that 11 repetitions were observed in this S's protocol. By Formula 1 the expected number of repetitions is 1.17 and the difference between the observed and expected number is 9.83. Without going further one might conclude that the two Ss evidence almost the same amount of clustering. However, for the first S the SD (by Formula 2) is 2.40 and for the second S it is .98. Thus, when these SDs are used to divide the above difference scores, the resulting clustering indexes are 4.17 and 10.03, respectively. Both values are considerably above chance, the second much more than the first. So it is clear that if groups are to be compared for amount of clustering when the numbers of categories recalled differ from group to group, the standard score method should be used.

Dallett also found differences in number of words recalled with a maximum mean of about 13.5 for the two-category group and a minimum of 10.5 for the eight. From Table 2 the effect of this would be to reduce differences in clustering, although in this case, the difference would be relatively small. It is clear, however, that anytime independent or task variables effect differentially the number of words recalled, the standard score method should be used, even if the number of categories represented from group to group is the same.

Several indexes of clustering have appeared in the literature

(Cohen, Sakoda, & Bousfield, 1954) and it is very possible that some are superior to the standard score index for specific purposes. However, when the Bousfield & Bousfield (1966) measure is to be used SD should be taken into account.

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NOTES

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Recall and anticipation methods in probabilistic associative learning¹

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Six $S-R_1$, $S-R_2$ modified paired-associates were presented for 60 trials. A 2 by 6 factorial design was employed in which method, recall or anticipation, and the $S-R_1$, $S-R_2$ probability-ratio were varied. The $S-R_1$, $S-R_2$ ratios were: 1.00-0.00, .90-.10, .80-.20, .70-.30, .60-.40, and .50-.50. The results indicated that the recall procedure yielded superior performance in early acquisition. In later stages, recall yielded results approaching matching, whereas the anticipation procedure yielded overmatching of R_1 anticipations and undermatching of R_2 anticipations. The results were interpreted as showing that as probability-ratio varies from .50-.50 to 1.00-0.00, and hence, as the relative difference of response strengths of $S-R_1$ and $S-R_2$ increases, the selection factor in the anticipation procedure yields a heavy weighting of the stronger response, R_1 , and the acquisition of the weaker association, $S-R_2$, occurs slowly; for the recall paradigm, however, the data suggest that R_1 is inhibited and $S-R_2$ is more readily acquired. The results also were interpreted as showing that one difference in the standard paired-associate recall and anticipation paradigms is that in the recall method, strong error tendencies may be inhibited, but in the anticipation method, strong error tendencies are weighted heavily.

In recent years the traditional paired-associate paradigm has been modified in order to study probabilistic rather than invariant occurrence of responses (e.g., Erdelyi, Watts, & Voss, 1964; Goss & Sugarman, 1961; Voss, Thompson, & Keegan, 1959). The procedure in such experiments has been to pair a stimulus with two (or more) responses, with the stipulation that only one of the responses is presented with the stimulus on any particular trial. Moreover, in the single-stimulus, two-response situation, $S-R_1$ and $S-R_2$ usually have a fixed probability-ratio, e.g., .70-.30, with $S-R_1$ and $S-R_2$ occurrence

randomized over trials. In addition, the anticipation method always has been used.

The purpose of the present experiment was to compare the acquisition of $S-R_1$, $S-R_2$ associations under conditions of recall (R) and anticipation (A) and under probability-ratios varying from 1.00-0.00 to .50-.50. In the paradigm, $S-R_1$ or $S-R_2$ is presented on a particular trial and subsequently upon presentation of the stimulus, S is asked to try to recall the correct response, i.e., R_1 or R_2 , that was presented with the stimulus on the same trial. Thus, the correct response is the response that most recently was presented with the stimulus. In the $S-R_1$, $S-R_2$ anticipation paradigm, the stimulus is presented on a particular trial and S is asked to try to anticipate the response that he thinks will be presented on that particular trial. In this case, the correct response also is designated as the response, R_1 or R_2 , that occurs on that particular trial. However, with R_1 and R_2 randomized, S cannot know whether it is R_1 or R_2 that is correct when he makes his response. The major difference, therefore, in the $S-R_1$, $S-R_2$ recall and anticipation paradigms is that in the former, whether R_1 or R_2 is correct is designated before S responds, but in the latter R_1 or R_2 is designated after he responds. Furthermore, it also should be pointed out that in the recall procedure, 100% correct responses is possible; in the anticipation procedure, however, with R_1 and R_2 randomized, 100% correct responses is a virtual impossibility.

Because of the previous findings which have indicated overmatching in the .60-.90 recall probability conditions, e.g., Voss, Thompson, & Keegan (1959), and because of the differences in the recall and anticipation paradigms, it was expected that Condition R would yield more correct responses and performance more closely approximating matching behavior. In addition to these hypotheses, which are somewhat obvious from the comparison of the recall and anticipation paradigms, it was anticipated that the relative difference of the recall and anticipation conditions would increase as the probability-ratio varied from 1.00-0.00 to .50-.50. Such performance was expected on the basis of the possible increase

Fig. 1. Per cent R_1 and R_2 appropriate responses (AR) as a function of trial block for all probability-ratio conditions.

in guessing and/or response competition in Condition A as the probability-ratio varied from 1.00-0.00 to .50-.50.

PROCEDURE

The experiment consisted of a 2 by 6 factorial design with method, anticipation vs recall, and S- R_1 , S- R_2 probability-ratio (PR) constituting the two variables. The PR values were: 1.00-0.00, .90-.10, .80-.20, .70-.30, .60-.40, and .50-.50. (R_1 designates the larger probability within each ratio, and R_2 designates the smaller probability. For the purposes of analysis, R_1 and R_2 designations were assigned arbitrarily in the .50-.50 condition.)

In each condition, six modified paired-associates were presented for 60 trials. In Condition R, the six pairs were presented on each trial followed by presentation of the same stimulus and the respective response (R_1 or R_2) designated for that trial. Presentations in both recall and anticipation occurred at a 2-sec rate with a 4-sec intertrial interval.

The six modified paired-associates within each PR condition had the same response probability-ratio. Six different random orders of R_1 and R_2 occurrence were employed for the six respective S- R_1 , S- R_2 associates within each PR condition. The R_1 and R_2 responses were randomized within 10-trial blocks and the random orders of R_1 and R_2 occurrence were identical in Conditions A and R. In Condition R, a different random order was employed in each trial for testing than that used in pairing presentations.

MATERIALS

Low-frequency words were used (Horton & Kjeldergaard, 1961). In each of the 12 conditions, the two-response words assigned to R_1 and R_2 for a particular S- R_1 , S- R_2 combination were counterbalanced for one-half of the Ss.

SUBJECTS

The Ss were introductory psychology students at the University of Pittsburgh. The N/ condition was 12 and the 144 Ss were assigned to the conditions via a table of random numbers.

RESULTS

The term "appropriate response" (AR) in Conditions A and R refers to S's statement of either R_1 or R_2 to the appropriate stimulus, regardless of whether R_1 or R_2 occurred on that particular trial.² The term "correct response" (CR) in Conditions A and R refers to S's statement of R_1 or R_2 to the appropriate stimulus when that response (R_1 or R_2) occurred on that particular trial. The term "opposite correct response" (OCR) refers to S's statement of R_1 to the appropriate stimulus when R_2 occurred on that trial or a response of R_2 when R_1 occurred on that trial. Thus, AR frequency = CR frequency + OCR frequency.

AR. Figure 1 presents the per cent R_1 and R_2 appropriate responses as a function of trial block for the experimental conditions. The data of the anticipation condition are in general agreement with previous findings (Goss & Sugarman, 1961; Voss, Thompson, & Keegan, 1959). The data of Fig. 1 indicate that recall tended to yield more AT responses in earlier trials than Condition A, and that Condition A tended to yield more R_1 and fewer R_2 AR responses than Condition R in later trials.

Table 1 presents the mean $R_1 + R_2$, R_1 , and R_2 AR frequencies for the experimental conditions. An analysis of variance revealed that for the $R_1 + R_2$ data, mean AR frequency was significantly greater for recall than for anticipation [$F(5,132) = 7.32$, $p < .01$]. The A vs R by PR interaction is not significant [$F(5,132) < 1.00$]. The significant A vs R by Trial Block (TB) interaction [$F(5,660) = 21.76$, $p < .01$] indicates that Condition R yielded more AR responses than Condition A in early trials. In addition, AR frequency increased more rapidly over trials as PR varied from .50-.50 to 1.00-0.00 [$F(25,660) = 2.79$, $p < .01$].

Analysis of the R_1 AR data revealed that R_1 AR frequency increased as probability-ratios varied from .50-.50 to 1.00-0.00 [$F(5,132) = 99.29$, $p < .01$], but the A vs R and the PR by A vs R sources of variation are not significant. The analysis also revealed, however, that the Trial Block by A vs R source of variation is significant [$F(5,660) = 32.79$, $p < .01$], as is the Trial Block by A vs R by PR source of variation [$F(25,660) = 2.41$, $p < .01$]. Inspection of Fig. 1 indicates that R_1 AR frequency increased more rapidly in early trials in Condition R than in Condition A, especially for PR approaching .50-.50. However, at the second or third trial block, the AR frequency of R_1 responses in Condition A was greater than in Condition R. The lack of a significant difference in total R_1 anticipations in Conditions A and R is likely due to the relative change in A and R response frequency as a function of trials.

Analysis of the R_2 AR data revealed that appropriate response frequency increased over the .10 to .50 PR

Table 1
Mean $R_1 + R_2$, R_1 and R_2 Appropriate Responses (AR)
Responses for the Experimental Conditions

PR	$R_1 + R_2$		R_1		R_2	
	A	R	A	R	A	R
1.00-0.00	312.4	322.1	-	-	-	-
.90-.10	291.3	303.3	286.3	278.6	5.0	24.7
.80-.20	284.9	291.5	259.4	248.3	25.5	43.2
.70-.30	257.6	293.3	222.1	208.8	35.5	84.5
.60-.40	253.3	280.3	186.3	165.5	67.1	114.8
.50-.50	248.9	274.9	127.8	136.7	121.1	138.3

Table 2
Mean $R_1 + R_2$, R_1 , and R_2 Correct Responses (CR)
for the Experimental Conditions

PR	$R_1 + R_2$		R_1		R_2	
	A	R	A	R	A	R
1.00-0.00	312.4	322.1	-	-	-	-
.90-.10	256.1	297.1	255.9	273.3	0.2	23.8
.80-.20	208.8	277.2	204.7	236.1	4.1	41.1
.70-.30	161.3	251.2	152.8	187.4	8.6	63.8
.60-.40	135.7	230.7	109.9	143.7	25.8	87.0
.50-.50	121.3	219.0	62.8	109.2	58.5	109.8

[$F(4,110) = 88.39$, $p < .01$], that Condition R yielded a greater R_2 AR frequency than Condition A [$F(1,110) = 48.57$, $p < .01$], and that the difference in anticipation and recall conditions increased as R_2 PR varied from .50 to .10 [$F(4,110) = 2.90$, $p < .05$]. In addition, the Trial Block by PR source of variation is significant [$F(20,550) = 10.16$, $p < .01$], as is the interaction of Trial Block by A vs R [$F(5,550) = 6.01$, $p < .01$], and the Trial Block by A vs R by PR interaction [$F(20,550) = 1.94$, $p < .01$]. These findings indicate that R_2 AR frequency was greater for Condition R than Condition A, that this difference increased as R_2 probability varied from .10 to .50, and that such an increase became greater over trials.

CR. Table 2 presents mean correct $R_1 + R_2$, R_1 , and R_2 responses for the experimental conditions. For all three measures, recall, as expected, yielded more correct responses than anticipation: $R_1 + R_2$, $F(1,132) = 147.92$, $p < .01$. There also were more $R_1 + R_2$ correct responses as PR varied from .50-.50 to 1.00-0.00 [$F(5,132) = 71.51$, $p < .01$], and the increase over PR was greater in Condition R than in Condition A [$F(5,132) = 6.84$, $p < .01$].

With respect to the R_1 and R_2 CR data, the per cent correct response at each probability condition was computed by each S because opportunities for a correct response increased systematically from .50 to 1.00 for R_1 data and increased systematically from .10 to .50 for the R_2 data. Analysis of the R_1 arc sin transformed per cent correct response data revealed that per cent correct responses in anticipation was greater than in recall [$F(1,132) = 38.22$, $p < .01$]; per cent correct responses increased as the probability ratio varied from .50 to 1.00 [$F(5,132) = 58.08$, $p < .01$], and that the difference in per cent correct response in Conditions R and A increased as PR varied from 1.00 to .50. The arc sin transformed per cent correct response R_2 analysis also revealed a greater R_2 correct response in Condition R than in Condition A [$F(1,110) = 433.19$, $p < .01$], an increase in per cent correct responses as R_2 varied from .10 to .50 [$F(4,110) = 8.72$, $p < .01$], and a relatively greater difference in Conditions R and A occurred as R_2 varied from .50 to .10 [$F(4,110) = 13.29$, $p < .01$].

OCR. Figure 2 presents per cent opposite correct responses for the experimental conditions. The percentage data were obtained by dividing the number of presentations of a particular response, e.g., 42 for an R_1 response in the .70-.30 condition, into R_2 occurrences during the 42 R_1 presentations. Thus, these data take into account the different number of presentations of R_1 and R_2 in the respective PR conditions. An analysis of variance performed on the R_1 OCR data revealed that a greater percentage of R_1 responses occurred on R_2 presentations as PR varied from .50 to .90 [$F(4,110) = 16.69$, $p < .01$], that Condition A had a significantly greater percentage of such responses than Condition R [$F(1,110) = 533.99$, $p < .01$], and the difference in anticipation and recall decreased as the probability ratio varied from .90 to .50 [$F(4,110) = 18.89$, $p < .01$]. Further analysis of the individual curves indicated that in Condition A, per cent R_1

responses on R_2 presentations decreased linearly over PR [$F(1,55) = 137.21$, $p < .01$]. For the recall condition, however, there is no significant curve component.

With respect to R_2 responses on R_1 presentations, there was significantly greater per cent opposite correct response percentage in Condition A than in Condition R [$F(1,110) = 39.12$, $p < .01$], a greater per cent of OCR responses as PR varied from .10 to .50 [$F(4,110) = 74.22$, $p < .01$], and the difference in Conditions R and A decreased as PR varied from .50 to .10 [$F(4,110) = 4.71$, $p < .01$]. Further analysis revealed that per cent R_2 occurrences when R_1 was presented increased linearly in Condition A as PR varied from .10 to .50 [$F(1,55) = 183.48$, $p < .01$]. In Condition R, the same effect was found [$F(1,55) = 116.51$, $p < .01$].

The Condition A OCR findings thus indicate that as PR varies from .90-.10 to .50-.50 per cent, R_1 response frequency decreases when R_2 is presented and per cent R_2 response frequency increases when R_1 is presented. For Condition R, however, only per cent R_2 OCR increased over PR.

DISCUSSION

The AR and CR data indicate that performance in Condition R was characterized by a gradual increase in correct R_1 and R_2 recalls such that Ss apparently were approaching the asymptotic level of matching which, in the recall method, would yield 100% correct responses. This finding, at first glance, suggests that in Condition R, the S- R_1 and S- R_2 associations are acquired independently. The OCR data, however, are in opposition to this view since these data indicate that R_1 interfered with R_2 acquisition and R_2 interfered with R_1 .

Of particular interest is the finding that although there was a greater percentage of R_1 recalls on R_2 trials than the reverse, the R_1 recalls on R_2 trials did not vary significantly with probability ratio. The likely reason for this result is suggested by an experiment by Bloch & Voss (1967) who found, in the S- R_1 , S- R_2 .50-.50 recall situation, that strong S- R_1 normative associates provided less interference in R_2 acquisition than weak associates. The hypothesis was advanced that strong R_1 associates may be inhibited during R_2 acquisition. In the present experiment, it may be suggested that the reason the per cent R_1 OCR responses did not increase over PR from .50 to .90 is that the R_1 responses could be inhibited during R_2 acquisition. In other words, as S- R_1 strength increased, it became easier for S to inhibit R_1 in the learning of S- R_2 . On the other hand, the strength of S- R_2 , never reaching the level

Fig. 2. Per cent opposite correct responses (OCR) as a function of probability condition.

of S-R₁, except at the PR of .50-.50, did produce increasing interference over the PR of .10 to .50. This finding also may be related to the Bloch & Voss (1967) results in that moderately strong S-R₁ associates interfered more in the acquisition of S-R₂ associates than weak associates. In summary, the Condition R results suggest that as S-R₂ strength increases, over .10 to .50, and becomes more equated to S-R₁ strength, S-R₂ produces increasing interference; as S-R₁ strength increases over .50 to .90, the interference produced is constant, with the explanation offered that the Ss inhibit the stronger R₁ responses.

The AR and CR data indicate that performance in Condition A was characterized by a gradual increase in R₁ and R₂ anticipations with the finding of overmatching of R₁ anticipations and undermatching of R₂. It may be assumed that the random nature of the S-R₁, S-R₂ sequence produced fewer correct responses than in the recall condition.

Of particular interest is the finding that R₂ occurrences on R₁ trials and R₁ occurrences on R₂ trials both vary linearly over probability ratios. The most reasonable explanations for these data is in terms of either response competition or guessing behavior in the Condition A paradigm. Specifically, it may be assumed that as PR is varied from .50-.50 to .90-.10, the relative differences of S-R₁ and S-R₂ strength increases. With respect to performance, as PR varies from .50-.50 to .90-.10, R₁ response frequency relative to R₂ increases. Thus, as the relative difference in the strength of the S-R₁ and S-R₂ associates increases, the selection factor in the A paradigm produces an increasing weighting of R₁ responses. This finding supports previous results (Erdelyi, Watts, & Voss, 1964). With respect to guessing, the relative increase of performance of R₁ compared to R₂ could be attributed to a guessing factor compared to R₂ could be attributed to a guessing factor involving a more likely chance of being correct with an R₁ rather than an R₂ response.

Comparison of the anticipation condition and recall condition S-R₁, S-R₂ paradigms therefore leads to the following tentative conclusion: As the relative differences of S-R₁, S-R₂ probability ratios increases from .50-.50 to .90-.10, the role of the R₁ responses varies as a function of procedure; in Condition R, strong responses tend to be inhibited in the acquisition of S-R₂ associates, while in Condition A, strong responses tend to be weighted and produce slower acquisition of S-R₂ associates.

The present findings are relevant to experiments designed to compare the standard paired-associate recall and anticipation tasks. Evidence for the superiority of the recall procedure has been provided (e.g., Battig & Brackett, 1961) whereas other experiments (e.g., Battig & Brackett, 1963; Cofer, Diamond, Olsen, Stein, & Walker, 1967) have failed to yield consistent re-

sults. The present findings suggest that a major factor involved in the comparison of the recall and anticipation methods is the degree of response competition within a list. Specifically, it would be expected that the role of error tendencies within a list interacts with method: when incorrect error tendencies are relatively large, the incorrect responses may be more easily inhibited in the recall procedure and weighted more heavily in the anticipation method. Little direct evidence, however, is available to either support or not support this hypothesis, although recent work on the role of interpair interference in paired-associate acquisition (e.g., Brown, 1964; Voss, 1967) provides a method to test such a hypothesis.

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NOTES

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2. The term, "appropriate response," is used in the same way that A₁ and A₂ are used in probability learning experiments to designate anticipations of R₁ and R₂, respectively. "Appropriate-response" rather than "anticipation" is employed in the present experiment in order to avoid the confusion possible in using the word, "anticipation," to refer to one of the procedures and to a type of response.