A DIRECT TEST OF THE MINIMAL INTERFERENCE THEORY OF NEW ITEM PRIORITY IN RECALL

by

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INTRODUCTION

Over the past twenty years increasing investigation into the nature of human memory has been directed toward establishing the relationship between item availability and recall order. The reason is twofold. First, the concept of item availability is central to a better understanding of memory because it is viewed as a fundamental condition of recall (Tulving, 1968). In order for items to be retrieved from memory they must be available. Secondly, the order in which items are recalled from memory is assumed to reflect their availability. By examining the relationship between item availability and recall order the processes which influence memory may be elucidated.

The notion that item availability and recall order are related is an old one. Early in the century Thumb & Marbe (1901) demonstrated in a free association task that a relationship existed between the frequency of word associates and the individual reaction time required to emit these words. More specifically, they found that when a subject (S) freely associates to a stimulus word, high frequency associates are emitted more quickly than low frequency associates. This relationship between word frequency and latency of emission became known as Marbe's Law; it suggested that high frequency associates are the most available in memory since they require shorter latencies of emission than do low frequency associates.

The importance of Marbe's Law for contemporary students of memory was the implication or corallary that in tasks of retention recall order also might reflect the availability of to be remembered items in memory. In other words, an item's availability or strength might be reflected by its relative location (latency of emission) in the recall sequence. The most available or strongest items ought to be recalled first followed in order by items of decreasing strength.

The most convincing evidence supporting Marbe's corallary (the strength principle) comes from the free recall paradigm (a retention task similar to free association in that responding is unrestricted). In the free recall (FR) task, a stimulus list is presented to S one or more times. Following each presentation, S reproduces, in any order, as many of the items as he can recall. Since the recall sequence is subjectively determined, the FR procedure is a suitable technique for testing the assumption that the order in which items are recalled directly reflects the strength of those items in memory.

Bousfield, Cohen, & Silva (1956) conducted the first direct assessment of Marbe's corallary in single trial FR. They related the order in which individual Ss recalled words to the probability of recall of each word by all Ss in the group. In this manner, words with a high probability of recall and words with a low probability of recall were determined independently of each S. In support of the strength principle, they found that individual Ss emitted high frequency words earlier in the recall sequence than low frequency words. More recently, Underwood & Schulz (1960) reviewed a number of studies ranging in diversity from the determination of perceptual thresholds to single trial FR learning. On the basis of these studies, they reaffirmed the strength principle by postulating the spew hypothesis which states that in a free responding situation the order in which items are emitted in recall is directly related to their strength or frequency of prior experience.

Evidence favoring the strength principle has been demonstrated in another manner. When recall immediately follows the first presentation of a stimulus list, probability of recall is found to vary as a function of input position (Murdock, 1962). Specifically, words occupying terminal input (recency) positions have the highest probability of recall followed by words occupying initial input (primacy) positions. Items occupying the middle input positions have the lowest probability of recall. If it is assumed that probability of recall is an index of item strength, then the strength principle predicts that recall should be ordered in terms of diminishing item strength. Consistent with this prediction has been the demonstration in single trial FR that Ss tend to order their recall such that recency items are emitted before primacy items which in turn are followed by items from middle input positions (Bousfield, Cohen, & Silva, 1956; Deese, 1957; Deese & Kaufman, 1957; Postman & Phillips, 1965). These studies indicate that when item strength is defined in terms of input location, a direct relationship obtains between item strength and recall order.

The studies cited thus far provide substantial support for the strength principle. As a result, for several years the strength principle has held a preeminent position in depicting the nature of the relationship between item strength and recall order. It has been assumed that the order in which items are retrieved from memory is based on item strength whereby the strongest items are emitted in recall before the weaker items. However, a different picture of the relationship between item strength and recall order has emerged when recall is extended for several trials.

In multi-trial free recall (MTFR), item strength (probability of recall) may be defined in terms of degree of learning (Underwood, 1964). On any given trial, the probability that an item will be recalled is influenced significantly by whether or not it was recalled on previous trials. Old items (strong) recalled on previous trials have a higher probability of recall than new items (weak) never recalled on previous trials. Consequently, the relationship between item strength and recall order may be assessed across trials of a MTFR experiment. The strength principle predicts a direct relationship between item strength and recall order such that old items will be emitted in recall before new items.

Contrary to this prediction, Battig, Allen, & Jensen (1965) provided evidence that in MTFR the relationship between item strength and recall is not direct but, rather, inverse. They demonstrated that new items which are recalled for the first time tend to be emitted earlier in the recall sequence than old items which have been recalled on previous trials. Battig et al. called this tendency to recall new or weak items before old or strong items the priority of newly learned items (PRNI) effect.

This apparent contradiction to the strength principle posed an important theoretical question. Why do <u>S</u>s recall weak items before strong items? Battig et al. suggested that <u>S</u>s adopt a strategy whereby they pay special attention to new items during presentation and attempt to recall these items before old items in order to prevent their loss from output interference (proactive inhibition). In line with this reasoning, Tulving & Arbuckle (1963) have demonstrated that probability of recall decreases as the amount of interpolated recall increases between the presentation of an item and its subsequent recall.

Some investigators have argued that the PRNI effect does not represent the operation of a learning strategy but, rather, is an artifact stemming from a position bias which favors the recall of new items from initial and terminal input positions (Baddeley, 1968; Postman & Keppel, 1968; Shuell & Keppel, 1968). If this claim were true, then the PRNI effect could be understood without recourse to the psychological interpretation offered by Battig et al. Recently, however, this possibility was discounted (Battig & Slaybaugh, 1969; Mandler & Griffith, 1969). The PRNI effect was obtained even when new items occupied only unfavorable middle input positions.

With the demonstration that the PRNI effect is not an artifact, two contradictory conclusions could be advanced concerning the nature of the relationship between item strength and recall order. On the one hand, studies of single trial FR support the conclusion of a direct relationship between item strength and recall order whereby the strongest items are retrieved from memory before the weaker items. On the other hand, studies of MTFR support the conclusion of an inverse relationship between item strength and recall order whereby the weakest items are retrieved from memory and emitted in recall before the stronger items. Why should conclusions based on single trial and multi-trial FR result in such incompatible descriptions of the relationship between item strength and recall order?

Brown & Thompson (1971) suggested the reason is that the factors which influence item strength have been separated in the two learning situations. In single trial FR, item strength is influenced by input location but not degree of learning. In MTFR, item strength is influenced by both input location and degree of learning. However, previous attempts to specify the relationship between item strength and recall order in MTFR have considered only the influence of degree of learning in determining item strength and not that of input location. Brown & Thompson argued that in order to achieve a clearer understanding of the relationship between item strength and recall order the joint influence of both input location and degree of learning on item strength must be taken into account. In a comprehensive analysis of MTFR, they related order of recall to both input location and degree of learning. In so doing, they demonstrated that the relationship between item strength and recall order is neither direct nor inverse but, rather, curvilinear. The first items emitted in recall tend to be new items occupying recency positions which have an intermediate probability of correct recall. The next items emitted are new items from middle input positions which have a relatively low probability of recall. Old items with the highest probability of recall from any input position follow new items. Finally, overt errors with, by definition, zero probability of correct recall are the last items to be emitted. Clearly, items of intermediate strength (new) tend to be recalled earlier than items of higher (old) or lower (errors) strength when both input location and degree of learning are considered simultaneously in the determination of item strength. Brown & Thompson suggested that this curvilinear relationship reflects the operation of a minimal interference strategy that Ss employ to facilitate the recall of items which otherwise might be lost or forgotten as a result of output interference. New items are recalled first because they are most susceptible to output interference. Since old items are better learned and least subject to output interference, their recall is delayed until after the new items have been emitted. The Ss recall last those items (errors) about which they are least certain. Presumably, these difficult items require considerable deliberation prior to their recall. For this reason, the recall of difficult items is postponed until last so that time consumed for their retrieval will not interfere with the retrieval of items which otherwise would be recalled correctly.

The major implication to be derived from the formulations of Battig et al. and Brown & Thompson is that ordering in recall subserves a functional purpose. That is, Ss facilitate recall by according priority to those items which are likely to be lost or forgotten as a result of output interference. To date, there has been no conclusive direct test of this proposition. Such a test must demonstrate that recall is retarded when Ss are prevented from recalling first those items which are likely to be subject to output interference. Only one attempt (Roberts, 1969) has been made to substantiate the fundamental prediction of the strategy hypotheses. For reasons which will be outlined below, this investigation proved to be inconclusive. As a result, the question remains as to how accurately the strategy hypotheses describe the processes which determine the PRNI effect. Therefore, a direct test of this prediction is necessary in order to provide support for the notion that the PRNI effect reflects the operation of a learning strategy which functions to maximize recall.

Roberts attempted to assess the basic prediction of the strategy hypotheses by manipulating recall order in a part-whole MTFR transfer experiment. In an experiment of this design, Ss learn a list of words (the part list) after which they learn a second list (the whole list) composed of the same part list words plus an equal number of new words. Roberts assumed that at the beginning of whole list learning, all the words in the list could be classified on the basis of item strength as either strong or weak; old words of the part list were considered strong and resistant to output interference and new words were considered weak and susceptible to output interference. Roberts reasoned that if ordering in recall subserves a functional purpose then recall performance ought to be facilitated or retarded by instructing Ss to order their whole list recall in terms of the two item strength classes. In accordance with the strategy hypotheses, the performance of Ss required to recall new items before old items should be superior to the performance of Ss required to recall old items before new items.

In two separate experiments, two groups of Ss learned a 16 item part list before they learned a 32 item whole list comprised of the 16 part list items (old items) and 16 new items. Although only Experiment II was concerned with manipulating output order, it will be necessary later to refer to Experiment I when discussing the results of Experiment II. For this reason a description of Experiment I and the resultant findings are reported first.

In Experiment I, after part-list learning, Ss were told only that another list would be presented for them to learn. The Ss neither were instructed as to the composition of the whole-list nor that they should recall items in a particular order. Roberts found that Ss tended to recall first the new items in the whole list. Moreover, Ss recalled more new items than old items from primary memory (PM). He defined an item which occurred in both the terminal input positions and the early output positions as a PM item if no more than five other input or output items intervened between successive appearances of the item. In short, his measure equates PM with recency.

In Experiment II, prior to whole list learning all Ss were instructed as to the composition of the list. Moreover, one group (N-O) was instructed to recall new items before recalling old items. The other group (O-N) was instructed to recall old items first before recalling new items. Roberts found that recall performance on the whole list was initially superior for those Ss instructed to recall new items before old items (Group N-O) and that they maintained this superiority in recall throughout whole list learning. In order to determine the nature of the difference between groups in total recall, the new item and old item components were analyzed separately. No differences were found between the groups in old item recall. However, the analysis of new item recall indicated significant differences between the groups. The Ss instructed to recall new items first (Group N-O) recalled more new items on every trial of whole list learning than Ss instructed to recall old items first (Group O-N).

Roberts interpreted the results of both experiments as providing direct evidence in support of the notion that ordering in recall subserves a functional purpose. In agreement with earlier and more recent formulations (Battig et al., 1965; Brown & Thompson, 1971), he asserted that the PRNI effect reflects the joint operation of an encoding and a retrieval strategy. These two strategies develop over the course of learning as a consequence of the successes and failures which S experiences in his attempts to recall the list items. The S soon discovers that list items differ in their encodability and retrievability. Items which are processed easily in a form which makes them accessible are the most resistant to forgetting and may be retrieved during late as well as early stages of recall. Items which are difficult to encode are the least resistant to forgetting and may be retrieved only during the early stages of recall. Once S is able to discriminate among the list items in terms of their encodability and retrievability he adopts the following learning strategies in order to maximize recall. The encoding strategy that S employs during input is to concentrate on new or weakly learned items in order to process them in a form which will make them accessible for retrieval. Old items are given less processing time because they already have been encoded in a form which makes them accessible. The retrieval strategy S employs during output is to recall new items before old items which maintains the accessibility of new items and prevents their loss from output interference. Old items are recalled last because they are not susceptible to output interference.

Although Roberts' account of the PRNI effect is interesting, the results of his study can only be considered suggestive since they do not provide direct support for the notion that recall is either facilitated or retarded by the order in which new and old items are recalled. There are a number of reasons why Roberts' findings may be viewed as unequivocal. Two major reasons are:

1. In both experiments Roberts assessed priority in terms of list membership and not item strength directly. New items in the whole list always were considered as "new" across all recall trials regardless of whether or not they had been recalled previously during the course of whole-list learning. This raises the question as to whether or not priority as Roberts measured it reflects the operation of the same processes that determine priority within the context of learning a single list. In other words, the operation of priority within a single list requires discriminations among items which vary in item strength as learning progresses. It could be argued that the Ss in Roberts' study discriminated among whole-list items on the basis of list membership rather than variations in item strength during learning. If this were the case, then any group performance differences in either experiment can not be attributable to priority based directly on item strength.

2. Previous investigators (Battig et al., 1965; Battig & Slaybaugh, 1969) have speculated that Ss not only accord priority to new items at the time of retrieval but also pay special attention to them during input. Roberts reaffirmed this notion by suggesting that the PRNI effect reflects the dual operation of both an encoding strategy and a retrieval strategy. The encoding strategy insures that a maximal number of new items will be accessible for retrieval and the retrieval strategy insures that a minimal number of new items will be lost to output

interference. If in fact Ss adopt an encoding strategy whereby they pay special attention to new items during input, then it is reasonable to assume that instructions to recall new items before old items might facilitate the operation of such a strategy by increasing the likelihood that Ss would attend more closely to new items than old items. Conversely, it is just as reasonable to assume that instructions to recall old items before new items might interfere with the operation of the encoding strategy by increasing the likelihood that Ss would attend more closely to old items than new items during input. Therefore, it could be argued that the critical determinant of recall performance in Experiment II was the degree to which Ss attended to new items during input rather than the order in which Ss recalled new items during output. In other words, the recall instructions may have directed Ss in Group N-O to pay more attention to new items than Ss in Group O-N. As a result, a greater number of new items would have been made accessible at the time of retrieval by Ss in Group N-O than by Ss in Group O-N. If this were the case, then performance differences between the two groups could have resulted from the disparity in the number of new items accessible for retrieval and not from the order in which new items were retrieved.

Although of less importance, two more reasons may be cited which question Roberts' findings:

a. It has been demonstrated (Brown & Thompson, 1971) that over the course of learning in MTFR new items from recency positions have a higher probability of recall than new items from any other input position. It seems likely, then, that in Experiment II the superior performance of Ss in Group N-O could be attributable to the fact that the order in which they were required to recall new and old items did not interfere with new item recall from recency positions. However, this was not the case for Ss in Group O-N. The order in which they were required to recall new and old items prevented new item recall from recency positions. As a result, their performance suffered. Therefore, the performance differences between the two groups may reflect only the degree to which recall order influenced new item recall from recency positions and not new item recall from all input positions. In order to demonstrate the functional utility of ordering new items before old items in recall, Roberts would have had to discount new item recall from recency positions and found that Group N-O still exhibited superior recall performance relative to Group O-N.

b. In Experiment II, Roberts failed to include a random control group permitted to recall old and new items in any order after receiving prior instructions as to the composition of the whole-list. Without such a group it is difficult to tell, in an absolute sense, whether the old-new and/or new-old instructions facilitated or retarded new (and old) item recall. Since Ss in Experiment I were not instructed as to the composition of the whole-list as were Ss in Experiment II, it would be inappropriate to make comparisons between the two experiments in order to evaluate the overall facilitory or inhibitory effects of instructions on recall.

In view of the above considerations, it is evident that the results of Roberts' study fail to provide unequivocal support for the notion that recall performance is either facilitated or retarded by the order in which Ss recall words that vary in item strength. In order to more adequately test such an assumption, the following experimental conditions must be met:

1. The learning task must permit Ss to make discriminations among list items only on the basis of variations in item strength within a single list.

2. All Ss must receive identical instructions to insure the operation of similar encoding strategies.

3. The order in which list items are recalled must be manipulated independently of the Ss normal inclinations.

4. The influence of recency must not favor different orders of recall.

5. An appropriate control group must be included in the experimental design to provide a baseline against which the relative effects of different orders of recall on performance may be evaluated.

These points provide the framework for the present experiment. Its purpose was to demonstrate that recall performance is either facilitated or retarded by manipulating the order in which items of varying strength are recalled. Specifically, the following two classes of items were manipulated:

1. New (N) items. Those not previously recalled correctly and assumed to have relatively low response strength and,

2. Old (O) items. Those recalled correctly on one or more preceding trials and assumed to have relatively high response strength.

The manipulation of recall order was based on these two classes of item strength as they developed over the course of practicing a multi-trial paired-associate task. In the paired-associate task, Ss are required to first study pairs of words and then to recall the right-hand (response) member of each pair when shown just the left-hand (stimulus) member of the pair. Consequently, it is possible to manipulate, beginning with trial 2, the order in which Ss are tested for recall of the pairs on the basis of performance on previous trials (degree of learning). Specifically, S's recall on any trial may be ordered in terms of item strength. One of the conditions of this experiment tested S's recall for N items before O items and another condition tested O items before N items. Immediately following the first presentation of the paired-associate list, the experimenter (E) presented each stimulus term in a random order and recorded S's responses to them. On all subsequent recall trials, E ordered S's recall by presenting first all of the stimulus terms paired with N(O) response terms followed by all of the stimulus terms paired with O(N) response terms. In this manner, E determined order of recall on the basis of the S's previous history of performance. Although the order of presentation of a class of stimulus terms (N or O) was predetermined, the order of stimulus term presentation within a class was random. This procedure minimized recall from recency positions regardless of which class of cues was presented first.

In addition to controlling the order of recall of N and O items, a subclass of O items was identified and manipulated independently in recall. Battig et al. (1965) showed that Ss not only emit N items first in the recall sequence, but also tend to emit early in recall those old items which were not recalled on the immediately preceding trial. This class of O items will hereafter be referred to as intermediate (I) items since it is assumed that their response strength is intermediate between N and O items. As with N items, it was predicted that the correct recall of I pairs would be facilitated when tested early in the recall sequence.

METHOD

Subjects

The Ss were 98 Kansas State University undergraduates of both sexes. Participation in the experiment earned the Ss bonus points which were applied to their final grade in Introductory Psychology.

Materials

A 20-item paired-associate word list (presented in Appendix I) was constructed of 20 male and 20 female first names selected from the Battig & Montague Norms (1969). Names were used to increase intralist similarity and, therefore, difficulty of learning. Differences between conditions should be more likely to occur when learning is difficult. The names varied in individual word frequency from a low of 10 to a high of 96. The total word frequencies for the sets of male and female names was 901 and 906, respectively. All four combinations of male and female name pairings were used. Each combination contained five different pairs. The pairing combinations and the total word frequencies of their stimulus and response components were as follows:

Combination 1. Female (236) - Male (222)

Combination 2. Male (223) - Female (225)

Combination 3. Male (230) - Male (226)

Combination 4. Female (224) - Female (221)

Procedure and Conditions

All Ss received the same instructions (presented in Appendix II) and learned the paired-associate list by the recall method. Specifically, Ss were tested individually and administered eight trials. Each trial consisted of a study period, a 30-second unfilled interval, and a self-paced recall period. During study, the list was presented by Carousel projector which successively exposed each pair for a duration of three seconds. The last pair to be presented was followed by the unfilled interval. After the 30 seconds had elapsed, E began the recall period by saying aloud and one at a time the stimulus term of each pair. The S was instructed to reply orally as he heard each stimulus term with the response term that had been previously paired with it. Following S's response, E pronounced the next stimulus term. The Ss were not told whether they had responded correctly or incorrectly. In the case where S could not recall the response term, he instructed E to present the next stimulus term. Immediately following the end of recall the list was presented again for study.

On the first trial all Ss were treated identically. The pairs were presented randomly for study and randomly for recall. Two different random study-recall orders were used equally often so that half the Ss (49) practiced one order and half the Ss the other order.

Beginning with Trial 2, Ss were assigned to one of three experimental conditions. These conditions differed from one another as to the order in which pairs were tested for recall. Specifically, two sets of pairs were distinguished and designated as old (O) pairs (those recalled correctly on one or more previous trials) and new (N) pairs (those never recalled correctly on previous trials).

The Ss in each of the three conditions recalled response terms according to a different combination of these N and O pairs as follows:

Condition N-O. The 42 Ss in this condition recalled N pairs before O pairs. In addition, two types of O pairs were distinguished. Those recalled correctly on the immediately preceding trial were designated as O pairs and those previously recalled correctly but not on the immediately preceding trial were designated as intermediate (I) pairs. The Ss were assigned to one of three equal size (14) groups which differed only in the order of recall of O and I pairs.[1]

1. Group NIO (New, Intermediate, Old). The Ss recalled first response terms associated with N pairs, followed by response terms associated with I pairs, and, finally, response terms associated with O pairs.

2. Group NOI (New, Old, Intermediate). In this group, Ss recalled first response terms associated with N pairs, followed by response terms of O pairs and, finally, response terms of I pairs.

3. Group NR (New: Old and Intermediate intermixed). These Ss recalled first response terms associated with N pairs followed in random order by response terms of O and I pairs mixed together.

Condition O-N. All 42 Ss recalled O and I pairs before N pairs. Following the same procedure as used within Condition N-O, each of three equal sized (14) groups received a different order of recall of O and I pairs.

1. Group ION (Intermediate, Old, New). The Ss recalled first response terms associated with I pairs, followed by response terms of O pairs and, finally, response terms of N pairs.

2. Group OIN (Old, Intermediate, New). The Ss recalled first response terms associated with O pairs, followed by response terms of I pairs and, finally, response terms of N pairs.

3. Group RN (Old and Intermediate intermixed: New). The Ss recalled first and in random order response terms of O and I pairs mixed together followed by response terms of N pairs.

Condition R (Random). The 14 Ss under this condition continued to recall the list using a random order of testing of N, O, and I pairs on each trial.

Assignment of Ss to conditions and to groups within conditions was based on first trial recall scores so that total correct recall and variability of these scores were matched (equivalent) for all groups and conditions.

For each S, the determination of N, O, and I pairs was made on the basis of his previous recall performance. For this purpose, specially constructed data sheets were utilized by E which enabled him to review, on each trial, an S's prior history of recall. During each recall period, E scored those items that an S had responded to correctly. Then, during the period in which the pairs were presented again for study and during the ensuing unfilled interval, E identified and color coded N, O, and I pairs. This procedure insured that by the beginning of each recall period E could order the pairs for recall according to the experimental requirements of the group to which each S had been assigned.

On Trials 2-8 a different, but predetermined, order of pair presentation was used on the study part of each trial, with the restriction that no pair occupy the same ordinal position more than once. To increase generality, two different sequences of random study orders were used, with half the Ss (7) in each group practicing one sequence and half the Ss the other sequence. The same procedure was followed during recall. That is, two different sequences of random recall orders were used equally often within each group. Under Conditions N-0 and 0-N, however, these predetermined recall orders were modified at the time of recall according to the particular group to which S was assigned. For example, in Group NOI all of the N pairs on each trial for a given S were blocked for recall but their order of recall within the block corresponded exactly to the order in which they appeared in the predetermined recall sequence. The same procedure was used for blocking 0 and I pairs.

RESULTS

Trial 1 Performance

Because the experimental manipulations began on Trial 2, matching on Trial 1 assured comparability of the various groups in terms of initial learning ability. The mean number of pairs recalled correctly for the 14 groups ranged from 4.6 - 5.6 (see Appendix III for a listing of the means). Neither the main effect of Groups, List Order nor the Groups X List Order interaction were significant ($F<1$) at the .05 level, the criterion of significance for all analyses to be reported.

Comparison of Intermediate (I) and Old (O) Pair Recall

For each S within each group a tabulation was made of the number of errors (failures of correct recall) on each trial of learning. The three groups within Condition N-O and within Condition O-N which received different orders of recall of I and O pairs were compared with respect to the proportion of I pairs recalled correctly immediately following an error. The scores were 1.0, .886, and .917, respectively, for Groups NIO, NOI, and NR, and .864, .736, and .917, respectively, for Groups ION, OIN, and RN. Analysis of covariance (using Trial 1 recall scores as the covariate) showed the effects of Order of Recall, Conditions and the Order of Recall X Conditions interaction to be nonsignificant (all F's<1).[2] Since further analyses also failed to reveal significant differences among subgroups within conditions, on any performance measure to be reported herein, only averages based on the three groups within the N-O and O-N Conditions will be reported hereafter.

Comparison of Recall under N-O, O-N, and R Conditions

Figure 1 presents the mean number of correct recalls on Trials 2-8, separately for Conditions N-O, O-N, and R. For purposes of comparison, Trial 1 scores also are shown. As can be seen, Ss in Condition N-O recalled more pairs on each trial, after the first, than did Ss in either Condition O-N or R, the latter two being virtually identical

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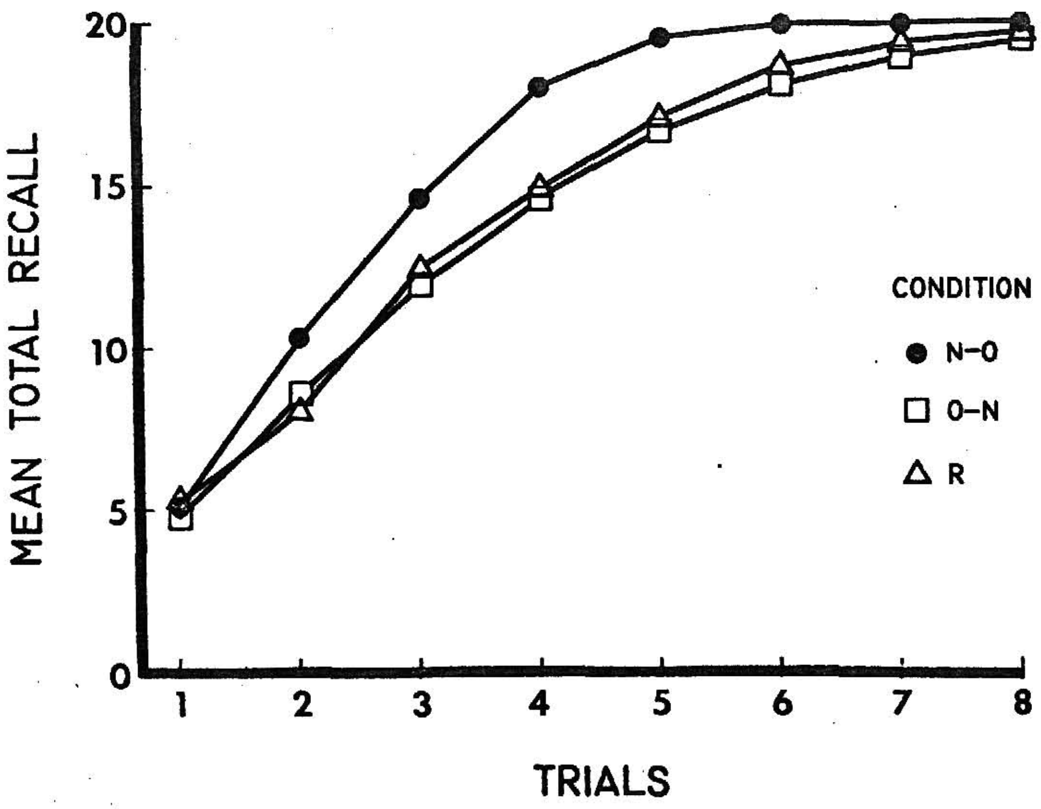

Figure 1. Mean number of correct recalls on each trial for Conditions N-O, O-N, and R.

to one another. Analysis of covariance showed the overall better performance of Condition N-O (112.7) relative to Condition O-N (108.7) and R (110.4) to be significant in both instances, F's (1,91)>15.00. The difference between Conditions O-N and R was not significant (F<1). In addition, there was a significant main effect of Trials, F (6,552) = 647.00 as well as a Trials X Conditions interaction, F (12,552) = 6.22. The latter effect reflects the initial divergence and subsequent convergence of the three conditions as trials progressed. There was no significant effect of List Order or interactions involving this variable (F's<1).

Central to the hypothesis that Ss in Condition N-O would exhibit superior recall performance was the expectation that their superiority should be manifested in a faster rate of N pair acquisition, owing to the use of a recall order which minimizes loss of pairs to output interference. To test this prediction, a tabulation was made, separately for each S, of the total number of errors preceding the first correct response to each pair in the list (hereafter referred to as before errors), following the procedure used by Brown & Battig (1962). As shown in Table 1, most of the difference between conditions in total errors can be attributed to before errors. The mean number of before errors committed by Ss in Condition N-O was substantially less than that of Ss in either Condition O-N or R. The differences between Condition N-O and each of the other two conditions were both significant, F's (1,91)>11.00. The difference between Condition O-N and R was not significant, F (1,91) = 1.07, as was also the main effect of

Table 1

Mean Number of Total, Before, After and Proportion After Errors for Conditions N-O, O-N and R.

Condition	Type of Error: Total Errors	Before Errors	After Errors	Proportion After Errors
N-O	17.3	16.1	1.2	.011
O-N	31.3	29.1	2.2	.025
R	29.6	26.0	3.6	.037

List Order and the List Order X Conditions interaction (F's<1). Thus, the before error data support the prediction of faster N pair acquisition under Condition N-O relative to Conditions O-N and R.

In addition to analyzing rate of acquisition of N pairs, it was deemed of interest to analyze retention of O pairs. For this purpose, the number of errors occurring after the first correct response to each pair was calculated separately for each S following Brown & Battig (1962). It should be noted that after errors correspond exactly to the number of I pairs occurring in learning. In this analysis, however, the focus of attention was on differences between Conditions N-O, O-N, and R as opposed to the previous comparison which centered on differences between I-O groups within Condition N-O and I-O groups within Condition O-N.

The analysis of after errors was based on proportions rather than the absolute number of after errors committed by each S. The reason was to prevent distortion of differences between conditions in 0 pair retention resulting from differential opportunities to commit after errors during learning (e.g., Ss in easy conditions acquire pairs at a faster rate than Ss in more difficult conditions and, therefore, have more opportunities to make after errors). Accordingly, after error scores were computed by dividing each S's total number of opportunities to commit after errors during learning into the actual number of after errors made during learning.

As shown in Table 1, Condition N-0 produced the smallest proportion of after errors, Condition R the largest, and Condition 0-N an intermediate proportion of after errors leading to a significant main effect of Conditions, F (2,91) = 5.34, by analysis of covariance. This finding indicates that Ss in Condition N-0 retained more old pairs than Ss in either Condition 0-N or R and suggests that even the retention of old pairs is favored when new pairs are recalled before old pairs. There also was a significant main effect of List Order, F (1,91) = 4.06, indicating that a larger proportion of after errors occurred under one of the two orders. However, there was no significant Conditions X List Order interaction ($F<1$).

Analysis of Recency Effects

As noted in the Method Section, the present procedure minimized recency effects (i.e., the higher probability of recall of N pairs from terminal input positions when these are tested early in recall). This was accomplished by testing randomly at recall so as to reduce the likelihood that a recency pair would be tested early in recall. Nonetheless, the superiority of Condition N-0 still could have derived wholly or in part from the earlier average testing of N pairs from recency positions. This possibility was examined by comparing the proportion of N pairs recalled correctly from recency input positions (18-20) to that of nonrecency input positions (1-17). For each S, a tabulation was made of the proportion of N pairs recalled correctly from recency and nonrecency input positions on Trials 2-8. (Only data from trials wherein there were N pairs recalled correctly from both recency and nonrecency positions were included in the analysis.) The mean proportion scores are presented in Table 2, separately for Conditions N-0, 0-N, and R. As can be seen, the proportion of N pairs recalled correctly was, in fact, higher from recency than nonrecency input positions, leading to a significant main effect of Recency, $F\ (1,92) = 10.57$. However, the relative magnitude of the recency effect was comparable under all conditions, as evidenced by a nonsignificant Conditions X Recency interaction ($F<1$). Thus, the location of N pairs in the input list can be ruled out as a factor contributing to the superior recall performance of Condition N-0.

There also was a significant main effect of Conditions, $F\ (2,92) = 5.67$, owing to the better overall performance of Condition N-0 relative to Conditions 0-N and R.

Table 2

Proportion of New Pairs Recalled Correctly from Recency (Positions 18-20) and Non-recency (Positions 1-17) Input Locations under Conditions N-O, O-N and R.

Input Location	Condition N-O	Condition O-N	Condition R	Total
Recency Positions	.567	.416	.477	.489
Non-recency Positions	.449	.350	.390	.390
Total	.508	.383	.405	

DISCUSSION

The basic premise which underlies the minimal interference interpretation of the PRNI effect (Battig et al., 1965; Brown & Thompson, 1970) is that the order in which Ss recall new and old items subserves a functional purpose. That is, Ss recall newly acquired items before old or better learned items to reduce the loss of new items to output interference. The utility of ordering recall in such a fashion is that the effects of output interference are minimized and total recall maximized. This notion was tested directly in the present study by manipulating the order in which Ss recalled new and old pairs. In accordance with the above interpretation of the PRNI effect, it was found that Ss who recalled new pairs before old pairs (Condition N-O) exhibited significantly better total recall performance than Ss who recalled either old pairs before new pairs (Condition O-N) or old and new pairs in a random order (Condition R). Also in agreement with original expectation, the superiority of Condition N-O was manifested largely in a faster rate of new pair acquisition.

The present results are in agreement with those obtained by Roberts (1969) in a part-whole transfer experiment. However, as noted in the introduction, the Roberts' study did not permit an evaluation of the locus of facilitation for at least two reasons. First, his instructions might have caused Ss to attend predominantly to either new items or old items during encoding. The Ss instructed to recall new items before old items may have thought it more important to recall new items than old items (and vice versa). In the present experiment, all Ss received the same instructions. Secondly, the act of recalling new items before old items may facilitate performance either because it favors new item recall from recency input positions or because, as the minimal interference interpretation implies, it reduces the loss of new items to output interference from all input positions. Therefore, support for the minimal interference interpretation can be obtained only by the demonstration that recall of new items before old items facilitates new item recall from all input positions and not just recency positions. In the present experiment, all recall conditions showed a recency effect (i.e., better recall of new pairs which appeared in terminal input positions relative to other input positions). However, the better recall of new pairs under Condition N-O was evidenced across all input positions (i.e., the magnitude of the difference between conditions did not vary as a function of input location). Therefore, it seems reasonable to conclude that an output order in which new items are emitted before old items facilitates the acquisition of the list by reducing the forgetting of new items from all input positions.

The finding of a recency effect for new pairs under Condition O-N was unexpected. According to two process notions of memory, the most recently acquired items are stored in a short term memory and maintained through rehearsal processes (Glanzer & Cunitz, 1966; Waugh & Norman, 1965). Accordingly, they predict that the recency effect should be eliminated when a period of interpolated activity intervenes between the end of list presentation and the beginning of recall. The reason is that interpolated activity prevents the rehearsal and maintenance of items in short term memory. For Ss in Condition O-N, the act of recalling old pairs before new pairs constituted a period of interpolated activity and should have eliminated the recency effect. The fact that it did not suggests that in multitrial experiments wherein the same item must be recalled more than once, Ss may process end items in the list in a qualitatively different fashion than they would in a single trial experiment. The result of such processing is that the availability of end items may be maintained over a longer period of interpolated activity. In contradistinction, dual process theories are based on single list experiments in which Ss are not required to recall items more than once. As a consequence, Ss may process list items more superficially. It should be noted, however, that in the present study a 30-second unfilled interval intervened between presentation and recall and may have provided Ss the opportunity to rehearse new pairs from terminal input positions thereby increasing the resistance of these pairs to output interference.

On the basis of the minimal interference theory it is not surprising that Ss in Condition N-0 exhibited superior new pair recall. New pairs were tested early in recall and, therefore, suffered little output interference. By the same token, however, if the effects of output interference are maximal for items that are delayed in recall, then one ought to expect poorer retention of old pairs under Condition N-0 relative to Conditions 0-N and R. Surprisingly, Ss in Condition N-0 also showed better retention of old pairs. The reason for this unexpected finding is unclear. However, its importance would seem minimal since the proportion of after errors under any condition was very small (i.e., only three such errors under the poorest condition).

A P P E N D I C E S

APPENDIX I
Pairing Combinations

Listed below are the name pairs which comprised the paired-associates list, the individual word frequency (F) of each stimulus (S) and response (R) term, the four pairing combinations of male and female names, and the total frequency (TF) of each set of S and R terms within a pairing combination.

Female-Male Pairing Combination

S	F		R	F
Joan	(96)	-	Nick	(10)
Nancy	(92)	-	Kevin	(12)
Sarah	(21)	-	Doug	(20)
Rita	(17)	-	Steve	(89)
Irene	(10)	-	Harry	(91)
TF	236		TF	222

Male-Female Pairing Combination

S	F		R	F
Paul	(70)	-	Laura	(14)
Fred	(59)	-	Peggy	(18)
Eddie	(49)	-	Diane	(59)
Allan	(25)	-	Joyce	(61)
Roger	(20)	-	Susan	(73)
TF	223		TF	225

Male-Male Pairing Combination

S	F		R	F
Frank	(74)	-	Carl	(38)
Mark	(51)	-	James	(38)
Bruce	(40)	-	Gary	(39)
Henry	(38)	-	Pete	(49)
Ralph	(27)	-	Dave	(62)
TF	230		TF	226

Female-Female Pairing Combination

S	F		R	F
Betty	(77)	-	Gail	(30)
Sally	(55)	-	Janet	(35)
Helen	(40)	-	Ruth	(39)
Marie	(27)	-	Alice	(46)
Donna	(25)	-	Karen	(71)
TF	224		TF	221

APPENDIX II

Instructions

The experiment in which you are about to participate is concerned with learning. The session will last about one hour and you will receive one credit hour for your participation.

In this experiment, you are to learn pairs of words. More specifically, I want you to learn 20 word pairs which have been printed on slides and which will be projected on the wall in front of you for study. Each word pair is constructed so that there is a top word and a bottom word. The 20 word pairs will be presented one at a time at a three second rate. After all 20 word pairs have been presented, a 30-second unfilled interval will follow. When 30 seconds have elapsed, I will ask you to recall the bottom member of each word pair in the following manner.

Immediately following the 30-second unfilled interval, I will say the top word of a pair and you will respond by saying the bottom word that was paired with it. Then, I will say the top word of another pair and you will say the bottom word that was paired with in. In this manner, I will say the top word of each pair and you will try to recall as many of the corresponding bottom words as you can remember. When I say the top word of a pair, you may take as much time as you need to respond with the appropriate bottom word. If I should say a top word and you are unsure as to the correct bottom word, please guess. However, if you do not know the correct bottom word to a top word and you cannot guess what it is, please tell me to go on to the next top word.

After I have said the top words of all pairs and you have tried to respond to each with the correct bottom word, I will present the word pairs again for you to study. We will proceed in this fashion for several trials. That is, a learning trial consists of three parts--a study part, a 30-second unfilled interval, and a recall part. During the study part of a trial, your task is to learn as many word pairs as you can while they are being presented. The recall part of a trial begins immediately following the 30-second interval. I will say the top word of all pairs and you will try to recall the correct bottom words. Please do not try to learn the word pairs in the order that they are presented for study or tested for recall because the order of the word pairs will be different for every trial.

Do you have any questions about the procedure or your task? It is important that you understand what it is you are to do. Please ask these questions now because I will not be able to answer your questions once the experiment begins.

APPENDIX III

The Mean Number of Pairs Recalled Correctly on Trial 1 by Each Group

Group	Mean
NIO-01	5.3
NIO-02	4.6
NR-01	5.3
NR-02	5.0
NOI-01	4.9
NOI-02	4.9
R-01	5.3
R-02	5.0
OIN-01	5.6
OIN-02	4.7
RN-01	4.6
RN-02	4.9
ION-01	4.7
ION-02	5.1

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FOOTNOTES

[1] By definition, I pairs could not be manipulated until the third trial.

[2] The proportion of I pairs recalled correctly under Condition R was .654. This score was not significantly different from any other score, however, based on the Newman-Keuls test for ranked treatment means (Winer, 1971).

A DIRECT TEST OF THE MINIMAL INTERFERENCE THEORY OF NEW ITEM PRIORITY IN RECALL

by

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B. A., University of Colorado, 1968

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