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Independence of A-B and A-C Associations in Retroaction[1]

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After learning an A-B list to a criterion where every pair was correctly anticipated at least once, an A-C, C-D mixed list was introduced for 12 trials. Degree of A-C learning was varied within the list. Contingency analyses on the recall of B and C responses in a subsequent MMFR test were done separately for each A-C condition and for all A-C conditions combined. Either way, the B and C responses were recalled independently of each other. The results provide generality for the DaPolito independent retrieval phenomenon and affirm McGeoch's independence hypothesis.

The stimulus for this experiment was DaPolito's (1966) discovery that in the continuous paired-associate learning situation where some of the pairs satisfy the A-B, A-C interference paradigm, the competing B and C responses are emitted independently of each other in a stimulated response recall test (MMFR). DaPolito (1966), Greeno (1969), and Martin (1969) have accumulated considerable evidence through reanalysis of extant experiments (including Abra, 1969; Birnbaum, 1965; Ceraso & Henderson, 1965; Koppenaal, 1963; Postman, 1964; Postman & Stark, 1965; Silverstein, 1967) that after *S*s have learned paired associates in an interference transfer paradigm, if they are presented with the stimuli one at a time and asked to recall both responses as best they can, recall of one of the responses has no influence on the likelihood of recalling the other. If the paradigm is A-B, A-C, this independent retrieval phenomenon may be expressed as follows:

$$P(B|C) = P(B);$$

that is,

$$P(B\&C) = P(B)P(C).$$

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Although this result has been observed primarily in the MMFR test, DaPolito has demonstrated that these equalities also hold in a forced-choice recognition test.

The existence of this independent retrieval phenomenon may be taken as strong evidence against associative unlearning theory: If the probability of recalling response C after A-B, A-C learning indexes the strength of the A-C association, and if learning A-C entails unlearning of the corresponding A-B association, then we must expect

$$P(B|C) < P(B);$$

that is,

$$P(B\&C) < P(B)P(C).$$

That these inequalities do not hold means that A-C learning does not entail A-B unlearning in a corresponding-pairs fashion.

In none of the experiments examined for independent retrieval of B and C was the degree of A-C learning deliberately manipulated. Thus an implicit assumption behind the presumed importance of the phenomenon is that A-C association strength varies sufficiently over the pairs within the A-C list to allow a fair inference against unlearning theory. Thus the present experiment was designed to vary deliberately the strength of A-C pairs.

Another way to view the present experiment is as an attempt to find a boundary condition on the DaPolito independent retrieval phenomenon.

Method

Design

The only a priori independent variable was degree of second-list learning in the A-B, A-C paradigm. This was a within-list variation.

The first list (A-B) was learned until every pair was responded to correctly at least once; that is, first-list learning continued to the first correct response on the most recalcitrant pair.

Second-list learning continued for 12 trials and was a staged mixture of A-C and C-D pairs. Of the 16 pairs in A-B learning, four did not have corresponding A-C pairs; instead, four C-D pairs were learned during the 12 trials of the second task. This condition will be denoted AC(0) when referring to degree of A-C learning, CD(12) when referring to the complementary degree of C-D learning. Four other A-B pairs were replaced by C-D pairs for the first four trials of second-list learning, and then the corresponding A-C pairs were introduced for the remaining eight trials. This condition will be denoted AC(8) or CD(4). The two remaining conditions were AC(4) or CD(8), and AC(12). The latter refers to those four A-B pairs for which there were 12 A-C trials in the 12-trial second-list task.

Materials

The stimuli were CVCs of 47–53 % association value according to Glaze (Underwood & Schulz, 1960, Appendix A). The responses were common four-letter nouns. Intralist similarity, both formal and semantic, was minimized.

Sixteen A-B pairs were constructed and then divided into four subsets of four pairs each. Each of the four subsets entered into the AC(0), AC(4), AC(8), and AC(12) conditions equally often over *S*s. For C-D learning, there were three sets of four pairs each. These sets served equally often in the CD(12), CD(8), and CD(4) conditions. In all, there were 36 different constructions of the second list, each satisfying the general experimental design.

Subjects

The *S*s were 36 University of Michigan undergraduates who volunteered for paid participation. One *S* was assigned to each of the 36 list constructions just mentioned. Each *S* was tested individually.

Procedure

Learning was by the anticipation method. The lists were presented on a Stowe memory drum at a 2:2-sec rate with a 4-sec intertrial interval. The learning criteria were described above.

During the approximately 2-min interval between first- and second-list learning, the *S*s were instructed fully as to the general nature of the second list.

After completing the second task, an MMFR test was administered. All the stimuli the *S*s had seen in both lists, 28 in all, were presented singly in a 28-page booklet. Each page contained one stimulus and two underscored blanks to the right of the stimulus. The *S*s were instructed to recall the response or responses that went with the stimulus on each page. This test was self-paced with no time limit.

Results

Acquisition

The mean number of trials to criterion on the A-B list was 13.4. A partition of the pairs on the basis of pair difficulty will be taken up later.

The learning curves for the various conditions of the second task are shown in Figure 1. As is evident, the acquisition rates for the three C-D conditions are identical (the upper, coincidental three curves). There is no sign that introduction of A-C pairs disrupted the progress of C-D learning.

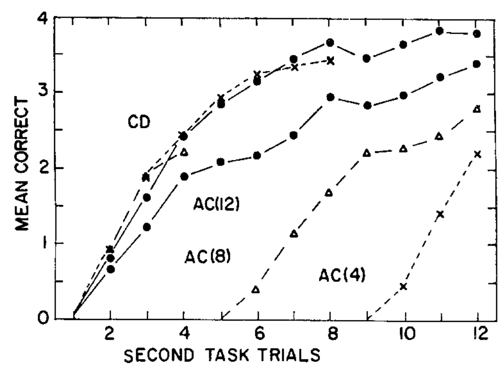

FIG. 1. Mean number correct responses in second-task learning.

The three lower curves in Figure 1 describe acquisition of the A-C pairs from their various points of introduction. Their acquisition rates are similar among themselves but slower than for the C-D pairs. The mean number of correct responses, out of 12 possible, over the first three anticipation trials after the first trial of introduction are 4.1 for AC(4), 3.2 for AC(8), 3.8 for AC(12), and 5.0 for the three C-D conditions combined.

The terminal levels of A-C learning are properly ordered over the AC(4), AC(8), and AC(12) conditions, 2.2, 2.8, and 3.4 correct responses on the average, out of 4 possible, and differ among themselves significantly, $F(2, 70) = 19.00, p < .001$.

Recall

The solid curve with filled circles in Figure 2 shows the proportion first-list responses, P(B),

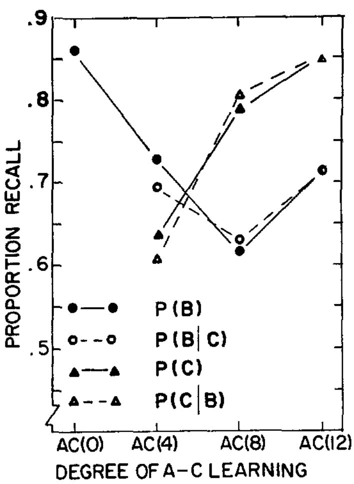

FIG. 2. Unconditional and conditional proportion recall of B and C responses in MMFR as a function of degree of A-C learning.

recalled in the MMFR test as a function of degree of A-C learning. Recall in the AC(0) condition was significantly superior to each of the other three conditions according to the Newman-Keuls multiple comparison test, $p < .01$. The AC(4), AC(8), and AC(12) conditions did not differ among themsleves, $F(2, 70) = 2.07, p > .10$.

For a given A stimulus in the MMFR test, four different response-recall outcomes were possible: Both responses recalled (B,C), only one response recalled (B,$\bar{C}$ or $\bar{B}$,C), or neither response recalled ($\bar{B}$,$\bar{C}$). For the AC(4), AC(8), and AC(12) conditions, the observed frequencies of the four possibilities are posted in Table 1, along with their respective chi squares.[2] Evidently, the marginal totals reflect very closely the individual cell entries.

At the bottom of Table 1 are posted the observed proportion B and C joint recalls, P(B&C), and the expected proportion under an independence assumption, P(B)P(C). Their agreement is essentially perfect.

At the risk of belaboring this outcome, we have plotted in Figure 2 the conditional proportions P(B|C) and P(C|B) along with the unconditional proportions P(B) and P(C).

[2] Because each *S* contributed to more than one cell in each 2 × 2 contingency table, the resulting chi squares are *inflated* to a degree dependent upon the extent of subject-by-pair interaction effects. As for the possibility of the converse effect, it is evident in Figure 2 that there is no danger of the chi squares being suppressed owing to a ceiling effect.

TABLE 1

RECALL FREQUENCIES AND PROBABILITIES

	AC(4)		AC(8)		AC(12)		Pooled	
	C	$\bar{C}$	C	$\bar{C}$	C	$\bar{C}$	C	$\bar{C}$
B	64	41	72	17	88	15	224	73
$\bar{B}$	28	11	42	13	35	6	105	30
χ^2	1.46 ($p > .20$)		.42 ($p > .50$)		.00 ($p > .99$)		.28 ($p > .50$)	
P(B&C)	.444		.500		.611		.518	
P(B)P(C)	.466		.490		.611		.524	

Were B and C retrieval interdependent, we should observe $P(B|C) \neq P(B)$ and $P(C|B) \neq P(C)$. Clearly, however, the corresponding functions are quite coincidental.

Item Analysis

One might note two facts: First, for the AC(4) and AC(8) conditions in Figure 2 the conditional and unconditional proportions are not *exactly* coincidental. Second, over the conditions AC(4), AC(8), and AC(12) in Table 1, the chi squares decrease regularly as degree of A-C learning increases. These facts signal the possibility that a finer analysis might reveal recall dependency between weaker associations. Accordingly, we rank-ordered the four A-B pairs in each condition according to the number of times the response was correctly anticipated in A-B learning, from "strongest" (B_1) to "weakest" (B_4). Then the MMFR contingency analysis was done again for each B_i for each degree of A-C learning. The resulting conditional and unconditional recall proportions are plotted in Figure 3 as a function of A-B strength (B_i) in separate panels for conditions AC(4), AC(8), and AC(12).

Within each of the three A-C degree-of-learning conditions, the declining P(B) function over B_i (solid curves with filled circles) indicates a strong relation between likelihood of B recall in the MMFR test and number of correct B responses in A-B learning. The average heights of the P(C) functions over the three panels of Figure 3 (solid curves with filled triangles) attest to the effectiveness of varying degree of A-C learning.

For the AC(8) and AC(12) conditions, the corresponding conditional and unconditional functions are approximately coincidental; that is, irrespective of A-B associative strength (B_i), we observe $P(B|C) = P(B)$ and $P(C|B) = P(C)$. But for the AC(4) condition, $P(B|C)$ and $P(C|B)$ are less than, respectively, P(B) and P(C) for the weaker A-B pairs (B_2, B_3, B_4); however, the chi-square statistics for these three conditions are only 1.98, 2.06, and 1.00; none reached the value of 2.70 required for significance at the .10 level.

One might note in each of the three panels of Figure 3 that P(C) declines over A-B strength (B_i): The weaker the A-B association, the less likely is recall of the second-list C response in the MMFR test. Using B_i (the rank order of the number of correct anticipations in A-B learning) as the independent variable, we determined the corresponding number of correct responses in second-list A-C learning. For all three degrees of A-C learning, the number of correct second-list anticipations decreased with decreasing A-B strength (B_i), $F(3, 105) = 2.66$, 3.33, and 3.39, respectively, for AC(4), AC(8), and AC(12), with $F(3, 105) = 2.68$ required for $p = .05$.

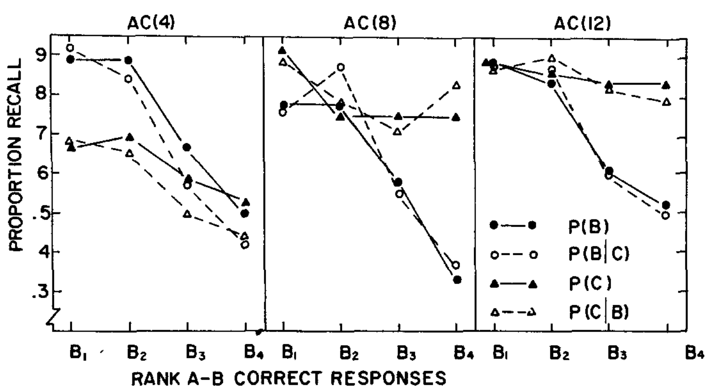

FIG. 3. Unconditional and conditional proportion recall of B and C responses in MMFR as a function of rank order of number of correct A-B responses for AC(4), AC(8), and AC(12) conditions.

Thus, on a *pair-by-pair* basis, ease of first- and second-list learning covary directly.

DISCUSSION

The results of this experiment provide a generalization of the DaPolito independent retrieval phenomenon that qualifies it as a fair inference against associative interference theory—retrieval of B and C in the MMFR test remains independent under deliberate manipulation of degree of A-C learning.

As for the possibility of a boundary condition on the phenomenon, the results are not definitive. The declining chi squares in Table 1 and the differences between the unconditional and conditional proportions for weaker A-B pairs in the AC(4) condition, as shown in the left panel in Figure 3, suggest that retrieval dependency arises when both A-B and A-C are weak. Should this suggestive pattern prove reliable, then the DaPolito independent retrieval phenomenon should be described as follows: The responses B and C are retrieved without mutual interference providing at least one of the pairs, A-B or A-C, is sufficiently encoded or stored in memory.

It is important to note that this independence phenomenon occurs in the face of both proaction and retroaction (Runquist, 1957; DaPolito, 1966; Greeno, 1969; Martin, 1969; present experiment). This means that neither proaction nor retroaction can be attributed to associative interference or unlearning. It means also that McGeoch (e.g., 1942, p. 495) was on the right track with his independence hypothesis and that Melton (1961, pp. 183–184) was justly suspicious of the analytic status of the associative unlearning hypothesis.

We are left in the position of observing retroaction, yet failing to observe pair-wise interference in the A-B, A-C paradigm. Part of McGeoch's (1942) position, in addition to associative independence, was that of response dominance at the time of testing. The Underwood–Postman list-differentiation hypothesis (e.g., Postman, Stark, & Fraser, 1968) is an attempt to give a workable interpretation to this idea. The list-differentiation hypothesis assumes that in A-C learning a response set for the C responses is developed, with a concomitant suppression of the B responses as a class. This is not a pair-wise hypothesis, and hence may be of value in explaining retroaction. On the other hand, there are two reasons why this hypothesis seems inadequate. First, it predicts list-determined clustering where after A-B, A-C learning the B and C responses are free recalled in the absence of the A stimuli. But Martin and Mackay (1970) were unable to observe such clustering; instead stimulus-determined clustering was observed. Second, the list-differentiation hypothesis would seem to predict equal amounts of retroaction in the AC(0), AC(4), AC(8), and AC(12) conditions in the within-lists design of the present experiment. All responses were changed in second-list learning, and under the list-differentiation hypothesis there is no basis for predicting that subsets of the B responses might be suppressed in differing degrees. Our data, however, show that condition AC(0) produced less retroaction than the other three conditions. Thus we are inclined to conclude that an acceptable explanative process for McGeoch's idea of response dominance, and hence for the observed facts of proaction and retroaction, has yet to be proposed.

The observation reported in the final paragraph of the Results section indicates that amount of negative transfer and amount of proactive interference covary with ease of first-list learning, where this covariance is determined on a pair-wise basis. Since the A stimulus is the only common factor in these three tasks (original acquisition, interpolated learning, MMFR test), it follows that stimulus identification learning or encoding might well be a central process in transfer and proaction phenomena. Arguments along these lines have been presented elsewhere (Martin, in press).

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