An analysis of double-function lists

NORMAN J. SLAMECKA

University of Toronto, Toronto, Ontario, Canada M5S 1A1

Double-function list acquisition was analyzed in three experiments which used mixed-list designs and forced-choice recognition tests. Findings showed that specific associative interference occurred both during learning and performance phases, that its source was limited to the immediate backward associate during the learning phase, but that it also involved items further removed in both the forward and backward directions during the performance phase, probably by way of mediated chaining.

In a double-function paired associates list, every item serves as a stimulus in one pair and as a response in some other pair, as A-B, B-C, C-A. Primoff (1938) was the first to employ such lists and to observe that they are quite difficult to learn. He suggested that the reason for this was interference from backward associations. To illustrate with pair B-C, the correct response C encounters interference from the simultaneous elicitation of A, which is the backward associate of B in pair A-B. Every pair in the list would have its own potentially interfering backward associate.

Since that first observation, the marked difficulty of double-function lists relative to conventional single-function lists (A-B, C-D, E-F) has been verified and extended across variations in materials and test procedures, and the findings have consistently been interpreted along the lines of Primoff's (1938) original explanation (Newman, 1964; Umemoto & Hilgard, 1961; Young, 1959, 1961; Young & Fuhrmann, 1965; Young & Jennings, 1964). The effect is quite substantial, with double-function lists taking about twice the trials to mastery as single-function control lists of the same length. Given its reliability and magnitude, it seems fair to say that the phenomenon, and especially its interpretation, has received comparatively little analytic investigation. This paper describes three experiments aimed at specifying in more detail the operation of associative interference in double-function lists.

Primoff's (1938) original suggestion, which has never been seriously modified, elaborated, or questioned, has at least two aspects deserving of clarification. One concerns the temporal locus of the interference, namely, whether it develops during learning, only during performance, or both. If interference from backward associates retards the actual formation of the prescribed forward associations, then it has a learning locus. If, on the other hand, all associations are acquired

without hindrance, but the subject cannot readily discriminate the correct one from its backward competitor, then it has a performance locus. The other aspect in need of investigation is the item locus of the interference. Although Primoff (1938) implicated only the immediate backward associate, it is entirely possible that items further removed, in both the backward and forward directions, could be sources of interference as well. If the list is viewed as a closed loop of associates, with one pair linked to another through their common member, then all items are interlinked and potentially able to elicit any others by activation of forward and backward mediational chains.

EXPERIMENT I

Method

The question of a learning or performance locus of interference was examined first. In order to establish the various necessary conditions, control over the subject's response alternatives was needed. Therefore, the task used was forced-choice associative recognition. Since the phenomenon under test had to do with associative interference, and not at all with response acquisition, the use of a recognition measure should in no way hinder its emergence.

Four conditions were tested simultaneously through a mixed-list design. One-quarter of the items in a paired associates list embodied each condition, as follows. The control subset was single function. The backward subset was double function, with the backward associate included among the recognition alternatives. The no-backward subset was also double function, but choice of the backward associate was precluded by its absence as an alternative. The reversed subset was a special double-function arrangement of the form A-B, B-A, where the forward associate to every stimulus was the same as the backward associate.

If the interference occurs only in the learning phase, the following should happen. Compared to the control, the backward and no-backward conditions would be inferior and equivalent. Since the only difference between these latter is in the test phase, it would be irrelevant. The reversed subset, having no interfering backward associates, is in that respect functionally similar to the control, and it should perform equally with the control. The possibility that the reversed might even exceed the control performance is regarded as problematic, so a conservative expectation of at least no inferiority is preferred. If the interference occurs also in the test phase, the following should happen. The control and reversed conditions would be equivalent, while the backward and no-backward would show im-

This research was supported by National Research Council Grant A-7663. The author is grateful for the assistance of Penny Cohen and Christian Mueller. Requests for reprints should be addressed to Norman J. Slamecka, Department of Psychology, University of Toronto, Toronto, Ontario, Canada M5S 1A1.

Figure 1. Results of Experiment I.

pairment. Between these latter two, the no-backward should perform better than the backward, since it lacks the test-phase source of interference which would additionally impede the backward subset.

Subjects and materials. Twenty University of Toronto students were tested in small groups. Sixty two-syllable nouns from the Toronto word pool were randomly selected and used to construct two independent 24-pair lists. Half of the subjects received one list and half received the other. Six pairs in each list were control, being single function. The backward and no-backward conditions each consisted of six pairs in a completely double-function arrangement. The remaining six pairs constituted the reversed subset, with an A-B, B-A structure.

The recognition test sheets listed the 24 stimuli, each followed by three response alternatives. With one exception, both incorrect alternatives were responses from other subsets of the list. One incorrect alternative for each stimulus of the backward subset was its backward associate. Three forms of test sheets were used consecutively across trials, wherein the order of stimuli and the left-to-right position of the same alternatives were randomly varied.

Procedure. The pairs were shown on slides at a 2-sec rate. Then, a subject-paced three-alternative forced-choice associative recognition test was given, requiring the use of a cardboard mask which exposed one question at a time. Starting at the top of the sheet, subjects were to work downward without omissions to the end, and then were to turn over the sheet and wait for the next trial. There were nine alternate training and test trials, with the slides in a new random order on each presentation and a new sheet for each test.

Results and Discussion

The mean proportions correct on each trial are seen in Figure 1. Analysis of variance ($\alpha .01$) showed all effects as significant: Conditions [$F(3,57) = 56.58$, $MS_e = .05$], Trials [$F(8,152) = 60.85$, $MS_e = .02$], and Interaction [$F(24,456) = 2.54$, $MS_e = .02$]. The various subsets segregated themselves into three distinct groups. Scheffé's test ($\alpha .01$, critical $t = 3.39$) indicated that the control performed no better than the reversed ($t = .83$), but better than the no-backward condition ($t = 5.42$), which in turn was superior to the backward ($t = 6.25$). These differences among conditions were

reflected in both of the two independent sets of materials employed. For the no-backward condition the two sets generated the same means, and for the other three conditions they differed from each other by no more than six percentage points. Thus, the combined data were not inadvertently confounded with an item difficulty artifact. The overall pattern of results is clearly in accord with the hypothesis that associative interference was operating during learning (thus, control superior to no-backward), as well as during performance (no-backward superior to backward) phases. These findings can be compared with those of Young and Fuhrmann (1965), who employed an entirely different methodology and type of analysis. In addition to detecting interference during the associative learning phase, they also suggested substantial difficulty in what they called a "response-consolidation stage." We prefer to identify this latter with the performance phase, as indicated by the present data.

The unhindered performance of the reversed subset lends weight to the view that the inferiority of the other conditions was caused by specific associative interference, and not simply to the fact that identical items occurred on both sides of pairs. Umemoto and Hilgard (1961, Experiment II) used a condition approximating the reversed and suggested that it actually facilitated performance. Since they employed no single-function control list, their statement is difficult to evaluate. The present data show that the reversed subset, although better than the backward and no-backward, produced no absolute facilitation when compared to the control baseline. Thus, it is best interpreted as simply generating no interference.

The upper row of Table 1 shows, for the backward condition, the probability that the backward associate, rather than the unrelated alternative, was responsible for the commission of errors on each trial. Statistical analysis was precluded because not all subjects contributed to every cell, but the data are useful at an inspection level. It is obvious that the overwhelming choice of error was the backward associate, which is consistent with the prior evidence for the existence of associative interference during the performance phase. Also, there appears to be a general upward trend for these figures, in keeping with the notion that, as associative strength grows across trials, so does the potential for associative interference.

EXPERIMENT II

Method

The question of the item locus of interference was taken up next, namely, whether connections in addition to the immediate backward one also contribute to the difficulty of double-function lists. These other potentially interfering items could be construed either as activated through forward and backward mediated links or through direct remote associations. Since the literature affords far better evidence for the existence of mediated chaining than it does for remote associations, the former mechanism seems more plausible to contemplate.

Table 1
Mean Probability of an Error of Each Type, Given That an Error Was Made

Condition	Trial								
	1	2	3	4	5	6	7	8	9
Experiment I: Backward	.72	.82	.84	.81	.92	.91	.94	.86	.92
Experiment II: Backward	.66	.64	.79	.76	.89	.93	.84	.86	.80
2 Forward	.44	.61	.63	.78	.72	.59	.64	.75	.80
2 Back	.50	.63	.63	.72	.70	.67	.64	.72	.52

The overall method was the same as in the prior experiment, utilizing a mixed-list design and a forced-choice associative recognition procedure. In addition to the single-function control subset, there were three other conditions, each represented by a complete double-function structure. These were distinguished only by the particular recognition alternatives available. The backward subset was tested with the immediate backward associate, as in Experiment I. The 2-forward subset was tested with the item twice removed from the stimulus in the forward direction, and the 2-back condition was tested with the item twice removed in the backward direction. To illustrate, consider a sublist A-B, B-C, C-D, D-E, E-F, F-A. For stimulus C the distinguishing alternative would be B if backward, E if 2 forward, and A if 3 back. If these distant items do not contribute to interference, then the control, 2-forward, and 2-back conditions should be equivalent, and superior to the backward. If these distant items do add interference, it is reasonable to suppose that, being mediationaly aroused, it would be weaker or less reliable than that generated by an immediate connection. Therefore, the performances of the 2-forward and 2-back subsets should fall somewhere between the control and backward levels.

Subjects and materials. Twenty subjects from the same source as before were tested in small groups. Two independent lists of 24 paired associates, consisting of two-syllable nouns, were used equally often. Each list had six single-function control pairs and three sets of six completely double-function experimental sublists. Test sheets had the same general layout as in the prior experiment, including the three varied formats. Of the two incorrect alternatives per stimulus item, both were responses from other subsets for the control condition. For the three experimental conditions only one was from another subset, while the other was related to the stimulus: For the backward condition it was the backward associate, for the 2 forward it was the item beyond the correct one, and for the 2 back it was the item two links prior to the stimulus.

Procedure. The procedure used in Experiment I was followed in all respects.

Results and Discussion

The mean proportions correct on each trial are seen in Figure 2. Analysis of variance ($\alpha .01$) showed all effects as significant: Conditions [$F(3,57) = 26.97$, $MS_e = .07$], Trials [$F(8,152) = 51.61$, $MS_e = .03$], and Interaction [$F(24,456) = 2.29$, $MS_e = .02$]. The various subsets segregated themselves into three distinct groups. Scheffé's test ($\alpha .01$, critical $t = 3.39$) indicated that the control performed better than the 2 forward ($t = 3.57$) and the 2 back ($t = 5.00$). The latter did not differ from each other ($t = 1.43$), but were both superior to the backward (2 back, $t = 3.93$; 2 forward, $t = 5.36$). These differences among conditions were also characteristic of the trends in the data for the two independent lists considered separately. The overall pattern of results

is clearly in accord with the hypothesis that associative interference was contributed not only by the immediate backward connections, but also, and to a lesser extent, by items indirectly connected in both the forward and backward directions.

The last three rows of Table 1 show, for all experimental conditions, the probability that the related associate, as opposed to the irrelevant alternative, was chosen in the commission of errors on each trial. It is evident that the related item was largely responsible for the errors in all cases, which fortifies the conclusion that the interference was specifically associative. Another aspect of these data offers at least suggestive support for a mediational mechanism. This is the fact that, on every trial, the backward error probability was absolutely greater than the corresponding 2-back probability. This is consistent with the notion that a mediationaly aroused response (2 back) is contingent upon arousal of the mediator itself (backward), so that the mediator should be a more reliable source of interference than the item which it probabilistically mediates.

In Figure 2 the differences among the three experimental sublists are logically attributable to interference arising at time of test, so that these were performance effects. However, the fact that all three were also inferior to the control level raises the question of whether

Figure 2. Results of Experiment II.

this indicated interference with the learning phase as well. In Experiment I, the fact that the no-backward was inferior to the control was evidence for a learning impairment. Was that impairment due only to competition from immediate backward associates, or did it also include contributions from more distantly related items? An answer to this question was attempted in the next experiment.

EXPERIMENT III

Method

In contrast to the prior experiments, this one was aimed at bringing out effects operative strictly at the time of acquisition. The exclusion of performance effects was achieved by using only irrelevant items as incorrect recognition alternatives. Within a mixed list there were single-function control pairs and discontinuous double-function lists. The latter consisted of two-pair subsets of the form A-B, B-C. Comparisons were made of the performance of each pair type: control, A-B, and B-C. If there were any learning impediments attributable solely to a mediated associate, it would be revealed by the A-B pairs, whose indirect connection with the C items would constitute the only possible source of interference. The B-C pairs should, of course, show the effects of competition from the immediate backward associate A, and no other, since the A items would constitute the only possible source of interference in that case.

Subjects and materials. Twenty-four convalescent patients at Riverdale Hospital in Toronto, all free of any psychiatrically related history, served as subjects. They were tested individually. Two independent lists of 24 paired associates each, consisting of randomly selected two-syllable nouns from the Toronto word pool, were used equally often across subjects. Each list contained eight single-function control pairs and eight discontinuous double-function sets (A-B, B-C) of two pairs per set. Test sheets had the same layout as in the prior experiments, including the three varied forms. Of the two incorrect alternatives per stimulus item, both were responses from unrelated pairs in all cases.

Procedure. Six alternate training and test trials were given, with the pairs shown on individual cards at a 2-sec rate of presentation. A new random order of pairs was obtained on each trial by simply shuffling the cards. The recognition tests were subject paced and involved the use of masks and the same instructions as with the prior experiments.

Results and Discussion

The mean proportions correct on each trial are seen in Figure 3. Analysis of variance ($\alpha .01$) showed both main effects as significant: Conditions [$F(2,46) = 7.42$, $MS_e = .03$], and Trials [$F(5,115) = 44.97$, $MS_e = .03$], with no interaction [$F(10,230) = 1.67$, $MS_e = .02$]. Thus, Figure 3 may be interpreted as showing that the B-C pairs were significantly more difficult than either the A-B or control pairs, which did not differ from each other. The two independent lists showed the same trends among their conditions. The overall pattern of results is clearly in accord with the hypothesis that interference with the learning phase came only from the immediate backward connection. The potential for interference from the indirect forward associate was not realized. It is acknowledged that this experiment actually tested only the forward mediate item but not the backward mediate item (testing for the latter in the same design would have led to intractable

Figure 3. Results of Experiment III.

interpretation problems), so that conclusions about mediated interference would seem to be limited to the forward direction only. However, reference to Experiment II shows that the 2-forward and 2-back subsets did not produce significant performance differences. Since the present A-B pairs tested for 2-forward learning interference and none was found, it could be tentatively inferred that the corresponding 2-back learning interference would also be nonexistent.

CONCLUSIONS

The foregoing analyses of the learning of double-function lists proved useful in bringing out several functional aspects of these materials which were not explicitly dealt with in Primoff's (1938) original explanation, or anywhere else. Taking into account the findings of all three experiments, the following series of conclusions appears to be warranted: (a) Standard double-function lists are more difficult than single-function lists even when the task is associative recognition, showing that response learning is not necessary for the effect. (b) The difficulty of these materials stems solely from specific associative interference, and not from some other consequence of the fact that the same item appears on the stimulus as well as the response side of different pairs. (c) Interference is encountered in both the learning phase, when the prescribed connections are being formed, and in the performance phase, when the prescribed connections must be discriminated from competing associatively related responses. (d) The locus of interference during the learning phase is the immediate backward associate, with items further removed contributing no additional interference. (e) The loci of interference during the performance or discrimination phase are the immediate backward associate and, to a lesser degree, items further removed both in the forward and backward directions. (f) The distantly related items which interfere at the time of test are probably aroused by a process of mediational chaining.

REFERENCES

- NEWMAN, S. E. A replication of paired-associate learning as a function of S-R similarity. *Journal of Experimental Psychology*, 1964, **67**, 592-594.
- PRIMOFF, E. Backward and forward association as an organizing act in serial and in paired associate learning. *The Journal of Psychology*, 1938, **5**, 375-395.
- UMEMOTO, T., & HILGARD, E. R. Paired-associate learning as a function of similarity: Common stimulus and response items within the list. *Journal of Experimental Psychology*, 1961, **62**, 97-104.
- YOUNG, R. K. A comparison of two methods of learning serial associations. *American Journal of Psychology*, 1959, **72**, 554-559.
- YOUNG, R. K. Paired-associate learning when the same items occur as stimuli and responses. *Journal of Experimental Psychology*, 1961, **61**, 315-318.
- YOUNG, R. K., & FUHRMANN, C. I. Function and percentage of occurrence of response members in paired-associate learning. *Journal of Experimental Psychology*, 1965, **70**, 169-175.
- YOUNG, R. K., & JENNINGS, P. C. Backward learning when the same items serve as stimuli and responses. *Journal of Experimental Psychology*, 1964, **68**, 64-70.

(Received for publication November 10, 1975;
revision accepted February 2, 1976.)