SEMANTIC CODING IN PRIMARY MEMORY

by

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Recently, several theorists (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965) have proposed a model of memory which organizes and summarizes existing data quite well and also provides a useful framework for guiding current research. According to this model, recall performance is a joint function of a short-term or primary memory (PM) and a long-term or secondary memory (SM).[1] An item is assumed to be automatically entered into PM upon its perception. PM is considered to be a limited capacity system whose major function is the rehearsal of the to-be-remembered (TBR) material. Although the exact role of rehearsal is not fully understood, it has been suggested that it involves some type of recycling of the TBR material. Rehearsal is assumed to be necessary to maintain information in PM and to increase the strength of the memory trace in PM (Rundus & Atkinson, 1970) as well as in SM (Glanzer & Meinzer, 1967). Entry of information into SM is not automatic but rather dependent on the amount, time and/or nature of the rehearsal in PM. SM is considered to be an unlimited, more permanent repository of information in memory. Since an item's strength of registration in this more permanent system is to a large degree dependent on rehearsal in PM, the objective of much current research is to more closely investigate the properties and functions of the primary memory system. The focus of this research is the investigation of the nature of semantic coding in primary memory. Since the general interest expressed here concerns the nature of coding in PM, investigations of auditory and visual coding will first be discussed followed by a detailed analysis of the studies of semantic coding in this memory system.

THE AUDITORY RE-CODING HYPOTHESIS

Evidence for auditory re-coding

A number of theorists have proposed that PM is an auditory coding system wherein all material, including visually presented material, is translated into some form of auditory representation. The evidence for an auditory PM was initiated by Conrad (1964). He found that errors made in recalling sequences of six visually presented letters of the alphabet tend to involve the substitution of letters which sound like the letters that had actually been presented. This finding suggests that letters are re-coded in PM as combinations of vowel and consonant phonemes. The importance of phonemic coding was also shown in a study by Conrad and Hull (1964) in which they found that lists of letters with a common vowel sound were more difficult to recall than lists of words with different vowel sounds.

The functional significance of phonemic units in PM is further supported by Wickelgren (1965) who replicated the original Conrad study under somewhat different conditions. Using auditorily presented lists of eight items (four digits, four letters), he found the same relationship between acoustic similarity and intrusion errors. Additional studies by Wickelgren (1965, 1966) have shown that proactive and retroactive interference in short-term recall are affected by the acoustic similarity of the interfering material. He found that an interference list containing no letters in common with the correct letter(s) produced greater interference if the interference letters had the same vowel sound as the correct letter(s) than if the interference letters had a vowel sound different from the correct letter(s). This interference of highly acoustically confusing lists in short-term retention has also been found with words (Baddeley, 1964, 1966; Dale & Gregory, 1966) and with recognition (Wickelgren, 1966) as well as with recall.

Evidence against auditory re-coding

The general view expressed by the above studies is that coding in PM is auditory (acoustic, phonemic) in nature. Recently, however, data from short-term memory experiments have been accumulating which are not easily accounted for by an auditory re-coding hypothesis. These data suggest the possibility that visual, as well as auditory, information may be coded in PM. Studies comparing auditory and visual presentation in which short sequences of items are presented (Murdock, 1966, 1967; Laughery & Pinkus, 1966) have consistently shown a superiority for auditory over visual presentation. This effect has been obtained with recognition tasks (Murdock, 1968), serial and paired-associate lists (Murdock, 1967) as well as with probed recall (Murdock, 1967; Murdock & Walker, 1969). In studies of free recall (Craik, 1969; Murdock & Walker, 1969) - used primarily because the procedure provides a useful way of localizing effects in PM or SM (Glanzer & Cunitz, 1967) - the advantage of auditorily presented words is limited to the recency portion of the serial position curve. Murdock and Walker (1969) note that these results lend support to the hypothesis that auditorily and visually presented materials are coded in different stores in PM. For if auditory and visual materials were coded in the same store (auditory PM) as Conrad's data suggest, then the retention curves for lists presented in the different modalities should be identical. That is, if the visual material were recoded or translated into some form of auditory representation (Sperling, 1967), then there should be no differences in any portion of the serial position curve between auditorily and visually presented material.

This argument notwithstanding, one might still contend that PM is an auditory store. The superiority of auditory over visual presentation may reflect only the <u>difficulty</u> of translation of the visual material into an auditory form and not that auditory and visual material are coded in different stores. However, there are a series of experiments which show differential effects on recall of auditory and visual material produced by auditory and visual interpolated tasks. Specifically, Scarborough (1972) tested the retention of visually and auditorily presented trigrams (CCC's) using the Peterson distractor technique. He found that the memory for visually presented stimuli is less disrupted by the interpolated task (counting backward) than is the memory for auditorily presented stimuli. This effect has also been obtained by Gardiner, Thompson and Stash (in preparation) who used auditorily presented lists of 12 words with the counting backward task. Finally, Watkins, Watkins, Carik and Mazuryk (1972) gave either visually or auditorily presented lists for either immediate recall or recall following 20 seconds of pursuit rotor activity (a highly attention demanding, non-verbal task). They found that the interpolated task reduced the recency effect for auditory presentation and virtually eliminated the recency effect for visual presentation.

Since encoding must be assumed to be completed prior to the onset of the interpolated task, the modality differences in these studies can be attributed only to modality specific coding in PM. That is, if the modality differences are due to the difficulty of translation of visual material into an auditory form, then any interpolated task should reduce the recency portion of auditory and visual materials proportionately. In other words, there should be a reduction in the recency portion for both auditory and visual lists but the serial position curve should be higher for auditory than visual presentation. But, as the experiments above demonstrate, there is a differential reduction in recall depending on the mode of the test and interpolated lists. This differential effect strongly suggests coding by modality in primary memory.

In a similar line of investigation, Brooks (1968) tested the notion that verbal and spatial (visual) material are handled in modality specific manners. Using sentence memorization and tracing of line diagrams, he found that recall of verbal information (sentences) is most readily disrupted by concurrent vocal activity; recall of spatial information is more readily disrupted by concurrent spatially monitored activity.

An experiment by Kroll, Parks, Parkinson, Bieber and Johnson (1970) not only provided strong evidence for modality specific coding but also demonstrated the existence of a highly persistent visual trace. In this study, subjects were required to shadow letters they heard while trying to remember a particular letter that had been presented visually or auditorily. If a visually presented letter were coded auditorily, it would be subject to as much interference from the shadowing task as would the auditorily presented letter. However, if less forgetting were to be found for the visual letter, this would suggest that it was coded in a visual form. Results after a retention interval of one second indicated that visual and auditory letters were recalled equally well suggesting that they were perceived equally well. However, after a retention interval of 25 seconds, all subjects recalled more visual letters than auditory letters. This finding suggests not only that visual and auditory materials were coded differently but also that subjects have some ability to hold a visual representation for at least 25 seconds.

Current status of auditory and visual coding in primary memory

In the experiments discussed thus far, several lines of investigation have presented fairly conclusive evidence that phonemic features are coded in primary memory. Indeed, one line of investigation, showing that intrusion errors in recall of alphabetic characters tend to involve the substitution of letters which sound like the letters that had actually been presented, indicate that primary memory is essentially an auditory system. That is, the data from these experiments suggest that all material, including visually presented material, must be recoded or translated into some form of auditory representation. However, further research has provided evidence that is not easily accounted for by an auditory recoding hypothesis and has suggested that visual features can also be coded in primary memory. The most conclusive evidence for visual coding comes from studies which have shown differential effects on the recall of auditorily and visually presented material produced by auditory and visual interpolated activity. Such effects can only be explained by postulating modality-specific coding in which auditory and visual material are coded in primary memory.

THE SEMANTIC ENCODING CONTROVERSY

Evidence for semantic coding in primary memory

In addition to those studies investigating auditory and visual coding in PM, another line of investigation has questioned whether or not semantic coding occurs in this memory system. One set of experiments which report finding evidence that semantic coding does occur in PM can be excluded on procedural grounds. These investigations of semantic coding have been conventionally classified as studies of primary memory (Baddeley & Dale, 1966; Dale & Gregory, 1966; Wickens, 1970) but they have used the Brown-Peterson short-term memory procedure. The retention function obtained with this procedure reflects the contribution of both PM and SM. Thus, it is doubtful, as Shulman (1971) and Baddeley (1972) point out, whether these studies reflect semantic coding solely in PM.

Perhaps the strongest evidence for semantic coding in primary memory was reported by Shulman (1970) who used a probe recognition test. In this study, subjects judged whether the probe was identical to, a synonym or homonym of one of the list words. Lists of 10 words were visually presented with each list followed by a cue specifying which of the three types of recognition judgments the subject had to make. The probe word, which did or did not have the specified relationship to one of the ten words in the list, appeared 1.3 seconds after the cue. The results revealed a pronounced difference in reaction times associated with the three probe types with identical probes being the fastest, homonym probes next and the synonym probes being the slowest. However, the retention functions for the three types of probes were similar. Since the same recency effects were obtained with synonym recognition as with the other two probe types, Shulman concluded that semantic coding had been demonstrated in PM. However, the interpretation of the above results depends on the assumption that synonym recognition could not be done on the basis of other kinds of stored information. That is, list words could have been stored phonemically and recoded to a semantic form on those trials requiring synonym recognition. Raser (1972) performed a study which was in major respects identical to Shulman's but which provided a test of this recoding notion. Every synonym recognition trial which included a synonym of the probe in the list (e.g., list word - bare, probe word - nude) was matched with a trial which included the same acoustic input but without the synonym relationship (e.g., list word - bear, probe word - nude). If the subject has only an acoustic representation of the words in the list, his performance should be identical in the above two conditions. The results, however, revealed significant differences between the two conditions. The findings replicated Shulman's results and Raser thus concluded that both studies provide considerable evidence for semantic coding in PM.

Baddeley (1972) objects to this interpretation. He notes that in both the Raser and Shulman studies, each list was followed by a cue indicating the recognition criterion to be used. In Shulman's study this cue lasted 1.3 seconds while it lasted one second in Raser's study. Baddeley contends that it is possible that some type of recoding might begin as soon as the subject knows what recognition criterion to use. It is therefore not clear whether the list words were coded semantically, phonemically or both. In addition, both Raser and Shulman identify the recency effects obtained with the three probe types with primary memory. It is important to point out, however, that the positive recency effect reflects the contribution of both PM and SM. Therefore, although these two studies provide some suggestive support for semantic coding, the evidence for such coding in PM remains inconclusive.

Evidence against semantic coding in primary memory

Another set of studies has marshalled empirical evidence suggesting that semantic features of words are not coded in PM. Kintsch and Bushke (1969) used the serial probe method to investigate the effects of both phonemic and semantic similarity in primary memory. Similarity was manipulated by including either eight synonym or eight homonym pairs in a list of 16 words. Results showed that phonemic similarity affected recall from PM but not SM while semantic similarity affected SM but not PM. This study would seem to provide evidence that primary memory is not affected by semantic similarity. However, it is difficult to argue from the null hypothesis. As Shulman mentions, subjects faced with certain task demands may opt to code items phonemically even when tested with semantic probes. But this is far different from claiming that the memory trace in primary memory is by nature phonemic.

Another type of study providing some evidence that PM is not affected by semantic features of words was reported by Tulving and Patterson (1968). In this study lists of words were presented which contained four highly related words in addition to unrelated words. The four highly related words appeared as a cluster at the middle or end of the list. Their findings suggest that highly related words are retrieved from SM as a single functional unit while the unitization of related words in PM occurs only to a small extent. On the other hand, the recall probabilities of the terminal cluster of related words were somewhat higher than the recall probabilities for corresponding words in control lists. These data would seem to imply that semantic features are coded in PM. However, Craik and Levy (1970) point out that this enhanced recency observed by Tulving and Patterson is essentially an SM phenomenon since performance on terminal items reflects retrieval from both PM and SM. In an essentially identical experiment, Craik and Levy demonstrated that when the enhanced terminal probabilities were "corrected" for retrieval from SM (Waugh & Norman, 1965), the apparent advantage to retrieval from PM disappeared. That is, the overall enhancement of the recency effect by semantic similarity found by Tulving and Patterson and confirmed in the Craik and Levy study is not a PM effect but appears to be due to a greater contribution from SM.

The function of the procedure used in the two above studies is to produce a facilitory effect on the recall of terminal items implying therefore that semantic coding had occurred. This procedure may be an inappropriate one to use for the study of primary memory. Two-memory theorists describe PM items as being immediately available and accessible. It does not seem reasonable to expect any type of procedure to facilitate retrieval from PM.

<u>Current status of semantic coding in primary memory</u>

In contrast to the fairly clear evidence for auditory and visual coding in primary memory, the results of studies investigating semantic coding in PM have not been as definitive. Several studies which report evidence for semantic coding in PM are inconclusive because the procedure did not allow for the separation of PM and SM components. The two studies which have been cited as providing the strongest support for semantic coding in PM are suspect (Baddeley, 1972) since the possibility exists that list words may have been stored phonemically and recoded semantically on those trials requiring semantic recognition. Thus, there is no strong evidence for semantic coding in PM.

Similarly, studies reporting evidence against semantic coding face two basic problems of interpretation. First, the evidence is difficult to interpret since one is arguing from the null hypothesis. Second, the failure to use semantic encoding under one set of conditions does not mean semantic coding could not be used under another set of conditions. In addition to these studies which have interpretative problems, one subset of studies providing evidence against semantic coding in PM used an inappropriate procedure. The procedure was intended to facilitate recall of terminal items but, since PM items are assumed to be immediately available and accessible, it is unreasonable to assume that any procedure would be able to facilitate recall of primary memory items.

In summary, while there have been a number of studies investigating the possibility of semantic coding in primary memory, there is no conclusive evidence for or against such coding in this memory system.

A PROPOSED TEST OF SEMANTIC CODING IN PRIMARY MEMORY

A review of the literature on semantic coding in PM indicates that there is a good deal of controversy regarding the role of meaning or semantic features in the coding of verbal material in primary memory. Close inspection of this literature reveals that one of the major difficulties with many of these studies is the procedure used to investigate such coding in this memory system. As noted in a previous section, the procedures either do not allow for the separation of PM and SM components or are inappropriate for testing PM. The experiments to be reported here used a different procedure designed to provide information on the role of semantic coding in PM in the attempt to resolve this controversy.

The rationale used in the present investigations was adopted from Wickens and his associates (Wickens, 1970; Wickens, Born & Allen, 1963). The rationale is that materials which do not interfere with one another must be, to some extent, coded along different features. In contrast, materials coded along the same features produce the most interference. Thus, the greater the number of identical features used to code materials the greater the amount of interference. Given these assumptions, it follows that if semantic coding does occur in PM more interference would result for TBR items followed by an interpolated task also requiring semantic coding than for TBR items followed by an interpolated task which does not require semantic coding. More specifically, the subjects in the present experiment were given lists of 12 unrelated words. Immediately following a list, subjects shadowed a list of either (a) unrelated words, or (b) paralogs (non-sense words), (see Appendix 2). If semantic coding occurs in PM, more interference would result for items followed by word shadowing since semantic features are assumed to be coded for words in both test and interpolated lists. Items followed by paralog shadowing would not suffer as much interference since paralogs (which have no semantic content) are not assumed to be coded along semantic features to the same extent as words.

While the major objective of the present experiment was to provide evidence for semantic coding in PM, the study was also used to extend our information concerning the characteristics of auditory coding in PM. Previously mentioned studies (Conrad, 1964) propose that auditory coding in PM is based primarily on phonemic features - features of words which may be considered to be independent of situational characteristics. It is assumed here that PM is a flexible coding system in which any salient cues in the experimental situation may be used to code items. In this experiment, the gender of voice used in the test and interpolated lists was used in the attempt to investigate whether such information might provide salient features along which PM items may be coded. (Gender of voice was selected since studies of dichotic listening have found this to be a salient cue, e.g., Cherry, 1953.) If such cues are coded in PM, less interference would result with interpolated lists in which the gender of voice has been changed from that used in the test lists than with interpolated lists where the same gender of voice was used to present both the test and interpolated lists.

Experiment 1

Method

Subjects.--The subjects were 36 general psychology students at Kansas State University who participated for extra credit. All subjects were tested individually.

Materials.--Sixteen 12-word test lists were generated by sampling without replacement from a pool of 600 high-frequency, two-syllable nouns (Murdock, 1968). To insure that results were not list specific, 6 sets of 16 lists were constructed and each set was used for 6 different subjects.

The words used in the interpolated task consisted on 58 nouns from the above pool not used in construction of the test lists and 62 two-syllable words ranging in frequency from 10 to 500 per million taken from Kucera and Francis (1967). A five minute series of words was recorded such that no one word was repeated in any 30 second segment.

The paralogs (two-syllable nonsense words) used in the interpolated task were constructed by randomly combining the syllables of words used in the word interpolated task. The pronunciation of the syllables comprising these paralogs was made to be nearly identical to the pronunciation of these syllables when they formed words. A five minute series of these paralogs was recorded so that no one syllable was repeated in any 30 second sequence.

Design.--Each subject recalled 4 lists under each of 4 conditions represented by the factorial combination of type of interpolated task (shadowing words, shadowing paralogs) and the gender of voice used in the interpolated task (same or different from the gender of voice used in the test list). In any one condition, the gender of voice was counterbalanced across the 4 lists. All subjects received the 16 lists in a single one-hour session. The order of conditions was randomized such that no one condition appeared more than twice in succession.

Procedure.--The subjects received two practice trials on each type of interpolated activity prior to the start of the experiment. The subjects were given the auditorily presented test lists via a Sony tape recorder at the rate of one word every two seconds. Immediately after the presentation of a test list, a brief tone was sounded which signified the onset of the shadowing interpolated task. A 30 second segment of words or paralogs taken from a five minute series was presented to the subject. The interpolated list items were also presented via a Sony tape recorder at the rate of one item per second. After this period of interpolated activity, the subjects were orally instructed to recall. Two minutes were provided for written free recall but subjects could terminate recall at any point before this period elapsed. Separate pages in an answer booklet were provided for the recall of each list.

Results

Since two-memory theorists suggest that output from PM is essentially restricted to the recency portion of the serial position curve, an analysis testing the effects of experimental manipulations on PM was restricted to serial positions 7-12. Since two-memory theorists also assume that these interpolated task manipulations will not affect recall from the initial portion of the curve, a separate analysis was performed for serial positions 1-6. The data in each analysis was based on the total number of words correctly recalled by each subject at each serial position summed across the four lists in each of the four conditions. The data, expressed in terms of probability of recall, is presented in Figure 1.

The results of primary interest are contained in the analysis of the last six serial positions. As predicted, the word interpolated task (WI) resulted in a lower probability of recall for terminal items than did the paralog interpolated task (PI), $F\ (1,35)=46.38$, $p < .001$, (mean probability of recall for WI=.26; PI=.35). The interaction of serial position and type of delay task was also reliable, $F\ (5,175)=3.69$, $p < .01$. This interaction represents the diverging recall functions for the word and paralog interpolated tasks. The systematic decrease in probability of recall over terminal positions is reflected by a significant main effect of serial position, $F\ (5,175)=5.66$, $p < .001$.

Changing the gender of voice used in the interpolated task did not result in a reliably higher probability of recall of terminal items compared to the condition in which the same gender of voice was used in both the test and interpolated lists. The interaction of voice change and serial position was not statistically reliable and neither was the interaction of voice change and delay task. Although the triple order interaction of voice change, delay task and serial position was significant, $F\ (5,175)=12.32$, $p < .001$, a subsequent

Figure Caption

Fig. 1. Probability of recall by serial position presented separately for recall following word and paralog shadowing interpolated tasks under each voice change condition.

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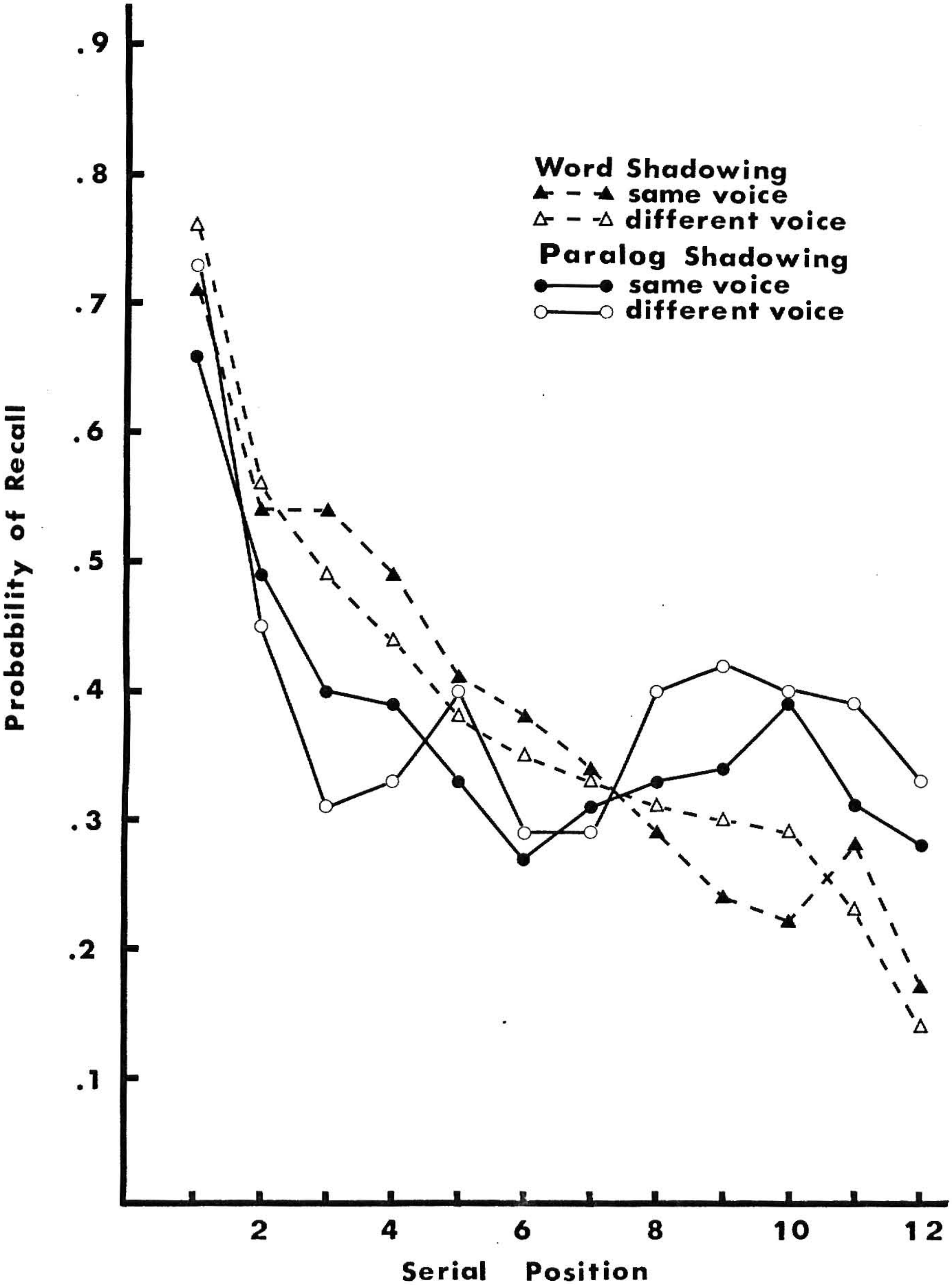

Word Shadowing
same voice
different voice
Paralog Shadowing
same voice
different voice
Probability of Recall
.9
.8
.7
.6
.5
.4
.3
.2
.1
2
4
6
8
10
12
Serial Position

Newman-Keuls revealed no discernible, overall effects of voice. This interaction, therefore, does not lend itself to unambiguous interpretation.

As can be seen in Figure 1, a marked negative recency effect was obtained for the WI conditions but there is no such effect for the PI conditions. Although there were no overall effects of voice, separate trend analyses were performed on each of the four conditions to provide the most conservative test for negative recency. Both WI conditions produced reliable negative linear trends, $F's \geq (1,35)\ 7.77$, $p < .01$. The linear trends for the PI conditions were not statistically reliable, $F's < 1$.

The finding that the word (semantic) interpolated task produced a greater decrement in recall probability for terminal items than the paralog (nonsemantic) task provides suggestive evidence that the initial hypothesis of semantic coding in primary memory has been supported. However, the initial hypothesis also stipulates that the interpolated task manipulations would not affect recall from the initial portion of the list (assumed to reflect the SM component). In direct contradiction of this prediction, the results of the analysis of the first six serial positions demonstrates large differences in recall between the word and paralog interpolated tasks, $F\ (1,35)=18.18$, $p < .001$, (mean probability of recall for WI=.51; PI=.42). The significant main effect of serial position $F\ (5,175)=54.74$, $p < .001$, simply reflects the primacy effect. The interaction of serial position and delay task was not reliable.

As in the previous analysis, the main effect of voice change was not statistically reliable nor was the interaction of voice change and delay task. However, the interaction of voice change and serial position was significant, $F\ (5,175)=2.30$, $p < .05$, as was the triple order interaction of voice change, serial position and delay task, $F\ (5,175)=5.50$, $p < .001$. A subsequent

Newman-Keuls indicates that these interactions can be best described by noting that recall for the different voice conditions drops more sharply over serial positions 2-4 than does the recall for the same voice conditions and that the same voice condition in PI drops most sharply of all. There are, however, no overall effects of voice.

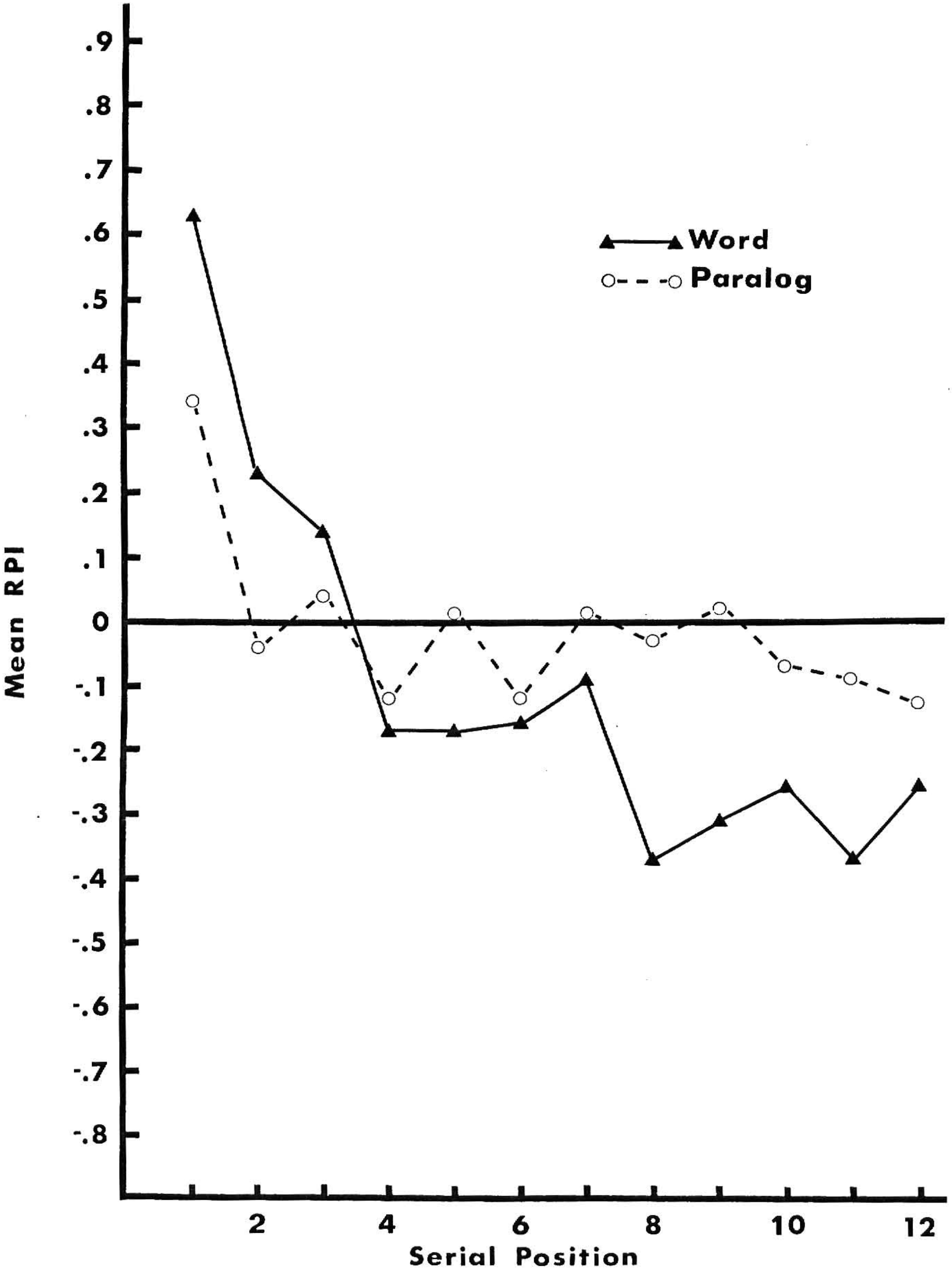
Since the results indicate differential effects on both primary and secondary memory, the effects of the interpolated tasks cannot be attributed solely to differential interference in primary memory. The decrease in recall probability for terminal items and the increase in recall probability for initial items for lists followed by WI may instead reflect a tradeoff in recall between beginning and end items - perhaps as the result of a retrieval strategy on the part of the subject. Note, in Figure 1, that the serial position curve for the WI conditions is very similar in shape to the serial position curve obtained with a serial recall procedure. To assess whether the subjects are employing a serial recall strategy following the WI conditions, the order of recall of items was examined using a relative priority index (RPI). The RPI (Flores, 1973) is a rank-order weighting measure which assigns a value of +1 to the first word recalled and -1 to the last with the appropriate, equal-interval sign-weights to words recalled in intermediate positions. The results obtained with this measure for PI and WI are presented in Figure 2. As can be seen, the priority weights in the PI condition tend to center around zero in all but the first serial position. This suggests that, with the exception of the first position, the recall of words following PI are not ordered in any particular manner. This is not the case for the WI condition. The marked decreasing trend suggests that the subjects are in fact tending to recall in serial order. Note, however, that although the last five items are apt to occur later in output than middle items, there is no differential order of output for these items.

To avoid the problem of unfilled cells for individual subjects, an analysis of variance was performed on mean RPI scores calculated for each subject for serial positions 1-3 and 10-12 in PI and WI for same and different voice conditions. Separate analyses were performed for serial positions 1-3 and 10-12. The results revealed that RPI scores for WI (.33) were reliably higher than PI (.12) for serial positions 1-3, $F\ (1,35)=11.59$, $p < .01$, and reliably lower than PI for serial positions 10-12, (WI -.30; SI -.10), $F\ (1,35) =4.96$, $p < .05$. There was no main effect of voice on the order in which words were recalled and the interaction of voice change and delay task was also not statistically reliable. Additional tests revealed that the RPI scores for the WI conditions were reliably different from zero for serial positions 1-3, F's $(1,35)\geq 23.0$, $p < .001$, as well as for serial positions 10-12, F's $(1,35)\geq 4.26$, $p < .05$. The only statistically reliable difference from zero for RPI scores in the PI conditions occurred for serial positions 1-3 for the same voice condition, $F\ (1,35)=5.14$, $p < .05$.

The evidence for serial recall suggests the possibility that subjects, under the WI conditions, adopt this strategy to reduce potential confusion between to-be-remembered (TBR) items and interpolated task items. That is, the use of WI presents of problem of list discrimination. Under these conditions the subjects order their recall beginning with initial items. The initial items by virtue of being first in a list can be more easily distinguished from interpolated list items than can the terminal items which are temporally nearer to the interpolated task items and are thereby more confusable with these items. If there is a problem of list discrimination with the WI task then in recall there should be more intrusions of interpolated task items (WI items) for lists followed by WI than for lists followed by PI. Mean number of prior list intrusions, interpolated task intrusions and extra-experimental

Figure Caption

Fig. 2. Mean relative priority scores by serial position for recall following word and paralog shadowing interpolated activity.



Word
Paralog
Mean RPI
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
2
4
6
8
10
12
Serial Position

intrusions are presented in Table 1. Analyses performed separately on each type of intrusion data revealed no significant differences in the number of prior list or extra-experimental intrusions between the PI and WI conditions. However, a significantly greater number of interpolated task intrusions occurred in recall of lists followed by WI, $F(1,35)=21.64$, $p < .001$, which suggests a possible problem of list discrimination. Note, however, that the number of intrusions is very low, on the average of .5 per list. The subjects' shadowing performance was also analyzed. Table 2 presents the mean number of errors made in the first fifteen seconds of shadowing words and paralogs. Note that the number of errors is quite low with no obvious differences between tasks.

Table 1

Mean number of intrusions in recall following word and paralog shadowing interpolated tasks presented separately for voice change conditions.

Delay Task		Intrusions: Prior-list	Intrusions: WI interpolated task	Intrusions: Extra-experimental
WI	same voice	.14	.25	.23
	different voice	.17	.22	.26
PI	same voice	.27	.05	.21
	different voice	.19	.04	.25

Table 2

Mean number of errors made in shadowing word and paralog interpolated material presented separately for voice change conditions.

	Word Task	Paralog Task
Same Voice	.02	.03
Different Voice	.03	.04

Discussion

The central hypothesis from which this study was developed was that semantic coding can occur in primary memory. The present experiment was designed to produce evidence in support of that hypothesis by revealing differential interference effects on primary memory items through the use of word and paralog shadowing interpolated activity. More specifically, the hypothesis was that, if semantic coding occurs in primary memory, more interference should result for terminal items followed by an interpolated task which requires semantic coding (words) than one which does not (paralogs). The results do not provide clear evidence in support of this hypothesis since there were differential effects on both primary and secondary memory and since there is evidence for serial recall following WI. Note, however, that the probability of recall for terminal items followed by WI show a clear negative trend while the RPI scores for these items do not show this negative trend. This suggests that the systematic decrease in recall performance over these end items is not due entirely to the output order of these items. Therefore, the decreasing trend in recall for end items most probably should be attributed to differences in the coding of these items presumably due to the differential interference effects from the WI task.

Further suggestive evidence in support of the initial hypothesis comes from the comparison of the data obtained with the paralog task with the recall functions obtained in other delayed free recall studies. More specifically, previous experiments using auditorily presented test lists with auditorily presented interpolated activity (shadowing digits, counting backward) have consistently reported a negative recency effect (Gardiner, Thompson & Stash, in preparation). In the present experiment, however, a negative recency effect was not obtained for the auditorily presented test lists followed by the auditorily presented paralog interpolated task. The major difference between those studies and the present experiment is that the previous investigations have used digit shadowing or counting backward which involves the use of meaningful (semantic) material while the PI condition in the present study did not. Thus, the failure to obtain negative recency with PI together with the finding of negative recency for WI in the absence of differential output for terminal items provides fairly strong suggestive evidence in support of the initial hypothesis that semantic coding occurs in primary memory. However, a second study was designed to provide more conclusive support for the original hypothesis. In order to eliminate the problems of interpretation produced by serial recall in the WI conditions, the present study used three interpolated tasks: shadowing words, shadowing paralogs and shadowing numbers. The digit shadowing (NI) was incorporated because it involves the coding of semantic information but eliminates the problem of list discrimination. As in the first experiment, the prediction is that those tasks requiring semantic coding (words, numbers) should produce a greater decrement in recall of terminal items than a task which does not (paralogs). Since there were no overall effects of voice in the previous experiment, this manipulation was not included in this study.

Experiment 2

Method

Subjects.--The subjects were 50 general psychology students at Kansas State University who participated for extra credit. All subjects were tested individually.

Materials.--Fifteen 12-word lists were generated in the same manner and from the same pool as in Exp. 1. In this experiment 10 sets of 15 lists were constructed and each set was used for 5 different subjects. The word and paralog interpolated material were the same as that used in Exp. 1. The number shadowing material consisted of a random series of single digits 1-9.

Design.--All subjects received the fifteen 12-word lists in one session. Each subject recalled 5 lists under each of three conditions: recall following 30 seconds of shadowing words; recall following 30 seconds of shadowing paralogs; recall following 30 seconds of shadowing numbers. The order of conditions was randomized such that no one condition appeared more than twice in succession.

Procedure.--The subjects were given one practice trial on each of the three delay tasks before the start of the experiment. The subjects received the auditorily presented test lists and interpolated lists via a Sony tape recorder. Words in the test lists were presented at the rate of one every two seconds. Immediately following the presentation of a test list, a brief tone was sounded signifying the onset of the shadowing task. Words were presented at the rate of one item per second as were the paralogs while the numbers were presented at the rate of two per second. As in Exp. 1, the subjects had no prior knowledge of what type of interpolated task would be presented. After this period of shadowing the subjects were orally instructed to recall. Two minutes were given for written free recall but subjects could terminate recall at any point.

Results and Discussion

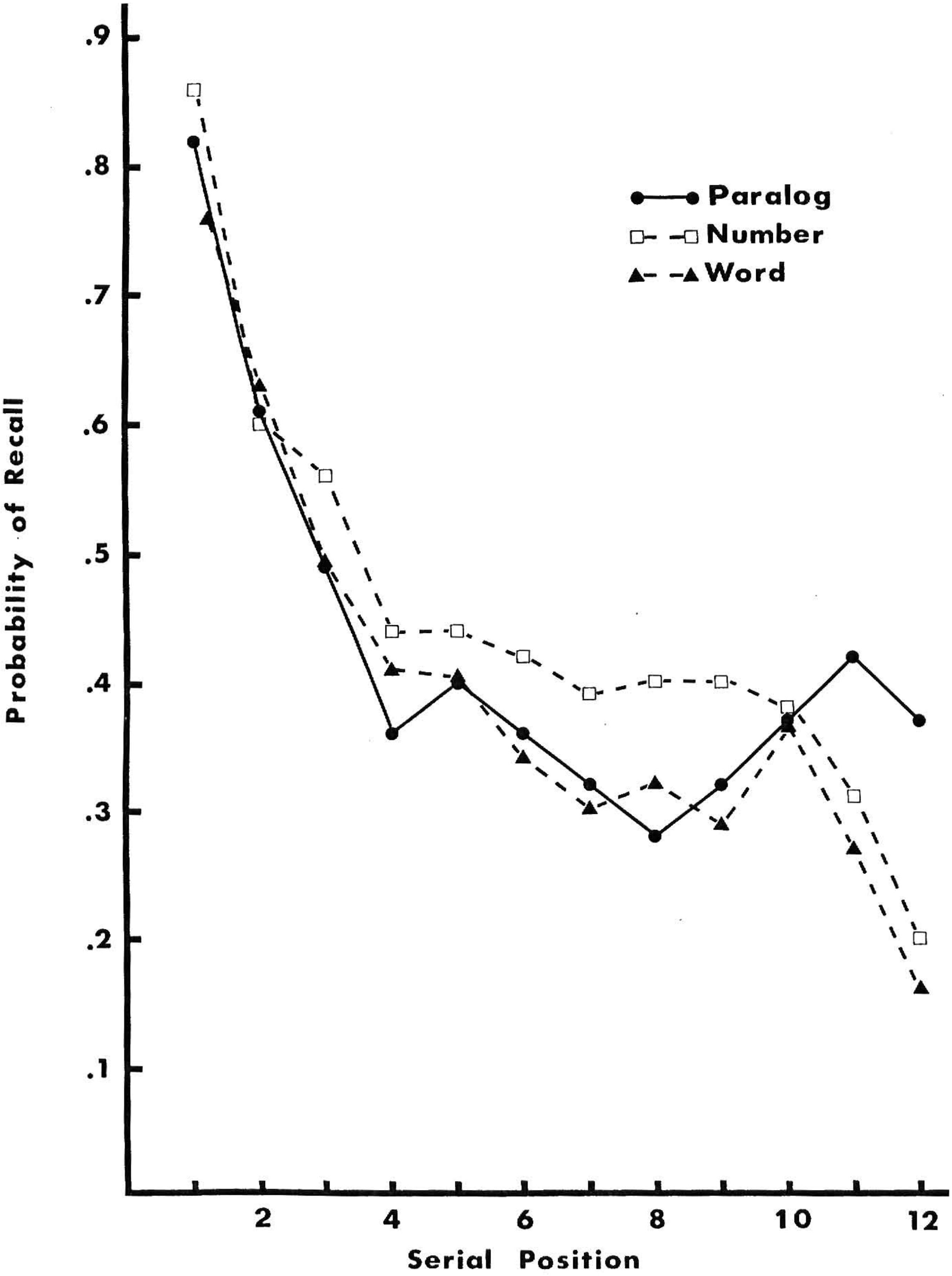
As in Experiment 1, separate analyses were performed for serial positions 1-6 and 7-12. The data in each analysis was based on the total number of words correctly recalled by each subject at each serial position summed across the five lists in each of the three delay conditions. The data, expressed in terms of probability of recall, is presented in Figure 3.

Again, the analysis of primary interest is that performed on serial positions 7-12. The analysis revealed a significant main effect of delay task, $F(2,98)=9.86$, $p < .01$. Post tests revealed that, as predicted, the word interpolated task (.29) resulted in a greater decrement in recall probability than did the paralog task (.35). Post tests also indicated that WI and NI (.35) were significantly different and that the expected difference between PI and NI was not obtained. However, the results of critical importance are reflected in the interaction of serial position and delay task. This significant interaction, $F(10,490)=6.10$, $p < .01$, represents the diverging recall functions of the delay task conditions. A subsequent Newman-Keuls on interaction means revealed that NI and WI are reliably different at the penultimate position but PI and NI are not. Although the serial position curve for NI is well above both WI and PI for serial positions 7-9, a significant difference occurred only at position 8 where NI is reliably different from WI but not from PI. Finally, the systematic decrease in probability of recall for end items is reflected in the main effect of serial position, $F(5,245)=6.23$, $p < .01$.

In addition to these results, inspection of Figure 3 shows that there is a marked negative recency effect for both WI and NI but there is no such effect for the PI condition. Both WI and NI produced reliable negative linear trends,

Figure Caption

Fig. 3. Probability of recall by serial position plotted for recall following word, number and paralog shadowing interpolated tasks.


.9
.8
.7
.6
.5
.4
.3
.2
.1
Probability of Recall
Paralog
Number
Word
2
4
6
8
10
12
Serial Position

F's (1,49)≥9.61, $p < .01$. The trend test for the PI condition revealed the reverse effect, a significant positive linear trend, F (1,49)=7.81, $p < .01$.

In contrast to the results obtained in Experiment 1, analysis of the first six serial positions does not reveal significant differences between WI and PI. Although the main effect of delay task was significant, F (2,98)=5.16, $p < .01$, this result is due to the superiority in recall performance of NI (.55) over both PI (.51) and WI (.51), as revealed by a Newman-Keuls test. The main effect of serial position, F (5,245)=81.40, $p < .001$, reflects the primacy effect. The interaction of delay task and serial position was not statistically reliable.

As stated previously, the surprising finding is that there are no reliable differences between PI and WI for initial items. Although in this study the serial position curve for all delay tasks does not appear to be similar in shape to the function obtained with serial recall, relative priority scores and intrusion data were nevertheless tabulated. The plot of the RPI scores in Figure 4 shows that the conditions did not differ in the order in which words were recalled. Statistical analyses, performed in the same manner as in Experiment 1, revealed no significant differences between conditions in RPI scores for serial positions 1-3 or 10-12, F's < 1. Additional tests indicated that all conditions were reliably different from zero at serial positions 1-3 and 10-12, F's (1,35)≥30.0, $p < .001$. Note that all conditions exhibit the type of RPI function found in the WI condition in the first experiment. The important point to note, however, is that significant differences in order of recall occurred between PI and WI in Exp. 1, but in the present study there were no significant differences between conditions in the order in which words were recalled.

The analysis of the intrusion data, presented in Table 3, show that there were no significant differences between conditions in the number of prior list or extra-experimental list intrusions. However, a significantly greater number of word interpolated task intrusions occurred in the recall of lists followed by WI than for lists followed by NI or PI, $F\ (2,98)=12.62$, $p < .001$. Note that no significant differences occurred between PI and NI in any type of intrusion.

In brief, since there were no significant differences between PI and WI in the recall of initial items and since significant differences did occur in the recall of terminal items followed by meaningful and non-meaningful material, these results can be interpreted as providing conclusive support for semantic coding in primary memory. On the other hand, the differences between PI and NI are difficult to interpret. A consistent superiority was found in recall of NI over both PI and WI for most serial positions. This superiority cannot be a function of output order since the RPI data show no differences between conditions in order of output. In any case, the superiority of NI over PI is reversed in the last few serial positions. When these data are considered in conjunction with the WI data, it seems likely that the sharp decrease in recall probability for items followed by both NI and WI can be best interpreted as the result of interference produced by the coding of semantic information.

Figure Caption

Fig. 4. Mean relative priority scores by serial position for recall following word, paralog and number shadowing interpolated tasks.

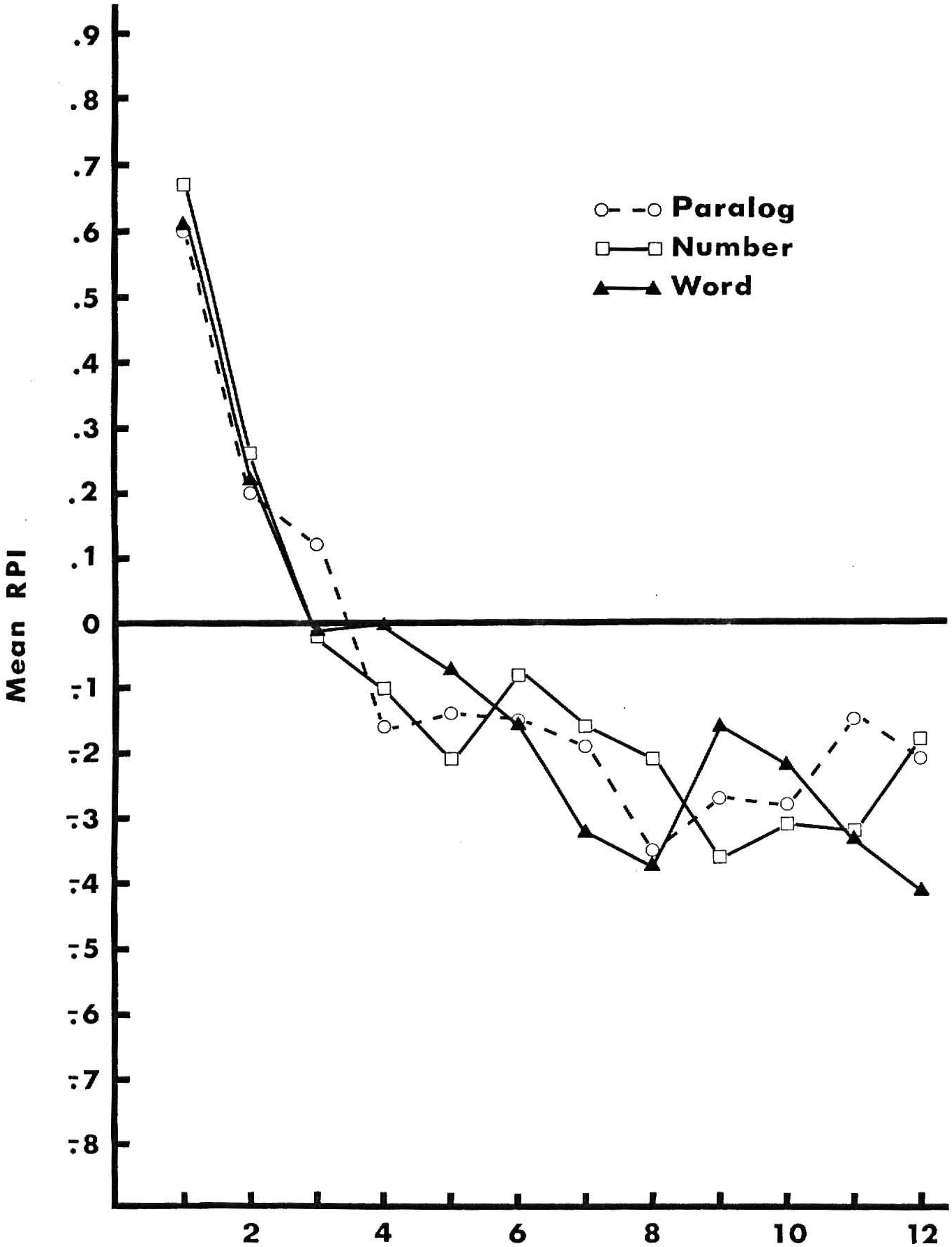

Paralog
Number
Word
Mean RPI
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
2
4
6
8
10
12
Serial Position

Table 3

Mean number of intrusions in recall following word, paralog and number shadowing interpolated tasks.

Delay Task	Intrusions Prior-list	(WI)interpolated task	Extra-experimental
Word	.12	.22	.36
Number	.14	.05	.31
Paralog	.12	.04	.28

General Discussion

The results obtained in the present studies provide support for the hypothesis that semantic coding does occur in primary memory. In order to more adequately evaluate these results, we must consider the manner in which semantic coding has been implicitly defined in these experiments. Unlike most previous studies (e.g., Craik & Levy, 1970; Tulving & Patterson, 1968) which have manipulated semantic features in terms of the conceptual similarity between items in a list (e.g., cat, dog, cow, horse), the view taken here, and represented in other current research (e.g., Wickens, 1970), is that meaning (semantic features) of a word results from the encoding of the word on a number of dimensions, such as taxonomic category, part of speech, number of syllables, frequency, imagery, etc. The basic idea is that these dimensions or attributes combine in some way to eventuate in the unique meaning of the word. Note that while a word such as cow may be coded along a set of attributes loosely defined as four-footed, farm animal, the meaning of the word cow would not necessarily include the relationship of cow to other words such as horse, pig or lamb which are also coded along those dimensions. Thus conceptual similarity refers to only one (or one set of) dimension(s) along which words _may_ be coded whereas we take the semantic features of a word to refer to that constellation of psychologically prominent attributes unique to an individual word. By our definition, whenever meaningful verbal material is presented, it is presumed that some form of semantic coding occurs. This view suggests that all conditions in all previous investigations using meaningful material involved some form of semantic coding.

In order to test whether semantic coding occurs in PM, the present studies used a procedure based on the assumption that materials coded along the same features produce much more interference with one another than materials coded along different features (Wickens, 1970). If subjects are coding PM items along semantic features then more interference would result for these items if they are followed by an interpolated task which is also coded along semantic features than if these PM items are followed by an interpolated task which is not coded along semantic features. As predicted, the data from the present studies demonstrated a greater decrement in recall probability for terminal items for lists followed by words and numbers (meaningful or semantic material) than lists followed by paralogs (non-meaningful material).

Thus, the results of these studies were interpreted as providing support for the notion of semantic coding in primary memory. It should be pointed out that it is not clear whether the meaningful material in the interpolated tasks interfered with the process of semantic coding or the semantic code. With regard to the first point, since the TBR and WI words were unrelated and since the semantic features for digits are likely to be somewhat different from those for words, it seems reasonable to suggest that the reason for the obtained effects may not be interference resulting from encoding items along the same dimensions. Instead, it may be plausible to postulate a limited capacity semantic encoder which processes all material categorized as "meaningful". Such an encoder would therefore process meaningful material in an interpolated task (NI, WI). Since this is assumed to be a limited capacity encoder, the processing of interpolated material will reduce the amount of processing of the TBR material and result in poorer recall. On the other hand, presentation of non-meaningful material (PI) does not engage the encoder and performance does not suffer to the same extent as in the case with meaningful material.

Alternatively, the possibility remains that the effects obtained in these studies may be the result of interference with the semantic code. That is, although the TBR and WI items are unrelated they are similar in that all were two-syllable words, all words were of high frequency, most words were nouns, etc. The digits are also similar to these words in that they are also of very high frequency and are also rated highly in concreteness. The similarity of these features or attributes may have produced the interference effects obtained in these studies.

The design of the present studies does not permit one to distinguish which of these two interpretations accounts for the observed interference effects. Such a distinction is not essential for the argument presented in this paper. Regardless of the nature of the interference, the important point is that "semantic" information occurs in primary memory.

In addition to investigating whether PM items can be semantically coded, the first experiment was designed to examine whether words can also be coded as to the manner of their physical presentation. Specifically, differences in gender of voice used in the test and interpolated lists were employed in the attempt to detect whether such features are salient in coding in PM. If such features are coded in PM, the assumption is that more interference would result for test items in which the gender of voice was the same in both the test and interpolated lists. The results revealed no overall effects of change of voice. Thus, there studies provide no support for the notion that transient, situational characteristics such as voice are used to code items in PM. On the other hand, these results do not preclude the possibility that voice change in other contexts might be used to code PM material. It is certainly possible that in many situations not all potential dimensions or attributes are used to code items.

In summary, the data from the present studies provide strong evidence supporting the hypothesis of semantic coding in PM. Although the question concerning the nature of this coding still remains, the finding that such coding does in fact take place is a significant contribution to our knowledge of the functioning of the primary memory system. Although the present studies failed to demonstrate encoding of items along transient, situational features, the results of other investigations (e.g., Murdock & Walker, 1969; Kroll, et al., 1970) suggest that primary memory is a flexible coding system wherein a number of features (e.g., auditory, visual, semantic) of the material may be coded.

Appendix I

WORD INTERPOLATED LIST ITEMS

after	April	happen	system
never	chimney	apple	triumph
enough	fifty	balance	habit
power	traffic	sickness	vacuum
member	parker	textile	slender
perhaps	technique	beauty	venture
problem	plenty	German	differ
minute	fiction	echo	earnest
mature	native	darling	lemon
data	angry	extra	voyage
hundred	vigor	garden	whiskey
river	suffer	shelter	lecture
issue	foster	latin	vessel
entire	urban	suggest	voltage
acid	baroque	level	berger
result	sharply	music	lagoon
question	sudden	orchard	razor
district	dirty	linen	vocal
image	lily	nephew	cluster
degree	chlorine	oyster	rabbi
bishop	lumber	puzzle	concert
heavy	tragic	series	enzyme
visit	signal	princess	fatigue
current	troubled	refuge	suspect
poet	fiber	senate	gamble
convert	marshall	process	magic
dinner	flower	husband	pigeon
index	employ	shepard	uncle
favor	survey	fiscal	sulfur
pointed	water	stanza	squirrel

Appendix II

PARALOG INTERPOLATED LIST ITEMS

af res	fic troub	en nay	nest fa
ter ult	tion led	lin pen	er tigue
a shar	hap cur	sys la	ech fuge
pril ply	ture rent	goon tem	o re
nev ques	nay sig	ap sic	pect lem
er tion	da po	mu ple	on sus
chim sud	ta et	tri ray	ex sen
ney den	ang fi	umph zor	et tra
e dis	ry ber	bal ew	whis gam
nough trict	hun vert	neph ance	key ble
fif dir	con dred	hab vo	gar se
ty den	vig mar	et cal	den ries
pow gree	or shal	beau orch	gic voy
de er	riv ner	ty ard	age ma
traf lil	er din	ter vac	wer fin
y fic	in sue	uum clus	ter hus
mem age	puz re	oy fis	lec un
ber im	len sak	ster cal	ture pig
lum par	er suff	slen bi	in shep
ker bur	ter em	der rab	ard lat
per bish	fos ploy	tex prin	un ves
haps op	tir fa	tile cess	sel cle
chlor nique	vor en	cert ven	lev ness
tech ine	ur vey	ture con	el sick
prob heav	ban sur	Ger ess	vol fur
y lem	a roque	man proc	sul tage
plen tra	cid poin	diff zyme	sug za
ty gic	ted ba	fer en	stan gest
it min	ter was	dar puz	rel ber
ut vis	tive nal	zle ling	squir ger

Appendix III

INSTRUCTIONS

This is an experiment in memory. You will be listening to lists of words which are tape recorded. There are 16 lists all together and each list contains a different set of 12 words. The words are two-syllable nouns and you are to try to remember as many of the 12 words in each list as you can.

Each list in this experiment is preceded by the word "ready". This word is a cue to tell you that the next thing you will hear will be the first word in the list. One word will be presented every two seconds until you have heard all of the 12 words. Immediately after the last word in each list you will hear two beeps. These beeps are a signal for two things: (a) that is the end of the list and (b) following the second beep you will hear a series of items. Sometimes these items will be words and sometimes they will be paralogs (two-syllable nonsense words). What you have to do with these items is merely to repeat them out loud. That is, as soon as you hear an item you are to repeat (echo) it. You do not have to remember these items. The items are recorded at a fairly fast pace so you must repeat the items quickly so you do not miss the next one. You will repeat items for approximately 30 seconds. At the end of 30 seconds I will say "recall". You will then stop repeating and write down as many of the 12 words as you can remember (these are the 12 words you heard first). Write down the words you remember in the answer booklet in any order you wish. Use a separate sheet for each list. You will be given 2 minutes for the recall of each and I will let you know when this period is up. But if you feel that you cannot remember any more words before then, let me know and we will go on to the next list.

Also, sometimes the 12 words you will try to remember and/or the items you are to repeat will be recorded in a male voice and sometimes they will be recorded in a female voice.

Indicate when you are finished with the instructions. If there are any questions, please ask. You will have 2 practice trials to further acquaint you with the procedure before we start the experiment.

Appendix IV

INSTRUCTIONS

This is an experiment in memory. You will be listening to lists of words which are tape recorded. There are 15 lists all together and each list contains a different set of 12 words. The words are two-syllable nouns and you are to try to remember as many of the 12 words in each list as you can.

Each list in the experiment is preceded by the word "ready". This word is a cue to tell you that the next thing you will hear will be the first word in the list. One word will be presented every two seconds until you have heard all of the 12 words. Immediately after the last word in each list you will hear two beeps. These beeps are a signal for two things: (a) that is the end of the list and, (b) following the second beep you will hear a series of items. Sometimes these items will be words, sometimes they will be numbers and sometimes they will be paralogs (two-syllable nonsense words). What you have to do with these items is merely to repeat them out loud. That is, as soon as you hear an item you are to repeat (echo) it. You do not have to remember these items. The items are recorded at a fairly fast pace so you must repeat the items quickly so you do not miss the next one. You will repeat items for approximately 30 seconds. At the end of 30 seconds I will say "recall". You will then stop repeating and write down as many of the 12 words as you can remember (these are the 12 words you heard first). Write down the words you remember in the answer booklet in any order you wish. Use a separate sheet for each list. You will be given 2 minutes for the recall of each and I will let you know when this period is up. But if you feel that you cannot remember any words before this period is up, let me know and we will go on to the next list.

Indicate when you are finished with the instructions. If there are any questions, please ask. You will have 3 practice trials to further acquaint you with the procedure before we start the experiment.

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Footnotes

[1]The notations PM (primary memory) and SM (secondary memory) will be used throughout the paper instead of STM (short-term memory) and LTM (long-term memory). This distinction is made because the expression short-term memory has been used operationally to refer to a paradigm that involves a single presentation of a small amount of material followed by interpolated activity which is then followed by a recall test. Primary memory is the memory system assumed to play a role in such a situation but it is clear that SM can also be involved in recall under these conditions. The expression long-term memory has been used to refer to that situation typified by multiple presentation of a large amount of material. The stable memory system assumed to operate in such situations is secondary memory. Again, however, primary memory can be involved when an immediate recall procedure is used.

SEMANTIC CODING IN PRIMARY MEMORY

by

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A.B., Youngstown State University, 1971

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ABSTRACT

The present studies produced evidence for semantic coding in PM by revealing differential interference effects on PM items through the use of word, digit and paralog interpolated activity. The use of the differential interference procedure is based on the assumption that materials coded along the same features produce the most interference while materials coded along different features do not interfere with one another. Two experiments revealed a greater decrement in recall probability for terminal items in lists of words followed by word or number shadowing (meaningful material) than in lists followed by paralog shadowing (non-meaningful material). The data were interpreted as providing strong evidence that semantic coding occurs in primary memory.