Title

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Abstract

Rehearsal during the presentation of free-recall lists was made observable by having Ss rehearse aloud as items were shown for study and taperecording their output. Items studied early in the list were found to receive more rehearsal than other list items; probability of recall for individual items was found to be an increasing function of amount of rehearsal; items being rehearsed immediately prior to test were recalled with high probability. A U-shaped serial position curve was found. It is suggested that the recency effects may be attributed to the high probability of recall observed for items rehearsed just prior to test, while the additional rehearsal accorded initial items of the list results in the primacy effect.

REHEARSAL PROCESSES IN FREE RECALL:

A PROCEDURE FOR DIRECT OBSERVATION[1]

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In a free-recall task S is presented with a word list for study and then asked to recall in any order as many words as possible. As the list is presented, S presumably engages in some form of rehearsal of the list items which may be the formation of mnemonics, visual imagery, repetition (either overt or covert) or a combination of these. The nature of the rehearsal process is then inferred from the results of the free-recall test. This study attempts to make the rehearsal process directly observable by instructing S to rehearse using overt repetition of items from the list and recording the rehearsal. Thus, it should be possible to relate the observed rehearsal process to recall of items from the list.

One finding appearing consistently across many variations of the free-recall task is a U-shaped relationship between the probability of recalling an item and that item's serial position in the study list (e.g., Tulving, 1968). Items presented at the beginning or at the end are better recalled than items in the middle of the study list. The high probability of recall for items from the beginning of the list has been labeled the primacy effect, while the high probability of recall for the last items presented has been termed the recency effect.

One approach to the analysis of the effects of input position on recall has been the division of memory into a short-term store (STS) and a long-term store (LTS). The STS may be viewed as a temporary memory store in which information about recently presented items is maintained in a highly available state. While items are present in STS, they may be rehearsed. The result of this rehearsal is the accumulation of information about the items in the more permanent LTS. It is tempting to attribute the high probability of recall for items presented at the end of a study list to the availability of information about these items in STS. Experiments by Postman and Phillips (1965) and Glanzer and Cunitz (1966) support this assumption. In their experiments an unrelated mathematics task was interpolated between the study of a list and a free-recall test on that list. This interpolated task could be expected to disrupt any ongoing rehearsal and allow information about items in STS to decay. The effect of the interpolated task was to eliminate the recency effect while having essentially no effect on primacy.

What may be said about an item no longer retrievable from STS? One approach to this problem (Atkinson and Shiffrin, 1968; Atkinson and Wickens, 1969; Shiffrin and Atkinson, 1969) is to assume that while an item resides in STS it may be entered into a rehearsal buffer where it is rehearsed in conjunction with a limited number of other recently presented items. Rehearsal of an item serves two purposes: the item is maintained in the highly available STS and rehearsal results in the transfer of information about the item to LTS. The amount of information transferred is thus related to the duration of the item's residence in the buffer. The choice of items to be maintained in the buffer is under the control of S; however, since the buffer is assumed to be of a fixed size (determined by the nature of the material being studied and the length of the study period) the entry of a new item into a full buffer necessitates the deletion of one of the items currently residing there. Since information transfer to LTS occurs only while an item resides in STS, items that are retained in STS via rehearsal for long periods of time will accrue more LTS information (and consequently have a higher probability of recall) than items whose residence in STS is short.

By recording S's rehearsal as the study list is being presented, the relationship between the amount of rehearsal accorded an item and its probability of recall can be specified. It will also be possible to observe which items are being rehearsed at the conclusion of list presentations and relate their presence in the final rehearsal set to the recency effect. The probability of recalling an item following a second presentation of the free-recall list will also be considered and related to rehearsal of the item on the first and second presentation of the list.

METHOD

Eight Stanford students served as paid Ss for two, 1-hour sessions with one day intervening between sessions. Nine lists of 20 nouns with frequencies of occurrence from 5 to 20 per million (Thorndike and Lorge, 1944) were presented to each S, four lists during the first session and five lists during the second session.[2] Three trials were given on each list. A trial involved presentation of the list (randomized on each presentation) followed by a 2-minute written free-recall test on that list. Items were displayed singly on cards, each card being shown for 5 sec. A tone followed each 5-sec. interval and signaled the display of a new card. The Ss were instructed to study by repeating aloud items from the current list during the 5-sec. study intervals. There were no restrictions placed on the choice of items to be rehearsed or the rate of rehearsal as long as S's rehearsal filled the interval. A tape recording was made of S's rehearsal on every trial.

RESULTS

The recorded rehearsal protocols were coded numerically and analyzed on a computer. The tone pulses that had served to signal the display of a new item were used to partition the recorded rehearsal from each trial into rehearsal sets (RS). A RS was associated with each item of the list and consisted of all rehearsals occurring while that item was being presented. Thus, the tenth RS includes the rehearsals that occurred while the card bearing the tenth list item was being shown. The size of a RS was taken to be the number of different items in RS. If an item was repeated more than once in a given RS, each rehearsal was counted in determining the total number of rehearsals accorded the item but not in the measure of the size of RS. The only rehearsals that were not items from the list being studied (less than 1% of the rehearsals) were variants of items from that list. These rehearsals were not included in the analysis. The first list of the first session for each S was treated as a practice list and not analyzed. The results reported are based on the first and second presentation of each of five uncategorized lists.

Although not explicitly instructed to do so, Ss always rehearsed each newly presented item at least once while the item was being shown. Several other results concerning the makeup of RS during the initial presentation of a list are shown in Table 1. The mean number of rehearsals per RS as a function of its serial position in the study list is shown in the second column. With the exception of the first RS, the mean number of rehearsals appears roughly constant over all list positions. The third column gives the mean size of RS as a function of serial position. The size of RS is necessarily one for the first RS and is seen to rise rapidly to a maximum of 3.5 with a gradual decline toward the end of the list. Although mean RS size rises to a fairly stable value, inspection of individual S protocols showed that the actual size of RS varied from 1 to 8 items (e.g., for the first presentation of List 9 to the eighth S, the size of RS for serial positions 1 to 20 were observed to be 1,2, 2,3,3,1,2,3,1,3,5,4,3,2,4,5,3,3,3,2). The mean number of rehearsals accorded to each item in RS as a function of the serial position of the RS is shown in the fourth column. With the exception of the first few list positions the mean number of rehearsals per item in RS appears quite constant. Items were usually rehearsed in more than one RS. The last column shows the mean number of different RSs in which an item appeared as a function of the serial input position of that item. The number of RSs in which the item was included decreases steadily with serial position to a value of one for the final item presented. An item's residence in RSs was not always continuous; that is, an item might be rehearsed in one or more consecutive RSs, then be absent from one or more RSs, and finally reappear in a later RS. The probabilities of return were .14, .038, .033, .021, and .014 for items absent from 1, 2, 3, 4, and 5 intervening RSs, respectively. Items which appeared in the final RS prior to testing were recalled with probability .92. It

Table 1

Changes in the Rehearsal Set (RS) as a Function of Serial Position in the Study List

Serial position m	Number of rehearsals in RS	Number of different items in RS	Number of repetitions per item in RS	Number of RSs in which item m appears
1	3.5	1.0	3.5	6.5
2	4.3	1.9	2.3	5.3
3	4.9	2.7	1.8	5.0
4	4.9	3.2	1.5	4.4
5	4.7	3.5	1.4	3.6
6	4.9	3.5	1.3	3.2
7	4.8	3.4	1.4	3.2
8	4.6	3.3	1.4	2.6
9	4.4	3.2	1.4	2.8
10	4.5	3.4	1.3	3.0
11	4.4	3.1	1.4	2.5
12	4.5	3.2	1.4	2.3
13	4.2	3.0	1.4	2.3
14	4.4	3.0	1.5	2.4
15	4.2	3.0	1.4	1.9
16	4.4	3.1	1.4	1.7
17	4.1	3.0	1.4	1.9
18	4.0	2.7	1.5	1.7
19	4.4	2.7	1.6	1.6
20	4.6	2.9	1.6	1.0

is interesting to note that the probability of recall for the final item of the list was the same as that for any other item present in the final RS.

Recall of an item following the first presentation of a list will be denoted as R_1; recall of an item following the second presentation of a list will be denoted as R_2. The solid curve of Fig. 1 is a plot of the mean probability of an R_1 response, $P(R_1)$, for an item as a function of its serial input position. The resulting U-shaped curve shows definite primacy and recency effects, with the primacy effect being somewhat more pronounced than that found in other free-recall tasks (Postman and Phillips, 1965; Glanzer and Cunitz, 1966). Also shown in Fig. 1 is a plot of the mean number of rehearsals given to an item during the first presentation of a list. Number of rehearsals is seen to be quite high for the early items of the list and to decrease steadily as a function of serial position.

Figure 2 presents $P(R_1)$ for an item as a function of the number of rehearsals of the item. The only items included in this analysis were those having their last rehearsal in the fourteenth through the seventeenth RS. This assured that items were not in the RS immediately prior to testing and minimized any possible interaction between number of rehearsals and the time elapsing between the final rehearsal and the test. The $P(R_1)$ is seen to increase as the number of rehearsals increases. A similar increasing function was found when the data were further restricted to those presented in serial positions 8 to 14, indicating that the result is not an artifact of the high mean number of rehearsals accorded to items from the beginning of the list.

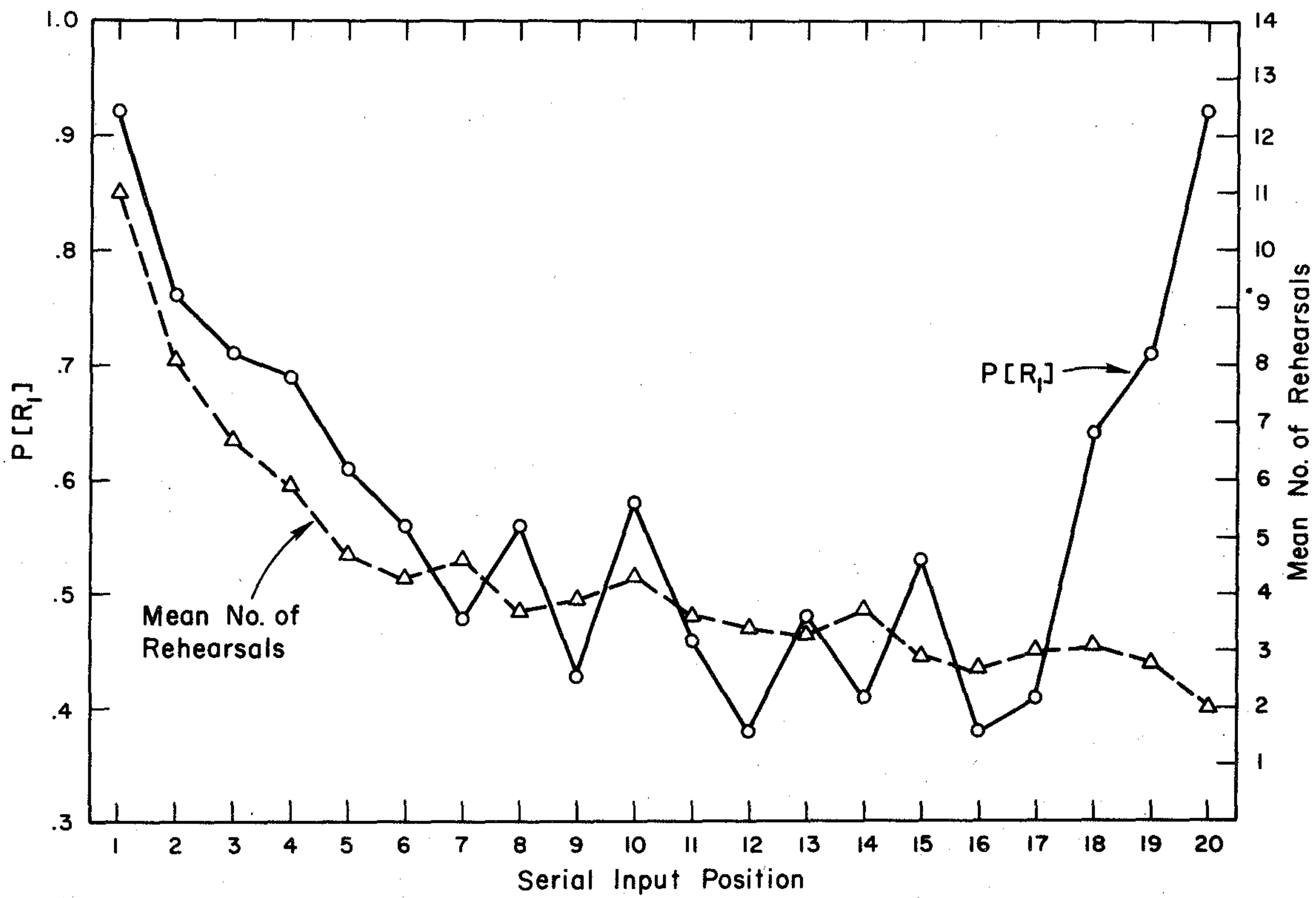

Fig. 1. The probability of recalling an item as a function of its serial input position, and the mean number of rehearsals accorded an item as a function of its serial input position.

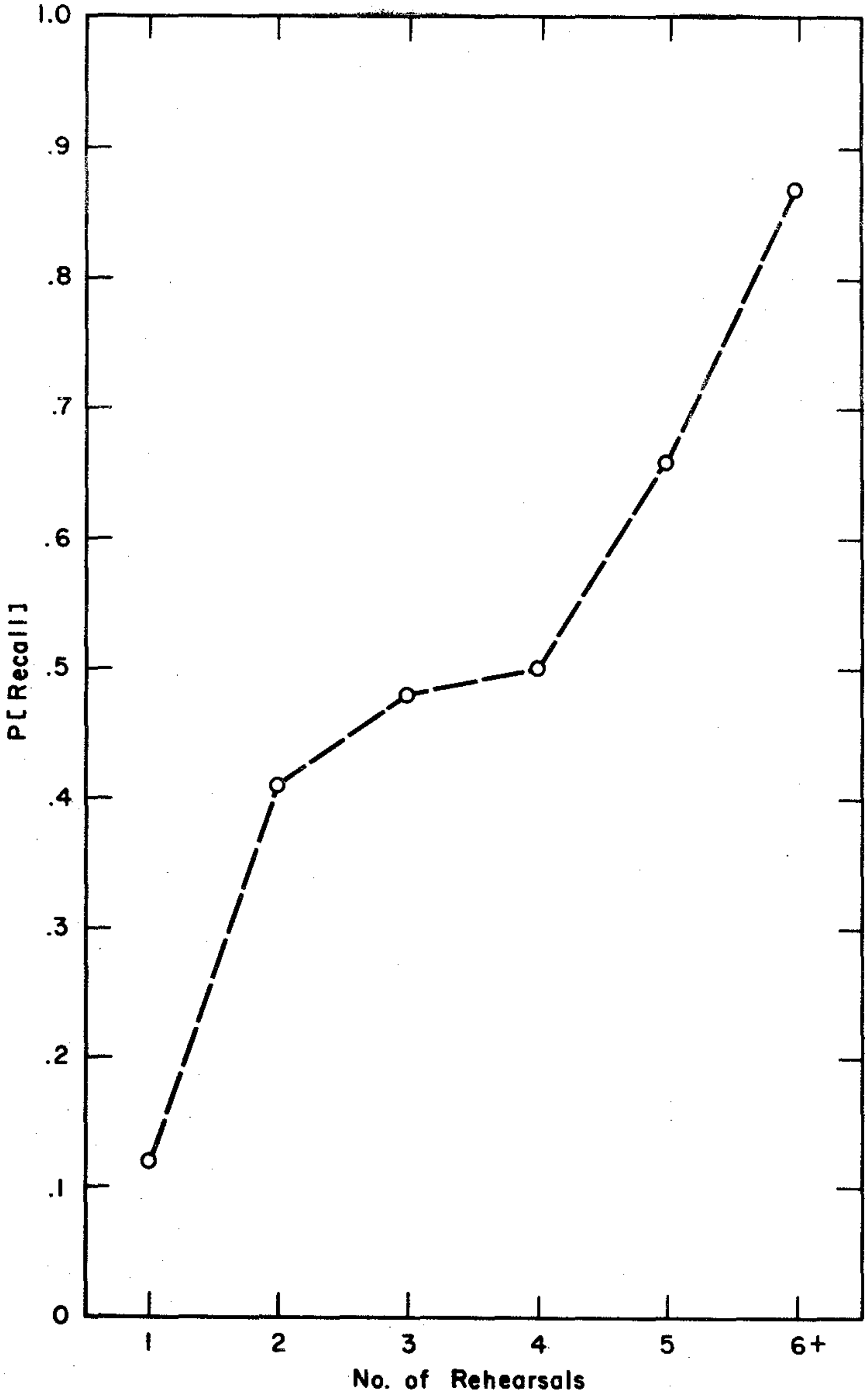

Fig. 2. The probability of recalling an item as a function of the number of rehearsals of that item.

Figure 3 shows $P(R_2)$ as a function of the total number of rehearsals of an item on the first and second presentation of a list. To avoid recency effects, only items in serial positions 1 to 17 on both presentations were included. The increasing function shown is similar to that for $P(R_1)$. The results for $P(R_2)$ are also shown conditionalized on recall (R_1) or non-recall $(\bar{R}_1)$ of the item on Trial 1. It should be noted that recall of an item on Trial 1 does not assure its recall on Trial 2. Both conditionalized results indicate that $P(R_2)$ increases with the total number of rehearsals.

The results shown in Fig. 3 illustrate only the effects of total rehearsals on $P(R_2)$; no distinction is made between those items that receive nearly equal numbers of rehearsals on Trial 1 and Trial 2 and those items whose total rehearsals were unequally apportioned. Figure 4 plots $P(R_2)$ for an item as a function of the proportion, k, of the total number of rehearsals accorded the item which occurred on the first trial. Low values of k represent items receiving most of their rehearsals on Trial 2, whereas high values of k signify that the bulk of the rehearsals occurred on Trial 1. To avoid recency effects only items presented in positions 1 to 17 on both trials were included. The items were further restricted to those with 5 to 15 total rehearsals. As seen in Fig. 4, items whose rehearsals were fairly evenly distributed between Trial 1 and Trial 2 (k values near .50) were less frequently recalled on the second test than were items with rehearsals divided unequally between the two presentations of the list. To assure that these effects were not the result of an unequal number of total rehearsals, the mean total rehearsals as a function of k was calculated

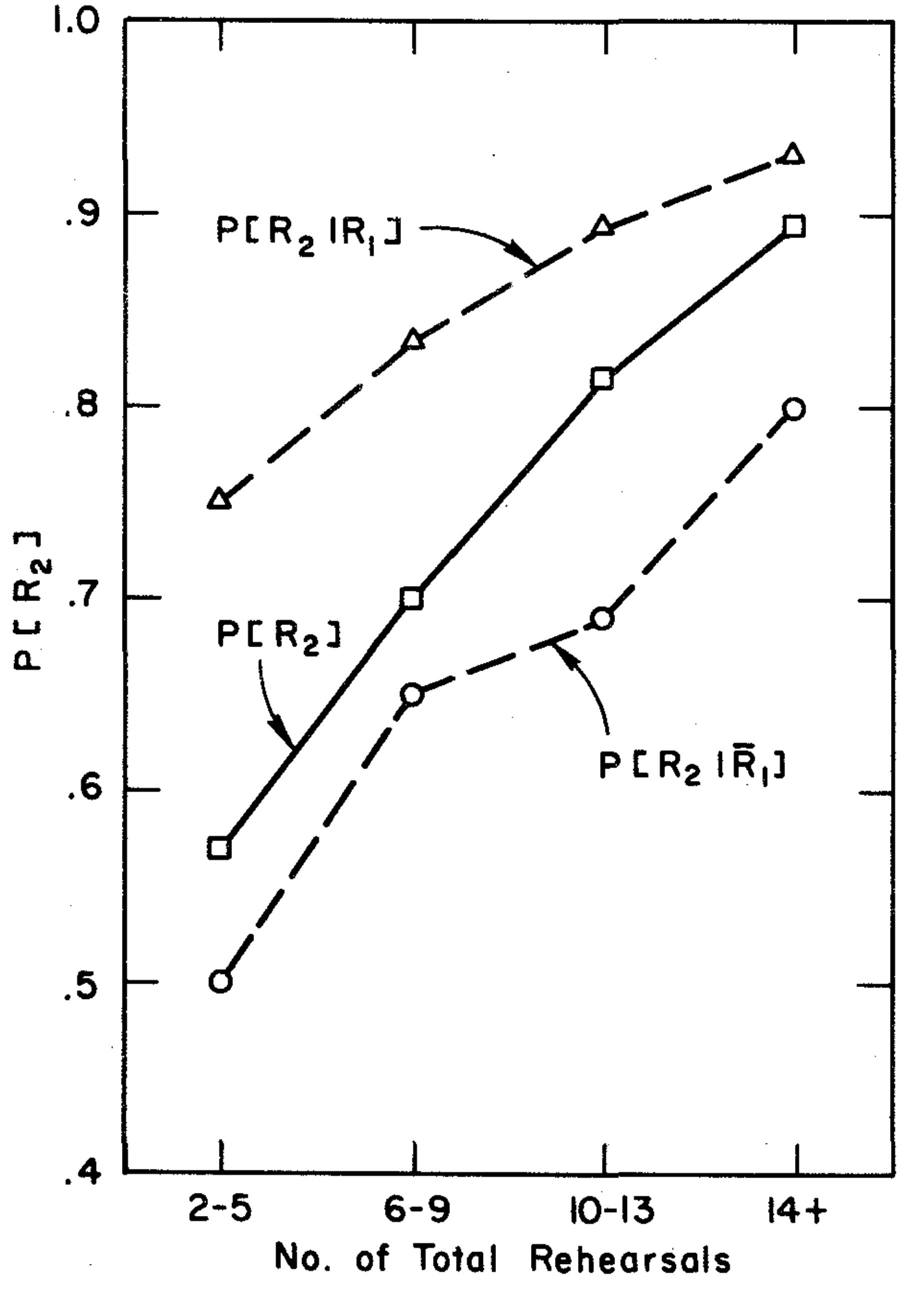

Fig. 3. The probability of recalling an item following the second presentation of a list as a function of the total number of rehearsals of that item. Also shown conditional upon recall of that item following the first presentation of the list.

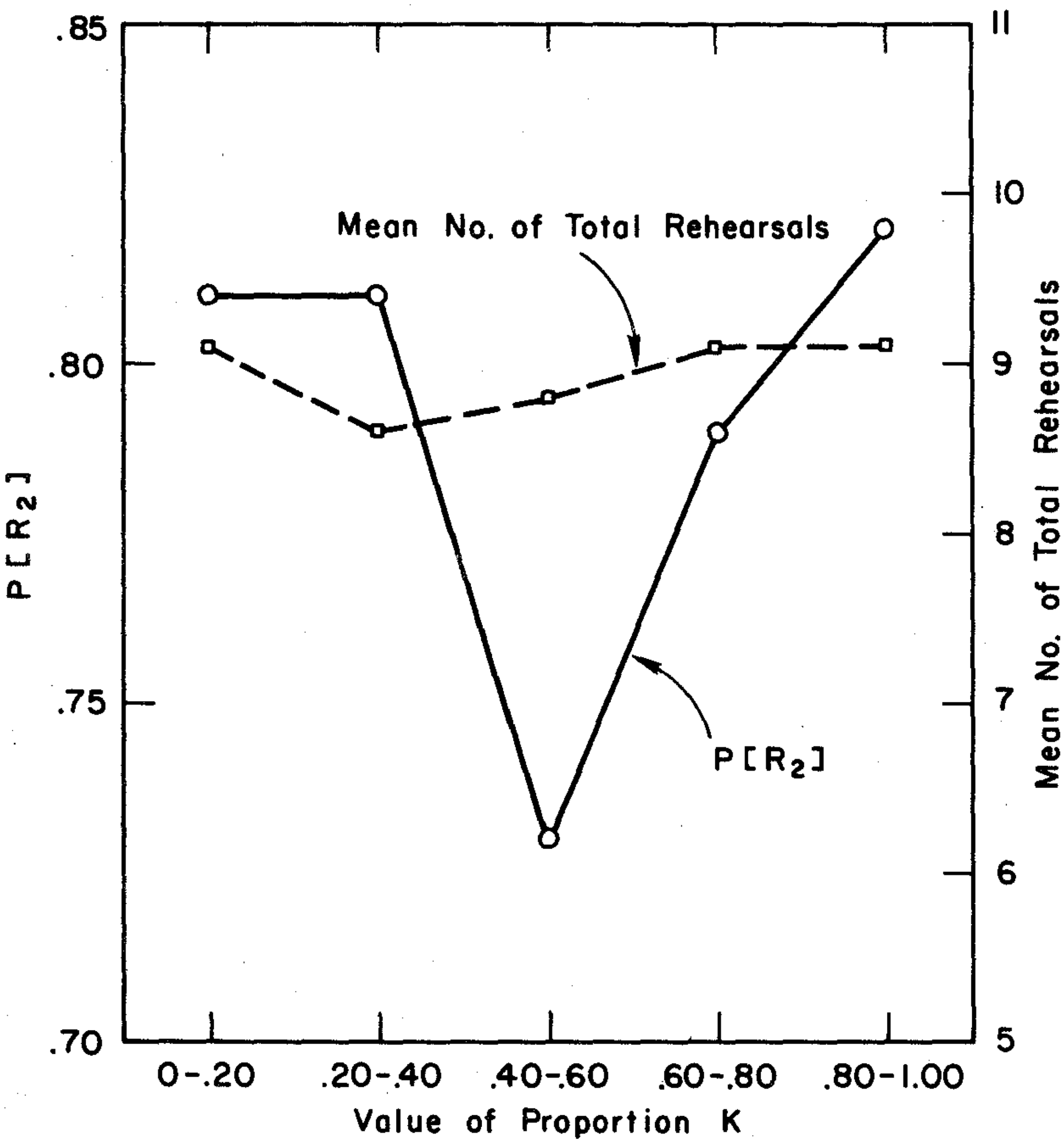

Fig. 4. The probability of recalling an item following the second presentation of a list as a function of the proportion, k, of the total rehearsals of the item which occurred on the first presentation of the list. Also the mean total rehearsals of an item as a function of k.

and is also shown in Fig. 4. It is seen to be nearly flat indicating that an unequal number of total rehearsals was not the cause of the previous result.

The relationship between $P(R_2)$ and k is shown in Fig. 5 conditionalized on the recall (R_1) or non-recall ($\overline{R}_1$) of an item on Trial 1. Whereas $P(R_2|\overline{R}_1)$ appears to be a nearly linear decreasing function of k, $P(R_2|R_1)$ is seen to be constant for all but the lowest k values.

DISCUSSION

Several interesting features of the rehearsal process were observed in this study. The mean size of RS increased rapidly to a fairly stable level as the study list was being presented. Thus for the analysis of mean data, the RS could be assumed to have a fixed size and be only partially filled as the first items were presented. Items from the beginning of the study list received many more rehearsals and appeared in more RSs than did items from the remainder of the list; however, in spite of the limited rehearsal accorded items from the end of the list these items were recalled quite well.

As mentioned earlier, the U-shaped curve relating serial input position to probability of recall has been observed in a wide variety of free-recall tasks. A dual-storage model of memory might explain this result by assuming that recall of an item is a function of the information about that item which is retrievable from both STS and LTS. Because there are fewer items competing for S's attention at the beginning of list presentation, it might be expected that more information is accumulated about these items in LTS. The most recently presented items have

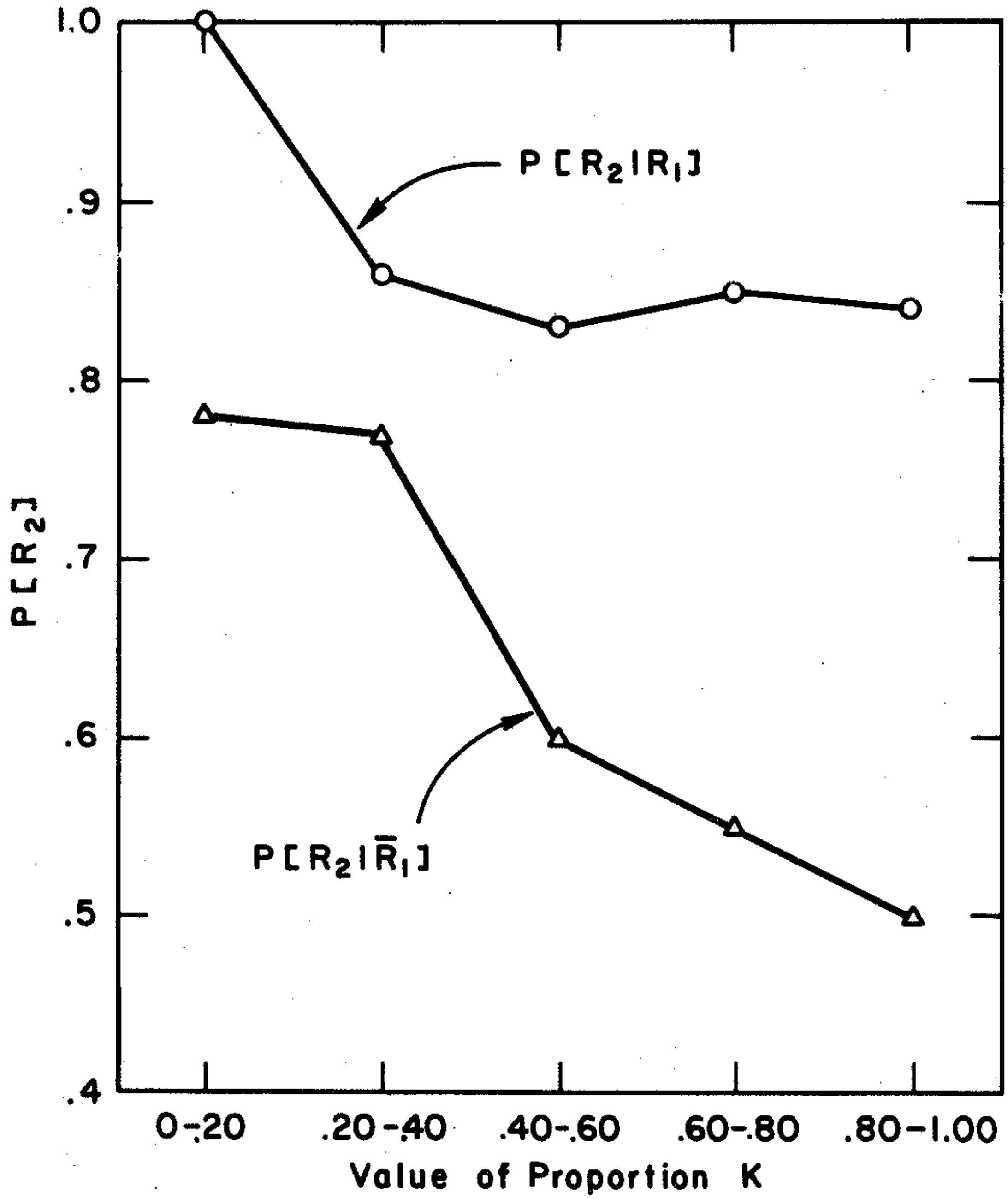

Fig. 5. The probability of recalling an item following the second presentation of a list as a function of k, conditional upon recall of that item following the first presentation of the list.

less opportunity to be stored in LTS; however, they should be retrievable from STS. Thus, the recency effect is a STS phenomenon while primacy is due to the fact that more LTS information accrues for the early items. The results presented in Fig. 1 indicate that items presented early in the study list are accorded more rehearsal than items appearing subsequently. Figure 2 shows that probability of recall for an item is an increasing function of rehearsal for the item. It was also found that all items present in the final RS were recalled with a high probability, in fact, the last item presented had the same probability of recall as any other item that was included in the last RS. These results provide correlational support for the interpretation of the serial position curve provided by at least one class of dual-storage models (Atkinson and Shiffrin, 1968).

Recall following two presentations of a list, while shown in Fig. 3 to be an increasing function of total rehearsals, appears also to be affected by the distribution of these rehearsals between the two presentations as shown in Fig. 4. The reasons for this distribution effect are not entirely clear. The differences between $P(R_2|R_1)$ and $P(R_2|\bar{R}_1)$ as functions of the distribution ratio k suggest that the act of recalling an item on Trial 1 in some way increases the stored information about that item resulting in a higher $P(R_2)$. As k increases, the number of Trial 1 rehearsals increases and it has been shown that this leads to an increase in the likelihood of recalling an item on the first test; thus, the probability that the stored information about an item in LTS receives an increment due to its recall on the first test increases with k. The LTS information about an item which is accrued during Trial 1 rehearsal may not be as available for use in recall as is information stored as the result of the subsequent Trial 2 rehearsal. If this is the case, then $P(R_2)$ should be seen to decrease as the proportion of Trial 2 rehearsals decreases (increasing k). Thus $P(R_2)$ as a function of k may be viewed as the composite of two functions, one increasing and one decreasing, yielding one possible interpretation for the relationship found between $P(R_2)$ and k shown in Fig. 4.

The main purpose of this study was to provide a means of observing the rehearsal processes involved in the study of a free-recall list and to relate the observed rehearsal to the recall of individual items from that list. These observations have provided support for two important assumptions of the class of dual-storage models discussed by Atkinson and Shiffrin (1968). Probability of recall was indeed found to correlate with amount of rehearsal, and items in the final rehearsal set were recalled with high probability. In conclusion it should be noted that the procedure used in this study is not only applicable to results concerning the probability of recall of items, but should also be of use in the investigation of ordering and clustering effects in both categorized and uncategorized lists.

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FOOTNOTES

[1]This research was sponsored by the National Aeronautics and Space Administration Grant No. NGR-05-020-244, and by a National Science Foundation Graduate Fellowship to the first author.

[2]Three of the lists presented were chosen so as to contain categories. Data from these lists will not be considered here.