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An investigation of the effectiveness of mnemonic strategies employing imagery in paired-associate learning

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AN INVESTIGATION OF THE EFFECTIVENESS OF MNEMONIC STRATEGIES EMPLOYING IMAGERY IN PAIRED-ASSOCIATE LEARNING

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Abstract

This study attempted to distinguish between two classes of explanations for the effectiveness of mnemonic strategies employing imagery in paired-associate learning. It has been suggested that imagery enhances the distinctiveness of the stimulus member of the paired-associate, making it less susceptible to intralist interference. An alternative explanation attributes the effectiveness of imagery to its ability to form stronger associations between the stimulus and response words.

Forty-eight Lehigh University undergraduates served as subjects in this study. They were divided randomly into three experimental groups which differed in the mnemonic strategy used to learn a 20 item paired-associate list. The first group generated an image which contained both nouns in each paired-associate interacting with each other; the second group generated a separate image for each noun; and the third group generated a separate image for each noun in which that noun was interacting with something. If interactive visual imagery enhances stimulus distinctiveness then both the interactive and separate/interactive image groups were predicted to learn the list faster than the separate image group. However, if interactive imagery aids directly in the formation of associations, then the interactive image group was expected to exceed the other two groups in

learning the paired-associates.

The results supported a relational association explanation. The interactive image group learned the list in one third the time it took the other groups, and it was also superior on a test of backward recall. The interactive image group was also consistent in their use of mediating images, whereas the other groups tended to drop their images which they had formed initially and employ alternate strategies to learn the list.

The final section of the study discusses the results within the context of the theoretical issues concerning imaginal processes.

The ancient Greeks and Romans considered memory an art. The Greeks went as far as to deify it in the person of Mnemosyne, the Muse of memory. Many of the mental shortcuts and mnemonic strategies described in the memory books which populate the magazine racks and newsstands today were advocated by such authorities as the Greek poet Simonedes (circa 500 B.C.) and the Roman masters of rhetoric, Cicero and Quintillian (Yates, 1966). The use of mental imagery was an integral part of these classical mnemonic systems (and their modern counterparts.) For example, the orator wishing to remember the basic outline of his speech was advised to construct an image of a familiar place, such as a house. In the various rooms of this mental house, the orator would place objects which would recall the keywords in the outline of his speech. While delivering the talk, the orator would mentally "stroll" through his house and recover the objects (outline) he had placed there earlier. For those who wished to leave nothing to chance, a quick prayer to Mnemosyne was also advocated.

Within the past decade, psychological investigations into the role of imagery in learning and memory have begun to verify the effectiveness of many mnemonic techniques. In his comprehensive review of the research literature, Allan Paivio (1971) demonstrates quite conclusively that imagery is a potent variable affecting a subject's performance on tasks of associative and serial learning. Bower (1969) demonstrated the effectiveness of strategies employing imagery in tasks designed to create a high memory load. Subjects were required to learn five 20 item paired-associate lists. Half the subjects learned the lists by rote memorization and the other half were instructed to imagine the objects in each pair interacting in some fashion. The presentation protocol for each list consisted of a study trial, a test trial, and one final study trial. After the fifth list was presented, recall was tested for all 100 noun pairs. On both the immediate and delayed recall tests, subjects using imagery recalled one and a half times more paired-associate items than the rote memory subjects.

Schnorr and Atkinson (1969) demonstrated that the use of imagery increases the long term retention of paired-associate learning. Subjects learned half of each of three 32 pair lists by rote memory and the other half by imagery. Immediate retention for the imagery half of the lists ranged from 80 to 90 percent after a single study trial as compared to 30 to 40 percent for the rote half of the lists. After one week the retention for the imagery half of the lists ranged from 35 to 45 percent, whereas only 24 to 30 percent of the lists memorized by rote repetition was retained. The difference between the imagery and rote repetition strategies is actually much greater since these percentages after one week represent the proportion of paired-associates correctly recalled given correct recall on the first test.

While many studies have demonstrated the effectiveness of mnemonic strategies using imagery, relatively little work has been done to explain why imagery is so effective in associative learning. Bower (1970) conducted a study which attempted to distinguish between two classes of explanations for why imagery is such an effective strategy. One class of explanations attributes the effectiveness of imagery to the enhanced distinctiveness of the functional stimulus. The term functional stimulus refers to the result of the learner's interaction with the actual (nominal) stimulus. It may be a fractional part of the original stimulus, such as a letter or a syllable, to which the learner selectively attends, or in the present case the embellishment of the nominal stimulus by its corresponding image. (Cf. Underwood (1963) for a discussion of the nominal/functional distinction.) The word plus its imaginal referent produces a stimulus complex which is more distinct and outstanding than the word alone. This distinctiveness makes the functional stimulus less susceptible to intralist generalizations from other pairs in the list, resulting in less interference for the associations which form between the functional stimulus and the response.

Another consequence of the enhanced distinctiveness of the stimulus is the reliability with which the nominal stimulus in a paired-associate list arouses the functional stimulus to which the response is associated. Theoretically, an image results in a more stable encoding of the nominal stimulus on the study trial. Consequently, on subsequent test trials the presentation of the nominal stimulus is more likely to arouse the same functional stimulus each time, thus decreasing the overall time to learn the list.

The other class of explanations attributes the effectiveness of imagery to its ability to form stronger associations between the stimulus and response items. The process of imaging the referents of two nouns in some sort of interaction combines the two words into one conceptual unit. On the test trials, the presentation of the stimulus word cues the retrieval of the complex image and makes the response word available. This type of explanation, which emphasizes the relational association between the stimulus and response, is the basis for Paivio's "conceptual peg" hypothesis (Paivio, 1971, 1972). The stimulus word functions as a peg to which its response associate is hooked during the study trials and from which it is retrieved on the recall trials.

In order to distinguish these two types of explanations experimentally, Bower had three groups of subjects learn three 30 pair noun-noun paired-associate (PA) lists. Each group employed a different strategy to learn the lists. The first group was instructed to learn the word pairs by overt rote repetition of the words in each pair. The second group was instructed to construct an image in which the words of each pair were interacting in some fashion. The third group also formed images of the words in each pair, but they were told to keep them separate in their imaginal space, as if they were looking at two pictures hanging on the wall.

The pairs in each list were presented for ten seconds each during the study trial. On the recall trial immediately following, the 30 stimulus nouns were randomly mixed with 30 distractors. Each subject was asked to indicate whether he had seen the word before (stimulus recognition test), and if so to produce the response which had been associated with it. If the stimulus distinctiveness hypothesis was correct, then the interactive and separate imagery groups were expected to exceed the rote group in stimulus recognition and in response recall given stimulus recognition. If the relational associativity hypothesis was correct, then all the groups were expected to be about equal in stimulus recognition, but the interactive imagery group should have exceeded the other groups in recall given recognition.

The results seemed to favor the relational association hypothesis. There was no difference among the groups in the percentage of stimulus words correctly recognized over all three lists. However, in recall given recognition the interactive imagers scored 61 percent correct as compared to 34 and 36 percent for the separate image and rote repetition groups, respectively.

Bower concluded that an interactive imagery strategy improves paired-associate learning without improving stimulus recognition. The superior performance of the interactive over the separate imagers seems to suggest that the benefit in the image mnemonic is in the formation of associations rather than the enhancement of the functional stimulus. However, it is still possible that the interactive imagers' performance was mediated by a more distinct functional stimulus than that of the other two groups. It can be argued that imagining two objects in interaction with each other is a qualitatively different experience than imagining those same two objects separately. The interactive image is more interesting, and distinctive especially when the two words are not normally thought of as going together (such as house-cigar, for example.) An image of a house with a smoking cigar as its chimney is certainly more novel than either an image of a house or a cigar; it is also more elaborated, more detailed.

If the above argument is correct, then the interactive image group in Bower's study should have exceeded the separate and rote subjects in the stimulus recognition test. Although the overall $\underline{F}$ was not significant, the interactive group did slightly better (87 percent as compared to 83 and 84 percent for the separate and rote groups.) A specific statistical comparison between the interactive and the other groups may have revealed a significant difference where the overall $\underline{F}$ did not.

The present study attempted to tie up the loose ends in Bower's experiment in order to distinguish between the two explanations for imagery's effectiveness in paired-associate learning. In addition to the interactive and separate imagery groups, a third group was instructed to learn the PA list by imaging each word in the pairs interacting with something, but not the other word in the pair. Thus, for each noun pair in the list the subject constructed two separate but interactive images.

Therefore, if the distinctiveness of the functional stimulus of the PA unit, mediated by imaginal elaboration through interaction of the stimulus word with other elements in the image, is the effective variable, then the interactive and separate/interactive image groups will perform equally as well and better than the separate image group in mastering the PA list. The interactive and separate/interactive groups will also be expected to average more correct stimulus recognitions than the separate image group.

On the other hand, if the association between the stimulus and response members of the PA unit, mediated by the mnemonic strategy of interactive imagery, is the effective variable, then the interactive image group will perform better than the separate and separate/interactive image groups in mastering the PA list.

While the stimulus distinctiveness hypothesis concerns itself primarily with the stimulus encoding process, the relational association hypothesis makes specific predictions about the retrieval process. If the stimulus and response words are coded as one complex imaginal unit in memory, then theoretically either the stimulus or the response word should be capable of cueing the retrieval of the image, thus making the other word available. The associations formed in interactive imagery are symmetrical (Paivio, 1971, p. 278); each word in the PA unit should be equally as likely to produce its associate as a response. A test of backward recall is especially appropriate to test for this associative symmetry. Therefore, if the relational association hypothesis is correct, then the interactive image group will average more correct stimulus recalls given the response member of the PA unit than will the separate and separate/interactive groups.

Method

Subjects

Fifty students enrolled in an introductory psychology course at Lehigh University participated in this experiment in fulfillment of a requirement for the course. Two subjects were discarded for a failure to follow the instructions. The 35 males and 13 females remaining were randomly assigned to the three groups. There were 16 subjects in each group.

Materials

Forty high imagery nouns (I value greater than 6.00) were drawn from the normative list published by Paivio, Yuille, and Madigan (1968). All the words were four and five letters in length, and the Thorndike-Lorge frequency was between 10 and 49 occurrances per million. Twenty paired-associates were constructed by randomly pairing the forty nouns.

The twenty noun pairs were randomly ordered and placed on three by five index cards. One randomization was used for all subjects on the study trial. Two different randomizations were constructed for the test trials.

The response words of the 20 PAs were randomly ordered and typed on index cards to be presented to all the subjects during the backward recall test. The stimulus recognition test was constructed by taking the twenty PA stimulus words and randomly mixing them with 60 other four and five letter high imagery nouns from the list by Paivio et. al..

A portable cassette tape recorder was used to record the subject's image reports during the study trial. A Standard Electric Co. Model S-1 chronometer was used to time the presentation of the PAs during the study trial, and the response words during the backward recall test. For the test trials, a Lafayette long tape memory drum was used to present the PA stimuli.

Procedure

The three groups in this study were distinguished according to the strategies they employed to learn the PA list. Initially, all the subjects were given the following instructions:

"This is an experiment in learning and memory. You will be shown a list of 20 pairs of nouns. Your task will be to learn the list so that when you are shown one noun of a pair you will be able to respond with the noun it was paired with. One particularly effective way of learning materials of this kind is through the use of mental imagery. I would like you to learn the list by forming mental pictures of the nouns in each pair."

The first group was instructed to learn the PA list by using the strategy of interactive imagery:

"The image you generate should in some way include both of the nouns in each pair interacting with each other. Imagine that you are looking at a wall upon which is projected a movie scene in which are both nouns of the particular pair you are learning. For example, if the pair were Dog--Hat, you might imagine that you were watching a movie of a big Irish Setter putting on a black silk top hat. Don't be too concerned with how weird or strange the image may appear to be. A good image is one which will help you learn which nouns go with each other in the list of 20 noun pairs."

The separate image group was given the following instructions:

"Imagine that you are looking at a wall upon which are hung pictures of the nouns of a particular pair. For example, if the pair were Dog--Hat, you might imagine a picture of an Irish Setter hanging on the wall on the left, and over on the right a picture of a black silk top hat. Don't be too concerned with how weird or strange the image may appear to be. Use this technique to learn which nouns go with each other in the list of 20 noun pairs."

Finally, the separate/interactive group was instructed as follows:

"The images you generate should in some way include each noun of the pair interacting with something else. Imagine that you are looking at a wall upon which is projected two different movies. In each movie is one of the nouns in the particular pair you are learning interacting with something. For example, if the pair were Dog--Hat, you might imagine that on the left wall is a movie of an Irish Setter chasing a cat. Over on the right wall might be a movie of a man chasing his black silk top hat blowing in the wind. Use this technique to learn which nouns go with each other in the list of 20 noun pairs. Don't be too concerned with how weird or strange the images appear to be."

As with the separate image group, the importance of keeping the images separate was emphasized by the experimenter before the study trial was begun.

After being instructed in the particular mnemonic strategy to be used, each subject was shown for 15 seconds each of the 20 noun pairs typed on an index card. At the end of 15 seconds the subject reported the image(s) he had generated for that particular pair, and his image report was recorded on tape. The same presentation order was used for all subjects in the study trial.

After the study trial, the subject was transferred to the memory drum for the test trials. The following stimulus configuration was used to present the PA list on the memory drum. The stimulus word appeared for two seconds, followed by a blank space for two seconds, and finally the stimulus and response words appeared for two seconds. When the stimulus word appeared in the window of the memory drum, the subject was instructed to anticipate the appearance of the response word by saying it aloud. A two second interval separated the tests for each pair in the list. The subject was instructed to use this interval to rehearse the image(s) he generated in the study trial. Each subject was run to a criterion of one perfect trial of correct response anticipations. The test trials were terminated if the subject had not reached criterion on the twelfth trial.

Following the test trials on the memory drum, the subject was given a test of backward recall. The response associates were typed on index cards and presented to the subject for five seconds. He was asked to respond with the stimulus word which had been paired with it.

Next, the subject was given a test of stimulus recognition. A dittoed sheet containing the 20 stimulus nouns and 60 distractors was given to the subject, and he was asked to circle the words he had seen before in the experiment. There was no time limit for this test.

Finally, the subject was given a questionnaire which contained the 20 PAs which he had just learned. For each noun pair the subject was asked to write the final form of the image(s) he had used to learn that pair. The final form was compared to the original study trial image(s) as a check on image mediator consistency.

The subject was also asked to rate each noun pair for its imageability on a seven point Likert scale. Imageability is the degree to which a word or words arouse an image with ease (or difficulty).

Results and Discussion

The major dependent variable was the trial on which each paired-associate was learned without any further errors. Altogether eight subjects, five from the separate image group and three from the separate/interactive group, failed to reach criterion by the twelfth test trial. At this point the trial of learning for all the unlearned noun pairs was recorded as twelve, and the test trials were terminated. The mean trial of learning for the three groups is presented in Table 1. The data presented refer to the test trials and do not include the first study trial in which the images were generated. The group employing interactive imagery is clearly superior, having learned the PA list in one third the time it took the other groups. The significance of this difference was confirmed by an analysis of variance ($F(2,51) = 12.41$, $p \leq .01$) which is presented in Table 2. The analysis of the trial of learning data entailed the calculation of a quasi-F ratio to assess the significance of the difference among the three groups (cf. Winer, 1962, pp. 199-202 for the details on the calculation of the quasi-F and its degrees of freedom.)

A significant effect for Stimuli was also observed ($F(19,855) = 6.93$, $p \leq .01$). Such a result indicates that the subjects found some noun pairs easier to learn than others. Inspection of the data in Table 3, which

Table 1

Mean Trial of Learning

	M
Interactive	1.28
Separate	4.40
Separate/Interactive	4.57

Table 2

Analysis of Variance of Trial of Learning Data

Source of Variation	SS	d.f.	MS	F
A (Image Type)	2202.61	2	1101.30	12.41+ **
B (Stimuli)	480.52	19	25.29	6.93**
S (Subjects)	3740.74	45	83.13	22.77**
A x B	223.68	38	5.89	1.61*
B x S	3121.95	855	3.65	-

+ d.f. = 2,51

* $p \leq .05$

** $p \leq .01$

presents the significant Image Type x Stimuli interaction ($\underline{F}(38,855) = 1.61$, $\underline{p} \leq .05$), reveals that the variability in time to learn the pairs is confined mainly to the separate and separate/interactive groups. The group using interactive images learned all the PAs quickly and at approximately the same rate. Nevertheless, as the correlations between the interactive image group and the separate ($\underline{r}_{xy} = .64$) and the separate/interactive image group ($\underline{r}_{xy} = .63$) indicate, noun pairs which were difficult for one group to learn were difficult for the other groups as well.

The results are consistent with those of a study reported by Bower (1972) which contained an experimental condition similar to the separate/interactive image condition in this study. Instead of having his subjects generate images, Bower provided one group of subjects with three related stimulus nouns to be connected with a single response noun. A second group was provided with three unrelated stimulus nouns, and the final group used a single word nominal stimulus. Both groups employing triple stimuli performed worse than the group using only a single stimulus. (As Bower summarized the results, "Tripling is crippling.")

It could be argued that the reason the interactive image strategy is so effective is not due to its superiority in aiding the formation of associations, but simply

Table 3

Mean Trial of Learning for Each Associate According to the Image Strategy Used in Learning

Paired-Associate	Image Type: Int.	Sep.	Sep./Int.
Harp-Dirt	1.06	3.63	3.44
Oven-Skull	1.06	3.76	3.94
Claw-Ankle	1.44	2.76	3.70
Candy-Tomb	1.87	6.70	6.37
Elbow-Fork	1.19	4.75	4.88
Thorn-Swamp	1.38	4.45	3.82
Hoof-Jail	1.31	5.00	5.01
Vest-Monk	1.00	2.06	2.88
Moss-Toast	1.56	5.70	6.00
Foam-Peach	1.38	5.39	3.56
Cord-Limb	1.00	2.94	3.56
Snake-Oats	1.31	5.50	4.95
Chin-Geese	1.31	5.01	5.39
Tank-Cane	1.12	4.95	5.00
Salad-Mast	1.12	4.56	5.12
Doll-Arrow	1.19	4.64	4.88
Golf-Frog	1.00	2.76	3.50
Dove-Cash	1.38	3.56	5.01
Lark-Mule	1.19	5.00	5.25
Jelly-Hound	1.69	4.88	5.25

because it involves an easier task for the subject during the study trial than the separate and separate/interactive image strategies. To test for this possibility each subject was asked to rate the noun pairs on the ease with which they had aroused the particular type of image(s) he was instructed to generate. Table 4 presents the mean imageability ratings given to the 20 PAs by the three groups. The higher the mean rating, the easier it was to generate images for the PAs in the list. As the analysis of variance, presented in Table 5, indicates, the mean imageability ratings did not differ among the three groups ($F(3,67) = 1.17$, $p. > .05$). Even though the interactive group learned the PAs much faster, their responses indicate that interactive images were just as available for the PAs as separate and separate/interactive images were for their respective groups.

It should be kept in mind that the imageability ratings were noncomparative. That is, the subjects in the interactive group judged the ease with which the PAs aroused that type of image during the study trial without having generated separate or separate/interactive images also. Without a common standard of comparison across groups the interpretation of the analysis is not as unambiguous as would be desired. However, given the almost identical mean imageability ratings for the three groups, and the fact that the subjects reported no difficulty

Table 4

Mean Imageability Ratings

	M
Interactive	4.92
Separate	4.62
Separate/Interactive	5.11

Table 5

Analysis of Variance of Imageability Ratings

Source of Variation	SS	d.f.	MS	F
A (Image Type)	39.38	2	19.69	1.17^{+}
B (Stimuli)	120.59	19	6.35	2.77^{**}
S (Subjects)	662.62	45	14.73	6.44^{**}
A x B	156.56	38	4.12	1.80^{**}
B x S	1955.62	855	2.29	-

+ d.f. = 3,67

** $p. \leq .01$

in following the instructions, an argument based on a hypothesized differential task difficulty among the groups would be hard to defend.

A test of stimulus recognition was used to test the hypothesis that the interactive component in the image imparts an enhanced distinctiveness to the stimulus term of the paired-associate. If the distinctiveness hypothesis is correct, then both the interactive and separate/interactive groups should be superior to the separate image group in stimulus recognition. Table 6 presents the mean stimulus recognition scores for the three groups. An analysis of variance of the recognition scores, presented in Table 7, revealed (not surprisingly, given the almost identical mean scores) no significant differences among the groups ($\underline{F}(2,47) = 0.65$, $\underline{p}. > .05$). A perfect score on the recognition test was 20. As the means indicate, very few subjects in any of the groups got less than a perfect score. There is the possibility that a ceiling effect is masking significant differences among the groups in these results. Although there is no direct evidence against a ceiling effect, the fact that the stimulus recognition results parallel those of Bower's (1970), where his groups were similarly identical in their ability to recognize the PA stimuli, suggest that they reflect more than an artifact of the test's design.

A test of backward recall was used to test the

Table 6

Mean Stimulus Recognition Scores

	M
Interactive	19.81
Separate	19.94
Separate/Interactive	19.81

Table 7

Analysis of Variance of Stimulus Recognition Scores

Source of Variation	SS	d.f.	MS	F
Treatments	0.17	2	0.084	0.651
Error	5.81	45	0.129	
Total	5.98	47		

associative directionality implications of the relational association hypothesis. Table 8 presents the mean number of stimulus PA terms given when cued by the response term. Although there was no overall significant difference among the groups ($\underline{F}(2,47) = 3.55$, $\underline{p}. > .05$), the relational association hypothesis is quite specific as to where the differences should lie among the three groups. Since the interactive group combined both words into one image, the association between the words was assumed to be symmetrical. Either noun in the pair should be equally as likely to cue recall of the image and thus make the other word available as a response. Therefore, the interactive image group should be superior to the other groups in a test of backward recall. To test this hypothesis, a planned comparison was made between the interactive image group and the separate and separate/interactive image groups. The results of that comparison are presented in Table 9. As predicted, when the interactive group is compared against the other two, the difference is significant ($\underline{F}(1,47) = 6.34$, $\underline{p}. \leq .05$).

It will be recalled that eight subjects from the separate and separate/interactive groups failed to master the list by the twelfth test trial. It could be argued that these subjects were at a disadvantage when taking the backward recall test, and that the differences among the groups might be accounted for by these subjects.

Table 8

Mean Backward Recall Scores

	M
Interactive	19.81
Separate	18.31
Separate/Interactive	18.81

Table 9

Analysis of Variance of Backward Recall Scores

Source of Variation	SS	d.f.	MS	F
Comparison	16.67	1	16.67	6.34*
Residual	2.00	1	2.00	0.76
Treatments	18.67	2	(9.33)	(3.55)
Error	118.31	45	2.63	
Total	136.98	47		

* $p. \leq .05$

To correct for this bias an analysis was performed in which only the items learned during the test trials were considered. Those subjects who failed to reach a criterion of one perfect test trial were held accountable for only those PAs which were correct on the twelfth test trial. A score was assigned to each subject which represented the ratio of items correct on the backward recall test to the total items tested. The results of the analysis, presented in Table 10, remained essentially unchanged. Therefore, it seems reasonable to conclude that the difference observed between the interactive image group and the other two groups reflects more than an artifact of the study's procedure.

The results of the backward recall test contain implications for Paivio's associative directionality hypothesis (Paivio, 1971, p. 278). According to this hypothesis, if an association involves visual imagery it will be symmetrical, and if it involves the verbal symbolic system, it will be directional. However, all three groups in this study used some sort of imagery to form associations, yet the group using interactive imagery was superior to the other two in the test of backward recall. Thus, Paivio's associative directionality hypothesis might be more accurate if it were revised to read: "To the extent that associations involve interactive visual imagery, they will be symmetrical."

Table 10

Analysis of Variance of Backward Recall Ratio Scores

Source of Variation	SS	d.f.	MS	F
Comparison	0.0403	1	0.0403	6.26*
Residual	0.0036	1	0.0036	0.57
Treatments	0.044	2	(0.022)	(3.41)
Error	0.290	45	0.006	
Total	0.334	47		

The evidence has thus far been overwhelmingly in favor of the relational association hypothesis. Subjects employing an interactive image strategy learned the PA list in one third the time it took the subjects using separate and separate/interactive images, and they had nearly perfect backward recall. If interactive imagery is such an effective strategy for learning paired-associates, then one might expect that once an interactive image for a particular PA is found, it will tend to be retained unmodified during learning. The subjects in the separate and separate/interactive groups, however, upon finding that their original mnemonics were not effective, might be expected to have modified their images or switched strategies altogether. To test this hypothesis the original images reported by each subject during the study trial were compared to the image reports given on the post-experimental questionnaire. An image consistency score which represented the number of images left unchanged was assigned to each subject. Table 11 presents the mean image consistency scores for the three groups. The subjects using interactive imagery retained more of their images in their original form than did the subjects in the other two groups ($\underline{F}(2,47) = 7.19$, $\underline{p}. \leq .01$). A statistical comparison between the interactive group and the other two, presented in Table 12, indicated that the significant differences could be accounted for solely

Table 11

Mean Image Consistency Scores

	M
Interactive	18.44
Separate	13.69
Separate/Interactive	11.78

Table 12

Analysis of Variance of Image Consistency Scores

Source of Variation	SS	d.f.	MS	F
Comparison	346.99	1	346.99	13.27**
Residual	29.02	1	29.02	1.11
Treatments	376.01	2	(188.01)	(7.19)**
Error	1176.86	45	26.45	
Total	1552.87	47		

** $p. \leq .01$

by the difference between the group using interactive images and the other two groups.

A further indication of the superiority of the interactive image mnemonic is revealed by looking at the images which were changed by the subjects in the separate and separate/interactive groups. In the separate group, 63 percent of the images which were modified became interactive images; for the separate/interactive group, 60 percent of the modified images became interactive. Thus, without any prompting, the subjects in these two groups spontaneously adopted an interactive image strategy. Indeed, it was difficult to prevent some of these subjects from using an interactive strategy during the study trial!

Paivio and Yuille (1969) reported similar results in their study of changes in associative strategies. Probing trial by trial, they found that the effect of instructional set was washed out by the third trial, and that interactive imagery was the most frequent strategy reported when one member of the PA was a concrete noun. Blick and Boltwood (1972) reported the results from their study which indicated that imagery was one of the primary mnemonic strategies used by college students given no initial learning set for memorizing a list of PAs.

These results indicate that the differences observed among the three groups are not as great as they might have been. If the subjects in the separate and separate/interactive groups had followed their instructions faithfully, it would have probably taken them much longer than it did to learn the PA list.

The results argue persuasively for the superiority of the mnemonic technique of interactive imagery, and also seem to indicate that separate but elaborated images are no more helpful in associating PA noun pairs than simply imagining the referents of those nouns. However, this conclusion must be tempered by the understanding that no matter how much the separate and separate/interactive image groups were different theoretically, in actuality they were not as distinct as would have been desired. It proved extremely difficult to find subjects who followed the instructions exactly and produced either type of image consistently. Typically, the subjects in both groups produced a mixture of both types of images during the study trial. The separate and separate/interactive groups, then, were more alike than different, and this might explain the fact that the mean trial of learning for both groups was practically identical. The possibility remained that separate/interactive images may have facilitated the subject's learning, and that this effect was masked by the production of separate images by the same subjects.

An attempt was made to tease apart the effects of generating separate and separate/interactive images post hoc. The 1,280 images reported by the 32 subjects in the two groups were written out, and two judges placed each image into one of three categories: separate, separate/interactive, and interactive. From this initial pool of images, a sample of separate and separate/interactive images was chosen. Each PA was associated with two images (one for the stimulus and one for the response word), and only homogeneous image pairs were considered for the sample. If, for example, a subject had generated a separate image for the stimulus and a separate/interactive image for the response associate, that image pair was not considered for the sample. Both types of image pairs were collected in this manner for each of the 20 PAs in the list. From this sample five of each of the two types of images were randomly selected for each PA. The final sample consisted of 100 of each of the two types of image pairs. The agreement between the judges for the image pairs in the final sample was 98 percent.

The trial of learning for each image pair sampled from the two image types was recorded, and an analysis of variance, presented in Table 13, was used to assess the difference in learning rate for the two types of images. The mean trial of learning for the two types of

Table 13

Analysis of Variance of Trial of Learning for a Sample of Separate and Separate/Interactive Images

Source of Variation	SS	d.f.	MS	F
A (Image Type)	1.45	1	1.45	0.18
B (Stimuli)	260.70	19	13.72	1.59
A x B	157.46	19	8.29	0.96
Error	1377.60	160	8.61	

image samples (Separate = 4.18 and Separate/Interactive = 4.01) is barely unchanged from that of their corresponding experimental groups (cf. Table 1), and the difference between them remained nonsignificant ($\underline{F}(1,19) = 0.176$).

The results of the post hoc analysis suggest that had the separate and separate/interactive groups remained distinct procedurally, they would not have differed in their effect on the subjects' rate of learning, and the interactive image group would have remained superior in its learning of the paired-associates.

Conclusions

The results of this study clearly favor the relational association hypothesis. The group employing interactive imagery learned the PAs faster than the groups using separate and separate/interactive images, and they also exceeded the other two groups in a test of backward recall. Both of these results were predicted from the relational association hypothesis. It would be difficult to argue that interactive imagery enhances stimulus distinctiveness given the performance of the separate/interactive group in this study, and the results of the stimulus recognition test. The results of this study, taken together with those of Bower's (1970), offer strong support to the assertion that imagery facilitates PA learning by aiding directly in the formation of associations.

It is one thing, however, to say that interactive imagery facilitates the formation of associations, and quite another to interpret that statement. How is interactive imagery facilitative? What are the mechanisms by which associations are formed and maintained in imagery? These are the primary and most complex questions which must be resolved. They are questions which transcend the relatively isolated study of mental imagery, and encompass the whole area of human associative learning and memory.

Three theoretical approaches taken to the interpretation of the imagery data are outlined by Anderson and Bower (1973). The first of these approaches is the "radical imagery" hypothesis. A variant of this approach is advocated by Bugelski (1970). According to Bugelski, the meaning of words is dependent on imagery. A word arouses a given set of sensory-perceptual responses in the person (denotative dimension of meaning) and certain emotional responses (connotative dimension of meaning). In associative learning the information is encoded as images, and the associations are formed, stored, and retrieved as images.

The radical imagery position is based on a metaphor which likens images to mental pictures. The metaphor has been taken too seriously in this case, however; it has been reified (see Sarbin, 1964). The statement that images appear _as if_ they are mental pictures has become: Images _are_ mental pictures. The result is a theoretical position that has mental pictures being shuttled back and forth in memory, and placed before a "mind's eye" for inspection. The experience of people born blind makes Bugelski's position questionable. Since they have never had any visual experiences, these individuals could hardly be said to possess visual mental imagery. Yet blind people have no trouble acquiring linguistic competence, and they perform associative learning tasks with little difficulty.

The second theoretical position, which has been most vigorously advocated by Paivio (1971), is the dual coding hypothesis or the coding redundancy hypothesis. This position advocates two separate systems for the representation and storage of information with many interconnections between them. One system is specialized for the storage of visual-spatial information (including images), and the other system is specialized for the storage of verbal-linear information. Associations are formed and stored separately in each system. This hypothesis explains why concrete verbal material is learned much faster than abstract material in associative learning studies. Concrete material has both systems available for storage and association formation, whereas abstract material is handled exclusively by the verbal system. If the associations formed between the abstract words are forgotten they are gone for good, but the associations between the concrete words can be lost in one system and still remain in the other.

The dual coding hypothesis receives indirect theoretical support from the studies of split brain subjects. These studies have revealed that the two cerebral hemispheres have quite specific specializations (Sperry, 1961). The information processing in the left cerebral hemisphere is predominantly linear and sequential. It is involved with language production and logical, analytic thinking. The right cerebral hemisphere, on the other hand, is predominantly spatial and holistic. It is involved with orientation in space and artistic endeavors. There is, then, some physiological evidence to support the notion that there are two different systems available for coding and processing verbal information (in individuals with their corpus callosum intact, of course), a verbal system localized in the left cerebral hemisphere, and an imaginal system localized in the right cerebral hemisphere.

However, direct experimental evidence favoring the dual coding hypothesis has been far from overwhelming. It has been extremely difficult to demonstrate the distinctiveness of the two representational systems. Paivio's arguments rest primarily upon an experiment by Paivio and Foth (1970). Earlier studies had suggested that the failure to demonstrate the dual coding theory of mediator production was due to the subjects' failure to maintain the instructional sets they had been given before learning (e.g. Paivio and Yuille, 1969). Paivio and Foth had their subjects learn a list of either concrete or abstract noun PAs, but to insure that they would continue to follow instructions, they had the subjects draw simple pictures connecting the PAs to be learned by imaginal mediation, and write sentences linking the PAs to be learned by verbal mediation. From the dual coding hypothesis, an interaction was predicted in which imaginal mediators would facilitate the learning of the concrete PAs more than the verbal mediators, and verbal mediators would facilitate the learning of abstract PAs more than imaginal mediators. As you might have guessed, the results were exactly as predicted.

The results from this study are not as unambiguous as Paivio presents them, however. Confounding elements in the procedure might account for the results. Even though presentation time for all noun pairs was constant, it could be argued that it takes longer to sketch a picture than it does to write a simple sentence. Thus, the PAs learned by imaginal mediation had a study time effectively longer than the PAs learned by verbal mediation. This might explain the facilitative effect of imagery in learning the concrete noun pairs. Even though the same argument would hold for the abstract noun pairs, it could be argued further that the task of linking two abstract nouns together in a sentence is much easier than the task of imaging and drawing a relationship between those same nouns. Thus, differential task difficulty might explain why sentence generation was better than imaging for learning abstract PAs.

How does interactive imagery facilitate associative learning? A "radical imagery" solution to this question seems inappropriate, and a strict dual coding hypothesis is questionable at best. Anderson and Bower (1973), based on their work with a computer model of human associative memory (HAM), have proposed a "conceptual-propositional" hypothesis to explain imagery's mnemonic effects. Our knowledge of the world is represented in memory not as a collection of images or words, but in terms of properties of objects and the relationships between them. It is an abstract propositional system which is distinct from the symbol systems we use to communicate our knowledge of the world. It is in this abstract propositional system that associations between items are formed. It is also tempting to speculate that within such a system the interface between physiological events and conscious experience can be found (Piaget, 1968). The representation of the associations is neutral with respect to the modality in which the information was received, whether it be verbal or perceptual-imaginal. Indeed, these modalities are often mixed in association formation; this would explain why one can associate the color black to the stories of Poe, for example.

The associations which are formed in this abstract conceptual system can be expressed in images, verbally, or sometimes both ways. A modification of the dual coding hypothesis is suggested which might be called the dual modality hypothesis. There are two modalities in which we can express propositions (associations): a verbal modality which outlines the proposition, and an imaginal modality which details it. A similar position is contained in Bower (1972) where he makes a distinction between propositional memory, which contains the "what" of a proposition, and memory imagery which contains the "how" of a proposition. For example, the sentence "Mary hit John" is a verbal statement of the relationship between John and Mary. It answers the question, What is the association between John and Mary? A mental image of the sentence adds detail to the proposition; it might illustrate how John looked as he was hit by Mary, what he was wearing, etc..

An implication of the dual modality hypothesis is that any activity which encourages the formation of associations between objects will facilitate the memory for those objects. Experimental evidence from the comparison of sentence generation mnemonics to imagery mnemonics in associative learning seems to support the hypothesis. Bower and Winzenz (1970) found that subjects using either imagery or sentence generation strategies both had high PA recall scores. Although the imagery subjects had a slight but significant edge over the sentence subjects, both groups performed twice as well as the group which learned by rote repetition. Anderson and Bower (1973) report a study in which subjects, instructed to use either a sentence or image strategy to learn a list of PAs, could not remember on a subsequent test trial which strategy they had used any more than a control group could remember whether the pair was presented on the left or the right (even though the recall for the PAs learned by each strategy were equal.)

The effectiveness of an interactive image mnemonic, therefore, may reside not in the properties of the image itself, but in what the mnemonic encourages the subject to do. Interactive imagery causes the individual to search for and to compose a propositional relationship between two objects. As long as this relationship is formed it may not even matter if it can be pictured. Neisser and Kerr (1973) had two groups of subjects learn object pairs by forming images of the relationship between the objects described in a sentence. For one group the sentence described relationships which were picturable (e.g. "The gun is in the holster.") For the other group the sentence described a relationship which was only partially picturable (e.g. "The gun is in the breast pocket of Napoleon's coat.") Both groups performed equally in the recall tests, and both were superior to a group which imaged each object separately. Thus, the crucial variable was the formation of object relationships, and not the quality of the images of those relationships.

It goes without saying that much more research needs to be done on these questions. The results of the present study suggest that the facilitative effects of imagery in paired-associate learning are due to the formation of associations between stimulus and response, and not to any effect of imagery on the functional stimulus. The results do little to resolve questions raised by Paivio's dual coding hypothesis, and they tend to support the emphasis which Anderson and Bower place on the formation of propositional relationships. The resolution of the issues discussed will have important implications not only for the study of imagery, but for the understanding of human associative memory in general.

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Vita

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