THE EFFECTS OF CONCURRENT SHADOWING ON RECOGNITION MEMORY FOR DIFFERENTIALLY CODABLE PICTURES

by

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ABSTRACT

In the present experiment, subjects were presented with a mixed list containing pictures of human faces rated to be either easy or difficult to describe verbally. Subjects were either engaged in shadowing a sequence of rapidly presented (108/min) auditory letters, listening to the auditory letters, or simply viewing the pictures under either a fast (1 item/sec) or slow (1 item/2 secs) list presentation rate. Both shadowing and fast presentation rate conditions yielded approximately equal decrements in recognition memory for high and low codable pictures. The results were tentatively interpreted as supportive of the elaborated dual-coding hypothesis (Paivio & Csapo, 1973).

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Introduction

One of the ubiquitous findings supportive of Paivio's (1971) two process theory of memory is the positive relationship obtained between the degree of concreteness of the to-be-remembered information and retention. Objects and pictures are remembered better than concrete words, which, in turn, are superior to abstract words. These findings are consistent across many verbal learning and memory paradigms: free recall (e.g., Paivio & Csapo, 1969; Paivio & Csapo, 1973; Santa, Ruskin, & Yio, 1973), serial learning (e.g., Paivio & Csapo, 1969; paired-associates learning (e.g., Lynch & Rohwer, 1971; Dominowski & Gadlin, 1968), and recognition memory (e.g., Gorman, 1961; Shepard, 1967).

In its simplest form, the two process theory states that pictures and concrete words can be encoded along both verbal and imaginal dimensions, but abstract words, having no object referents, are less likely to be encoded imaginally. This position leads to the prediction that the probability of recall is a direct function of the availability of both codes, as opposed to either one alone. If one of the codes is lost from memory, there is still a likelihood that the information may be retrieved from the other code. It is assumed that a verbal label for a picture is more likely to be available than an image for a concrete word, accounting for the higher retention of pictures over concrete words. Suggestive empirical support for this assumption is provided by the comparisons of the relative latencies of verbal and imaginal referential reactions to pictures and words (Paivio, 1971, pps. 74-76).

In addition to varying stimulus attributes, tests of the dual coding hypothesis have centered on manipulation of instructional sets (e.g., Yarmey & Csapo, 1968; Paivio & Yuille, 1967), stimulus presentation rate (e.g., Paivio & Csapo, 1969) and intentional-incidental learning sets (e.g., Paivio & Csapo, 1973). Each of these approaches is designed to control the differential availability of the imaginal or verbal code during acquisition. Instructional sets have been used in those paradigms which are most sensitive to the establishment of associations between the to-be-remembered information (e.g., paired-associates learning). Typically, subjects would be instructed either to link the to-be-remembered items in some meaningful verbal context or to form a "mental picture" of these items in some kind of an interaction. Mediational instructions usually produce superior recall relative to nonmediational controls. When mediational set and imagery value are varied orthogonally, a more critical theoretical prediction results. Specifically, verbally instructed subjects should demonstrate equivalent recall of both abstract and concrete materials, whereas imaginally instructed subjects should show superior recall of concrete relative to abstract materials. While these patterns of results have been obtained (e.g., Yarmey & Csapo, 1968), failures to confirm the predicted interaction have also been reported (e.g., Paivio & Yuille, 1967). These inconsistencies with theoretical predictions have been attributed to the abandonment of instructional sets that provide an inefficient strategy for acquisition. Experimental support for this conclusion is provided by Paivio and Yuille (1969). Subjects learned a list of noun-noun pairs in which the concreteness of stimulus and response members was varied factorially. Different groups were given imaginal, verbal, repetition, or control (no set) instructions to link the members of the pairs. Subjects within each instructional set were tested and questioned about their acquisition strategies after one, two, or three trials. Recall was facilitated by stimulus and response concreteness across all trials and by imaginal and verbal mediation sets relative to repetition and control conditions on the first two trials. The latter effect was qualified by an interaction with response concreteness, such that noun pairs with concrete rather than abstract responses enjoyed a greater increase across trials in the case of verbal and repetition sets, but not imaginal and control sets. These data are best understood in light of the subjects' reports of mediational strategies. Reported use of imagery increased across all trials, especially for concrete-abstract and abstract-concrete pairs. Verbal mediators increased across the first two trials, particularly for abstract-abstract pairs. Repetition set subjects reported frequent use of repetition on Trial 1, with a precipitous decline on subsequent trials. A concomitant increase in verbal mediation was reported in Trial 2, and an even greater increase in imaginal mediation was reported in Trial 3. Thus, imagery emerged as the primary mediator when at least one pair member was concrete.

The availability of imaginal and verbal memory codes has also been controlled by the rate of presentation of the stimulus materials. Conceptually, this manipulation has its effect at the referential level of memory (i.e., pictures can be encoded verbally and words can be encoded imaginally). Evidence for the existence of an additional transformation comes from the comparison of reaction times for imaginal and verbal responses to stimuli differing in concreteness. Fraisse (1968) found no difference in identification between words and their pictorial representation as indexed by motor reaction time, while much longer latencies were associated with the production of the label for pictures relative to words. Paivio (1966) reports that while no difference exists in verbal reaction time to concrete and abstract words, the latency for the production of an image is considerably longer for abstract words. These data suggest that presentation rate and concreteness can be varied simultaneously to determine the availability of one or both symbolic systems. Paivio and Csapo (1969) controlled the availability of imaginal or verbal codes for line drawings, concrete nouns, and abstract nouns by varying the rate at which the items were presented. It had been hypothesized that imagery functions primarily as a parallel processing system, whereas the verbal system is specialized for sequential processing. Thus, performance in nonsequential memory tasks would vary directly with the availability of both memory codes, but the verbal code alone would be crucial for sequential memory tasks. Immediate memory span and serial learning constituted the sequential tasks; free recall and recognition memory, the nonsequential tasks. The findings were generally consistent with the predictions. Memory for line drawings was significantly inferior to words only in the sequential memory tasks at the fast rate (.1875/sec.). In memory span, line drawings were reliably inferior to abstract words at the fast rate, while none of the stimulus differences were reliable at the slow rate (.5/sec.). In serial learning, as in memory span, line drawings were reliably inferior to words at the fast rate, while at the slow rate, line drawings and concrete words were significantly superior to abstract words. This inconsistency was not discussed. Finally, line drawings were significantly superior to abstract words at the slow rate in both nonsequential tasks, with concrete words intermediate in both cases.

While the Paivio and Csapo (1969) study provides results consistent with the dual-coding interpretation, it is possible that performance was not due to the availability of both codes but rather to the increasing availability of the imaginal code alone. This implies that the imagery code for some reason is superior to the verbal code for the storage or retrieval of the to-be-remembered information. Paivio and Csapo (1972) proposed three alternative explanations for the fast rate effect. Perhaps the fast rate, (a) interfered more with the imaginal encoding of line drawings than with the verbal encoding of words; (b) provided insufficient time for the organization of line drawings into higher-order memory units that might be the basis of picture superiority under slow rates; or, (c) simply interfered with effective verbal elaboration in the case of pictures. Paivio and Csapo (1973) tested the imagery superiority hypothesis in each of five experiments concerned with the control of imaginal and verbal codes for pictures and concrete words presented for brief exposures ($\frac{1}{16}$ or $\frac{1}{8}$ sec.). Experiments 1-3 used incidental-intentional learning sets in which associative arousal of the memory codes was controlled by various orienting tasks. The orienting tasks for pictures and concrete words were writing the verbal label (Experiment 1), writing the label or drawing a rough sketch of the pictures and words (Experiment 2), and covertly pronouncing the word or generating an image of the pictures and words (Experiment 3). They found that orienting tasks designed to prohibit imaging to concrete words resulted in a significant decrement in free recall relative to an intentional learning group, but orienting tasks designed to prohibit verbalizing to pictures did not produce a similar decrement. Experiment 4 involved a probability learning task in which subjects were instructed to anticipate the form (i.e., picture or word) of each succeeding stimulus. Incidental recall of pictures was approximately twice as great as that for concrete words. Experiment 5 involved the same probability task, but was extended to include picture-picture, word-word, picture-word, or word-picture repetitions along with the once presented pictures and words. Recall of pictures was approximately twice as high as recall of words and picture-picture stimuli were equivalent to picture-word or word-picture stimuli. This pattern of results provides compelling evidence for the imagery superiority hypothesis, but the marked superiority of picture-word and word-picture stimuli relative to pictures alone led Paivio and Csapo to conclude that recall was a function of both imaginal superiority and dual coding. These authors acknowledge that these data do not provide unequivocal support for a difference in code effectiveness. Despite the set created by the orienting tasks and the probability learning task, which clearly did not require any verbalization to pictures, subjects may nevertheless have implicitly labeled some pictures but were less likely to image to words. Support for this interpretation is provided by Snodgrass and McClure (1975), in which storage and retrieval properties of line drawings and words were studied within a recognition memory paradigm. Storage was manipulated by instructing subjects either to image or to verbalize to both picture and word stimuli during the inspection set. Retrieval was manipulated by representing a proportion of the old picture and word items in their opposite form during the recognition test. It was found that recognition performance for line drawings was identical under the two instructional conditions, whereas recognition performance for words was markedly superior under imagery instructions. They concluded that subjects may engage in dual coding of simple line drawings naturally, independent of instructions, whereas dual coding of words may occur only under imagery instructions.

In a recent test of the elaborated dual-coding notion, Rogers and Rowe (1975) investigated the effects of concurrent auditory shadowing of alphabetic characters on recall and recognition of line drawings, concrete and abstract words. The shadowing technique (repeating aloud sequences of task irrelevant auditory information during the presentation) was used during list presentation. It was predicted that to the extent verbal processes facilitated recall, recall performance after shadowing should be poorer than that of a nonshadowing control group. This effect should be greatest for concrete and abstract words. If, in fact, the imaginal code is qualitatively superior to the verbal code, a smaller shadowing effect should occur for recall of line drawings. Although a main effect for item type was evident (i.e., pictures and concrete words were recalled better than abstract words), the critical interaction was not obtained. A second, procedurally similar experiment employing a recognition memory task was undertaken, but abstract words were not included in the design. Using confidence ratings as the criterion measure and employing a strict criterion to define hits and misses, effects identical to those in the free recall data were obtained. These authors concluded that their data provided no support for the elaborated notion, rather that the simple dual-coding hypothesis could adequately account for these data.

However, the effects reported by Rogers and Rowe (1975) have not been consistently obtained in the literature. Allport, Antonis, and Reynolds (1972) assessed the effects of shadowing on recognition memory accuracy for auditorily presented concrete and abstract words and complex, colored scenes from magazines. Although this experiment was designed to test the single channel hypothesis of human attention (Broadbent, 1958), its results are germane to the dual coding hypothesis. The essential finding was that the shadowing condition did interact with item type in such a way that pictures were less adversely affected by shadowing than visually presented concrete words, which in turn were less adversely affected than auditorily presented concrete words, relative to a no shadowing control.

An experiment by Rollins and Thibadeau (1973) shed light on these disparate findings. They investigated the effects of shadowing on recognition of auditorily and visually presented words, line drawings of common, labelable objects, and line drawings of fictitious characters. The fictitious characters were selected so as to be highly discriminable but lacking ready verbal labels. A d' analysis revealed that shadowing resulted in a significant decrease in recognition for auditorily and visually presented words and common, labelable line drawings, but not for line drawings of fictitious characters. A second dependent measure which corrected for guessing (hits - false alarms) was also analyzed and the results were identical to the d' analysis.

Rowe and Rogers (1975) speculated that the results obtained in these studies may depend upon the type of pictorial item under consideration. When an unambiguous label can be readily applied to a picture, subjects will augment the visual memory representation with verbal encoding. This suggestion closely parallels the conclusions drawn by Snodgrass and McClure (1975). Thus, shadowing will adversely affect recognition performance for labelable pictures. When a label cannot be readily applied to a picture, as in Rollings and Thibadeau (1973), recognition accuracy will not be affected.

The above discussion suggests that an experiment designed to assess the contribution of verbal processes to recognition memory employ experimental operations which have the effect they are designed to have. This is demonstrated by the sometimes conflicting results obtained when orienting tasks and instructional sets have been employed to affect subjects coding strategies. The purpose of the present study was to determine whether the availability of a verbal code plays a role in recognition memory when an imaginal code is directly available. Shadowing and rate of presentation were manipulated to preclude verbal coding of pictures of high and low codable human faces. If low codable pictures were shown to be less adversely influenced by these procedures than high codable pictures, a dual coding interpretation would be favored. On the other hand, if both high and low codable faces were similarly influenced by these procedures, it would suggest that the imagery code alone was used.

Method

Subjects

Seventy-eight undergraduates (32 males and 46 females) enrolled at The University of Alabama participated in the experiment. Subjects were given course credit for participation.

Materials

The stimuli in the study phase of the experimental sequence were 150 black and white and colored pictures of human faces. The 32 critical pictures of the 150 in the study phase had been selected previously (Martin, 1976) on the basis of their rated codability. Martin's (1976) scaling procedure consisted of having subjects rate 80 pictures, on a 5 point scale, on the basis of the ease or difficulty with which subjects were able to think of an identifying word or phrase (1 = very hard, 2 = hard, 3 = average, 4 = easy, 5 = very easy). The 16 pictures assigned the highest and the 16 assigned the lowest codability ratings comprised the critical items (see Appendix A). The remaining 118, unrated pictures, randomly selected from popular magazines (e.g., Look, National Geographic, Cosmopolitan) served as filler items.

The stimuli in the test phase were 64 black and white and colored pictures of human faces. The 32 target pictures, "old" items, which appeared in the study phase and 32 unrated pictures, randomly selected from popular magazines (e.g., Look, National Geographic, Cosmopolitan) served as "new" items.

A practice task was fashioned with an additional 24 unrated pictures 18 of which were tested among 8 distractors in a test phase. All items were photographed on 16 mm Kodak Ecktachrome film.

Design

The design included two types of stimuli (high and low codable pictures), two rates of presentation (fast = 1 item per second, and slow = 1 item per 2 seconds), and shadowing conditions (shadowing, listening, and control). Codability was varied within subjects, while rate and shadowing were varied between subjects.

Procedures

A study-test recognition memory procedure was employed. Prior to the study phase, subjects were instructed concerning the nature of the task (see Appendix B for detailed instructions). The 150 pictures comprising the study phase were randomly arranged except that none of the 32 critical items occurred in the first or last fifteen positions and no more than three critical items appeared consecutively. The 64 pictures of the test phase were randomly arranged except that the mean lags for high and low items were approximately equal ($\overline{X}_{HIGH\ CODABLE} = 111.63$, $\overline{X}_{LOW\ CODABLE} = 108.19$) and no more than three critical or distractor items appeared consecutively.

The pictures were presented on a screen by a 16 mm filmstrip projector (LW Super Sport Analyst, Model 800) from a room adjacent to the experimental chamber. The resulting image on the screen was approximately 34 mm X 46.5 mm. Each subject was seated approximately 172.5 mm from the screen. During the study phase, the projector was pulsed by an external electromechanical timer at the rate of 1 item per second (fast) or 1 item per 2 seconds (slow). The rates were selected on the basis of reaction time data (Fraisse, 1968) of associative code arousal and pilot data which indicated the need for the present stimulus exposures. The test phase was subject paced, i.e., the subject could take as much time as needed to reach a decision. Subjects indicated their decisions by verbally responding "old" if the item had appeared during the study phase or "new" if it were appearing for the first time. The experimenter marked each decision on a prepared form.

The shadowing material consisted of random sequences of letters (excluding W) recorded stereophonically on a tape recorder (Roberts 770X) and played through headphones (Channel Master 6407). Five sequences of 120 letters each were used as practice sets for all subjects in the shadowing and listening groups. The practice sequences were recorded at increasingly rapid rates, i.e., 90, 95, 100, 108, 108 letters per minute. Most subjects experienced little difficulty in learning to repeat the letters aloud, but the few who did went through the sequences a second time. The listening group heard the practice sequences without attempting to shadow. The control group, given standard recognition memory instructions, neither listened to nor repeated aloud the letter sequences.

The second aspect of practice provided experience with the recognition task under shadowing, listening, and control conditions. A shadowing list, 100 letters in length, was simultaneously presented with a picture sequence at a rate of 108 letters per minute. Subjects in the shadowing and listening conditions repeated letters and listened, respectively, for approximately 15 seconds prior to the beginning of the picture presentations (i.e., the shadowing task began before the recognition task) but it terminated at approximately the same time as the final picture in the study phase. Because of slight variation in the reaction time of the experimenter, the termination of the picture and letter sequences were not effected at exactly the same time for each subject. However, care was taken to insure that the letter sequence never ended before the termination of the last study picture. Control subjects simply observed the pictures. Approximately 10 seconds intervened between the termination of the study phase and initiation of the test phase. As in the shadowing practices, subjects experiencing difficulty performing the concurrent tasks repeated the practice sequence.

The recognition task was performed under shadowing, listening, and control conditions. The shadowing task, consisting of 600 letters, was presented at a rate of 108 letters per minute. As in the above described practice task, subjects in the shadowing and listening conditions repeated letters and listened, respectively, for approximately 15 seconds before the initiation of the picture sequence. Approximately 10 seconds intervened between the termination of the study phase and the introduction of the test phase. Shadowing performance was recorded on a separate cassette recorder (General Electric M8459A). One subject in the shadowing condition produced more than 25% shadowing errors (i.e., omissions, inversions, substitutions) and was replaced. Two additional subjects were replaced, one because of a stuttering problem and the other due to time demands which necessitated his departure before the completion of the experiment.

Subjects were assigned randomly to conditions and tested individually. Fifteen subjects were run in each of the three fast rate, between-groups conditions, and ten subjects were run in each of the three slow rate, between-groups conditions. To simplify data analyses, five subjects were randomly eliminated from each of the three fast rate, between-groups conditions. This yielded 10 subjects for analysis in each of the six between-groups conditions.

Results

The proportion of items correctly recognized as "old" (i.e., hits) and incorrectly recognized as "old" (i.e., false alarms) were used to determine d' values for each subject in each condition. The mean proportion of hits and false alarms and the corresponding d' values are shown in Table 1 for high and low codable pictures under all shadowing and presentation rate conditions.

A summary of the analysis of variance of d' values with shadowing, presentation rate, and codability as factors is presented in Table 2. The codability effect is attributable to greater accuracy for high codable relative to low codable pictures. An F_{max} statistic was computed to determine the tenability of the assumption of homogeneity of variance for these data. The assumption was not met, F_{max} (9,12) = 17.51, $p < .01$. However, Norton (1952) has shown that the

TABLE 1

Proportion of hits and false alarms and d' as a function of Codability, Shadowing, and Presentation Rate conditions.

		Shadowing Condition			Listening Condition			Control Condition		
	Codability	Mean Hits	Mean False Alarms	Mean d'	Mean Hits	Mean False Alarms	Mean d'	Mean Hits	Mean False Alarms	Mean d'
Fast Rate	High	.6188	.2813	1.04	.8063	.1689	2.13	.7188	.1500	2.00
	Low	.4375	.2813	.50	.5625	.1689	1.21	.5875	.1500	1.33
Slow Rate	High	.6250	.2313	1.25	.8063	.2000	2.26	.8563	.1875	2.46
	Low	.5875	.5875	1.03	.6563	.2000	1.78	.7063	.1875	1.63

TABLE 2

Summary of analysis of variance of d' for Presentation Rate, Shadowing, and Codability conditions.

Source	SS	df	MS	*F*
Rate	3.675	1	3.68	2.837
Shadowing	20.773	2	10.39	8.018*
Rate X Shadowing	.008	2	.004	.003
Error (B)	69.949	54	1.295	
Total (B)	94.387	59		
Codability	11.781	1	11.782	30.679**
Rate X Codability	.208	1	.208	.543
Shadowing X Codability	.963	2	.481	1.253
Rate X Shadowing X Codability	.701	2	.350	.912
Epror (W)	20.737	54	.384	
Total (W)	34.390	60		
Total	128.777	119		

*$p < .01$

**$p < .001$

F distribution is robust despite marked departures from homogeneity of variance.

The source of the significant shadowing effect was examined by pairwise *t* test comparisons between shadowing, listening and control conditions, with the data collapsed across presentation rate and codability. Due to the heterogeneity of variance, separate pooled variance terms were computed for each comparison. The one-tailed *t* test comparisons showed that the Listening condition was reliably superior to the Shadowing condition, $t(18) = 2.06$, $p < .05$, and the Control condition to be reliably superior to the Shadowing condition, $t(18) = 2.54$, $p < .025$. No reliable difference was obtained for the listening-control condition comparison, $t(18) = .020$, $p > .05$. None of the interaction effects were reliable.

A one-tailed *t* test was performed on the numbers of letters correctly shadowed under fast and slow presentation rates. No reliable difference was obtained, $t(18) = 1.05$, $p > .05$.

Several subjects in each group had perfect hit rates. Since d' is not defined for these values, the closest estimate of d' was employed. A second dependent variable that corrects for guessing (p(0/0) - p(0/N)) was also analyzed. A summary of the analysis of variance of these corrected data with Shadowing, Presentation Rate, and Codability as factors are presented in Table 3. Recognition was lower for low codable pictures than for high codable pictures. A main effect for shadowing condition was also found. An

TABLE 3

Summary of analysis of variance of corrected data (P(0/0) - P(0/N)) for Presentation Rate, Shadowing, and Codability conditions.

Source	SS	df	MS	*F*
Rate	.129	1	.129	2.816
Shadowing	1.535	2	.768	16.732**
Rate X Shadowing	.071	2	.035	.768
Error (B)	2.477	54	.046	
Total (B)	4.212	59		
Codability	.782	1	.782	38.882**
Rate X Codability	.072	1	.072	3.575
Shadowing X Codability	.047	2	.023	1.167
Rate X Shadowing X Codability	.007	2	.004	.176
Error (W)	1.086	54	.020	
Total (W)	1.994	60		
Total	6.206			

$^{**}p < .001$

F_{max} statistic was computed on these data and the results indicated that the assumption of homogeneity of variance was met, $F_{max}(9,12) = 5.703$, $p > .05$. The overall variance term was used for the pairwise t comparisons between shadowing, listening and control conditions. These comparisons demonstrated superior performance for the listening vs. shadowing condition, $t(54) = 2.235$, $p < .025$, and the control vs. the shadowing condition, $t(54) = 2.643$, $p < .01$. No reliable difference was obtained for the listening-control condition comparison, $t(54) = .423$, $p > .05$. The results of the analysis of the corrected data mirror those performed on d'.

Discussion

The present study attempted to determine whether the availability of a verbal code contributed reliably to recognition accuracy when an imaginal code is directly available. The failure of high and low codable pictures to be differentially affected by operations designed to preclude verbalization suggests that imagery alone was the mode of representation employed. If it can be assumed that a descriptive phrase or word is more difficult to generate for pictures of human faces than for line drawings of objects, these data are consonant with the conclusions of Rowe and Rogers (1975) and Rollins and Thibadeau (1973). However, despite the failure to obtain a differential effect of shadowing and presentation rate on high and low codable pictures, high codable pictures enjoyed a marked overall superiority to low codable pictures. This finding is explicable if it can be shown that the present stimuli differed not only in codability but also along some other dimension, such as imaginal distinctiveness.

Two experiments by Martin (1976), employing the same high and low codable pictures used in the present experiment, bear on this issue. Instructional set (imaginal, verbal, and control) was orthogonally varied with codability of paired-associate stimuli in an attempt to provide evidence for the dual-coding or the imaginal-superiority hypothesis. It was assumed that high and low codable pictures were equally concrete, and therefore "imaginable," but differed in verbal referential meaning. Support for the dual-coding hypothesis would result if paired-associates with high codable stimuli had been learned significantly better than pairs with low-codable stimuli, particularly under the verbal instructional set. Support for imaginal superiority would have resulted if no difference between the high and low codable pictures had been obtained and the verbal instructional set failed to differentially affect high and low codable pictures. The only reliable effect obtained indicated overall superiority of high over low codable pictures.

The assumption of imaginal equality for high and low codable pictures was tested in a study-test recognition memory task. High and low codable pictures were presented at either fast (2.7 items per second) or slow (1 item per second) presentation rate. The fast rate was designed to preclude associative arousal of the verbal referential code to the pictures. If these stimuli differed only in codability, recognition should be equivalent for both high and low codable pictures at a fast rate, but high codable pictures should be favored by the slow rate. The predicted advantage favoring high codable pictures with a slow presentation rate was obtained, but high codable pictures were also superior to low codable pictures at the fast presentation rate. This finding led Martin (1976) to conclude that high-codable pictures exceeded the low codable pictures not only in verbal codability, but also in imaginal distinctiveness. Thus, precise interpretation of the paired-associates learning data was prohibited. In an attempt to account for the strong codability effect in the paired associates data, two partial correlations were computed. In one, rated codability (i.e., the mean verbal codability rating assigned to each picture) was partialed out of the relationship between distinctiveness (i.e., the total number of correct recognitions of each picture at the fast presentation rate) and paired associates learning. In the other, distinctiveness was partialed out of the relationship between codability and paired associates learning. Results revealed that with distinctiveness partialed out, codability still correlated highly and reliably with learning. However, with codability partialed out, distinctiveness was found to be unrelated to learning. The finding that codability could account for all of the variance in paired associates learning that was attributable to imaginal distinctiveness led Martin to conclude that recall was mediated primarily by verbal symbolic processes, and therefore, supported the dual-coding hypothesis.

The only finding consistent with this conclusion was the abovementioned interaction effect between codability and presentation rate in the recognition memory task. Given that the superiority of high codable pictures at the fast rate was attributed to imaginal distinctiveness, it seems equally plausible that the advantage favoring the high codable pictures at the slow rate could be attributed to the same factor. This is to say that the codability effect could be explained entirely in terms of differential availability of images during encoding and storage, which was maximized during the slow presentation rate.

The partial correlations reported by Martin (1976) are not congruous with this interpretation, unless we assume that the codability ratings tapped imaginal distinctiveness rather than verbalizability. The strong relationship obtained between codability and paired-associates learning can then be ascribed to imaginal distinctiveness. How is it that recognizability failed to account for any of the variance in paired-associates learning when codability was partialed out? Consideration of the presentation rates during the rating procedure, paired-associates learning, and the fast rate of the recognition memory experiment may shed light on this question. During the rating procedure, pictures were timed for an 8 second presentation and paired-associates were exposed for 5 or 8 seconds. Recognizability measures were based on a presentation rate of .375 seconds. Given that the extraction of visual information is positively related to increasing exposure durations (Potter & Levy, 1969), it may be that there was insufficient time to maximize the usage of the highly salient visual characteristics. This should have the effect of substantially reducing the correlation between recognizability and paired-associates learning. Given the close correspondence of the presentation rates for the rating procedure and paired-associates learning, it is not surprising that a reliable relationship was obtained between codability and paired-associates learning. This assumption would be supported if correlations between the recognition scores at a slow presentation rate and paired-associates learning, with codability partialed out, yielded a stronger relationship than that obtained with a fast presentation rate. In light of the results of the present study, a reappraisal of the validity of the codability rating procedure seems warranted.

Perhaps the codability variable needs to be assessed more rigorously. Brown and Lenneberg (1954) measured the codability of colors in the following five ways:

1) the average length of the naming response by counting syllables.

2) the average length of the naming response by counting words.

3) the average reaction time for each color by ranking all of the reaction times for an individual subject and determining the mean rank across subjects.

4) the degree to which subjects agreed with one another in naming a color.

5) the degree to which subjects agreed with themselves from one time to another in having a color.

Intercorrelations of these five measures indicated that positive relationships were obtained in all cases, and reliable relationships were obtained in most cases. A factor analysis of these data revealed that the degree of agreement between subjects had the largest factor loading and was selected as the index of codability for a subsequent recognition memory experiment. This measure of codability proved to be related to the subjects' ability to recognize color. The critical importance of discovering a sensitive measure of codability is highlighted by this study.

Finally, the soundness of the conclusions drawn from the present experiment depends upon the validity of the index of codability employed. If the codability measure is valid, these data provide suggestive support for imagery superiority as a mediator of recognition memory. On the other hand, no tenable conclusion could be reached if the codability ratings failed to distinguish between differentially codable pictures.

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APPENDICES

APPENDIX A

Mean Verbal Codability ratings for high and low codable pictures.

High Codable			Low Codable		
Picture Number	$\overline{X}$	S.D.	Picture Number	$\overline{X}$	S.D.
1	4.52	.81	1	2.89	1.23
2	4.39	1.02	2	2.85	1.13
3	4.35	.90	3	2.83	1.04
4	4.33	1.06	4	2.83	1.16
5	4.28	.91	5	2.80	1.07
6	4.24	.95	6	2.80	1.09
7	4.24	1.08	7	2.78	1.15
8	4.22	.99	8	2.74	1.20
9	4.22	1.25	9	2.70	.92
10	4.20	1.00	10	2.70	1.13
11	4.17	1.12	11	2.61	.93
12	4.17	1.14	12	2.61	1.04
13	4.13	1.27	13	2.59	1.17
14	4.11	1.12	14	2.57	1.05
15	4.11	1.12	15	2.52	1.39
16	4.04	1.11	16	2.50	1.19

APPENDIX B

Instructions for Recognition Memory Experiment.

Shadowing Instructions

The purpose of this study is to determine how easily human faces can be recognized. The study consists of two phases. During the first, you will be shown a series of pictures of human faces and at the same time you will hear a series of letters through these headphones. Repeat the letters aloud, you don't have to remember them but you do have to say them accurately. It may be helpful to repeat the letters two at a time. If you make an error, don't worry, just listen carefully and continue on. After you have seen all the pictures, some of them will be presented again more slowly with some new pictures that you have not seen before. During this test phase, you will be allowed enough time to view each of the pictures and decide whether or not you have seen them before. When you see the first picture in the test phase, say aloud "old" if you think it did appear before and "new" if you think it did not appear. You do this for each picture in the test phase. There are equal numbers of "old" and "new" pictures. Be as accurate as you can because only your first response will be recorded.

Now let's practice repeating aloud a few series of letters and then we'll go through a sample task to see that you understand what to do.

Listening Instructions

The purpose of the study is to determine how easily human faces can be recognized. The study consists of two phases. During the first, you will be shown a series of pictures of human faces and at the same time you will hear a series of letters through these headphones. Just listen to the letters, don't repeat them aloud. After you have seen all the pictures, some of them will be presented again more slowly with some pictures that you have not seen before. During this test phase, you will be allowed enough time to view each of the pictures and decide whether or not you have seen them before. When you see the first picture in the test phase, say aloud "old" if you think it did appear before and "new" if you think it did not appear. You do this for each picture in the test phase. There are equal numbers of "old" and "new" pictures. Be as accurate as you can because only your first response will be recorded.

Now let's practice listening to a few series of letters and then we'll go through a sample task to see that you understand what to do.

Control Instructions

The purpose of the study is to determine how easily human faces can be recognized. The study consists of two phases. During the first, you will be shown a series of pictures of human faces. After you have seen all the pictures, some of them will be presented again more slowly with some pictures that you have not seen before. During this test phase, you will be allowed enough time to view each of the pictures and decide whether or not you have seen them before. When you see the first picture in the test phase, say aloud "old" if you think it did appear before and "new" if you think it did not appear. You do this for each picture in the test phase. There will be equal numbers of "old" and "new" pictures. Be as accurate as you can because only your first response will be recorded.

Now let's go through a sample task to see that you understand what to do.

APPENDIX C

Proportion of "Hits" (P(0/0), "False Alarms" (P(0/N), corresponding Corrected Data (P(0/0) - P(0/N))) and d' for Subjects under Presentation Rate, Shadowing, and Codability conditions.

Slow (1 item per second), Shadowing,
High Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P(0/N))	d'
1	.6875	.1875	.5000	1.4
2	.6875	.3750	.3125	.8
3	.6250	.1250	.5000	1.5
4	.6875	.3125	.3750	1.0
5	.5000	.3438	.1562	.4
6	.6875	.0313	.6562	3.3
7	.6875	.1250	.5625	1.7
8	.6875	.2813	.4062	1.1
9	.3750	.3750	.0000	0
10	.6250	.1563	.4687	1.3

Slow (1 item per second), Shadowing,
Low Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P()/N))	d'
1	.5625	.1875	.3750	1.1
2	.8750	.3750	.5000	1.5
3	.6250	.1250	.5000	1.5
4	.6875	.3125	.3750	1.0
5	.5000	.3438	.1562	.4
6	.2500	.0313	.2187	.8
7	.5000	.1250	.3750	1.2
8	.8125	.2813	.5312	1.5
9	.6250	.3750	.2500	.6
10	.4375	.1563	.2812	.7

Slow (1 item per second), Listening, High Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P(0/N))	d'
1	.7500	.0313	.7187	3.5
2	.6250	.3125	.3125	.8
3	.9375	.3750	.5625	1.8
4	.6250	.4375	.1875	.5
5	.8125	.2813	.5312	1.5
6	.7500	.0938	.6562	2.0
7	1.0000	.1250	.8750	4.2
8	.9375	.0313	.9062	4.3
9	.8750	.1250	.7500	2.4
10	.7500	.1875	.5625	1.6

Slow (1 item per second), Listening, Low Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P(0/N))	d'
1	.3750	.0313	.3437	2.5
2	.3750	.3125	.0625	.2
3	.7500	.3750	.3750	1.0
4	.8125	.4375	.3750	1.1
5	.4375	.2813	.1562	.4
6	.8125	.0938	.7187	2.2
7	.6250	.1250	.5000	1.5
8	1.0000	.0313	.9687	5.8
9	.7500	.1250	.6250	1.9
10	.6250	.1875	.4375	1.2

Slow (1 item per second), Control,
High Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P(0/N))	d'
1	.8750	.1875	.6875	2.1
2	1.0000	.0625	.9375	5.5
3	1.0000	.1563	.8437	4.0
4	.9375	.1250	.8125	2.7
5	.7500	.2813	.4687	1.3
6	.8125	.0938	.7187	2.2
7	.8750	.0938	.7812	2.5
8	.5625	.2500	.3125	.9
9	.8750	.4063	.4687	1.4
10	.8750	.2188	.6562	2.0

Slow (1 item per second), Control,
Low Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P(0/N))	d'
1	.6875	.1875	.5000	1.4
2	.8125	.0625	.7500	3.4
3	.5625	.1563	.4062	1.2
4	.6875	.1250	.5625	1.7
5	.6875	.2813	.4062	1.1
6	.5675	.0938	.4687	1.5
7	.8125	.0938	.7187	2.2
8	.8125	.2500	.5625	1.6
9	.8125	.4063	.4062	1.1
10	.6250	.2188	.4062	1.1

Fast (1 item per 2 seconds), Shadowing,
High Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P(0/N))	d'
1	.8125	.0313	.7812	2.8
2	.7500	.3125	.4375	1.2
3	.3125	.0625	.2500	1.0
4	.3750	.1875	.1875	.6
5	.6875	.2500	.4375	1.2
6	.3750	.4063	-.0313	-.1
7	.6875	.4063	.2812	.7
8	.5000	.4375	.0625	.2
9	.8750	.3750	.4375	1.5
10	.8125	.3438	.4687	1.3

Fast (1 item per 2 seconds), Shadowing,
Low Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P(0/N))	d'
1	.2500	.0313	.2187	1.2
2	.3750	.3125	.0625	.2
3	.1875	.0625	.1250	.6
4	.2500	.1875	.0625	.2
5	.4375	.2500	.1875	.5
6	.8125	.4063	.4062	1.1
7	.6250	.4063	.2187	.5
8	.5000	.4375	.0625	.2
9	.4375	.3750	.0625	.1
10	.5000	.3438	.1562	.4

Fast (1 item per 2 seconds), Listening, High Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P(0/N))	d'
1	.9375	.2500	.6875	2.2
2	.8125	.2500	.5625	1.6
3	1.0000	.0938	.9062	4.3
4	.8125	.0313	.7812	2.8
5	.4375	.2188	.2187	.6
6	.6875	.0625	.6250	2.0
7	.8125	.2500	.5625	1.6
8	.8750	.0938	.7812	2.5
9	.8125	.2500	.5625	1.6
10	.8750	.1875	.6875	2.1

Fast (1 item per 2 seconds), Listening, Low Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P(0/N))	d'
1	.6250	.2500	.3750	1.0
2	.3750	.2500	.1250	.4
3	.6875	.0938	.5937	1.8
4	.2500	.0313	.2187	1.2
5	.4375	.2188	.2187	.6
6	.6875	.0625	.6250	2.0
7	.5625	.2500	.3125	.9
8	.6875	.0938	.5937	1.8
9	.6875	.2500	.4375	1.2
10	.6250	.1875	.4375	1.2

Fast (1 item per 2 seconds), Control, High Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P(0/N))	d'
1	.7500	.0625	.6875	2.2
2	.8750	.1563	.7187	2.2
3	.9375	.2500	.6875	2.2
4	.8125	.1250	.6875	2.1
5	.8750	.0938	.7812	2.5
6	.9375	.2188	.7187	2.3
7	.7500	.0938	.6562	2.0
8	.6250	.2188	.4062	1.1
9	.6250	.1250	.5000	1.5
10	.8125	.1563	.6562	1.9

Fast (1 item per 2 seconds), Control, Low Codable conditions

Subject Number	P(0/0)	P(0/N)	(P(0/0) - P(0/N))	d'
1	.4375	.0625	.3750	1.3
2	.5625	.1563	.4062	1.2
3	.5625	.2500	.3125	.9
4	.6250	.1250	.5000	1.5
5	.6875	.0938	.5937	1.8
6	.7500	.2188	.5312	1.5
7	.5625	.0938	.4687	1.5
8	.3750	.2188	.1562	.5
9	.7500	.1250	.6250	1.9
10	.5625	.1563	.4062	1.2