Journal of Experimental Psychology
1970, Vol. 84, No. 3, 404–411

RESPONSE AVAILABILITY AND ASSOCIATIVE RECALL[1]

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The influence of response retraining on associative recall was investigated. All *S*s learned a list of paired associates (PAs) and were tested for recall of the pairs after 48 hr. There were six conditions of response retraining immediately prior to the test of PA recall: (*a*) none, (*b*) free recall of the responses without additional study, (*c*) four reexposures of the set of responses without tests, (*d*) four reexposures followed by a single test of free recall, (*e*) four cycles of free recall learning, and (*f*) four cycles of serial recall learning. The conditions of retraining had substantial effects on the level of response availability, but failed to have a significant influence on subsequent PA recall. An item analysis showed a Condition of Retraining × Degree of Original Learning interaction. The recall of weak items is likely to be enhanced by reexposure to the responses, whereas response relearning produces either no effect or a net loss for strong items. It is concluded that the retraining task is a source of both facilitation and interference.

The acquisition of a list of paired associates (PAs) requires both response recall and the establishment of associations between the members of individual pairs. For purposes of analysis, these component processes may be assumed to develop independently, and they have in fact been shown to be influenced differentially by prior training and by the manipulation of task variables (Horowitz & Larsen, 1963; Jung, 1965; Underwood, Runquist, & Schulz, 1959). After the end of acquisition, the availability of responses and of specific associations may decline at different rates. On a delayed test of retention, cued recall of PAs is likely to be lower than free recall of the responses (Saltz & Youssef, 1964; Underwood & Ekstrand, 1967). The results of recent investigations of retroactive inhibition showed that responses are more subject to unlearning than are specific associations (Postman & Stark, 1969; Postman, Stark, & Fraser, 1968). Thus, the integrity of associative connections may be maintained while the responses become unavailable. On the other hand, in the recall of lists composed of conceptually related items, the repertoire of responses may remain more available than the specific associations (cf. Postman, 1967; Underwood & Ekstrand, 1968).

To the extent that forgetting in any given case reflects the loss of the responses per se rather than of the associative connections, it should be possible to increase the amount of recall by giving *S*s an opportunity to relearn the responses prior to the test of retention. While such an outcome may appear obvious at first, further consideration leads to some qualifications of the prediction. First, as already noted, the retraining procedure may be expected to facilitate the recall of only those items for which the associative connection has remained intact but the response has dropped out. The availability and the associative strength of individual responses are, however, likely to be correlated. Such a correlation should normally be present since, during acquisition, the speed with which an item enters into the associative phase depends on the availability of the response. Insofar as losses in response availability and in associative strength develop concomitantly, there occurs a shrinkage in the number of items that can be restored to recall by response pretraining. Second, the process of response relearning may have consequences that are detrimental to subsequent associative recall. If the retraining procedure consists of free recall

[1] This research was facilitated by Grant MH-12006 from the National Institute of Mental Health, United States Public Health Service.

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learning, the responses may be grouped into higher order units and, as a consequence, become less accessible for later cued recall. Incorporation into higher order units may change the connotations of individual response terms established during PA practice; whatever sequential grouping of the responses occurs is likely to be at variance with the order in which they have to be given in recall. In short, the vertical organization of the responses achieved during retraining may come to conflict with the horizontal organization of the PA list.

The performance of the retraining task may also entail the weakening or suppression of the associations between the responses and the stimulus terms of the PA list. Elicitation of the stimulus terms in the course of retraining is liable to interfere with the optimal processing of the entire pool of responses. Stimulus recall and rehearsal of list pairs would, therefore, tend to be inhibited in the interest of maximizing the efficiency of response relearning. It is the requirement to relearn the forgotten responses that is viewed as incompatible with the rehearsal of list-specific associations. Such associations may well be rehearsed if *S* has to recall only those responses that are available without additional study. In general, the interpolation of any kind of learning or relearning task with requirements of its own may be expected to have some adverse effect on the recall of a previously learned list, if for no other reason than because a shift in performance set is imposed on *S*. These considerations temper the expectation of a substantial increase in associative recall after response retraining.

The relevant experimental evidence is limited and contradictory. Saltz and Youssef (1964) used the method of free recall learning, with alternating study and test trials, to provide response retraining prior to PA recall. The response terms were adjectives which were paired with nonsense syllables as stimuli. Both relatively low and high degrees of original learning (OL) were used. While the results of the successive experiments in the Saltz and Youssef study were quite variable, response retraining clearly had no consistent effect on cued recall either immediately or 24 hr. after the end of original learning. By contrast, Weiss (1966), using some of the same materials, observed a significant increase in recall after retraining, but under conditions that differed from those in the study of Saltz and Youssef in a number of important respects. For present purposes, the most important changes were that (*a*) retraining consisted of a single exposure of the responses and did not include a test of free recall, and (*b*) only half of the responses in the list were used in retraining, with the remaining half assigned to the control treatment. Consequently, it was less likely than in the Saltz and Youssef study that cohesive new groupings of the responses would be developed. In any event, the two studies taken together suggest that response retraining may have a positive influence on cued recall only under highly circumscribed conditions.

The problem warrants further investigation because of its implications for the two-stage analysis of associative learning and recall; a detailed analysis of the retraining paradigm should contribute to an understanding of the operations used to manipulate the factor of response availability. In the present study, an attempt is made to determine the consequences for cued recall of the following component processes that may come into play, singly or in combination, during response retraining: (*a*) recall of the responses that have remained available at the end of the retention interval; (*b*) reexposure to the total response pool; and (*c*) relearning of the entire repertoire of responses, i.e., reexposures followed by tests of recall. As a limiting case of the latter treatment, relearning in a constant serial order was included in addition to the conventional procedure of free recall learning. According to the present analysis, both the positive effects of reacquisition of the responses and the interference from the interpolated task should increase for the successive conditions in the order named. The questions of interest concern the manifestations of these positive and negative influences and their net effects on recall.

Method

Design.—All *S*s learned a list of PAs and were given a test of cued recall 48 hr. later. The experimental design comprised six conditions that were distinguished in terms of the treatment administered just prior to cued recall. These treatments were as follows: (*a*) Cond. TFR—a test of free recall of the responses without retraining; (*b*) Cond. RE—four reexposures of the list of responses without any test of recall; (*c*) Cond. RE + TFR—four reexposures of the list of responses, followed by a single test of free recall; (*d*) Cond. FRL—four cycles of free recall learning of the list of responses, with each cycle consisting of a study and a test trial; (*e*) Cond. SRL—four cycles of serial recall learning of the list of responses, with a fixed order of presentation on study trials and instructions to *S*s to reproduce the items in that order; and (*f*) Cond. C—the control treatment, in which there was neither reexposure to the responses nor a test of recall.

Condition TFR provides a measure of the amount of response recall in the absence of retraining and, relative to Cond. C, permits an assessment of the effects of recalling available responses prior to the associative test. Condition RE was designed to reinstate the response repertoire without requiring *S* to organize or reorganize the list for purposes of recall. Condition RE + TFR was introduced in the first instance to obtain an estimate of the level of response relearning that is attained after four reexposure trials; with respect to the amount of response processing required of *S*, this procedure may be viewed as intermediate between Cond. RE and FRL. Finally, Cond. SRL imposed a serial organization on the list that was clearly at variance with the sequence of responses on the associative test.

Lists.—The learning materials were lists of 12 PAs, with CVC trigrams as stimuli and two-syllable adjectives as responses. Three different lists were used equally often. The stimulus terms were the same in all lists, but the responses were different. Formal stimulus similarity was kept as low as possible. There were no letter duplications in either the first or the third position; four consonants were used twice each, once in the first and once in the third position. The five vowels and the letter *y* were used twice each in the middle position. The association values of the syllables in Archer's (1960) norms ranged from 47% to 55%. Each of the adjectives in a list began with a different letter. Meaningful similarity of the responses was minimized by inspection.

Original learning.—In OL, the PA list was presented for one study trial and six anticipation trials at a 2:2-sec. rate, with a 4-sec. intertrial interval. The list was presented in four different random orders.

Response retraining.—The *S*s returned for a test of retention 48 hr. after the end of OL. The cued test of PA recall always took place 10.5 min. after the beginning of the session. For Cond. FRL and SRL, this interval was filled entirely with the administration of instructions and the performance of the retraining task. Under the remaining conditions, whatever part of the interval was not used up by instructions and the appropriate retraining activity was occupied with the performance of a symbol-cancellation task. This task was performed during the entire interval in Cond. C and during the period leading up to the 45-sec. test of free recall in Cond. TFR. In Cond. RE, in which re-exposure trials only were given, the symbol-cancellation task was performed between successive presentations of the list, i.e., during the periods corresponding to the test trials in Cond. FRL and SRL. The same was true for Cond. RE + TFR, except that there was a test trial after the final exposure of the list. It should be noted that under all treatments the final (or only) test trial occurred at the same point in the session.

The retraining instructions identified the items to be presented as the response terms from the PA list and indicated that a test on that list would follow later. To reduce uncontrolled rehearsal, the initial instructions to groups C and TFR made no reference to such a test. On presentation trials, the words were exposed at a 2-sec. rate. A different random order was used on each exposure trial, with the exception of Cond. SRL in which the order remained fixed. All tests of recall were written and were 45 sec. in duration.

Paired-associate recall.—There were five successive cued recall trials without feedback. The drum was again operated at a 2:2-sec. rate with a 4-sec. intertrial interval, but a blank space was exposed in the response position when the shutter rose.

Subjects.—There were 18 *S*s in each of the six conditions. The *S*s were undergraduate students at the University of California who were not necessarily naive to verbal learning experiments. Assignment to conditions was in blocks of six, with 1 *S* from each condition per block. Each of the three lists was used once within a group of three successive blocks.

Results

Acquisition.—The mean total number of correct responses in OL was 27.46, with the means of individual groups ranging from 25.50 to 29.89. The overall mean score on the last trial of acquisition was 6.87, with a range of group means from 6.67 to 7.22. For both measures, the value of *F* was less than 1.00.

Response retraining.—The *S*s in Cond. TFR were tested for recall of the responses without retraining. The mean number of items given correctly was 5.39. More than half the responses were, therefore, unavailable at the end of the retention interval. This level of performance defines the magnitude of the relearning task for the groups that were given retraining. The mean scores on the terminal test trial of Groups RE + TFR, FRL, and SRL (scored without regard to serial order) were 8.50, 9.78, and 11.17, respectively. Analysis of variance of these scores, which reflect the level of response availability just prior to the test of cued recall, showed the differences among conditions to be significant, F (3, 68) = 55.30, $p < .01$. Each of the retrained groups differed reliably from Group TFR ($p < .01$) by Dunnett's test. The variation among the former was likewise significant at the .01 level. Four cycles of study and test trials yielded a higher level of recall than did the same number of study trials alone. This difference was, of course, to be expected since the tested groups spent more time in processing the responses than did the untested one. Furthermore, SRL produced better response recall than FRL. While the results are not reported in detail, it should be noted that the amount recalled without regard to order was initially lower in SRL than in FRL, but that there was a clear reversal of this difference as practice continued. In Cond. SRL, the scores were consistently lower for ordered than for unordered recall.

Cued recall.—The mean numbers of correct responses on the first trial of PA recall are shown in Table 1. (At this point, attention is given only to the part of the table listing the total scores.) With the exception of Cond. SRL, all groups showed some advantage over the control treatment; the highest score was obtained by Group TFR. It is apparent, however, that the variations in performance were relatively minor, and the differences among conditions were not significant, $F < 1$. In spite of the great diversity of the retraining procedures, the level of recall showed a remarkable degree of stability. The earlier negative conclusion of Saltz and Youssef (1964) was thus confirmed and found to hold over a wide range of retraining procedures.

As was suggested earlier, the potential effectiveness of response retraining necessarily depends on the strength of individual stimulus–response associations. If the effects of a given condition of pretraining changed from positive to negative as some function of the degree of associative strength, the net recall score would not be influenced appreciably. This possibility deserved especially careful consideration in view of the fact that a fixed number of acquisition trials is likely to produce considerable variation in the associative strength of individual pairs. Comparisons of the experimental treatments were, therefore, made for subgroups of items representing different degrees of OL. For purposes of this analysis, the pairs learned by each S were ranked according to the number of correct anticipations in acquisition. The pairs were then grouped into three categories, viz., those of high strength (Ranks 1–4), medium strength (Ranks 5–8), and low strength (Ranks 9–12). Table 1 shows the mean recall scores for each category under the various experimental treatments. The presence of a Degree of OL × Condition of Retraining interaction is clearly in evidence.

When the degree of OL was low, recall was poorer for the two groups that were not reexposed to the list of responses (Cond. C and TFR) than for the remaining groups,

TABLE 1

MEAN NUMBERS OF CORRECT RESPONSES ON THE FIRST TRIAL OF CUED RECALL

Item strength	Cond.					
	C	TFR	RE	RE + TFR	FRL	SRL
High	2.66	3.28	2.73	2.59	2.72	2.11
Medium	1.21	1.70	1.42	1.24	1.32	1.33
Low	.52	.40	.85	.78	.74	1.00
Total	4.39	5.38	5.00	4.61	4.78	4.44

all of which received repeated presentations of the list. It is interesting to note that for this class of pairs, Group SRL, which attained the highest level of response recall at the end of retraining, ranked first on the test of associative recall. For items of high strength, recall performance was best in Cond. TFR and poorest in Cond. SRL. The other groups occupied intermediate positions and differed only slightly from each other. The scores for items of medium strength were relatively homogeneous, although Cond. TFR had an apparent advantage. In view of the opposing trends for the two extreme categories, it is not surprising that the amount of variation was least for items of medium strength, although the pattern of scores was more similar to that for the strong than for the weak items. The Condition × Degree of Learning interaction was significant, $F\ (10, 204) = 2.58$, $p < .01$. An analysis of the simple effects showed the differences among conditions to be significant for the high category ($p < .05$), but not for the low category. In the latter case, however, a significant difference ($p < .05$) was obtained in an orthogonal comparison between the groups that were reexposed to the responses and those that were not. There were no reliable differences among conditions in the recall of the items in the medium category. It is possible to conclude on the basis of this analysis that the conditions of response retraining had at least some differential effects on PA recall. However, both the direction and the magnitude of these effects depended critically on the degree of learning of the individual items.

Successive recall trials.—The mean numbers of correct responses on the successive trials of cued recall are presented in Table 2. All groups showed an improvement in performance over trials. The two groups with the highest scores on the first trial registered the smallest gains, which suggests the operation of a ceiling effect. As a consequence, there was a shift in the relative positions of the various groups on the terminal trial. However, the differences among conditions remained small throughout. A linear trend analysis showed that the overall amount of improvement was significant, $F\ (1, 102) = 76.27$, $p < .01$, but that there were no reliable differences among conditions, $F = 1.18$.

The changes over successive recall trials for different categories of items are not reported in detail. In general, the gains were greater for items of medium than of either high or low strength. Averaged over all groups, the mean increases were .29, .44, and .23 responses for the high, medium, and low categories, respectively. These differences in the amount of gain were significant, $F\ (2, 204) = 5.54$, $p < .01$, but they did not interact reliably with condition. The opportunities for improvement in the recall of strong items were limited by the relatively high level of performance on the initial trial; gains in the recall of weak items were constrained by the low degree of OL. There was little variation in this pattern from one condition to the next. The one exception of interest is that for Cond. TFR, which showed a sharp gradient as a function of associative strength on the initial recall trial, the amount of gain was greatest for the low category and smallest for the high category.

TABLE 2

Mean Scores on Successive Trials of Cued Recall

Trial	Cond.					
	C	TFR	RE	RE + TFR	FRL	SRL
1	4.39	5.38	5.00	4.61	4.78	4.44
2	4.94	5.44	5.39	4.89	5.56	4.72
3	4.94	6.06	5.50	5.44	5.94	5.17
4	5.50	5.94	5.72	5.78	6.28	5.17
5	5.44	6.00	5.61	5.72	6.17	5.44

When account is taken of the opportunities for improvement and the constraints imposed by the degree of OL, the trends over trials offer little additional information about the effectiveness of the different experimental treatments.

Overt errors in recall.—The increased availability of responses after retraining was reflected in the rate of overt errors during cued recall. Table 3 shows the relative frequencies of misplaced responses on the successive recall trials, expressed as percentages of total emissions. In the interest of stability, these percentages were determined for the pooled responses of all *S*s. The error rates were clearly higher for the retrained groups than for the two groups that were not reexposed to the responses (Cond. C and TFR). The trends over trials were not consistent, but there was a tendency for the relative frequency of errors to decline. The separation between the retrained groups and those not reexposed to the responses remained in evidence throughout. For purposes of statistical analysis, the percentage of errors based on all recall trials was determined for each *S*. The mean percentages are presented in Table 3. An orthogonal comparison yielded a significant difference between Cond. C and TFR, on the one hand, and the remaining conditions, on the other, F (1, 102) = 6.23, $p < .02$.

It should be noted that a substantial proportion of the misplaced responses did not also occur as correct ones on a given trial. Thus, the variation in error rates did not simply reflect differences in the tendency to repeat responses. The mean numbers of different errors (responses not also given correctly), which are shown in the last column of Table 3, exhibit the same pattern as the percentage measures. The orthogonal comparison between the two sets of conditions contrasted previously again yielded a significant difference, F (1, 102) = 11.18, $p < .01$.

Discussion

The present results focus attention on the complexity of the effects produced by independent manipulations of response availability in the context of a two-stage analysis of associative learning and recall. It has been recognized for some time that response familiarization prior to acquisition has consequences other than simply increasing the availability of the response terms. As Jung (1967) has pointed out, interitem associations developed in the course of the familiarization procedure are likely to become a source of interference during the acquisition of the test list. There is direct evidence that the members of a set of familiarized responses come to elicit each other as associates (Schulz & Thysell, 1965). Consequently, the associations formed in the pretraining and in the test stage conform to the A-B, C-B paradigm of transfer. That paradigm is known to produce associative interference. Thus, the amount of facilitation produced by response familiarization does not permit an unequivocal assessment of the role of response availability in associative learning.

The same considerations apply to the evaluation of the effects of response retraining on subsequent associative recall. The critical difference is, of course, that the familiarization procedure follows rather than precedes the acquisition of the test list. The training procedure now constitutes an interpolated task which may result in the unlearning of test list associations. It is known that under the A-B,

TABLE 3

Measures of Response Errors on Trials of Cued Recall

Cond.	Percentage of misplaced responses for Trials 1–5					M/S	Mean no. of different errors/trial
	1	2	3	4	5		
C	20.9	24.2	25.6	16.8	21.9	21.6	.98
TFR	20.3	20.6	15.0	16.4	18.2	19.3	.81
RE	30.3	30.7	26.1	27.6	34.8	31.5	1.67
RE + TFR	41.5	37.3	33.1	28.6	28.2	32.4	1.80
FRL	40.0	28.6	26.7	23.1	24.5	31.6	1.68
SRL	37.4	34.3	30.6	35.2	33.6	38.0	1.92

C-B paradigm the availability of forward as well as backward associations is reduced after interpolated learning (Greenbloom & Kimble, 1965). To the extent that this paradigm is, indeed, descriptive of the relation between the retraining and the test task, a negative effect on associative recall is entailed. In addition, as has already been noted, the subjective reorganization of the response terms and changes in the connotations of the individual items during the retraining trials may have damaging consequences for associative recall. The shift in task requirements between the retraining and the PA task adds to the potential sources of disruption at the time of cued recall.

While the performance of the retraining task must be viewed as a source of interference as well as facilitation, the absence of differences among the amounts recalled under the various experimental treatments remains surprising. The very large increases in response availability produced by several of the retraining procedures failed to influence associative recall to any appreciable degree. It appears that the negative effects of the retraining procedure fully balanced the positive ones. This conclusion must be tempered in light of the item analysis showing a significant Experimental Treatment × Degree of OL interaction. A favorable influence of retraining on recall was in evidence for the weakest pairs in the list. One possible reason for the net advantage shown by these items is that weak test list associations were unlikely to be elicited and suppressed during retraining. By the same token, strong test list associations were very likely to be elicited and suppressed. The pronounced Experimental Treatment × Degree of OL interaction which is apparent in a comparison of Cond. C and SRL is consistent with this assumption since the latter procedure was designed to maximize the conflict between interresponse and stimulus-response associations. While a net positive effect may be discernible for a limited number of items, it is slight at best and is likely to be masked in the total recall scores by negative or null effects for the preponderance of the items.

The high level of recall for strong items in Cond. TFR brings to the fore the distinction between retraining, on the one hand, and the review and rehearsal of responses that have remained available, on the other. In the latter case, there is no requirement to reproduce together all the responses, the previously forgotten ones as well as the retained ones. Thus, new interitem associations and groupings are not likely to develop. Moreover, the elicitation of list associations should not interfere with the recall of the responses, but might in fact facilitate it because of the cue value of the stimuli. Under these conditions, list associations for the available responses are likely to be rehearsed. The superior performance in Cond. TFR may be understood on this assumption.

In the evaluation of the recall results, it is well to emphasize again the inherent limitations on the potential positive effects of response retraining. Clearly, retraining cannot enhance recall if (*a*) the associative connection was either not acquired or has been lost, or (*b*) the association is intact and the response has remained available. The degree to which potential gains are thus constrained will, of course, vary with the degree of OL, the length of the retention interval, and the range of item difficulty within the list. There may well be combinations of these factors that would produce larger effects of retraining than were obtained in the present experiment.

It would be erroneous, on the basis of the present findings, to discount the role of response availability per se in associative recall. Such a conclusion would in the first instance be untenable because performance on a retention test is known to depend critically on whether or not response recall is required. After a given amount of practice, losses observed on a test of recall are often greatly reduced if not eliminated when a test of associative matching is used. Clearly, there are associations that remain intact but cannot be reflected in correct performance because the response is not available. The major implication of the largely negative results obtained here, as well as by previous investigators (Saltz & Youssef, 1964), is that it may prove very difficult to devise a procedure for restoring the availability of responses without at the same time interfering with subsequent cued recall. While the two-stage analysis of associative learning and recall has already proved its analytic usefulness, the independent manipulation of the inferred component processes continues to pose methodological difficulties.

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(Received September 19, 1969)