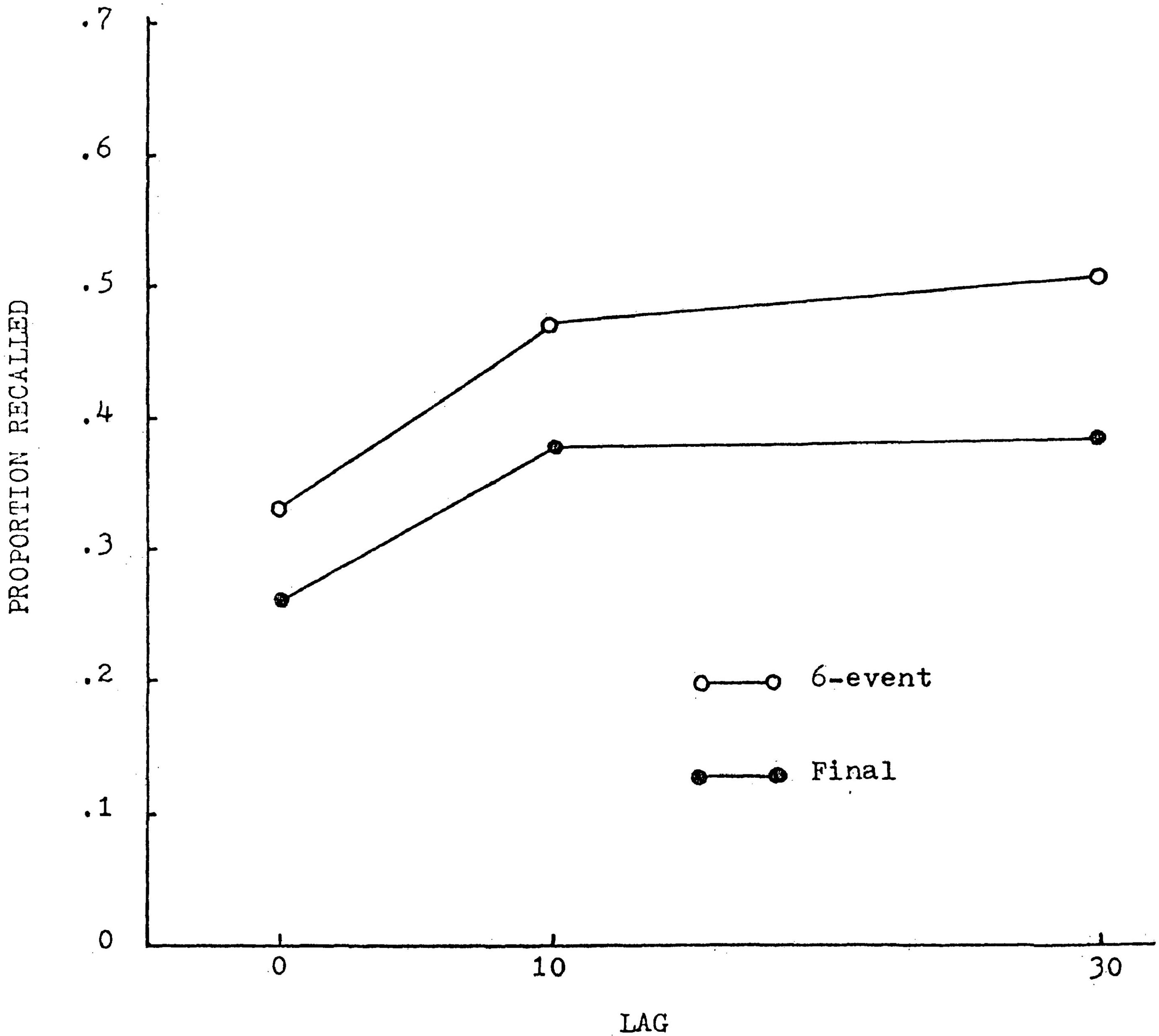

Figure V.
The proportion recalled of the response terms (object nouns) with successful study-phase retrieval, as a function of lag and retention interval in Experiment III.

study-phase retrieval hypothesis.

There are two possible explanations. First, the non-monotonic lag function may not be dependent on successful study-phase retrieval. Second, the recognition task imposed on each presentation event might have acquired the property of an intervening task. Therefore, according to Brown-Peterson's distractor experiment, the lag values might then be greater than they actually were. Similarly, the retention interval might well be greater than 6 events and hence a monotonic increasing lag function resulted.

Since no definite conclusion could be reached in Experiment III, the mechanism causing the shift in the lag function as retention interval increases remains unknown. One possible mechanism that might explain the cause of the shift as a function of retention interval has been mentioned earlier in this paper. It has been suggested that the lag effect may be attributed to differences in the accessibility of items presented at different lags. Experiment IV was designed to explore this rendition of the shift in the lag function.

EXPERIMENT IV

Experiment IV examined the lag effect as a function of retention intervals using free recall as a measure of dependent variable. The Brown-Peterson distractor technique was employed. It was anticipated that the beneficial effect of repetition associated with short-lag items could be assessed if retention interval was short. However, as retention interval increased, this beneficial effect of repetition would be subject to decay and interference. Therefore the rate of forgetting for short-lag items would be fast. With regard to long-lag items, the beneficial effect of repetition would be more resistant to decay and interference. The forgetting rate therefore would be slow. Consequently, the optimal recallability should shift from short-lag items to long-lag items when retention interval increased and thus the shift from nonmonotonic to monotonic lag function would occur.

METHOD

Design and Material. Eighty-seven common nouns ranging from 10-100 in the Thorndike and Lorge counts were selected. Three unrelated words formed a group and each group was printed on a 2" x 4" card; for instance, 'lady, wheel, coin'. A total of 29 three-word groups were formed. Six groups were assigned to each of four lag values and five groups were used as buffers to absorb any effect due to the build-up of proactive interference. Each group was presented twice and tested. The four lag values were 0, 6, 18 and 30 seconds. Test trials were held at 4, 12, and 24 seconds after P2 as well as a final free recall. The lag intervals (except for lag 0) and retention intervals were filled with intervening activities. During each period of intervening activities, a card containing 20 integers selected from a random number table would appear. These integers, ranging from 0 to 99, were arranged in a 4 x 5 matrix. Subjects were required to read out the integer located at the top left hand corner of the matrix first, and then report the result of subtracting three from this integer. Within the time allotted for intervening activities, this process was repeated for the remaining integers in the row and for the rest of the rows in that order.

Three seconds were given for each study trial and 10 seconds were allowed for written free recall. Three formats of presentation were constructed such that each word appeared equally often in each of the three retention intervals at 4, 12, and 24 seconds after P2. Each word appeared only in one lag value. This provided a means by which the forgetting rate of items repeated at the same lag value could be measured.

Procedure. Subjects were tested individually. Each subject was given a deck of cards and was required to turn over one card at a time signaled by a sequence of tones previously recorded. Written recall on a separate sheet was required. Approximately three minutes after a subject had finished the deck of cards, he/she was required to free recall all the words he/she could remember. Ten minutes were allotted for the final recall task.

Subjects. Fifteen volunteers were tested individually. twelve of them were University graduates and three of them were undergraduate students.

RESULTS AND DISCUSSION

The results were shown in Fig. VI. A 3 (formats) x 4 (lag values) x 4 (retention intervals) split-plot analysis of variance with the last two factors as the within-subjects factors was employed.

The effect of lag was significant, $F(3,36) = 21.28$, $P < .01$, as was the retention interval, $F(3,36) = 68.47$, $P < .01$. The critical interaction, lag by retention interval, was significant, $F(9,108) = 5.28$, $P < .01$. This indicates that the shapes of the lag function change with changes in the retention interval. Therefore, the lag effect at each retention interval was further analyzed in a one-way analysis of variance on the 4 lag values. At the 4-second retention interval the overall lag effect was not significant, showing that at 4-second retention interval, the effect of repetition had not been differentiated. This might well be due to the fact that the memory for the input at P2 had not

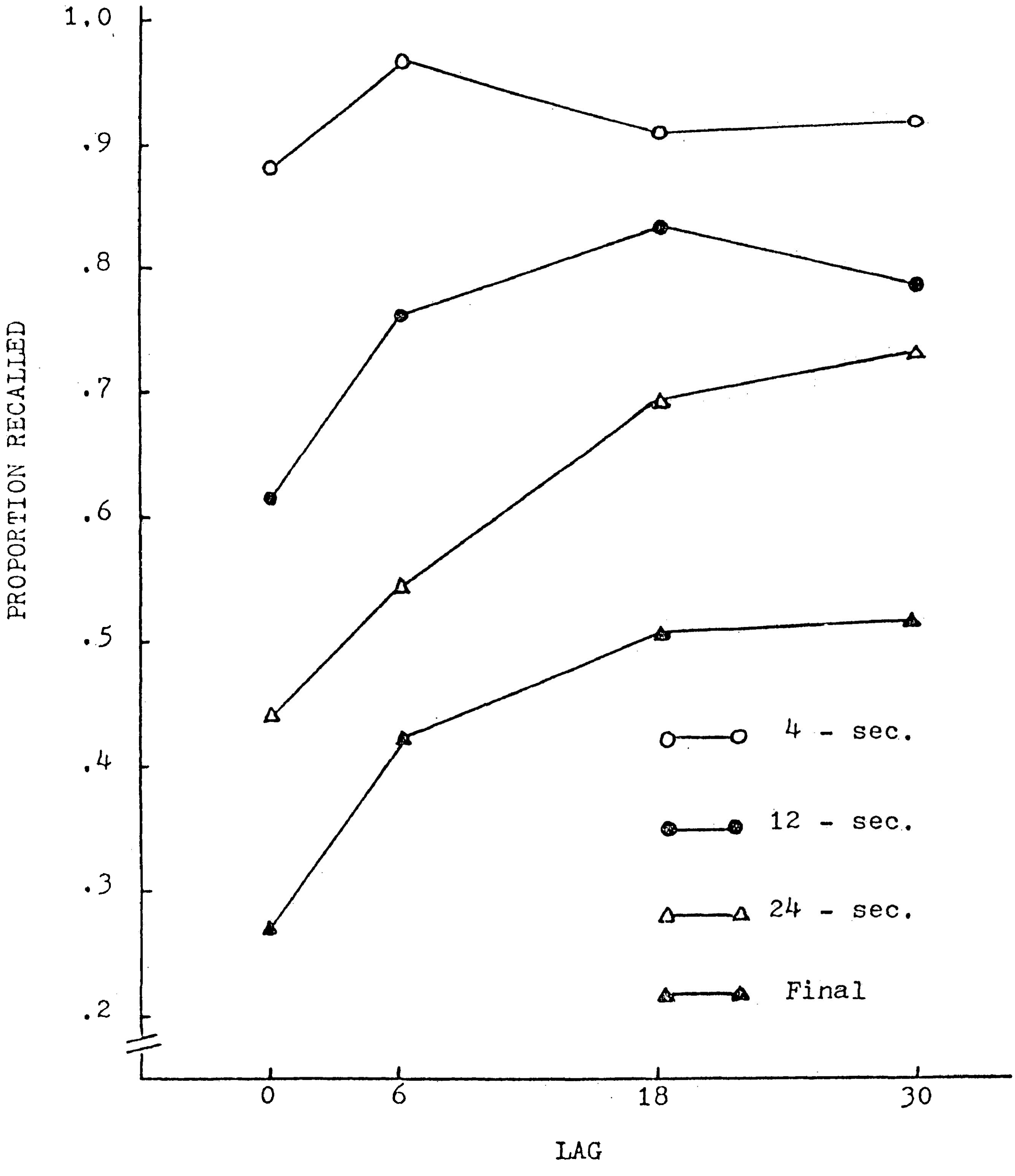

Figure VI.
The proportion recalled of repeated items as a function of lag and retention interval in Experiment IV.

been subject to any appreciable loss through decay or interference. At the 12-second retention interval, the overall lag effect was significant, $F(3,56) = 5.38$, $P < .01$. The linear and quadratic orthogonal components were significant, Fs $(1,56) = 8.03, 7.58$, respectively, $Ps < .01$. Fig. VI shows that the shape of the lag function at the 12-second retention interval is nonmonotonic. As the retention interval increased, the nonmonotonic lag function at the 12-second retention interval gave way to a monotonic increasing lag function. The overall lag effect at the 24-second retention interval was significant, $F(3,56) = 10.84$, $P < .01$, and so was the linear component, $F(1,56) = 32.13$, $P < .01$. This monotonic increasing lag function persisted as retention interval further increased.

This was confirmed by the analysis of the data in the final free recall. The overall lag effect in the final free recall was significant, $F(3,56) = 6.38$, $P < .01$. The linear component was also significant, $F(1,56) = 14.44$, $P < .01$. The persistence in the monotonic lag function as retention interval further increased can be explained by the concept of repetition unit. The longer the P1-P2 interval is, the stronger is the repetition unit so formed. Long-lag items are always more durable than short-lag items. The shape of the monotonic lag function should remain unchanged with further increase in retention interval.

The results from the 12- and 24-second retention intervals are in general agreement with the results obtained from paired-associate experiments. A shift from nonmonotonic to monotonic lag function occurred when the retention interval increased beyond 12 seconds of intervening activities. Judging from the data obtained, the optimal recallability associated with each lag value was a function of retention interval (see Table III). The shift from nonmonotonic to monotonic lag function as retention interval increased can be understood as a function of optimal recallability of repeated items. Items repeated at short lag are readily retrievable only if the retention interval is short. In other words, the beneficial effects associated with short-lag items are more transitory. A plot of proportion recalled as a function of retention interval and lag is shown in Fig. VII. The rate of forgetting was faster for the short-lag items. However, when retention interval was very short (4 seconds), the short-lag items were actually recalled better than the long-lag items. The differential rates of forgetting associated with items repeated at different lag values seemed to have accounted for the occurrence of the shift from nonmonotonic to monotonic lag function as retention interval increased.

Experiment IV thus showed that the shift from nonmonotonic to monotonic lag function could also be obtained using free

TABLE III

The optimal recallability of items repeated with different lags as a function of retention interval.

Retention interval	Optimal recallability	Orthogonal T-test
4 - second	——	——
12 - second	Lag - 18 item	$t_{15} = 2.51$ P .05
24 - second	Lag - 30 item	$t_{15} = 3.60$ P .01
Final recall	Lag - 30 item	$t_{15} = 2.23$ P .05

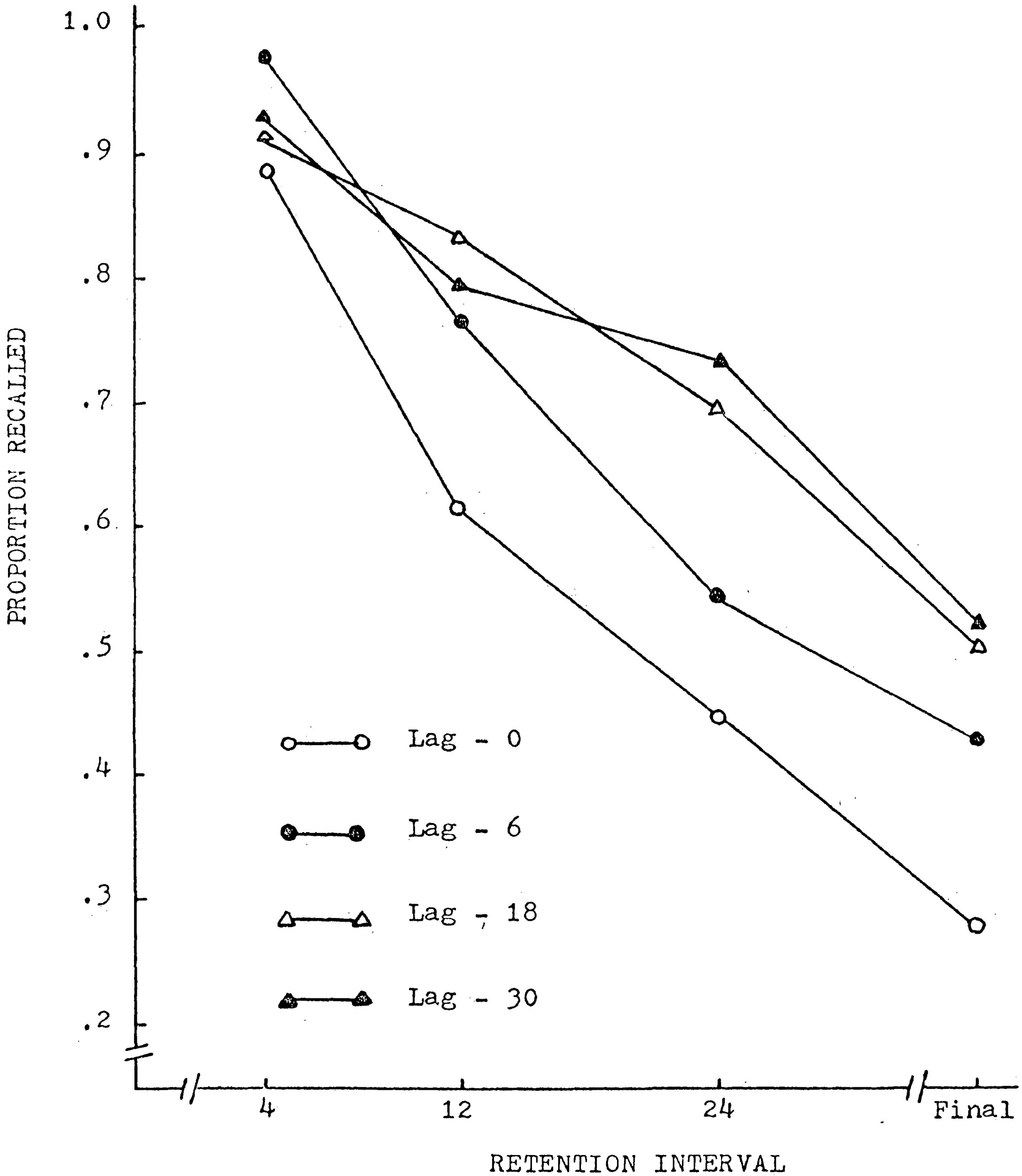

Figure VII.
The forgetting rates of repeated items as a function of retention interval and lag in Experiment IV.

recall. The occurrence of the shift was shown not to be a consequence of cueing as claimed by Glenberg (1976). It was found to be a function of differential rates of forgetting of repeated items as retention interval changed. The results of Experiment IV indicate that the lag effect seems to be largely dependent on retention interval which affects the probability of retrieving a repetition unit.

GENERAL DISCUSSION

The results of Experiments I, II, and IV support the contention that the lag effect is a function of retention interval regardless of whether a paired-associate or a free recall paradigm is used. At short retention intervals the lag function is nonmonotonic, while at longer retention intervals it is monotonically increasing. This finding refuted Glenberg's (1976) claim that the nonmonotonic lag effect is exclusively a result of cued recall. Using the modified paired-associate paradigm, Experiment I replicated the findings obtained in paired-associate experiments. The claim that a shift from nonmonotonic to monotonic lag function when retention interval increases is due to the cueing process was rejected by Experiment II. It showed that when two different codes were ensured at the encoding phase, the recall was not any better in the presence of two cues than in the presence of either single cue alone. If cueing did not lead to the shift in the lag function, then the other factor that had been manipulated was retention interval. Therefore, the shift in the lag function could be a result of change in retention interval. Experiment II further revealed that providing the subjects with two cues for all items in recall did not eliminate the lag effect in the 6-event recall. This is contrary to a version of the encoding variability theory suggested by Glenberg (1976). However, encoding variability cannot be totally ruled out. The final recall in Experiment II showed a rather flat lag function. This indicated that by ensuring variable encoding at P1 and P2 and providing both the P1 and P2 cues at the final recall, the lag effect could be eliminated. These findings are in complete accord with Madigan's (1969) results which showed that when different cues were associated with the first and second presentation of the same item, the lag effect was eliminated when recall was cued by both of the cues at P1 and P2. In view of these findings, the variable encoding theory remains the existing theory that can explain these empirical results. However, its adequacy in dealing with cued or noncued recall at short-term retention is doubted.

Experiment III failed to show a direct correspondence between successful study-phase retrieval and the shift in lag function when retention interval increased. The failure was explained by the suggestion that the intrapresentation recognition task had taken on intervening properties and masked the results. However, Experiment IV verified several propositions generated by the study-phase retrieval hypothesis. First, the results obtained in paired-associate paradigm could be replicated with the Brown-Peterson paradigm using free recall. This finding points out that the nonmonotonic lag effect is no longer a paradigm effect due to cueing, but a rather general effect that must be taken into consideration in a complete theory of spacing effect. Second, the repetition effect for short-lag items could be accessible if the retention intervals were short enough. Third, the shift from nonmonotonic to monotonic lag effect as retention interval increased could be seen as a joint result of retention interval and differential rates of forgetting of repeated items. Madigan's (1969) conclusion was supported. He suggested that the lag effect could be attributed to differences in the accessibility of items presented at different lags. And when there was a change in the conditions of accessibility of to-be-remembered items, for instance, change in retention interval, there was a corresponding change in the lag function.

Although the study-phase retrieval hypothesis has been shown to be adequate in accounting for the lag effect in free recall at long retention intervals (Thios and D'Agostino, 1976), it remains a matter of rigorous research to determine its capability in accounting for a nonmonotonic lag function when retention intervals are short.

The hypothesis regarding the numerosity and strength of different types of repetition units had been put forward to account for the shift in the lag function. Although these two factors had not been dealt with directly in this paper, the basic assumptions have been shown to be warranted. Experiment III showed that successful study-phase retrieval declined with increase in the P1-P2 interval. This indicated that the S-type repetition units formed at the long P1-P2 interval were fewer in number than the other types formed at shorter P1-P2 intervals. Experiment IV demonstrated that the rate of forgetting associated with long-lag items was much slower than the rate of forgetting associated with short-lag items. This finding supported the claim that the type of repetition units formed at long P1-P2 intervals were more resistant to forgetting than the other types formed at shorter P1-P2 intervals.

An important aspect of this research raises the notion of repetition unit. It strengthens the suggestion that in order for repetition to be effective, it must be a repetition of remembered information. It has also been argued that the lag effect can be attributed to differences in the accessibility of items repeated at different P1-P2 intervals. Perhaps the most significant finding in this research is that the shift from a nonmonotonic to a monotonic lag function is critically dependent on the shift in optimal recallability from short-lag items to long-lag items as retention interval increases.

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APPENDIX "A"

Source table for ANOVA in Experiment I

SOURCE	DF	SS	MS	F
Between Ss:-				
FORMATS	2	9.100301	4.550150	0.05
Ss W.G.	27	2362.2600	87.4900	
Within Ss:-				
RETENTION INTERVALS	1	238.04690	238.04690	67.88**
RETENTION X FORMATS	2	15.09993	7.549967	2.15
R x Ss W.G.	27	94.6800	3.51	
LAG	2	198.09780	99.048910	15.58*
LAG x FORMATS	4	33.199850	8.299965	1.31
LAG x Ss W.G.	54	343.3700	6.36	
LAG x RETENTION	2	15.233270	7.616638	6.09*
LAG x R x FORMATS	4	1.866662	0.46666	0.37
LAG x R x Ss W.G.	54	67.5600	1.25	

* $P < .01$
** $P < .001$

APPENDIX "B"

Source table for ANOVA in Experiment II

SOURCE	DF	SS	MS	F
Between Ss:-				
FORMATS	8	369.9094	46.238670	2.25*
Ss WITHIN GROUP	45	925.040	20.56	
Within Ss factors:-				
RETENTION INTERVALS	1	48.89045	48.89045	73.46**
RETENTION x FORMATS	8	6.495809	0.811976	1.22
RETENTION x Ss W.G.	45	29.9500	0.67	
LAG	2	19.50736	9.753685	3.53*
LAG x FORMATS	16	48.43579	3.027237	1.10
LAG x Ss W.G.	90	248.6000	2.76	
CUE - TYPE	2	2.545261	1.272631	0.59
CUE x FORMATS	16	18.56562	1.160352	0.54
CUE x Ss W.G.	90	194.100	2.16	
RETENTION x LAG	2	3.767369	1.883684	4.75*
RETENTION x LAG x F	16	7.621345	0.476334	1.21
RETENTION x LAG x Ss W.G.	90	35.6100	0.40	
LAG x CUE	4	6.158291	1.539573	0.84
LAG x CUE x FORMATS	32	96.72920	3.022787	1.66*
LAG x CUE x Ss W.G.	180	328.5400	1.83	
RETENTION x CUE	2	0.150194	0.075097	0.19
R x CUE x FORMATS	16	6.849739	0.428109	1.12
R x CUE x Ss W.G.	90	34.6600	0.39	
R x LAG x CUE	4	3.652238	0.913059	2.58*
R x LAG x CUE x FORMATS	32	11.903050	0.371970	1.08
R x LAG x CUE x Ss W.G.	180	63.4400	0.35	

*$P < .05$
**$P < .0001$

APPENDIX "C"

Source table for ANOVA IN Experiment III

SOURCE	DF	SS	MS	F
Between Ss:-				
FORMATS	2	114.099300	57.049660	0.73
Ss WITHIN GP	27	2108.6700	78.100	
Within Ss:-				
RETENTION INTERVALS	1	158.670700	158.670700	62.13**
RETENTION x FORMATS	2	0.544441	0.272220	0.11
RETENTION x Ss W.G.	27	68.9500	2.550	
LAG	2	364.230700	182.115300	32.38**
LAG x FORMATS	4	47.666320	11.916580	2.12
LAG x Ss W.G.	54	303.76	5.6300	
LAG x RETENTION	2	15.877620	7.938814	4.99
LAG x RETENTION x F	4	10.555530	2.638884	1.66
LAG x RETENTION x Ss W.G.	54	85.900	1.59	

$^{**}P < .01$

APPENDIX "D"

Source table for ANOVA in Experiment IV

SOURCE	DF	SS	MS	F
Between Ss:-				
FORMATS	2	4.074985	2.037492	0.52
Ss. W.G.	12	46.9500	3.9100	
Within Ss:-				
LAG	3	49.232520	16.41084	21.28**
LAG x FORMATS	6	1.391655	0.231942	0.30
LAG x Ss W.G.	36	27.7600	0.77	
RETENTION	3	283.2971	94.432370	68.47**
R x F	6	5.924974	0.987496	0.72
R x Ss W.G.	36	49.6500	1.38	
LAG x RETENTION	9	14.999960	1.666666	5.28**
LAG x R x F	18	10.074920	0.559718	1.78
LAG x R x Ss W.G.	108	34.0500	0.3200	

$^{**}P < .01$