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ABSTRACT

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SOURCES OF FACILITATION IN LEARNING CONCEPTUALLY STRUCTURED PAIRED-ASSOCIATE LISTS

Benton J. Underwood, Charles S. Reichardt, and Robert A. Malmi

Northwestern University

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Abstract

The concepts in a hierarchically structured list consisting of 24 number-word pairs were aligned systematically with position and numbers, or with the number stimuli only. Some lists involved an alignment appropriate to only the lowest conceptual level. Other lists were completely unstructured when viewed in terms of either position or number. The lowest-level concepts in the hierarchy were most heavily involved in learning, although the concepts at the higher levels had a small influence. When the hierarchy was aligned with the number series only, the structure was apparent to the subject but his learning was not greatly influenced. Conceptual structure facilitates learning most effectively with a constant order of the instances of the concepts.

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Benton J. Underwood, Charles S. Reichardt, and Robert A. Malmi

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If words are presented in a series so that their order or position in the series corresponds to a hierarchical-conceptual structure, learning is facilitated (Underwood & Zimmerman, 1973; Underwood, Shaughnessy, & Zimmerman, 1974). The present experiment is concerned with the particular aspects of the structure which are involved in the facilitation. The lists for the present study were patterned after those used in the second study referenced above. It will be useful initially to identify the parts of the conceptual structure of the lists for subsequent ease of reference. For the completely structured list, there were three levels of conceptual inclusiveness in the 24-pair list in which the numbers 1-24 were stimulus terms, the 24 words (making up the structure) were the response terms. In the previous studies, and in some of the lists for the present study, the order of the pairs, 1 through 24 as identified by stimulus terms, was constant. The conceptual levels are shown in Table 1.

As may be seen, at Level 1 there were eight concepts. For each of these concepts there were three instances, e.g., 1-robin, 2-owl, 3-bobolink, 4-trout, and so on. When the three instances or pairs under each Level-1 concept were presented in the order shown for the eight Level-1 concepts, the list was said to be maximally structured. In the earlier study (Underwood, et al., 1974), the integrity of the tie between the Level-1 concepts and position and stimulus number was destroyed by randomizing the six pairs under the Level-2 concepts across six positions, e. randomizing the three bird names and the three fish names across the stimulus numbers 1-6. It was possible to destroy the integrity of both Levels 1 and 2 by randomizing the 12 animate object names across the numbers (and positions) 1-12, and randomizing the inanimate object names across the numbers 13-24. Finally, all conceptual organization was eliminated by randomizing the words over all 24 positions and numbers. The results indicated that as the integrity of the conceptual levels from Level 1 through Level 3 was eliminated, acquisition became slower and slower. It was concluded that conceptual structure influences learning by restricting the range of possible positions and numbers for which any given word is appropriate.

The above evidence might seem to indicate that when the list was completely structured (when Levels 1, 2, and 3 were intact) that all three levels were involved in the rapid learning observed. However, because the previous studies were primarily concerned with retention, they were not analytical with regard to the role played by each level in a fully structured list. The overt-error data showed that most of the errors were appropriate to the Level-1 concepts, but such evidence does not necessarily indicate that the concepts at the other two levels were not involved in the error production. It seems apparent that to determine if two or more conceptual levels operate jointly to influence

Table 1

The Three Conceptual Levels in a 24-Pair List Where There Are Three Instances for Each Concept at Level 1

Level 1	Level 2	Level 3
Birds	Animals	Animate
Fish	Animals	Animate
Fruit	Plants	Animate
Flowers	Plants	Animate
Brass Instruments	Musical Instruments	Inanimate
String Instruments	Musical Instruments	Inanimate
Cutting Weapons	Weapons	Inanimate
Ballistic Weapons	Weapons	Inanimate

learning, the integrity of the levels must be eliminated from the top (Level-3) down. That was the first purpose of the present study, although we asked only about the joint effect of all three levels versus Level-1 alone.

A second purpose of the experiment was to examine the role of conceptual structure in learning when position in the series and stimulus number were not confounded. In one of the earlier studies (Underwood & Zimmerman, 1973) it was shown that numbers in consecutive order added nothing to the learning if the position of the words in the structured list was constant from trial to trial. We now ask if the number series can function independently to tie the structure together. This was accomplished by varying the order of the pairs from trial to trial as in the usual paired-associate procedure. With varying order of the pairs from trial to trial, a hierarchical conceptual structure would be tied to the stimulus terms only, and position in the series would be an invalid cue.

As will be seen, to obtain some reasonable degree of conclusiveness on the two issues prompting the experiment, seven different types of lists were constructed from the 24 words. Three of these used a constant order of presentation from trial to trial, four used a varied order.

Method

Lists. All lists involved the same 24 words as response terms, and the numbers 1-24 as stimulus terms. The conceptual levels of the list as shown in Table 1 were represented by the following 24 words: _robin_, _owl_, _bobolink_, _trout_, _guppy_, _bullhead_, _apple_, _lemon_, _fig_, _rose_, lilac, marigold, trumpet, tuba, bugle, guitar, banjo, fiddle, knife, bayonet, dagger, rifle, cannon, shotgun. These words were taken from the Battig and Montague (1969) tables, and as listed here, the words within a concept have decreasing frequency. In the present study no effect of frequency differences were found; therefore, no further mention will be made of it. The seven different lists as constructed from the 24 words will now be described.

List C-S. A constant (C)-order list, with complete structure (S). The 24 words as listed above were paired with the numbers 1-24, and this order occurred on each learning trial. Actually, three different forms of the list were constructed but all three had the same properties. For example, in a second form the inanimate object names occupied the first half of the list, the animate object names the second half. For all constant-order lists three forms were used to parallel the necessity of using three different orderings of the pairs when the order varied from trial to trial. The different forms will not enter into the analyses of the data.

List C-S3. A constant-order list in which blocks of three pairs occurred, with the pairs in each block representing one of the eight Level-1 concepts. The position of the blocks in the series of blocks was such that Level-2 and Level-3 concepts were not appropriate for the ordering of the blocks. For example, in one form the three bird names were followed by the three ballistic weapons, which were followed by the three brass instruments, and so on. The consecutive numbers 1 through 24 appeared with positions 1 through 24. Position and numbers, therefore, were useful in identifying response terms only within a block of three pairs. A comparison of the learning on this list with the learning on List C-S as described above should provide the evidence on whether Levels 2 and 3 are involved in learning the completely structured list.

List C-NS. A constant-order list with no structure (NS), in which the numbers occurred in the order 1 through 24, but the response words were paired randomly with the numbers. Therefore, the conceptual structure should in no way aid the subject systematically in the placement of words in the series during learning. The learning of this list will give evidence on the amount of facilitation produced only by Level-1 concepts if such facilitation appears in the comparison with Lists C-S and C-S3.

List V-S. In this list the orders of the pairs varied (V) from trial to trial. There were three orders determined by three random orderings of the numbers. However, the pairing of the words and numbers were such as to yield a completely structured list based on the stimulus numbers, just as was the case for List C-S.

List V-S3 For this varied-order list the pairings of numbers and words was exactly the same as for List V-S. In addition, the three words within each of the eight Level-1 concepts always occurred in adjacent positions and in the same order on each trial. Across trials, however, the position of these eight blocks was varied, subject to the restriction that no block followed another block more than once across the three orders, and that no block was used as the first block or the last block in the series more than once.

List V-NS. This list resulted from three random orders of the pairs with the pairings of the words and numbers being random. Thus, as with List C-NS, there was no relationship between the number series and the conceptual relationships among the words. Unlike List C-NS, the order of presenting the pairs varied across three trials before the orders were repeated.

List V-NS3. It seemed possible that the learning of List V-S3 might be facilitated simply because pairs within blocks of three pairs always occurred in the same order from trial to trial despite the fact that the order of the blocks varied from trial to trial. As a control for this, List V-NS3 was constructed. The numbers and words were paired randomly (no structure) but eight blocks of three unrelated words each were used. The order of the three words within the block was constant from trial to trial but the order of the blocks varied across the three different orders. The numbers within each block were consecutive numbers just as was true for List V-S3, but the response terms to those numbers were unrelated.

Procedure and subjects. The lists were presented at a 3:3 sec. rate for anticipation learning, with a 6-sec. intertrial interval. The criterion of learning was 18 correct responses on a single trial. Although recall and relearning measures were taken after 24 hr., the data on retention will not be reported since they add no information not given in the previous studies. The relearning measure mirrored almost exactly the original learning.

Thirty undergraduate students were assinged to each of the seven lists following a block-randomized schedule which included the three different forms used for the three constant-order lists.

Results

Learning. Two measures of learning are shown in Table 2; the mean number of correct responses on the first anticipation trial, and the mean number of trials required to reach the criterion. A careful inspection of these scores shows that the correlation between the two is very high; therefore, for the statistical analysis, only the trials-to-criterion measure will be used.

The first question asked was whether or not for the constant-order lists the higher conceptual levels (Levels 2 and 3) influenced learning over and above the influence produced by the Level-1 concepts. The answer is affirmative as given by a comparison of the scores for Lists C-S and C-S3. The difference in mean trials to learn the two lists (.83 trials) gave a t (58) of 2.52, $p < .05$. To examine the magnitude of the influence of Levels 2 and 3, the magnitude of the effect of total structure needs to be specified first. This total effect is given by the difference between Lists C-S and C-NS, which is 4.46 trials. Since all but .83 trials of the total is accounted for by the Level-1 concepts, it may be concluded that approximately 81% of the effect of the total structure is to be attributed to Level-1 concepts, 19% to Levels 2 and 3 combined.

The second question asked was whether the conceptual structure could be tied to the number series only (eliminating the confounding with serial position as exists in the constant-order lists), and thereby facilitate learning. The direct answer to this question is given by a comparison of the learning on Lists V-S and V-NS. List V-S was learned somewhat more rapidly than List V-NS, t (58) = 2.46, $p < .05$. However, the conceptual structure in the varied-order list was relatively ineffective without being combined with a constant serial order. This is shown by the contrast in the difference between the constant-order lists C-S and C-NS (4.46 trials), and the difference between the varied-order lists V-S and V-NS (2.24). A 2x2 analysis of variance using constant-varied as one variable, and structure-no structure as the other, showed that not only were the two main effects reliable as already inferred, but also that the interaction was reliable, F (1, 116) = 4.29, $p < .05$).

The final question concerns the role of a constant order of three instances of a concept (paired with sequential numbers) in an otherwise varied-order list (List V-S3). Performance on this list was nearly as good as on the constant-order list (List C-S3), and far better than for the list in which the constant-order of the three pairs within blocks involved unrelated words (List V-NS3), and also far better than for List V-S. These findings emphasize again the importance of the Level-1 concept blocks in the learning.

To summarize: the mean trials to learn for the seven lists varied from 2.50 trials (List C-S) to 8.77 trials (List V-NS). The reasons

Table 2

Mean Number of Correct Responses on the First Anticipation Trial, and Mean Number of Trials to Reach the Criterion of 18 Correct Responses on a Single Trial

	First Trial Correct		Trials to Criterion	
List	M	σ	M	σ
C-S	12.90	4.66	2.50	1.18
C-S3	9.67	4.00	3.33	1.28
C-NS	3.97	1.97	6.96	3.21
V-S	4.53	2.90	6.53	3.17
V-S3	9.83	4.41	3.57	1.70
V-NS3	3.57	2.24	8.30	3.99
V-NS	3.07	1.87	8.77	3.70

for the variations of the other five lists between these extremes can be rather specifically identified. Although all three levels (at least Levels 1 and 2) of the conceptual structure were involved in the learning, the bulk of the positive effect of hierarchical structure was produced by the lowest level concepts. A constant serial order of the paired-associate lists aided learning somewhat, but the largest change is produced by a joint effect of constant order and structure, with the major influence of the latter being confined to a constant serial order of the instances of the Level-1 concepts.

Overt errors. Several analyses of overt errors were undertaken in an effort to understand more thoroughly the mechanisms underlying the learning scores. In the first analyses to be reported, all overt errors (except extralist intrusions) were classified as to their appropriateness for blocks of increasing sizes, these blocks representing different degrees of inclusiveness of the conceptual levels. List C-S may be used as a model for describing the levels. Level-1 errors represented those within the appropriate block for Level-1 concepts as identified by stimulus numbers (1-3, 4-6, 7-9, and so on). Level-2 errors were those that fell within the appropriate block representated by Level-2 concepts, hence, identified by stimulus numbers 1-6, 7-12, 13-18, 19-24. Level-3 errors were those falling within the appropriate half of the list (1-12, 13-24), while Level-4 errors were those that fell in the inappropriate half. It should be clear that each error was classified only once, namely, within the smallest appropriate block size. These classifications were made for all seven lists in the same manner using blocks as identified by stimulus number. It can be seen that for the unstructured lists the classification by stimulus number produces values for overt errors related to stimulus numbers only (List V-NS), for overt errors resulting from the confounding of position and stimulus number (List C-NS), and to a combination of both (List V-NS3). For all other lists, the number blocks reflect in addition at least Level-1 concepts. For each subject the percentage of total errors falling at each level was determined For the initial discussion, the means for each level for the seven lists are referenced, and these values are shown in Table 3.

The learning data in Table 2 showed that List C-S was learned more rapidly than List C-S3. This was taken to mean that the concepts at Levels 2 and 3 added to the facilitation produced by the Level-1 concepts. If the concepts at Levels 2 and 3 produce facilitation by restricting possible positions (or numbers) for which a given word is appropriate, some evidence for this should be found in the overt errors. More particularly, the subjects assigned List C-S3 should have produced more errors at the higher levels than should the subjects assigned to List C-S. There is some support for this expectation in Table 3. The subjects learning List C-S3 made more errors at Levels 3 and 4 than did the subjects learning List C-S, at the expense, largely, of fewer Level-2 errors. This presumed interaction is most appropriately evaluated statistically by using the raw numbers of errors in each category. Such an analysis showed the interaction to be reliable,

Table 3

Mean Percent of Total Errors Falling at each of the Four Levels for the Seven Lists

(See text for explanation of levels)

List	Level 1	Level 2	Level 3	Level 4
C-S	44.4	31.0	10.6	13.8
C-S3	50.3	15.5	13.6	20.8
V-S	45.8	36.6	10.4	7.1
V-S3	40.3	24.0	23.5	12.1
C-NS	23.3	19.1	21.5	36.1
V-NS3	18.8	26.4	19.1	35.4
V-NS	16.3	25.5	24.5	33.7

F (3, 174) = 2.94, $p < .05$.

Although List V-S was learned at a relatively slow rate, the pattern of errors exhibited in learning this list was much like the pattern produced for the other lists having at least Level-1 structures intact. In fact, the first four lists as given in Table 3 have approximately the same error patterns (decreasing errors from Level 1 through Level 4), while the last three lists, which involved no structure, have the opposite pattern (increasing errors across levels). To return to List V-S, it may be asked why the list wasn't learned more rapidly in view of the fact that the error pattern indicated that responding was appropriately limited by the structure to relevant stimulus numbers.

It seems likely that in learning List V-S the subjects rather quickly learned the approximate range of stimulus numbers associated with each Level-1 concept. However, unlike the constant-order lists, and unlike List V-S3, the three instances within each concept never occupied adjacent positions; the instances were scattered throughout the 24 pairs on a given trial, and this differed from trial to trial. Within the trial, therefore, the subject may forget which instances occurred earlier in the series; this could include those given correctly or incorrectly as well as those instances present when no response was given. One conservative index of these possibilities would be the number of times on a trial which the subject produced an erroneous response which had been produced erroneously earlier on the trial. This is a conservative measure because it does not include those cases where the subject had responded correctly with a word and then later in the same trial responded incorrectly with the same word, nor does the measure include the reverse possibility. Nevertheless, an analysis of the proportion of total errors made which were repeated wrong responses within a trial shows the value to be .14 for List V-S, and .08 for List V-S3. The difference between the two means is reliable, t (58) = 2.26, $p < .05$. Whether this difference reflects a tendency of such psychological magnitude as to account for the differences in learning the two lists is not known, of course. In any event, the evidence in Table 3 clearly shows that the subjects who learned List V-S perceived the relationships between stimulus number and concepts although this knowledge did not have a substantial influence on the rate at which the list was learned. Again, the results for List V-S emphasize the importance of constant position for the facilitation of learning by conceptual relationships.

The overt errors per opportunity (number of overt Errors/no responses plus errors) were higher for the four lists with some structure than for the three with no structure. Again, within each grouping, the differences were small. For the 120 subjects given the structured lists the mean number of (CR) errors per opportunity was .29; for the 90 subjects who learned the unstructured lists, the corresponding value was .18, with the difference being reliable (t = 4.62). As the data in Table 3 demonstrated for the structured lists, overt errors made in learning such lists are more likely to represent "near misses" than are the errors made in learning the unstructured lists. This raises the possibility that more recorded correct responses represented guesses for the subjects who learned the structured lists than was true for the subjects who learned the unstructured lists.

Two types of evidence suggest that guessing did not play a major role in producing the responses recorded as correct. First, a subject who follows a "guessing strategy" would be expected to "learn" more rapidly than one who does not. Furthermore, guessing should lead to more overt errors as well as to more correct responses. Consequently, the correlation between errors per opportunity and trials to learn should be negative within each of the four groups of subjects learning the structured lists. This was not the case: the four correlations were .04, .26, -.24, and .10, for Lists C-S, C-S3, V-S, and V-S3, respectively.

The second fact which argues against guessing as being fundamentally involved in the recorded correct responses is shown by an examination of responding within the blocks of three pairs representing Level-1 concepts. The data show (for all lists with this structure) that the number of correct responses on the second pair in the block was higher than the number correct for the first pair, but the number correct on the third pair was not greater than the number correct for the second pair. An effective guessing strategy should result in a continuous increase in correct responding across the three pairs within a block.

Discussion

When the results for the present study are viewed in conjunction with those from two previous studies (Underwood & Zimmerman, 1973;

Underwood et al., 1974), a fairly clear picture emerges as to the way in which a hierarchical-conceptual structure influences learning. In the description of this picture, two cases are involved. The first is represented by the lists in which the stimulus numbers and position are both aligned with the three-level hierarchical structure, and the second is represented by the lists with varied orders of presentation in which only the stimulus numbers reflect the structure.

It seems beyond doubt that the concepts at Level 1 (e.g., birds) are represented in the implicit responses of the subjects to the instances. Based upon these implicit responses, the subject rather immediately learns (as inferred from first-trial performance) that the list consists of blocks of three instances of several concepts. Therefore, for at least the second two instances in each block, a restriction rule concerning the appropriateness of various alternative responses can be applied. Subsequent learning consists of acquiring the particular words fitting the concepts, the ordering of the three words within the block, and the order of the eight blocks. The evidence from the present study indicates that learning the order of the blocks is aided by the higher-level concepts, particularly we believe, the Level-2 concepts. Yet, overall, approximately 80% of the facilitation of learning due to the structure must be allocated to the influence of Level-1 concepts.

The above description refers to the constant-order lists, but this description is reflected in the results for the varied-order lists. When the 24 pairs were presented in completely random order from trial to trial, but with structure in correspondence with the number stimuli, the error data indicated that the structure was at least recognized by the subjects in spite of the fact that the structure did not markedly enhance learning. However, the moment the Level-1 concept instances were given a constant order within a block of three pairs, learning rate improved dramatically even though the blocks varied in position from trial to trial.

It appears that the lowest level of conceptual relations within a hierarchical structure is largely responsible for the facilitation observed in learning. This generalization must have limitations. Very likely, if the number of instances within a Level-1 concept was reduced from three, to two, to one, the next higher level (Level 2) would more and more dominate the learning. It is less clear as to what the consequences would be if the number of instances within a concept was increased since length of list would necessarily covary if Level 2 and Level 3 concepts remain the same in number.

In one of the earlier studies (Underwood & Zimmerman, 1973), constant-order lists were presented with and without number stimuli. Differences in learning and in other types of evidence, e.g., position effects, were small, thus implicating position as a critical correlate of structure. The present results give support to this inference. Structure tied only to the number series, and not position, had a relatively small influence on learning in spite of the fact that the error data indicated that the structure was limiting response placement.

Finally, in agreement with previous studies, the present results
show no evidence that the conceptual relationships among the words
produced interference in learning the nonstructured lists. Such inter-
ference should be indexed by overt errors in which the instance of one
concept replaces another instance of the same concept. When the proto-
cols for the three nonstructured lists were scored for these types of
errors it was found that of the total errors they constituted only 8%,
8%, and 12%. If a subject knew only one of the 24 response terms, and
if he "placed" it randomly opposite the stimulus terms, the chances
that it would result in an overt error within the appropriate Level-1
concept would be 8.7% (2/23). Thus, the overt errors do not indicate
interference. That the subject knew that there were instances of
several concepts represented in the list seems beyond doubt. That the
learning did not seem to suffer interference from this knowledge
represents another illustration of the capacity of subjects to select
information from memory which is to a relatively high degree appro-
priate to the demands of the task. Response learning of the words in
the unstructured lists is undoubtedly aided by the concepts represented
in the lists, but the subject appears to know that the pairings of the
words and numbers is in no way related systematically to the conceptual
information and his overt responding mirrors this knowledge.

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