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The anatomy of free recall*

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The relative importance of various covert cues used in free recall is inferred on the basis of conditional probabilities of free recall given success vs failure of cued recall of the same material. Thirty-six names associated with pictures arranged in a 6 by 6 matrix were learned. A free recall test of names was followed by cued recall of names, with pictures, positions, or joint pictures and positions used as cues. Matching tests based on these cues were also administered. The tests were given at one of two stages of training, immediately or after 2 days. Pictorial and position cues are equally well encoded, but pictorial cues are less accessible and, therefore, relatively more useful in cued recall than in free recall. Position and pictorial information related to the names appears to be encoded and forgotten independently, and there is no evidence for summation of subthreshold encoding effects.

Contemporary models of memory stipulate multidimensional encoding processes (Bower, 1967; Mandler, 1967; Wickens, 1970). The assumptions made vary in detail, but it is generally held that memory traces produced by events are anchored to various existing organizations of the memory system, e.g., temporal, spatial, or semantic, and that these organizational systems may provide access to recall of the information. Thus, a man on the witness chair trying to recall a particular experience may find it helpful to review the sequence of events leading up to the experience (access through temporal organization), or to reinstate the place where the experience occurred (access through spatial organization), or to be presented with fragments of conversation related to the experience (access through semantic organization).

In most real-life recall situations, there is little awareness of the extent to which various types of organization are involved in gaining access to the to-be-remembered material, particularly when the material is readily recalled. Search processes tend to become more explicit when recall is marginal, and it is in such situations that the effectiveness of specific retrieval cues related to various types of organization can be established empirically. Thus, the cued recall situation provides a significant and relatively unexploited source of information about the role of organization in the retrieval of information from memory.

The primary goal of the present research is to find out more about the importance of various covert cues operating in free recall. This is to be accomplished by examining conditional probabilities of free recall, given success vs failure in retrieving the same information by means of various types of cues. The rationale involved is straightforward. Suppose Ss are asked to recall the names of all the past vice presidents of the United States, and they list the names they can remember in a free recall test. After this test, the Ss are instructed to respond to a sequence of individual cues by giving the name of a particular vice president associated with each cue. The following three types of cues are used, each for one-third of the vice presidents regardless of whether their names appeared on the free recall protocol: (a) a picture of the vice president, (b) the name of the president who served with that vice president, and (c) the dates of the vice president's term of office. The conditional probability of free recall is then established for names which were successfully cued and for names which were unsuccessfully cued; this is done separately for each of the three types of cues. If it now turns out that free recall of a name is about equally probable whether or not the S could produce the name when he was presented with the picture cue, one may infer that pictorial self-cuing does not play an important role in free recall. On the other hand, if free recall is very likely for those names successfully cued with the associated president cue and much less likely when this cue fails, then it is plausible that the name of the associated president plays a role in the free recall retrieval process.

An additional goal of the present research is to find out more about the interrelations among the various encoding processes which anchor learning material to several types of cues. Most previous investigations of cued recall have made use of semantic cues or of other cues which have preexperimental associations with the to-be-remembered material (Bahrick, 1970; Bregman, 1968; Tulving & Pearlstone, 1966). The cues used in the above example of recalling the names of vice presidents are also of this type. When such preexperimental associations exist, it is difficult to delimit the effects of the experimental encoding processes and, therefore, difficult to reach conclusions about interrelations among these processes. The cues used in the present investigation are, therefore, nonsemantic and were chosen in such a way that all of their retrieval

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effectiveness is acquired during the experimental learning situation.

METHOD

General Design

The material to be learned consisted of 36 surnames, each to be associated with a picture. All names occurred with a frequency of 5-10 per million words (Thorndike & Lorge, 1944). Each name was printed below a xeroxed picture chosen from graduation photographs in high school yearbooks. Pictures of 18 males and 18 females were used, and two random assignments of names to pictures were made. The 36 pictures were arranged in a chart of six rows and six columns, and the Ss were instructed to learn each name in relation to the picture and the position of the picture in the chart. The task is analogous to that of a teacher who uses a seating chart as an aid in learning the names of the students in his class. He finds that his ability to use the correct names depends somewhat upon having each student occupy the seat assigned to him.

The study was conducted in two parts. Training procedures were the same in both parts, and the same 2 by 2 factorial design was used for the between-Ss variables. In each part, according to this design, training was interrupted after either three or six practice trials with the chart, and tests of retention were administered either immediately (IT) or following a delay of 2 days (DT). The first test was a free recall test for names. In Part I of the study, the second test was a cued recall test in which 12 of the names were cued by position cues, 12 by pictorial cues, and 12 by a combination of pictorial and position cues. In Part II the second test was an associative matching test. This test consisted of four subtests which required respectively matching names and faces, names and positions, pictures and positions, and pictures, names, and positions.

Procedure: Part I

Forty-eight male and female undergraduate volunteers were assigned alternately to four groups of 12 Ss each. The chart with pictures and names was positioned vertically at eye level at a distance of 30 in. from the S. The individual pictures measured 1½ x 2½ in.; they were separated vertically and horizontally from adjacent pictures by a distance of 1 in. Each picture and the printed name below it was covered by a shutter which permitted separate or joint exposure of the individual picture and the name. Ss were told to imagine that the board represented a classroom and that they must memorize the names, faces, and seating arrangement of the class. They were told that each picture together with the name belonging to it would be exposed and that E would go through the entire chart several times. E then proceeded to open and close the shutter of the individual pictures by using a timer which gave a 3-sec exposure and a ½-sec interstimulus interval. The exposure sequence was from left to right starting with the top row and progressing through the rows in order. A 3-sec intertrial interval was used after all 36 pictures had been exposed, and training was terminated after three or six trials, depending upon the S's group assignment. Those Ss who had been assigned to DT conditions were then dismissed and asked to return after 2 days. Ss in the IT groups were administered a free recall test immediately after training. In this test they were asked to write down as many of the 36 names as they could remember in any order. A time limit of 3 min was imposed. The cued recall test followed immediately. In the picture cued portion of this test, E presented a series of 12 pictures, one at a time, by placing the picture on a table in front of S. The pictures were duplicates of those shown on the chart. The S was asked to give the appropriate name and was allowed 20 sec for his response. If no response had occurred within 15 sec, he was instructed to guess. The next picture was then presented. In the position cued portion of the test, the chart was presented as it had been presented in training, but all pictures were covered. The E pointed to a particular location on the chart and asked S to recall the name of the person in that location. The time per response was again 20 sec. A new position was then indicated until 12 position cues had been administered. In the picture-position cued condition, E exposed a picture on the chart without exposing the name below it, and S was again allowed 20 sec per response before the picture was covered and another picture exposed until 12 pictures had been presented. Thus, each S was cued with 12 picture cues, 12 position cues, and 12 picture-position cues. Three variations of the cuing test were constructed so that each name was assigned to each of the three cuing conditions, and the three cuing conditions were administered in counterbalanced order to the various Ss of each group so as to control for sequence effects.

Procedure: Part II

Forty-eight male and female Ss were selected, assigned to groups, and trained as in Part I. The associative matching test was administered immediately after the free recall test. It consisted of four subtests, each utilizing different combinations of cues. Nine of the 36 names were assigned to each of the four subtests. Four variations of the associative matching test were constructed so that each name occurred in each type of matching. The sequence of the four subtests was counterbalanced among the Ss of each group. In the picture-name matching subtest, E presented S with a single picture and required S to choose the name associated with that picture from nine names selected from those used in original learning, each printed on a small card and arranged in a 3 by 3 matrix in front of S. After each choice E shuffled the name cards, rearranged them in a new matrix, and presented the next picture to S. This was repeated until each picture had been matched with a name. Ss did not have access to a record of their previous selections and it was possible for them to assign the same name to more than one picture. In the position-name matching subtest, E pointed to a position on the chart and S chose one of the nine names presented to him in the same manner as in the picture-name matching subtest. The picture-position-name matching test involved the same procedure as the position-name matching test except that E exposed the picture on the chart when he required S to choose one of the nine names. In the picture-position matching subtest, E pointed to a position on the chart and instructed S to select one of nine pictures arranged in a 3 by 3 matrix in front of him. As soon as S had made a selection, E shuffled the pictures, rearranged the matrix, and pointed to another position on the chart. On all of the matching tests S was allowed 20 sec per response and was requested to guess if no response was made within 15 sec.

RESULTS AND DISCUSSION

Part I

The number of correct free recall responses and the number of correct cued responses under each of the three cuing conditions was expressed as a proportion of the possible correct responses for each S and for all 12 Ss in each group. The overall proportions for the groups are shown in Table 1. To determine the interrelations between free recall and cued recall, the following four conditional probabilities were also calculated for each S and for each group for each method of cuing: (1) the probability of free recall of a name given cued recall success of that name, $P(FR|CR)$; (2) free recall given cued recall failure, $P(FR|\overline{CR})$; (3) cued recall given free recall success, $P(CR|FR)$; and (4) cued recall given free recall failure, $P(CR|\overline{FR})$. The conditional probabilities for each group for each method of cuing are shown in Table 2. In addition, Table 2 shows differences between the conditional probabilities of free recall given cued recall success vs cued recall failure [$P(FR|CR) - P(FR|\overline{CR})$] and differences between the conditional probabilities of cued recall given free recall success vs free recall failure [$P(CR|FR) - P(CR|\overline{FR})$].

The cued recall scores, the conditional cued recall scores, and the conditional difference scores for individual Ss were each subjected to 2 by 2 by 3 split plot ANOVAs in which degree of training and the retention interval are the between-S variables and the type of cuing condition is the within-S variable. The results are summarized in Table 3, except for two analyses omitted because of missing data, i.e., frequencies of zero in the denominator of proportions for more than 2% of entries.

The free recall scores were analyzed by a simple 2 by 2 factorial ANOVA which confirmed the expected significant effects due to the degree of training ($F = 30.20$, $p < .01$) and due to the retention interval ($F = 66.14$, $p < .01$), but indicated no significant interaction effect ($p > .05$).

Effectiveness of the Three Cuing Conditions. The overall effectiveness of cued recall was fairly low; the ANOVA indicates significantly increased effectiveness as a function of training and decreased effectiveness as a result of the retention interval, without significant interaction. The significant variation attributable to the cuing condition is the result of the greater effectiveness of the joint cues vs either individual cue. This finding will be discussed in detail below. The overall effectiveness of pictorial and position cues is about the same, with pictorial cues having a slight advantage.

Table 1
Proportions of Correct Responses in Free and Cued Recall

Group	Free Recall	Cued Recall: Pi Cue	Po Cue	Pi-Po Cue
3T-IT	.37	.22	.17	.30
6T-IT	.56	.38	.35	.55
3T-DT	.20	.13	.08	.15
6T-DT	.30	.19	.19	.31
Mean	.36	.23	.20	.33

Free Recall Dependence Upon Cued Recall. Although the overall effectiveness of pictorial and position cues is fairly low, the conditional probabilities $P(FR|CR)$ are very high for both types of cues. This indicates that encoding of both types of cues is closely related to free recall performance. This dependence can be interpreted more analytically by a separate examination of the conditional probabilities $P(FR|CR)$ and $P(FR|\overline{CR})$ and of the difference between these two conditional probabilities.

The $P(FR|\overline{CR})$ probabilities allow an estimate of the extent to which free recall must be based upon cues other than those under consideration. On this basis,

Table 2
Conditional Probabilities for Cued and Free Recall

Group	$P(FR\|CR)$ Pi	Po	Pi-Po	$P(FR\|\overline{CR})$ Pi	Po	Pi-Po	$P(FR\|CR) - P(FR\|\overline{CR})$ Pi	Po	Pi-Po
3T-IT	.78	.92	.70	.33	.19	.23	.45	.73	.47
6T-IT	.87	.90	.82	.35	.38	.25	.52	.52	.57
3T-DT	.79	.92	.91	.13	.11	.07	.66	.81	.84
6T-DT	.71	.85	.71	.24	.18	.07	.47	.67	.64
Mean	.79	.90	.79	.26	.22	.16	.53	.68	.63
	$P(CR\|FR)$			$P(CR\|\overline{FR})$			$P(CR\|FR) - P(CR\|\overline{FR})$		
3T-IT	.40	.50	.57	.09	.02	.14	.31	.48	.43
6T-IT	.61	.56	.80	.11	.08	.22	.50	.48	.58
3T-DT	.48	.42	.69	.04	.01	.02	.44	.41	.67
6T-DT	.42	.52	.82	.08	.04	.12	.34	.48	.70
Mean	.48	.50	.72	.08	.04	.13	.40	.46	.59

Table 3
F Ratios for Cued Recall and Conditional Recall Probabilities

Source	Cued Recall	$P(CR\|FR)$	$P(CR\|\overline{FR})$	$P(CR\|FR) - P(CR\|\overline{FR})$	$P(FR\|\overline{CR})$
Trials (T)	18.44†	6.71*	5.69*	n.s.	19.66†
Retention Interval (R)	18.44*	n.s.	5.33*	n.s.	44.23†
T by R	n.s.	n.s.	n.s.	n.s.	n.s.
Type of Cues (C)	9.68*	11.50†	7.16†	5.64*	9.01†
T by C	n.s.	n.s.	n.s.	n.s.	n.s.
R by C	n.s.	n.s.	n.s.	n.s.	n.s.
T by R by C	n.s.	n.s.	n.s.	n.s.	n.s.

†$p < .01$ *$p < .05$

Table 2 indicates that free recall is somewhat more dependent upon position cues than upon pictorial cues ($p < .05$) and that when both of these cues fail the conditional probability of free recall is low and declines significantly ($p < .01$) over the 2-day interval. Thus, the probability of free recall based upon all types of cues other than position or pictorial cues, e.g., name-name cues or context cues, is only .07 at the end of the 2-day period. The absolute probability of free recall independent of pictorial or position information can be estimated by multiplying the conditional probabilities $P(FR|\overline{CR})$ by their base probabilities $P(\overline{CR})$. This yields values of .16 and .11 for the three- and six-trial IT conditions and .06 and .05 for the DT conditions. If these values are expressed as proportions of the respective free recall probabilities in Table 1, the resulting estimates for the proportion of free recall independent of pictorial and position cues averages .27.

By contrast, if picture or position cues produce name retrieval, free recall is highly probable but not assured. The conditional probabilities $P(FR|CR)$ are short of unity and the gap provides a basis for estimating inaccessibility of the retrieval cue at the time of free recall. The fact that the name can be recalled with the help of a pictorial or position cue does not assure free recall of that name unless S himself can generate the cue at the time of free recall. It would appear from these results that picture cues are as potent as position cues when administered by E but that they are less accessible to S than position cues and, therefore, free recall is lower when conditional on them.

Finally, the difference between the two conditional probabilities $P(FR|CR) - P(FR|\overline{CR})$ can be regarded as an overall index of the extent to which free recall performance can be predicted on the basis of cued recall performance. Two days after training, nearly 70% of the possible variations in probability of free recall from zero to unity is accounted for on the basis of the effectiveness of the position cue. The effectiveness of combined pictorial and position cues does not permit greater accuracy of prediction than the position cue alone. This is true despite the fact that the double cue is much more effective than the individual cue, as can be seen in Table 1, and despite the fact that free recall is least likely when the combined cues fail. Success of the combined cues may be based on success of either cue alone, and, therefore, the probabilities of free recall given successful joint cuing are no higher than the conditional probability based upon the single cue having the lower predictive power.

Cued Recall Dependence Upon Free Recall. The predictability of cued recall based upon free recall is generally much lower than the converse conditional probabilities that have been discussed so far. Thus, free recall of a name is assured with a probability of .90 when a position cue is effective, but successful position cuing occurs only with a probability of .50 when free recall is successful. These findings are most directly explained by the fact that free recall of a name may be based upon position, pictorial, or other cues, and, therefore, free recall success cannot give high probability assurance of the encoding of any specific type of information. Successful cued recall, however, assures free recall unless S is unable to generate the cue at the time of free recall.

Probabilities of cued recall given free recall failure are much lower than the converse conditional probabilities of free recall given cued recall failure. Thus, $P(CR|\overline{FR})$ for position cues is only .04, while $P(FR|\overline{CR})$ is .22. Again, this is so because the failure of a single cue leaves the possibility of other cues as a basis for free recall success, while free recall failures rule out all types of cued recall success, except in cases where the encoded cues are inaccessible to S. The conditional probabilities $P(CR|\overline{FR})$ also provide a basis for estimating cue inaccessibility. The absolute probability of retrieval cues being inaccessible can be estimated by multiplying either of the respective conditional probabilities $P(CR|\overline{FR})$ or $P(\overline{FR}|CR)$ by their respective base probabilities, i.e., $P(CR|\overline{FR}) \times P(\overline{FR})$ or $P(\overline{FR}|CR) \times P(CR)$. This was done for each type of cue and at both levels of training and retention, and the resulting estimates of cue inaccessibility were entered in Row 3 of Table 7. The remaining content of that table will be discussed later.

Interdependence Among Pictorial and Position Cuing Effects. Comparison of the individual and joint effects of pictorial and position cues in Table 1 provides evidence regarding the independence of the respective encoding processes. To illustrate the basis of this inference, it is useful to consider the joint effect of the two types of cues to be expected under conditions of complete dependence and total independence. Assuming complete dependence in the form of positive correlation, a name is encoded pictorially whenever it is encoded in regard to position, and it is never encoded pictorially if it is not also encoded with regard to position. In this case, the joint effect of both cues would be the same as the effect of either cue individually. Thus, if pictorial cues have a .50 success probability and position cues have the same success probability, then using both cues together would produce no significant advantage and would yield an effectiveness of .50, since each cue is encoded only when the other cue is also encoded. The other extreme is illustrated in the case of perfect dependence of the two encoding processes in the form of negative correlation, i.e., position encoding occurs only when pictorial encoding does not occur and vice versa. In this case, the joint effect is additive in relation to the individual effects; thus, if position cues have a .50 probability of success and pictorial cues have a .50 probability of success, the combined effectiveness of both cues should be 1.00, since one cue is effective whenever the other is not. If the encoding processes are completely independent of each other, i.e., effectiveness of one cue does not permit more than a chance prediction of the effectiveness of the other, then the joint effect should be the sum of the individual effects less their product. Thus, if position cues produce a .50 probability of recall and pictorial cues also produce a .50 probability of recall, then the joint use of both cues should produce a recall probability of .50 + .50 − (.50 × .50) = .75. By examining the extent to which the observed joint effects are larger or smaller than those predicted for total independence on the above basis, it is possible to infer the existence of interdependence between the two types of encoding processes. The rationale is analogous to that involved in multiple regression problems where more than one predictor test is used. The joint predictive power of two tests, other things being equal, is lower if the tests have a high intercorrelation than if they have little or no intercorrelation. By determining individual predictive powers and intercorrelations among predictor variables, one can deduce joint predictive power. In the present case, the individual and joint predictive powers of the cues are known and the intercorrelation is inferred.

To determine whether significant dependencies exist between the two types of encoding processes, a dependence score based upon the above rationale was calculated for each S according to the formula

$$ID = p_{pi} + p_{po} - (p_{pi} \times p_{po}) - p_j \qquad (1)$$

where ID is the index of dependence, p_{pi} is the effectiveness of the pictorial cues, p_{po} is the effectiveness of the position cue, and p_j is the observed effectiveness of the joint pictorial and position cues. The mean dependence index obtained under the four training and retention conditions is .06 and .04, respectively, for the three- and six-trial IT conditions and .05 and .02 for the three- and six-trial DT conditions. All of these values suggest positively correlated encoding processes. However, a t test based upon the indicants for all 48 Ss shows that the overall mean of the dependence index does not deviate significantly from zero ($p > .05$), and a 2 by 2 factorial ANOVA indicates no significant variation of the index as a function of the degree of training or the retention interval ($p > .05$). This leads to the tentative conclusion that encoding processes related to pictorial and position information in the present experiment remain largely independent of each other during both acquisition and retention. This result can probably not be generalized to the learning of material of more heterogeneous difficulty. The characteristics which make individual items difficult or easy to learn are probably the same as those which make it easy or difficult to encode their various attributes. Thus, if very easy and very difficult items are included in the material to be learned, pronounced dependencies among the encoding probabilities related to various types of cues would appear inevitable.

The above analysis assumes an all-or-none encoding process with regard to individual cues, but the results also offer evidence against a different type of dependence which may occur as the result of the summation of subthreshold encoding effects, either during learning or at the time of retrieval.

Table 4
Proportion of Correct Responses for Free Recall and Matching Subtests

Group	Free Recall	Matching: Pi Name	Po Name	Pi-Po	Pi-Po Name
3T-IT	.40	.40	.44	.33	.60
6T-IT	.61	.69	.68	.62	.83
3T-DT	.22	.34	.30	.15	.44
6T-DT	.32	.47	.41	.22	.51
Mean	.39	.48	.46	.33	.60

Position and pictorial cues might individually fail to effect retrieval because the strength of each cue is below a critical threshold level. Joint presentation of cues might produce retrieval if subthreshold retrieval effectiveness summates and thus exceeds a threshold value. Results consistent with this prediction were obtained by McLeod, Williams, and Broadbent (1971) with single vs double semantic cuing effects, while Mandler and Anderson (1971) concluded that temporal and spatial encoding produce independent and additive retrieval effects in serial learning. If summation of cuing power were a significant factor in the present experiment, the effectiveness of the joint cues would exceed the prediction based on independent, individual cue effects. The results are in the opposite direction, though not statistically significant. Thus, there is no evidence for significant interaction effects during encoding or retrieval. It is possible, of course, that compensatory processes may cancel positive and negative dependencies, leaving a nonsignificant net effect. More definitive evidence regarding the issues of independent encoding and independent retrieval effects of individual cues will have to be based upon systematic comparisons of results obtained with joint vs successive presentation of the two cues.

Part II

The overall proportions of correct responses on the free recall test and on each subtest of the matching test are shown in Table 4. Conditional probabilities for the prediction of free recall given success vs failure in matching and for the prediction of matching given success vs failure in free recall are shown in Table 5. The scores for individual Ss were subjected to 2 by 2 by 4 split plot ANOVAs, with results reported in Table 6, except for two analyses omitted because of excessive data loss.

Comparison of Tables 1 and 4 shows that correct matching probabilities are in every instance higher than comparable cued recall probabilities. The differences are much larger than could be accounted for on the basis of greater chance success in matching. The best matching performance occurs for picture-position-name matching, i.e., when both picture and position cues are made

Table 5
Conditional Probabilities for Matching and Free Recall

Group	$P(FR\|MA)$				$P(FR\|\overline{MA})$				$P(FR\|MA) - P(FR\|\overline{MA})$			
	Pi–N	Po–N	Pi–Po	Pi–Po–N	Pi–N	Po–N	Pi–Po	Pi–Po–N	Pi–N	Po–N	Pi–Po	Pi–Po–N
3T-IT	.42	.62	.42	.62	.29	.33	.32	.21	.13	.29	.10	.41
6T-IT	.71	.71	.63	.64	.45	.46	.44	.44	.26	.25	.19	.20
3T-DT	.41	.59	.38	.33	.11	.12	.16	.13	.30	.47	.22	.20
6T-DT	.37	.55	.54	.51	.14	.22	.21	.25	.23	.33	.33	.26
Mean	.48	.62	.49	.53	.25	.28	.28	.26	.23	.34	.21	.27
	$P(MA\|FR)$				$P(MA\|\overline{FR})$				$P(MA\|FR) - P(MA\|\overline{FR})$			
3T-IT	.49	.59	.39	.82	.35	.31	.30	.42	.14	.28	.09	.40
6T-IT	.78	.76	.70	.88	.55	.53	.52	.76	.23	.23	.18	.12
3T-DT	.65	.68	.29	.67	.26	.16	.12	.38	.39	.52	.17	.29
6T-DT	.70	.63	.42	.68	.40	.29	.14	.40	.30	.34	.28	.28
Mean	.66	.67	.45	.76	.39	.32	.27	.49	.27	.34	.18	.27

available. Position and picture cues are about equally effective for name matching, just as was observed in the cuing task, while picture-position matching with no names involved is the most difficult of the subtests.

Comparison of Tables 2 and 5 shows that the conditional probabilities of free recall given matching success are lower in every instance than the comparable conditional probabilities based on successful cued recall. Position-name matching yields the highest conditional probability of free recall, but this probability is substantially lower than the comparable one based upon cued recall. This result is consistent with the view that cued recall and free recall involve common retrieval processes not involved in the matching task.

Failure of the matching task leads to conditional free recall probabilities comparable to or somewhat higher than those associated with failure of the cued recall task. This finding indicates that free recall does not benefit from encoding of either pictorial or position information insufficient to assure effective retrieval of the related name. In other words, failure of position cuing occurs much more frequently than failure on the position-name matching subtest. Obviously, there are many instances in which Ss have encoded enough position information to match name and position correctly, but they are unable to retrieve the name given the position cue. This level of encoding is apparently of no help at all in the free recall test. If it were helpful, the conditional probability of free recall given cued recall failure would be higher than the conditional probability of free recall given matching failure, since the former class includes many instances of such information and the latter does not.

Differential conditional probabilities based on matching success vs matching failure account for only a small portion of the free recall performance variation. These differential probabilities are smaller in every instance than the comparable differentials based upon cued recall, and this reflects the earlier finding regarding the much higher conditional free recall probabilities based upon cued recall success as compared to those based upon matching success. The conditional probabilities based upon cued recall failure vs those based upon matching failure play no significant role here. It is worth noting that the conditional probabilities $P(FR|MA)$ decline over the 2-day interval ($p < .01$), a result which confirms the findings of Ellis and Daniel (1971), but the predictive power of matching performance in relation to free recall, $P(FR|MA) - P(FR|\overline{MA})$, shows the opposite trend.

Independence of encoding of position and pictorial information was examined in regard to matching performance in the same manner as it was done for the cued recall task, and the results obtained were quite similar. For each S a dependence score was obtained by the formula

$$ID = P(M_{pi-n}) + P(M_{po-n}) - [P(M_{pi-n})\,P(M_{po-n})] - P(M_{pi-po-n}) \qquad (2)$$

Table 6
F Ratios for Matching and Conditional Matching Probabilities

Source	Matching	$P(MA\|FR)$	$P(MA\|\overline{FR})$	$P(MA\|FR) - P(MA\|\overline{FR})$	$P(FR\|MA)$
Trials (T)	12.47†	4.35*	9.50*	n.s.	7.0*
Retention Interval (R)	18.75†	n.s.	11.12†	n.s.	14.63†
T by R	n.s.	n.s.	n.s.	n.s.	n.s.
Types of Cues (C)	21.52†	9.5†	9.88†	n.s.	4.00*
T by C	n.s.	n.s.	n.s.	n.s.	n.s.
R by C	n.s.	n.s.	n.s.	n.s.	n.s.
T by R by C	n.s.	n.s.	n.s.	n.s.	n.s.

†$p < .01$ *$p < .05$

Table 7
Proportion of Responses at Various Levels of Performance Related to Picture and Position Information

	IT				DT			
	3 TR		6 TR		3 TR		6 TR	
Level of Performance	Pi	Po	Pi	Po	Pi	Po	Pi	Po
Matching Failure	.60	.56	.31	.32	.66	.70	.53	.59
Matching Success & Cued Recall Failure	.18	.27	.31	.33	.21	.22	.28	.22
Cued Recall Success & Free Recall Failure	.05	.01	.05	.03	.03	.01	.06	.03
Free Recall Success	.17	.16	.33	.32	.10	.07	.13	.16

where ID is the index of dependence, $P(M_{pi-n})$ is the probability of a correct picture-name match, $P(M_{po-n})$ is the probability of a correct position-name match, and $P(M_{pi-po-n})$ is the probability of a correct match when both picture and position information are available. The mean values for the three- and six-trial IT conditions were .02 and .06, respectively, and for the DT conditions .10 and .13, respectively. Again these four values are positive, but an overall t test indicates no significant deviation from an assumed mean of zero ($p > .05$) and a 2 by 2 ANOVA indicates no significant ($p > .05$) variation in the dependence index as a function of the degree of training, the retention interval, or the interaction between these factors. The results again suggest independent acquisition of pictorial and position information. Since retrieval aspects are minimized in the matching task, the results can now be applied to the encoding process with greater confidence than before. The results also yield no evidence of summation of subthreshold encoding of position and pictorial cues, since matching based on joint cues is no more successful than that predicted on the basis of success of independently operating individual cues.

The combined results from Part I and Part II form the basis of the analysis of levels of encoding for each type of cue shown in Table 7. The data permit a distinction among four performance levels in relation to each cue. The lowest level indicates no effective cue encoding, and the entries in the first row of the table simply reflect the proportions of failures in the cue-name matching task. The next level of encoding permits matching of cue and name, but does not permit retrieval of the name given the cue. These entries are obtained by subtracting the proportion of correctly cued recall from the proportion of correct matching based on the same cue. The third level designates access to the name by means of the cue but lack of access to the cue itself. These entries were obtained, as previously indicated, by multiplying the conditional probabilities $P(CR|\overline{FR})$ by their base probabilities $P(\overline{FR})$. The highest level of encoding cue information assures access to the cue itself, as well as to the name by means of the cue. This level is, therefore, an estimate of the free recall probability based upon individual cues. The entries are obtained by subtracting the sum of the proportions at the three other levels from unity. These estimates of free recall can be combined for position and pictorial cues by adding them and subtracting their product from the sum. The resulting values are estimates of the free recall probabilities based upon independent contributions of position and pictorial cues. When these estimates are expressed as proportions of the total free recall values listed in Tables 1 and 4, the resulting values average .77. This would suggest that about .23 of free recall is independent of position and pictorial cues, a value somewhat lower than the earlier estimate of .27. The discrepancy may reflect slight interdependence of position and pictorial encoding not reflected in the .23 estimate based upon conditional probabilities $P(FR|\overline{CR})$.

The methods of analysis applied in this study offer a general means of finding out more about the covert processes which operate in free recall. Here as elsewhere correlations do not guarantee identity of processes, but they do differentiate degrees of relevance.

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