Response selection in paired-associate learning*

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Ss were presented pairs of items on study cycles; on test cycles Ss were presented the stimulus items and required either to recall the correct response or to indicate the correct response from three alternatives. It was demonstrated that Ss who chose the correct responses from the alternatives tended to select from both stimulus and response compounds so that the association was between stimulus and response components. The amount of selection from the response compounds was comparable to that from the stimulus compounds.

It has been amply demonstrated (e.g., Harrington, 1969; Underwood, Ham, & Ekstrand, 1962) that the use of compound stimulus items, consisting of unrelated redundant components, results in stimulus selection during paired-associate learning, i.e., Ss tend to select one component from the compound as the functional stimulus. It has been suggested that stimulus selection is the result of an active attentional process that determines the identifying response to the compound stimulus and that the identifying response enters into any further encoding prior to storage in memory (Richardson, 1972b). Greeno, James, and DaPolito (1971) suggest that an association involves storing a record of the stimulus-response pair in memory as a unit. If this is a reasonable view of paired-associate learning, selection should also occur from compound response items, provided the responses required of S permit selection.

In the usual verbal paired-associate task, S is required to give a response to the stimulus item that corresponds to reading the response item aloud. This procedure forces S to learn the response item, so it is not reasonable to expect selection of one component from a compound response item. However, a different procedure is sometimes used that permits S to base his response on any part of the response item that enables him to discriminate it from other response items. This is a variation of the study-test method of paired-associate learning that, on the test trials, requires S to select the correct alternatives from a number of response items presented with each stimulus item. This has been called the multiple-choice method (Schulz, 1972). The usual procedure, which requires S to recall the responses to the stimulus items on the test trials, will be called the recall method.

The present experiment is a demonstration of selection from response items in paired-associate learning and compares the results from the multiple-choice and recall method. What is learned when S is required only to recognize the correct response item and has redundant relevant cues available to use as the basis for the recognition?

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METHOD

Lists

Each S learned a paired-associate list and was then given a recall test to determine the amount of selection. The paired-associate lists were constructed from six consonant trigrams (ZSG, BQD, TLN, RKH, XJM, and CFP) and the digits 2 through 7. Eighteen different consonants were used for the six trigrams, and a different digit was paired with each trigram so the three letters within a trigram were redundant and relevant. There were two basic lists differing only in whether the trigrams were stimuli and the digits responses (List T-D) or the digits were stimuli and the trigrams responses (List D-T). There were two different pairings of the trigrams and digits and each pairing was used equally often within each condition.

Design

There were seven conditions represented by different groups of Ss, and the conditions were designed to answer three somewhat different questions. First, the question of how much selection occurred with the multiple-choice (MC) method required control groups for comparison with the experimental groups. The two MC experimental groups learned either the T-D or D-T list and were then tested for selection. The two MC control groups went through exactly the same procedure, except they learned lists in which single letters replaced the trigrams. The single letters were those from the first, second, or third positions within the trigrams for equal numbers of Ss within each control condition. The MC controls gave an estimate of the maximum amount of selection, i.e., the results when S had the opportunity to learn to only one letter instead of three.

The second comparison was the amount of selection with the two learning methods. Two recall (R) experimental groups learned either the T-D or D-T list and were then tested for selection. The only difference in procedure from the MC experimental groups was the method of learning.

A seventh group of Ss learned the D-T list by the MC method but, instead of being tested for selection by recall of the digits to the individual letters, Ss were tested by recall of the letters with the digits as cues. This group was included to determine if forward and backward recall with the MC method would give comparable estimates of response selection.

In summary, there were two MC control conditions with lists consisting of pairs of single letters and digits instead of trigrams and digits, two MC experimental conditions, and two R experimental conditions. In each of the three, one group learned lists with letters as stimuli and digits as responses; for the other group the pairs were reversed. The recall procedure to test for stimulus selection was with single letters as cues for all six groups. A seventh group learned the D-T list by the MC method but was tested for selection by recalling the letters with the digits as cues.

Table 1
Mean Trials to Criterion and Mean Correct Recall Responses

Condition	Trials to Criterion				Correct Recall Responses			
	T-D		D-T		T-D		D-T	
	Mean	$\hat{\sigma}$	Mean	$\hat{\sigma}$	Mean	$\hat{\sigma}$	Mean	$\hat{\sigma}$
MC Control	6.50	4.19	5.61	3.65	21.28	4.04	21.39	4.03
MC Exp	8.33	4.04	9.61	5.03	22.33	5.39	29.61	10.34
R Exp	7.39	3.73	20.28	11.12	30.33	9.39	49.28	4.28
MC D Cue	—	—	9.39	4.97	—	—	26.83	9.41

Procedure

All Ss learned the appropriate paired-associate list to a criterion of two successive perfect trials. All lists were presented on a Stowe memory drum by the study-test procedure at a 2-sec rate with a 2-sec intercycle interval. Five different random orders of stimuli were used on the study cycles and another five orders were used on the test cycles.

On the study cycles, the pairs of items were presented in the same fashion for both methods of learning, and Ss were instructed to study them silently. Only the stimulus items were presented on the test cycles in the R conditions, and S was asked to say the correct responses aloud. In the MC conditions, the stimulus items were presented on the test cycles, and three response alternatives were presented to the right of each stimulus item. The S indicated the correct alternative by saying "first," "middle," or "last." Two of the correct alternatives occurred in each of the first, middle, and last positions within each test cycle. The response items from within the list were randomly assigned as incorrect alternatives, subject to the restrictions that the same combinations of response alternatives could not occur within a test cycle and a particular sequence of response alternatives was never repeated. The learning instructions to Ss were the usual ones for each method and Ss were not told there would be a recall task following the learning.

Following paired-associate learning, all Ss (with the exception of the one group) were presented the 18 letters from the six trigrams for three recall trials. Single letters were printed on cards, and Ss were required to turn the cards up one at a time and attempt to give the digit that had been paired with the letter during the learning trials. If they did not know the correct response or thought that the letter had not been presented during learning, they were required to guess one of the digits 2 through 7. The Ss were given no information concerning the correctness of the responses during the three recall trials and all responses were recorded by E. Three different orders of the 18 letters were used for the three recall trials, and the position of the letters in the trigrams was counterbalanced within each order. As the result of an error, the sequence of the three orders was confounded with conditions. However, this probably is not critical for the interpretation of the results.

The other group of Ss learned the D-T list by the MC method (MC D-cue condition) but the recall was different from the other conditions. Following learning, each S was presented with a deck of six cards. One of the digits, 2 through 7, was on the left of each card, followed by three blanks. The S's task was to turn up the cards one at a time and write the three letters that had been paired with the digit during learning in the three blanks. This was repeated two more times for a total of three trials and the order of the digits was random within each of the trials.

Subjects

The Ss were college students who had not previously served in a verbal learning experiment. The seven conditions were listed in counterbalanced orders and Ss assigned in sequence as they appeared in the laboratory. In addition to the 126 Ss who completed the experiment, 18 in each of seven conditions, 3

were dropped. One failed to learn the paired-associate list in 50 trials, and E made errors in recording and scheduling for the other two. In each case, these three Ss were replaced by the next S to appear at the laboratory.

RESULTS

The results will be discussed in terms of the comparisons of the control and experimental groups that learned by the multiple-choice method and of the comparisons of the multiple-choice and recall methods of learning. The comparison of the two MC D-T groups that recalled with the letters as stimuli and with the digits as stimuli (second and last rows of the two tables) gave no indication that the direction of recall made any difference in results. It will be assumed that response selection with the multiple-choice method is not due to the direction of recall.

Multiple Choice: Experimental vs Control

The mean number of trials required to learn the paired-associate lists to a criterion of two successive perfect trials are presented in the left half of Table 1 in Rows 1 and 2. Although there is a small tendency toward an interaction of direction (T-D vs D-T) and the control experimental difference, this did not approach statistical significance [$F(1,68) = 1.16$]. The experimental condition required more trials to learn than the control [$F(1,68) = 8.44$, $p < .01$]. The tendency for paired-associate lists with compound stimuli to be more difficult than those with single components as stimuli when learned by the MC method is comparable to that found when learning is by the R method (Richardson, 1972a).

The right half of Table 1 gives the mean number of responses, out of the 54 possible, given correctly during the three recall trials to the single letters. Direction [$F(1,68) = 5.83$, $p < .05$], control vs experimental [$F(1,68) = 9.19$, $p < .01$], and the interaction [$F(1,68) = 5.48$, $p < .05$] were all significant. However, examination of the means makes it apparent that the MC Exp D-T condition produced more correct recall responses than the other three conditions and that this single variation was primarily responsible for the statistical significance of the three sources of variance. It is not clear what produces the greater recall when the responses are compounds. The superior recall occurred

Table 2
Mean Different Correct Recall Responses and Efficiency Scores Based on the 3/3 Correct Recall Criterion

Condition	Different Recall Responses				Efficiency			
	T-D		D-T		T-D		D-T	
	Mean	$\hat{\sigma}$	Mean	$\hat{\sigma}$	Mean	No. 100s	Mean	No. 100s
MC Control	4.33	1.78	5.06	1.39	96	15	92	13
MC Exp	3.39	1.38	4.06	1.39	84	9	77	7
R Exp	4.72	1.18	5.89	.47	72	5	41	0
MC D Cue	—	—	4.22	1.66	—	—	69	6

on the first recall trial, as well as on the other two, so it was not due to the repeated recall procedure and must reflect differences that were the result of the paired-associate task.

The evidence that a more stringent criterion of recall gives better estimates of selection has been presented elsewhere (Richardson, 1972a). The other two measures, presented in Table 2, are based on the 3/3 criterion of recall, i.e., a recall was scored as correct only if it was correct on all three recall trials. The left half of Table 2 gives the mean number of different correct recall responses. This is the mean number of trigram stimuli, out of the possible six, for which one or more of the three letters elicited the correct digit on all three recall trials. There was a tendency for more different correct recall responses in the D-T than in the T-D condition, but this difference was not significant [$F(1,68) = 3.88$, $p < .10$]. There were more different correct recall responses in the control than in the experimental MC conditions [$F(1,68) = 7.60$, $p < .01$]. However, it is the relationship of the number of different correct recall responses to the total number of correct recall responses that is critical for comparing amounts of selection.

The efficiency score is the percentage of the total correct recall responses that would be necessary for S to give a single correct digit response to each trigram that is represented by a correct recall to one or more of the three trigram letters. An efficiency score was computed for each S by dividing the number of different correct recall responses by the total number of correct recall responses and multiplying the result by 100. The recall to a single letter was scored as correct only if it was given correctly on all three recall trials. The mean efficiency scores are presented in the right half of Table 2, along with the number of Ss who had efficiency scores of 100. The mean efficiency scores of 84 and 77 in the MC Exp conditions are smaller than those in the controls but still indicate an appreciable amount of selection in both cases. The number of Ss who selected perfectly (number of 100s) prohibited the use of analysis of variance. The number of Ss with perfect selection in the control groups were used as expected values for the corresponding experimental groups and significantly fewer experimental Ss scored 100s in the T-D [$\chi^2(1) = 12.10$, $p < .01$] and in the D-T [$\chi^2(1) = 8.38$, $p < .01$] conditions.

Method: Multiple Choice vs Recall

The scores for the MC and R experimental conditions, which differed only in the method of paired-associate learning, are in the second and third rows of the two tables. Table 1 shows that, as expected, learning by the recall method with the trigrams as responses (Condition R Exp D-T) was much more difficult than in the other three conditions. An analysis of variance on the four conditions found that all three sources of variance were significant beyond the .01 level. However, Table 1 shows that the R Exp D-T condition was the major source of this variance and that the within-groups variance was also larger in this condition. A separate analysis of variance computed on the other three conditions showed that conditions was not a significant source of variance [$F(2,51) = 1.21$]. The only difference in difficulty of learning seems to be due to the requirement for response integration when the trigrams are responses. The greater difficulty of the D-T list by the recall method confirms Hopkin's (1970) results.

Table 1 also gives the mean correct responses during the three recall trials. The trends are all significant beyond the .01 level. The D-T condition produces more correct recall responses than T-D [$F(1,68) = 51.02$], the R method is superior to the MC [$F(1,68) = 56.80$], and the change from T-D to D-T increases recall more by the R method of learning than by the MC method [$F(1,68) = 10.10$].

The trends for the mean number of different correct responses shown in Table 2 are the same as those for the mean number of correct recall responses in Table 1. The very small variance within the R Exp D-T condition was produced by the fact that 17 of the 18 Ss correctly recalled all six of the possibilities. However, reducing the df for the within sum of squares to 51 (essentially eliminating the R Exp D-T condition from the estimation of the error variance) still shows that D-T produced more different correct recall responses than T-D [$F(1,51) = 8.33$], and the R method produced more different correct responses than the MC [$F(1,51) = 24.85$], with the F for the interaction less than 1.00.

The efficiency scores presented in Table 2 show that the R Exp D-T condition, which required recall of the trigrams during learning, produced a very low efficiency

score of 41. This should be compared to the minimum score of 33 that is possible with compounds consisting of three components. The differences in efficiency among the three conditions other than the R Exp D-T are difficult to evaluate due to the large number of Ss who had efficiency scores of 100. However, χ^2 s on the number of Ss scoring 100 and median tests failed to even approach significance. There is no strong evidence that the mean efficiency scores differ significantly among these three conditions. The mean efficiency of 72 for the R Exp T-D condition is comparable to the efficiency scores previously found in stimulus selection studies (Richardson, 1972a).

DISCUSSION

It is clear that selection from the response items occurs with the multiple-choice method of paired-associate learning as well as selection from the stimulus items. The S tends to learn associations between single components of the two items in the paired-associate lists. The amount of response selection is at least equal to the stimulus selection found with the commonly used recall method.

The results are consonant with the finding that free recall of the responses does not increase as a function of multiple-choice paired-associate trials (Hopkins, 1970) and may have implications for the interpretation of studies concerned with response integration (e.g., Hopkins & Schulz, 1969). The multiple-choice method results in associative learning between stimulus and response components and this may be the basis of the recognition on the test trials during the paired-associate task.

There has been some consideration (e.g., Martin, 1972) of how the response might determine the encoding of the stimulus. The distinction between the response item as presented on the study trial of paired-associate learning and the response as emitted by S is so obvious that it may cause some problems. The nominal stimulus as presented on the study trial consists of both the stimulus item and the response item, the S-R pair. The S's task is to record or encode this nominal stimulus so that presentation of the nominal stimulus item leads to the encoding and the encoding leads to the response required of S. Changing the response requirements may change the encoding requirements

and, thus, the difficulty of the task, as demonstrated in the present study by the difference between the results from the multiple-choice and recall methods with trigrams as responses. Previous experiments (e.g., Weaver, 1969) have established a relationship between the stimulus item and response item, with the result that they were easy to encode so that the presentation of the nominal stimulus led to the encoding. This is a demonstration, not that the response required of S effects the encoding, but that the relationships among the stimulus components presented on the study trial effect the encoding.

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