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DEPTH, SPREAD, AND CONGRUENCE OF ENCODING IN MEMORY

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PERSONNEL AND TRAINING RESEARCH LABORATORY

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Four studies were performed to evaluate the effects of depth, spread (elaboration), and congruence of encoding on memory performance. Undergraduate students of educational psychology were trained in one or several strategies for learning paired associates, word recognition, or free recall of words. The several strategies employed differed in the depth, spread, or congruence of the encoding required. Strategies which were assumed to emphasize depth or congruence of encoding were found to facilitate recall. Self-reported strategies were most likely to facilitate recall when they involved

Item 20 (continued).

congruent encoding or were few in number. Results were interpreted as providing support for the view that depth and congruence of encoding facilitates retention, but there was no evidence for a beneficial effect of spread of encoding. Postexperimental questionnaire data indicated, however, that one of the strategies taught was not widely used by participants. In view of this finding, a case for spread of encoding is still possible. Results emphasize the need to obtain independent data on the strategies which participants report as actually being used.

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Basic Research in Training

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FOREWORD

The Personnel and Training Research Laboratory of the Army Research Institute for the Behavioral and Social Sciences (ARI) conducts research to support training methods to optimize skill acquisition and retention. A variety of research is being conducted on the effects of various learning strategies on skill acquisition and retention. ARI, in cooperation with the Defense Advanced Research Projects Agency (DARPA), is especially interested in training that improves the trainee's ability to learn.

This report is one of a series on the development of the Cognitive Learning Strategies Training Program. This report analyzes the depth, spread, and congruence of encoding in memory. Research was conducted at the University of Texas at Austin with the assistance of Walter E. Cubberly, Thomas P. Washington, and Magdalena M. Rood. It was done under contract DAHC19-76-C-0026, monitored by Joseph S. Ward of ARI under Army Project 2Q161102B74F, and funded by DARPA.

JOSEPH ZEIDNER
Technical Director

DEPTH, SPREAD, AND CONGRUENCE OF ENCODING IN MEMORY

BRIEF

Requirement:

To explore the effects of encoding variables on human learning. Encoding refers to the way in which a learner chooses to learn the material presented.

Procedure:

Four experiments explored a levels-of-processing framework of memory research, investigating three theoretical constructs: depth, spread, and congruence of encoding. Depth of processing refers to the idea that human information processing progresses from a physical or structural analysis stage to deeper, semantic analysis. Memory is the by-product of these operations, with increased memory resulting from deeper analysis. Spread of encoding refers to processing within a given level (semantic or structural); multiple encodings within one level should increase memory of the material to be learned more than a single encoding strategy. Congruence of encoding refers to how well the choice of strategy results in integrating the form of encoding and the material to be learned. Increased congruence may lead to increased memory.

Within each of the four experiments, learners were given the same practice tasks and tests: lists of paired-associate nouns in three cases and a list of nouns for free recall in the fourth. Type of instruction and training of encoding strategy were varied to test for differences in recall and recognition due to variations in depth, spread, and congruence of encoding. Participants were trained to use encoding strategies at a shallow level (looking for physical similarities and differences in words) or a deep one (forming sentences, defining words, noting similarities and differences in meaning); to use single or multiple strategies to test for effects of spread on encoding; and to use congruent strategies (forming sentences of word pairs, producing single definitions of words) or divergent strategies (noting differences between words, producing multiple definitions). Performance on test lists was measured as a function of the number and type of encoding strategies participants were trained to use.

Findings:

Depth of processing seems to facilitate learning; training in semantic analysis led to better performance than training in structural analysis. Congruence also facilitates learning; the search for semantic similarities tended to help more than the search for semantic differences, and producing a single synonym or definition helped more than producing multiple ones. There was little support for spread of encoding; combinations of different strategies did not clearly surpass single strategies. Self-reported strategies were most likely to aid recall when they involved congruent encoding or were few in number.

Utilization of Findings:

Encoding which involves semantic analysis of the material to be learned and the use of a single congruent encoding strategy will produce the best results when incorporated into a cognitive learning strategies training program.

DEPTH, SPREAD, AND CONGRUENCE OF ENCODING IN MEMORY

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DEPTH, SPREAD, AND CONGRUENCE OF ENCODING IN MEMORY

Introduction

Over the past 15 years multistore theories of information processing and memory have greatly influenced research on the psychology of learning. These theories assume an information flow among several kinds of storage, e.g., sensory stores, short-term stores, and long-term stores. Craik and Lockhart, in 1972, criticized the adequacy of the multistore memory models. They contended that the distinguishing features of the stores (capacity, coding, and forgetting characteristics) were vaguely defined and that the hypothesized characteristics of the stores were not consistent across different learning paradigms. In addition, these models were somewhat restrictive in the type of research and applications they generated.

Alternatively, Craik and Lockhart proposed a more parsimonious framework for research based on a levels-of-processing approach. They assumed that the perceptual processing of a stimulus can be described by a continuum of analyzing operations. Physical and structural properties were said to be processed first, followed by more elaborate semantic analyses. It was assumed, in addition, that the memory trace was a product of these analyzing operations and that deeper, semantic analyses yielded a stronger memory trace. Based on subsequent research, Craik and Tulving (1975) augmented this approach to include the concept of spread, or elaboration, of encoding within a given processing level. The concept of depth of processing implies a progression through levels of encoding. The spread of processing concept, on the other hand, presumes that at a given processing level a unit of information might be elaborated in several different ways, or for a greater or lesser amount of time.

The depth of processing framework implies that, among single encoding strategies, sentence formation and semantic analysis should result in better retention of information than shallow-level structural analysis (i.e., phonemic analysis, or analysis of surface features). In addition, sentence formation and semantic analysis should result in approximately equal retention of information because they both require a deep level of processing, i.e., an understanding of the meanings of the words. Furthermore, the depth of processing framework suggests that regardless of the number of strategies used in combination, those combinations involving semantic analysis should produce the best retention without significant differences among themselves. In other words, the depth of processing framework implies that as long as semantic analysis of the information occurs, whether by one encoding strategy or by several, there should be no differences in retention of the information.

In contrast, the spread of processing framework, as it is applied here, implies that, if depth of encoding were controlled, the use of several encoding strategies in combination should facilitate performance more than the use of a single encoding strategy. Additionally, among combinations that are controlled for depth of processing, those including more strategies should allow for more effective performance than those including fewer strategies. Our first study in this area was designed to test predictions from both depth-of-processing and spread-of-processing viewpoints.

Experiment 1: Depth and Spread of Processing

Method

Participants. One hundred fourteen students, drawn from undergraduate educational psychology classes at The University of Texas at Austin, were randomly assigned to one of six treatment groups. Participation was part of their course requirement.

Materials. The experimental materials consisted of six paired-associate training lists and one paired-associate test list. All lists were constructed using the concreteness, imagery, and meaningfulness norms of Paivio, Yuille, and Madigan (1968). One hundred eighty words were randomly selected with the restriction that half were high concrete (ratings ranged from 6.69 to 7.00 on a 7-point scale) and half were low concrete (ratings ranged from 1.18 to 3.54). In constructing the lists, one concrete noun was inadvertently converted to an adjective (slipper to slippery). These words were then randomly paired to make 90 word pairs, with the restriction that half of the pairs were high-high and half were low-low in concreteness. Thirty pairs of each type were randomly selected to form the six training lists, with five high-concrete and five low-concrete pairs per list. The remaining 15 word pairs from each group were used to form the test list of 30 word pairs. In this test list the average meaningfulness level of the word pairs was 5.96.

For training purposes the practice lists were printed for distribution to each student in all conditions. The test pairs and their corresponding stimulus words were printed separately on slides and presented with a Kodak slide projector controlled by an automatic timing device.

Design and Procedure. Students in each group were trained for 1 hour and 15 minutes in the application of one, two, or three specific encoding strategies. They were allowed 10 minutes to work on each of the six paired-associate training lists. During training, students in each group wrote out their elaborations so that the experimenter could monitor their use of the strategies and provide corrective feedback when necessary.

Students in the structural analysis group (N = 21) were trained only in structural analysis on all six lists of word pairs. They were asked to note as many similarities and differences in physical features (i.e., phonetic elements, spelling patterns, number of syllables) between the members of each pair as they could. For example, given the word pair, CABIN-FLAG, a student might note CABIN begins with one consonant, whereas FLAG begins with two; both words have a similar a sound; and CABIN has two syllables whereas FLAG has only one. Structural analysis was considered to be associated with shallow-level processing.

Students in the sentence formation group (N = 18) applied only sentence formation to each of the six lists of word pairs. This strategy involved forming a sentence which meaningfully related the two members of the pair. For example, given the word pair DOOR-DOVE, a student might form the sentence "Above the door perched the dove."

Members of the semantic analysis group (N = 19) were trained in the use of semantic analysis on all six lists of word pairs. This strategy involved relating the words of a pair using a common category or concept, or comparing the categories of meaning for the two words of each pair. For example, the pair EXPLANATION-SALARY might be related by the concept EXCHANGE. EXPLANATION involves a verbal exchange, whereas SALARY involves a monetary exchange. Or, comparing the pair BLUE-SOUR, a student might note that both of these words can be detected by one's senses, BLUE being detected by the sense of sight and SOUR being detected by the sense of taste.

Students in the structural/sentence group (N = 18) used the structural analysis strategy on three training lists and the sentence formation strategy on three lists. Members of the structural/semantic group (N = 19) used the structural analysis strategy on three lists and the semantic analysis strategy on the other three lists. Students in the structural/sentence/semantic group (N = 19) used all three strategies, two training lists per strategy. (The instructions presented to this group using all three strategies may be found in the Appendix.)

After training, each group was tested on a new list of 30 word pairs, using the study-test method (that is, pairs for study and stimulus terms for recall were presented in alternate blocks). Each of the test pairs was projected on a Da-Lite screen for 15 seconds. The students were asked to apply the strategy or strategies they had previously practiced to help them form an association between the words of each pair. Testing consisted of two complete study-test trials using a 15-second presentation rate for both study and test segments. Different random orders of presentation were used for each trial.

Results and Discussion

A 6 x 2 analysis of variance (groups x trials) with repeated measures on trials was performed with the number of correct paired-associate test responses as the dependent variable. The results are summarized in Table 1. Significant main effects were found across groups and across trials ($F(5,108) = 7.79$, $p < .001$ for groups; $F(1,108) = 592.62$, $p < .001$ for trials). A significant interaction ($F(5,108) = 3.53$, $p < .01$) probably reflected a ceiling effect in the second trial (see Table 2). (Trial 1 group means were negatively correlated with mean gain scores, $r = -.95$).

In order to specify sources of variance more precisely five planned

TABLE 1

Source Table for Repeated Measures Analysis of Variance on the Paired-Associate Test in Experiment I

Source	SS	df	MS	F	p
Groups	1744.76	5	348.95	7.79	< .001
Trials	4620.43	1	4620.43	592.62	< .001
Groups x Trials	137.46	5	27.49	3.52	< .01
Error Groups	4835.82	108	44.78		
Error Within	842.03	108	7.80		

TABLE 2

Means and Standard Deviations of Each Treatment Group on the Paired-Associate Test in Experiment I

		Trial 1		Trial 2	
Group	N	Mean	SD	Mean	SD
Structural Analysis	21	10.33	6.99	22.05	7.19
Sentence Formation	18	21.67	4.03	28.78	1.31
Semantic Analysis	19	17.16	5.61	25.84	3.55
Structural/Sentence	18	18.83	6.58	26.89	4.19
Structural/Semantic	19	16.47	5.88	26.84	3.24
Structural/Sentence/ Semantic	19	19.00	5.60	27.16	2.99

comparisons were performed (see Table 3). The comparisons were performed only on data from the first trial because of the aforementioned ceiling effect, which greatly reduced the between-group variance of the Trial 2 data, and because no floor effect was apparent on Trial 1. A comparison of the performance of all single-strategy groups versus all multiple-strategy groups did not yield a significant difference. Among the single-strategy groups, students in the sentence formation and semantic analysis groups combined significantly outperformed students in the structural analysis group ($F(1,108) = 24.69$, $p < .001$). Furthermore, students in the sentence formation group significantly outperformed those in the semantic analysis groups ($F(1,108) = 4.20$, $p < .05$). Among the multiple-strategy groups, students who received training in all three strategies did not significantly outperform those who received training in only two strategies. There was no significant difference between performances of students in the groups which used two strategies.

The non-significant single-strategy versus multiple-strategy comparison implies that sheer quantity of available encoding strategies is not sufficient to insure superior performance. The processing level at which these strategies operate must be taken into account. The results of the single-strategy group comparisons support this conclusion, and thus are compatible with Craik and Lockhart's depth-of-processing approach. Here, students who were trained to use an encoding strategy that operates at a deep, semantic level of processing (sentence formation or semantic analysis) significantly outperformed students trained to use an encoding strategy that operates at a shallow level of processing (structural analysis). The similar performance of the four groups of students who were trained to apply only one deep-level strategy (singly or in combination with the shallower structural analysis

TABLE 3

F Values and Associated Probabilities for Planned Comparisons Between Several Combinations of Treatment Groups in Experiment I

Comparison	F	p
Single Strategy Groups vs. Multiple Strategy Groups	1.86	N.S.
Single Strategy Groups: Shallow vs. Deep Levels (Structural Analysis vs. Sentence Formation and Semantic Analysis)	24.69	$< .001$
Single Strategy Groups: Deep Levels (Sentence Formation vs. Semantic Analysis)	4.20	$< .05$
Multiple Strategy Groups: Two vs. Three Strategies (Structural/Sentence and Structural/Semantic vs. Structural/Sentence/Semantic)	.51	N.S.
Multiple Strategy Groups: Two Strategies Only (Structural/Sentence vs. Structural/Semantic)	1.15	N.S.

strategy) also argues for the predictive value of the depth-of-processing model.

There was little support for the spread-of-processing framework in this study. Neither the comparison between single and multiple strategies nor the comparison between two and three strategies was significant.

Of the two deep-level tasks sentence formation was superior to semantic analysis. At this stage we can only speculate about what additional variable may be responsible for this result, but one possibility is unity or congruence of encoding. Recent investigations by Moscovitch and Craik (1976) show that congruence of encoding is an important factor in retrieval at deep levels. The syntactic unity of a meaningful sentence may have provided students with a more congruent deep-level encoding than semantic analysis would have provided.

In order to investigate the significance of the congruence of encoding concept, a follow-up study was designed. The semantic analysis strategy was selected for use in the follow-up study as it was felt that congruence could be manipulated more easily with this strategy than with the sentence formation strategy. Students were asked to note either similarities or differences between the two words of a pair rather than to find both similarities and differences. It was assumed that finding similarities results in greater congruence, or unity, than does finding differences. The factor of unity versus diversity of encoding was also manipulated by instructing students to make either one comparison or several comparisons between the words in a pair.

Experiment II: Spread of Processing and Congruence of Encoding

Method

Participants. One hundred students who were enrolled in an undergraduate course in educational psychology at The University of Texas at Austin participated in this study. Participation was part of their course requirement.

Materials. Two paired-associate lists of 10 pairs each were used for training purposes. These words were drawn from the lists used in Experiment I. Half of the pairs of each list were composed of high-concrete words (ranging from 6.69 to 7.00) and half were composed of low-concrete words (ranging from 1.18 to 3.54). An additional 30 pair test list was prepared, with 15 high-concrete pairs and 15 low-concrete pairs. The average meaningfulness level of these pairs was 5.96. The two training lists were mimeographed for presentation to the students. The test pairs and stimulus words were printed separately on slides and presented using a Kodak slide projector with an automatic timing device.

Design and Procedure. Each student was randomly assigned to one of four experimental conditions or to a control condition, with 20 students in each condition. Students in each of the experimental groups were trained for 30 minutes in the use of one of the following learning strategies: finding one similarity between the meanings of the two words of each pair, finding several similarities between the meanings of the two words of each pair, finding one difference between the meanings of the two words of each pair, or finding several differences between the meanings of these two words. All four groups practiced with the two training lists by actually writing down similarities or differences for each of the pairs. Students in the control group were instructed to learn the word pairs, but were given no specific method to use.

After training, all students were tested over two trials of the paired-associate test list, using the study-test method of presentation. The presentation orders were separately randomized for each trial. Students were told to apply the learning strategy which they had previously practiced to the pairs presented during the study portion of the test trials. An 8-second presentation rate was used for study and test segments.

Results and Discussion

A 5 x 2 repeated measures analysis of variance (groups x trials) revealed a significant between-groups effect ($F(4,95) = 4.99$, $p < .01$). The results are presented in Tables 4 and 5. An inspection of the means on Trial 2 suggested a ceiling effect, therefore, post hoc analyses using Newman-Keuls procedure were performed only on the data from Trial 1. The two groups that were trained to use the strategy of finding similarities and the control group performed significantly better than the group that was trained to find several differences between the words. The performance of the group trained to find one difference between the words was not significantly different from any of the other groups. The similarity strategies which were assumed to produce greater congruence of encoding resulted in the highest performance of the four experimental groups. This supports the view that congruity of encoding aids recall. The lack of significant differences between groups which found one similarity or difference and those which found several casts doubt on the hypothesis that one encoding would facilitate recall by producing greater congruity than would several encodings. The group means for Trial 1 indicate a tendency in this direction, suggesting the need for further consideration of this variable.

The superior performance of the control group might be accounted for by one or more of the following: (a) looking for similarities may be one of

TABLE 4

Source Table for Repeated Measures Analysis of Variance

on the Paired-Associate Test in Experiment II

Source	SS	df	MS	F	P
Groups	908.33	4	227.08	4.00	< .01
Trials	3880.81	1	3880.81	492.73	< .001
Groups x Trials	48.47	4	12.12	1.54	N.S.
Error Groups	4320.73	95	45.48		
Error Within	748.23	95	7.88		

TABLE 5

Means and Standard Deviations of Each Group on the

Paired-Associate Test in Experiment II

		Trial 1		Trial 2	
Group	N	Mean	SD	Mean	SD
One Similarity	20	19.30	6.03	26.85	4.00
Several Similarities	20	18.00	4.81	27.70	2.45
One Difference	20	14.85	6.80	23.75	6.01
Several Differences	20	13.20	5.62	23.25	5.48
Control	20	19.30	5.41	27.15	3.48

the strategies these students employ on their own, (b) the task of finding similarities or differences may have interfered with the already sophisticated information processing strategies of students in the experimental groups, and (c) the strategies of finding similarities or differences may not be as deep or as effective as the strategies that students would otherwise use.

The next study was similar in design to this study but different strategies and different learning and performance tasks were employed to examine further the effects of congruity of encoding.

Experiment III: Spread and Congruence with Discrete-item Learning

Method

Participants. Eighty students who were enrolled in an undergraduate course in educational psychology at The University of Texas at Austin participated in this study. Participation was part of their course requirement.

Materials. Test materials consisted of 40 target words ranging in concreteness from 1.63 to 7.00 and in meaningfulness from 4.80 to 7.00. In preparation, one of the nouns was inadvertently converted to a verb (committee to commit). The free recall answer sheet had 40 blank spaces. The recognition answer sheet consisted of 120 words, including all 40 target words. The words that served as distractors were also drawn from the Paivio et al. (1968) norms. They ranged in concreteness from 1.42 to 7.00 and in meaningfulness from 4.56 to 7.00. A Kodak slide projector with an automatic timing device was used to present the 40 slides that contained the target words.

Design and Procedure. Each student was randomly assigned to one of four experimental conditions, with 20 students in each condition. Students in the first group were told to try to learn 40 target words by thinking of _one_ synonym for each word. Students in the second group were told to learn the target words by thinking of _several_ synonyms. Both groups of students practiced providing _synonyms_ to the words FEAR, MEAGER, and RASCAL. Students in the third group were asked to provide _one_ definition of the target words. Students in the fourth group were asked to provide _several_ definitions for each word. Students in these two groups practiced providing _definitions_ for the words FEAR, MEAGER, and RASCAL.

Each target word was exposed for 15 seconds on a Da-Lite screen. After presentation of all the words, the students were asked to write down as many of the 40 target words as they could remember. After 5 minutes the answer sheets were collected. The recognition test was then distributed and students were asked to circle as many of the words as they recognized of the original 40. After 5 minutes these sheets were collected.

Results and Discussion

In a 2 x 2 analysis of variance (number of encodings x type of encoding strategy) of the recognition test scores, there was a marginally significant effect of number of encodings ($F(1,76) = 3.85$, $p \doteq .05$). In an analysis of the free recall test scores the main effect of number of encodings was also significant ($F(1,76) = 5.80$, $p < .02$). For both the recall and recognition tests, one encoding resulted in better performance than did several encodings. The effect of type of encoding strategy was not significant in either analysis; nor was the interaction. The results of these analyses may be found in Tables 6, 7, and 8.

One apparent anomaly in these results it that number of encodings had a significant effect in Experiment III but not in Experiment II. Moscovitch and Craik (1976) presented data indicating that congruence has a greater

TABLE 6

Source Table for Analysis of Variance on the

Recognition Test in Experiment III

Source	SS	df	MS	F	p
Type of Encoding Strategy	12.80	1	12.80	.68	N.S.
Number of Encodings	72.20	1	72.20	3.85	±.05
Type x Number	9.80	1	9.80	.52	N.S.
Error Within	1425.20	76	18.75		

TABLE 7

Source Table for Analysis of Variance on the

Free Recall Test in Experiment III

Source	SS	df	MS	F	p
Type of Encoding Strategy	5.51	1	5.51	.34	N.S.
Number of Encodings	94.61	1	94.61	5.80	.02
Type x Number	1.51	1	1.51	.093	N.S.
Error Within	1239.25	76	16.31		

TABLE 8

Means and Standard Deviations of Each Treatment Group on the Free Recall and Recognition Tests in Experiment III

Test	Number of Encodings	Type of Encoding Strategy	N	Mean	SD
Free Recall	One	Synonym	20	9.65	2.72
	Several	Synonym	20	7.75	4.45
	One	Definition	20	10.75	5.11
	Several	Definition	20	8.00	3.45
Recognition	One	Synonym	20	36.70	3.25
	Several	Synonym	20	34.10	4.82
	One	Definition	20	35.20	4.79
	Several	Definition	20	34.00	4.28

effect at deeper levels of processing. Perhaps the synonym and definition tasks of Experiment III require a deeper level of processing than the similarity and difference tasks of Experiment II. Or perhaps free recall and recognition tasks are more sensitive to such effects then are paired-associate tasks.

Experiment IV was designed to assess the spread of encoding hypotheses in a different way. Although Craik and Tulving (1975) had presented evidence which indicated that increased spread of encoding enhanced recall, multiple strategy groups did not surpass single strategy groups on the paired-associate task in Experiment I. To explain these conflicting results, it is suggested that a multiple strategy effect might operate only at deep levels, and further, that a shallow encoding strategy might serve as a distractor when included with deep-level strategies. The inclusion of a shallow-level strategy along with strategies requiring deeper levels of processing might then interfere with spread of processing at the deeper levels. Since Experiment I did not include a group of students who were asked to use multiple deep-level strategies only, Experiment IV was designed to test the hypothesis that use of multiple encoding strategies would be beneficial if all these strategies involved deep-level processing.

In addition, a post-experimental questionnaire was developed to collect self-report data about the strategies that participants used to perform the task. Comments during the debriefing sessions in previous studies indicated that a number of students may not have used the strategies they were trained to apply. This additional data was included as a check on how closely the participants were following the directions.

Experiment IV: Spread of Processing at Deep Levels

Method

Participants. One hundred twenty students from undergraduate educational psychology classes at The University of Texas at Austin were randomly assigned to one of six treatment groups. Participation was part of their course requirement.

Materials. The six paired-associate training lists of 10 pairs each were the same as those used in Experiment I. The words were selected from the Paivio et al. (1968) norms, and varied in concreteness values from 1.18 to 7.00. A list of 15 high-concrete and 15 low-concrete pairs, with average meaningfulness of 5.96 was used for testing. The six training lists were mimeographed for presentation. Test materials (pairs and stimulus words) were printed separately on slides and were presented with a Kodak slide projector using an automatic timing device.

A postexperimental questionnaire listed all the test word pairs on a sheet of paper. Students could circle one or more letters after each pair to indicate whether they had formed a sentence, formed an image, used semantic analysis, used structural analysis of physical features, used rote repetition, used some other strategy, or used no strategy at all on that pair. If they indicated use of some other strategy, they were asked to write a brief description of it.

Design and Procedure. Each student was randomly assigned to one of six experimental conditions, with 20 students in each condition. Students in each group were trained for 1 hour and 15 minutes in the application of one, two or three encoding strategies. They worked for 10 minutes on each of the six paired-associate training lists. The students wrote out their elaborations during training so the experimenter could monitor their use of the strategies and provide corrective feedback when necessary. Students in the sentence formation group were asked to apply only the sentence formation strategy to each of the six lists of word pairs. This strategy involved forming a sentence which meaningfully related the two members of each pair. Instructions were identical to those for the sentence formation group in Experiment I.

Members of the semantic analysis group were trained in the use of semantic analysis on all six lists of word pairs. This strategy involved relating the words of a pair using a common category or concept, or comparing the categories of meaning for the words of each pair. Instructions were identical to those for the semantic analysis group of Experiment I.

Students in the three sentence/semantic groups (-choice, -both, or -unspecified) used the sentence formation strategy to learn three of the lists and the semantic analysis strategy on three lists. These three groups were identical in the training they received. They differed only in the test procedures described below.

Members of the structural/sentence/semantic group used the structural analysis strategy on two training lists. This strategy involved noting similarities and differences in physical features between the pairs (i.e., phonetic elements, spelling patterns or number of syllables). These students then used the sentence formation strategy on the third and fourth lists, and the semantic analysis strategy on the fifth and sixth lists.

When studying the test list, students in the sentence formation group and those in the semantic analysis group were asked to apply the single strategy that they had practiced during training. Students in the sentence/semantic-choice group were asked to choose one of the two strategies on which they had been trained (the one they judged to be most effective) and to use it throughout the test list. Members of the sentence/semantic-both group were asked to apply both strategies to each word pair. Students in the sentence/semantic-unspecified group and the structural/sentence/semantic group were similar to the multiple strategy groups of Experiment 1 in that the instructions for testing did not specify the particular mix of strategies to be used. They were simply asked to apply the strategies previously learned with the training lists to help them learn the word pairs on the test list.

Testing consisted of two study-test trials using an 8-second presentation rate for both study and test segments. A different randomly determined order of presentation was used on each trial. After testing was completed, participants were given the postexperimental questionnaire on which they could indicate the strategies they had used in learning the test pairs.

Results and Discussion

A 6 x 2 repeated measures analysis of variance (groups x trials) indicated a significant effect of trials ($F(1,144) = 883.01$, $p < .01$). The effect of groups and the interaction were not significant, although the results were in the predicted direction. The means of the three groups which were trained in the use of two deep-level strategies (sentence/semantic-choice, -both, and -unspecified) were higher than groups trained in only one of these deep-level strategies and the group trained to use a shallow-level strategy in addition to the two deep level strategies (see Table 9). This trend is consistent with the view that elaboration of encoding facilitates memory at deep levels, and that the inclusion of shallow processing may interfere with this effect. Thus, it might be concluded

TABLE 9

Means and Standard Deviations of Each Treatment Group on the Paired-Associate Test in Experiment IV

Group	N	Trial 1 Mean	Trial 1 SD	Trial 2 Mean	Trial 2 SD
Sentence Formation	20	15.45	6.14	24.25	5.72
Semantic Analysis	20	14.95	6.00	25.40	4.42
Sentence/Semantic-Choice	20	16.35	5.98	25.55	4.47
Sentence/Semantic-Both	20	16.70	4.69	25.55	4.01
Sentence/Semantic-Unspecified	20	17.80	3.82	27.10	2.17
Structural/Sentence/Semantic	20	14.80	5.03	25.30	2.99

either that, if there is a spread-of-processing effect, it occurs only at deep levels of encoding.

The postexperimental questionnaire data are presented in Table 10. The mean number of word pairs for which each group reported using a particular strategy was calculated. These frequencies were then converted to percentages of 30, the total number of word pairs on which the strategy might be used. For instance, on the average, persons in the sentence formation group reported using a sentence strategy with 24 of the 30 word pairs appearing on the test or 79% of the word pairs. There were significant differences among groups in the number of pairs for which sentence strategies ($F(5,115) = 6.56$, $p < .001$) and semantic analysis strategies ($F(5,115) = 6.16$, $p < .001$) were reported. Duncan's Multiple Range Test indicated that students in the semantic analysis group differed from all other groups in their use of both of these strategies. They used the sentence strategy less and the semantic strategy more than the other groups. Table 10 indicates strongly that students were much more likely to use the sentence strategy than the semantic analysis strategy in all the multiple-strategy conditions. This preference for the sentence strategy occurs despite the fact that performance was not noticeably worse in the semantic analysis group than in the sentence group (see Table 9). It is likely that the sentence strategy required considerably less effort.

Table 11 gives percent recall as a function of the strategy or combination of strategies reported on the postexperimental questionnaire. Percentages for single strategies are in the diagonal and for the several combinations of two strategies are in the off-diagonal. There was a significant difference in percentage recall among the single strategies,

TABLE 10

Percentage of Total Word Pairs[1] for Which Each Strategy was Reported on the Postexperimental Questionnaire in Experiment IV

		Strategy Reported						
Group	N	Sentence	Semantic	Structural	Imagery	Rote	Other	None
Sentence Formation	16	79	7	1	24	3	0	5
Semantic Analysis	20	36	33	8	17	9	1	6
Sentence/ Semantic-Choice	20	60	9	4	25	14	< 1	4
Sentence/ Semantic-Both	20	67	15	4	26	8	1	6
Sentence/ Semantic-Unspecified	20	64	11	3	21	8	< 1	3
Structural/ Sentence/Semantic	20	58	14	8	10	10	1	8

[1]Percentages are based on the mean group frequency of report for the 30 word pairs.

TABLE 11

Percentage Recall for Each Single Strategy (Diagonal Values) and Each Pair of Strategies Reported on the Postexperimental Questionnaire in Experiment IV

	Single Strategy or Strategy Pair Reported					
	Sentence	Semantic	Structural	Imagery	Rote	Other
Sentence	56	13	6	23	2	2
Semantic		32	1	6	2	-
Structural			31	2	-	-
Imagery				49	2	-
Rote					14	-
Other						5

$F(5,545) = 44.77$, $p < .001$, and among the several combinations of strategies, $F(14,1526) = 16.24$, $p < .001$. Only three triple combinations of strategies were reported. Probability of recall was .05 for sentence-imagery-semantic, .02 for sentence-imagery-structural, and .01 for sentence-semantic-structural. Note that recall was much higher overall for those reporting fewer rather than many strategies at a time($F(2,218) = 136.66$, $p < .001$). Apparently the attempt to employ more than one strategy at a time results in a reduction of processing efficiency.

It can be seen in Table 11 that performance was best with the sentence and imagery strategies. The semantic strategy was not superior to the structural strategy. The sentence and imagery strategies are probably those two which involve the greatest congruence of encoding.

The groups also differed in their use of the structural strategy ($F(5,155) = 4.04$, $p < .01$). A Multiple Range Test showed that the semantic analysis group and the group trained to use all three strategies used this strategy more than the sentence formation group and the sentence/semantic-unspecified group although the only group trained to use the structural strategy was the one receiving training in all three strategies. The use of this strategy by the semantic analysis group suggests that the students may have had difficulty in following the semantic-analysis instructions. This difficulty may account for the lack of a significant effect of type of strategy on recall in this study. Note also, the low report of semantic strategy use in semantic-both group, where subjects had been explicitly requested to use both strategies.

The groups did not differ statistically in their reported use of imagery, rote, other, or no strategies. It should be noted, that an imagery strategy was used more often than the semantic strategy in four conditions where the semantic strategy was requested. Apparently, participants will often use the strategy they prefer rather than ones which are requested by the experimenter in memory experiments.

General Discussion

Results of these studies have some bearing on the concepts of depth of encoding, spread or elaboraton of encoding, and the degree of congruence or integration obtained in the encoding. The data from Experiment I are directly relevant to the concept of depth of encoding. The low performance of the only group not trained in any forms of meaningful elaboration (the structural analysis group) is consistent with that of previous studies indicating that qualitative shifts in the nature of encoding required can have a large effect on retention.

Data by Coltheart (1977) suggest that performance of the structural task produced interference which reduced the extent or detail of semantic processing involved. Whether the structural task produced such interference when it was one of several suggested strategies is a question addressed by Experiment IV, but the results of that study were somewhat ambiguous. Interference of the structural tasks was suggested but not demonstrated statistically. More research will be required on this issue.

With regard to spread of encoding the data were not supportive. Multiple-strategy groups did not surpass single-strategy groups in Experiments I and IV. Students who were asked to note several similarities, differences, definitions, or synonyms in Experiments II and III definitely did not surpass those asked to note only one. For several reasons, however, it would be premature to conclude against this construct from these data.

First, the questionnaire data of Experiment IV indicated that students were probably deviating from instructions in some conditions of all the studies. If these studies were repeated using strategies more often employed by students multiple-strategy effects might yet be obtained. Secondly, the number of encodings variable in Experiments II and III was designed to contrast the strength of unity and elaboration factors rather than to evaluate independently the strength of each. On the other hand, analysis of the postexperimental data suggest that use of multiple strategies hinders rather than helps recall. Thus, effects of greater elaboration may have been counterbalanced by effects of greater unity. Third, it is not clear that spread of encoding as operationalized here is equivalent to that term as operationalized in previous studies. Craik and Tulving (1975) were concerned with degree of elaboration in a single encoding of a single stimulus but the present studies were concerned with the variety of several encodings to the same stimulus. More research will be required to evaluate the role of this variable definitively, but results at present are not too encouraging.

The results of these studies provide more support for the concept of congruence or unity of encoding. For example, the search for similiarites and the search for differences in the meanings of two words would appear fairly comparable in terms of the depth and degree of elaboration called for, but the search for similarities could lead to a more unified encoding for the two words of the pair. And, indeed, paired-associate learning was superior with the similarities task. Additionally, the search for one synonym or definition may have been beneficial because it produced a single product, an integrated encoding which was easier to retain and employ in test trials than several definitions or synonyms would have been. Furthermore, self-reports of single strategies were associated with better recall than self-reports of multiple-strategies. These results are important because they provide evidence for the effect of the congruence factor with operations other than the contrast of yes or no questions (Craik & Tulving, 1975)

To summarize, results from these studies appear compatible with those of other recent studies in providing some support for the basic concepts of the depth-of-processing or domains-of-processing (Lockhart, Craik, & Jacoby, 1976) framework, suggesting that qualitative differences in encoding processes have great effects on learning, and in suggesting that other factors, such as congruence, are also important. This research also highlights the importance of getting postexperimental reports of strategies actually used in studies of this kind. Our questionnaire data may indicate that students will use the strategy which seems most effective to them, which seems easier, or which can be more clearly understood. Apparently, the sentence strategy surpasses the semantic strategy on one or more of these attributes. Further research will be required to discover why the semantic strategy is avoided and to find several strategies which are equivalent in probability of use.

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APPENDIX

Training Instructions Presented to the Structural/Sentence/Semantic Group in the Depth and Spread of Processing Study

(Experiment 1)

Hello. I want to thank you for coming today. My name is _________. I'm interested in developing better learning methods. During this period I will tell you about several methods that are helpful for certain kinds of learning. You will get to practice these methods or strategies for the first part of the period. Then, during the last half-hour, we will test you to see how well you learned them. This is not an intelligence test. You, the student, are not being tested, rather, together we will test the learning strategies you are going to learn. Obviously, the better you learn the strategies, the more we can find out about them when we test. So, even though you may find these learning strategies new and different, try to master them as best you can during the practice sessions.

Are there any questions?

Training and Testing Instructions

I'll now explain your first learning strategy.

Your task is to learn each of these pairs by forming an association between the two words such that if you were later given only the left-hand word, you could give its partner. You need not learn the order of the word pairs.

Structural Analysis Strategy Instructions

One strategy that you can use to learn the word pairs involves associating the physical structure of the two words. The two words might have a common spelling pattern. (Hold up example.) For example, if you

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were given the two words APPLY and COLLISION you could remember that both words have doubled consonants (point to consonants), that the left word begins with a vowel and the right with a consonant (point to the letters A & C) and that the left word has two syllables while the right has three. In the case of the word pair MIRAGE and ALGEBRA (hold up example) you might note that both words have an RA combination (circle the RA in each word), and a GE combination (circle GE), that the soft G sounds are similar, that the right begins with a consonant and the left with a vowel, and that MIRAGE has two syllables while ALGEBRA has three. In the case of CABIN-FLAG, CABIN has two syllables, whereas FLAG has only one. CABIN begins with a consonant, FLAG begins with two. Both words have a similar A sound. In short, this strategy uses physical similarities and differences in the spelling and/or the pronunciation. In using this strategy you should look for common spelling patterns, similar or different sounds, distinctive spellings or pronunciations, and contrasts between the number of syllables or letters. You should use any structural information about a word pair. One advantage of this strategy is that you need not even know the words in question for it to work.

We have reason to believe that this is an effective strategy, and that the more similarities and differences you can find, the more effective it will be. Please write down your ideas so I can look at them with you. Are there any questions?

As in any skill, this learning strategy will require some practice for you to become proficient at it. We will work with practice lists before moving on to the second learning strategy. Use these practice lists to master the Structural Analysis Strategy. Some of the word pairs will be more difficult to remember than others. That's all right. Do the best you can on each list. Remember, we are not interested in how well you learn the pairs as much as in seeing how well you can become proficient in using a particular strategy for learning. So please keep working on this strategy.

Now look at the list of 10 word pairs that you have before you. For the next few minutes use the new structural strategy that I've shown you to learn the word pairs. Please write down your ideas so that I can look at them with you. Remember, look at their similarities and differences in physical structure.

Questions?

Begin.

(Allow 12 minutes for practice.)

Please return your lists to me.

Now look at this list of 10 word pairs. For the next few minutes use the new structural strategy that I've shown you to learn the word pairs. Please write down your ideas so that I can look at them with you. Remember, look at their similarities and differences in physical structure.

Questions?

Begin.

(Allow 12 minutes for practice.)

Please return your lists to me.

Sentence Formation Strategy Instructions

Your task is to learn each of these pairs by forming an association between the two words such that if you were given only the left-hand word you could give its partner. You need not learn the order of the word pairs.

One strategy that you can use to learn these word pairs involves using a sentence or phrase that includes both members of a pair. For example, if you were given the pair, FRANCHISE-ROBBERY, you could use both words in the sentence, The detective arrived at the fried chicken FRANCHISE to investigate its ROBBERY. Given another pair, LORD-MULTIPLICATION, you might use the sentence, LORD Baltimore practiced MULTIPLICATION tables. For SNAKE-LIMB, you could use the sentence, The SNAKE dropped from the LIMB of a tree. In this way you make up one sentence for each pair of words. For long lists you could even make up a story using all or most of the word pairs. We have reason to believe that this is an effective learning strategy. Try to find a sentence that best brings out a meaningful relationship between the two members of each pair. Please write down your ideas so I can look at them with you. If you can associate the pair of words in a sentence, however strange it appears, you will be more likely to remember them.

Are there any questions?

As in any skill, this learning strategy will require some practice for you to become proficient at it. We will work with two more practice lists before moving on to the third learning strategy. Use this practice session to master it. Some of the word pairs will be more difficult to remember than others. That's all right. Do the best you can on each list. Remember, we are not interested in how well you learn the pairs so much as in seeing how well you can become proficient in using a particular strategy for learning, so please keep working on this strategy.

Now look at the list of 10 word-pairs that you have before you. For the next few minutes use the new Sentence Formation Strategy that I've just shown you to learn the word pairs. Remember, try to make a sentence using both words of each pair.

Questions?

Begin.

(Allow 12 minutes for practice.)

Please return your lists to me.

Now look at the list of 10 word-pairs that you have before you. For the next few minutes use the new Sentence Formation Strategy that I've just shown you to learn the word pairs. Remember, try to make a sentence using both words of each pair.

Questions?

Begin.

(Allow 12 minutes for practice.)

Please return your lists to me.

Semantic Analysis Strategy Instructions

Your next learning task is like the other two. You are to learn each of the pairs such that, if you were given only the left-hand word, you could give its partner. You need not learn the order of the word pairs.

The third strategy that you can use to learn these pairs involves finding meaningful similarities and differences between the words. You should think of the similarities and differences in the meanings. In addition, you should try to find one word that relates the two. As an example, (hold up example), the pair EXPLANATION-SALARY can be related to the word EXCHANGE. Contrasting the words, EXPLANATION is a verbal exchange, whereas SALARY, is a monetary exchange. Or, given the pair INVESTIGATION-NYMPH, you could remember the two words by means of SATYR, a mythical being most likely to investigate a NYMPH! Even if you are unable to find a single word that relates the pair, you can categorize the words and compare them in that way. For example, in comparing the pair COMPETITION-CREATOR, you might consider that COMPETITION is a category of activity that is usually measurable and repeatable. Further, it often involves more than one individual on the same task. In contrast, CREATOR is a category of consciously being involved in an activity that is not usually measured, and of which the products are considered unique. It refers to a single individual. As you can see, you have a great deal of freedom in relating the similarities and differences of meaning. There is no right or wrong way; there are many other possible ways of relating the previous examples. We have reason to believe that this is an effective learning strategy, and that the more similarities and differences in meaning that you can find, the more effective it will be. Please write down your ideas so I can look at them with you. Are there any questions?

As in any skill, this learning strategy will require some practice for you to become proficient at it. We will work with more practice lists before you are tested on your use of the three strategies. Use these practice lists to master the Semantic Analysis Strategy only. Some of the word-pairs will be more difficult that others to remember. That's all right. Do the best you can on each list. Remember, we are not interested in how well you learn the pairs so much as in seeing how well you can become proficient in using a particular strategy for learning. So please keep working on this strategy.

Now look at the list of 10 word-pairs that you have before you. For the next few minutes use the new Semantic Analysis Strategy that I've just shown you to learn the word pairs. At the end of that time I'll give you a list of only the left-hand words in a different order, and you should try to give as many of their partners as possible. Remember, try to relate the similarities and differences in meaning between the two words.

Questions?

Begin.

(Allow 12 minutes for practice)

Please return your lists to me.

Now look at the list of 10 word-pairs that you have before you. For the next few minutes use the new Semantic Analysis Strategy that I've just shown you to learn the word pairs. At the end of that time I'll give you a list of only the left-hand words in a different order, and you should try to give as many of their partners as possible. Remember, try to relate the similarities and differences in meaning between the two words.

Questions?

Begin.

(Allow 12 minutes for practice)

Please return your lists to me.

Testing Instructions - Trial 1

Now we would like to find out how well you've learned the strategies that you've just practiced. This will be similar to the practice trials you've already had but with a few important differences so listen carefully. This time I will show you a series of 30 slides. Each slide will have two words on it. Your task is to use the Structural Analysis Strategy, Sentence Formation Strategy, and/or the Semantic Analysis Strategy to associate the two words of each slide together. Please try to use only these three strategies. Use them either singly or in combination, whatever seems to work best for you. If you see only the left-hand word, you should be able to write down which word goes with it.

For example, suppose you saw the words SHIP and PIPE together on a given slide. You should use the learning strategies that you've practiced to associate the two words. When I show you the word SHIP by itself, you should be able to write down its partner, PIPE. You will have two trials on the same list of words. However, the order in which the word pairs are presented will not be the same over the two trials. You must concentrate on associating the two words of a pair rather than learning the order in which they are presented.

You will have 8 seconds to look at each word pair. Then after you've seen the entire list, you'll be shown only the left-hand partner. Try to learn as many word pairs as you can on the first trial. When we finish it, we'll repeat the process with the same list, but it will be in a different order. Are there any questions before we begin?

Remember, try to use the Structural Analysis Strategy, the Sentence Formation Strategy and/or the Semantic Analysis Strategy to learn the pairs. After you study the pairs I am going to give you the left-hand word and you will have to write down the right-hand word.

Please put your name in the upper right-hand corner of the first card in your pack. Make sure you also remove the rubber band.

Now I'll show you only the left word of each pair, and you give me the other item. Give your response by writing on the IBM cards in front of you. Please put just one response on each card and turn that card over immediately afterward. I will call out the number of each item as it is presented to you. That number should correspond to the number on the upper left corner of your card. If you cannot think of any response for a given card, leave it blank, and turn to the next card anyway.

Remember, for each left-hand word presented, give the corresponding right-hand item. Questions?

Begin.

Testing Instructions - Trial 2

Now you will again have 8 seconds to look at each word pair. Then, after you have seen the entire list, you will be shown only the left-hand words and you will try to supply its right-hand partner. Remember to use the learning strategy you have practiced to associate the two words. Questions? OK. Lets's begin.

Please put your name on the upper right-hand corner of the first card in your pack.

Remember, try to use the Structural Analysis Strategy, the Sentence Formation Strategy, and/or the Semantic Analysis Strategy to learn the pairs. After you study the pairs I am going to give you the left-hand word and you will have to write down the right-hand word.

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