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PROBABILITY LEARNING

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Armeliu, K., and Armeliu, B-Å. Detection of cue intercorrelation in multiple cue probability learning. Umeå Psychological Reports No. 84, 1975. - Detection of cue intercorrelation, r_{ij} , was tested in ten two-cue MCPL tasks after completion of a Learning stage. The values of r_{ij} ranged from $-.80$ to $.80$. The cue-criterion correlations, r_{ei} , and the predictability of the tasks, R_e^2 , were factorially combined. The results showed a positive linear relation between the subjective and the objective values of r_{ij} . The values of r_{ij} were, however, underestimated by about 50%. These results were consistent with previous studies on the detection of r_{ij} . There was no relation between detection of r_{ij} and performance or any of the task parameters r_{ei} or R_e^2 .

Multiple-cue probability learning (MCPL) tasks require the subjects to learn to infer the state of a criterion variable from the information provided by a set of cues. To reach the optimal level of performance, the subjects have to utilize these cues according to their validity. To assess the validity of a cue, the subjects have to consider two aspects: a) the cue-criterion correlations, and b) the intercorrelations among cues. Until quite recently most studies have employed orthogonal tasks where the intercorrelation, r_{ij} , has been zero. From those studies it is well known that the subjects detect what the cue-criterion correlations are (e.g. Armeliu and Armeliu, 1973) and that they are able to utilize these correlations quite well (e.g. Peterson, Hammond and Summers, 1965).

However, a few recent studies concerned with subjects' performance in MCPL tasks with intercorrelated cues have demonstrated that subjects are unable to learn these kinds of tasks in an optimal way. (Armeliu and Armeliu, 1974, 1975 a, c; Miller and Sarafino, 1970). One reason for this suboptimality may be that subjects never detect the information provided by the cue intercorrelation. This hypothesis has stimulated some studies which have

focused on subjects' detection of the cue intercorrelation.

Knowles, Hammond, Stewart and Summers (1972) investigated the detection of r_{ij} by a recognition method, and found that subjects detect the sign of r_{ij} . The authors were, however, unable to demonstrate any difference between various magnitudes of r_{ij} . Armelius and Armelius (1973), who used a reproduction method, also failed to demonstrate discrimination of magnitudes of r_{ij} . They suggested that the learning tasks in their study might have been too easy to learn and that a more difficult task would force the subjects to pay attention not only to r_{ei} , but also to other aspects of the task, such as r_{ij} . This suggestion was based on the fact that the values of the reproduced cue intercorrelations were close to the actual values of r_{ij} for the more difficult tasks, but not for the easy task. The difficulty of the tasks was determined by the magnitude of the cue-criterion correlations, r_{ei} . In a recent study Armelius and Armelius (1975b) demonstrated that subjects discriminate high and low values of r_{ij} both with a recognition and a reproduction method. In this study the difference between the values of r_{ij} was larger than in previous studies. One reason for the lack of consistent results concerning detection of r_{ij} may be that there has been no adequate control over important aspects of the tasks other than r_{ij} . In the study by Knowles et al. (1972), and the study by Armelius and Armelius (1973) total task predictability, R_e^2 , was held constant. The cue-criterion correlations varied either directly or inversely with the magnitude of the cue intercorrelation. In contrast, the cue criterion correlations were held constant but R_e^2 varied directly with the magnitude of the cue intercorrelation in the study by Armelius and Armelius (1975b). It is possible that the relations among r_{ei} , R_e^2 and r_{ij} are of importance for the detection of r_{ij} . Therefore, it is necessary to investigate detection of cue intercorrelation as a function of the characteristics of the task, such as r_{ei} , and R_e^2 . A further reason for the lack of consistent results is that very few values of the magnitude of r_{ij} have been employed in each separate experiment. This has made it impossible to assess what the functional relation between subjective and objective cue intercorrelation is. The results of each study are very much dependent on the particular values of r_{ij} chosen for the study.

The present study was undertaken to investigate the two problems mentioned above. The experiment is designed to evaluate the effects of r_{ei} and R_e^2 on

the subjects detection of r_{ij} over a wide range of r_{ij} values.

Method

Subjects. Eighty-two undergraduated psychology students from the University of Umeå participated in the experiment to fulfill a course requirement and 18 educational students from the University of Umeå were paid to participate in the experiment.

Learning stage. Eight different experimental two-cue MCPL tasks were constructed. The cue-criterion correlation for one of the cues was $r_{e2} = .00$ for all tasks. Two levels of cue-criterion correlation for the other cue, $r_{e1} = .60$ and $.80$, two levels of task predictability, $R_e^2 = 1.00$ and $.70$ and the sign of the cue intercorrelation were combined factorially. The difference in R_e^2 was due to differences in the cue intercorrelation. In addition, two orthogonal control tasks were constructed, with the same levels of cue-criterion correlations as in the experimental tasks, $r_{e1} = .60$ and $.80$ and, $r_{e2} = .00$. The Learning stage consisted of 5 blocks of 20 trials. Table 1 gives the characteristics for the ten learning tasks.

Table 1. Task characteristics for the ten learning tasks.

Experimental tasks	r_{ij}	r_{e1}	r_{e2}	β_{e1}	β_{e2}	R_e^2
1	.80	.60	.00	1.67	-1.33	1.00
2	.70	.60	.00	1.18	-.82	.70
3	.60	.80	.00	1.25	-.75	1.00
4	.30	.80	.00	.88	-.26	.70
5	-.80	.60	.00	1.67	1.33	1.00
6	-.70	.60	.00	1.18	.82	.70
7	-.60	.80	.00	1.25	.75	1.00
8	-.30	.80	.00	.88	.26	.70
Control tasks						
9	.00	.60	.00	.60	.00	.36
10	.00	.80	.00	.00	.00	.64

Procedure. The Learning tasks were presented in booklets. The cues were presented as two bars numbered from one through twenty with the value of each cue represented as the shaded part of the bar. The criterion value was presented as a number between one and thirty on the back of the page. On each of the 100 training trials the subjects observed the two values, gave their prediction of the criterion value on their answer sheet, and observed the correct criterion value. The subjects were allowed to work at their own pace. They were told to base their predictions on the values of the cues shown to them. The subjects were not informed about the structure of the task and it was emphasised that due to the nature of the task they should not expect to be perfectly correct on each trial.

Test stage. After completion of the Learning stage each subject received another 20 presentations of the two cues to test his detection of r_{ij} . For all trials the subjects were asked to judge how likely they considered the cue combination to be on the basis of their past training. A rating scale with five categories was used, where 5 was used for very likely combinations, 4 for likely combinations, 3 for neither likely nor unlikely combinations, 2 for unlikely combinations and 1 for very unlikely combinations. The cues were uncorrelated in the Test stage.

Results

The results of the Learning stage are described in detail in Armelius and Armelius (1975c). For the present purpose it is enough to show that the subjects learned their tasks relatively well and that they paid attention to both cues. The average correlation between the subjects judgments and the criterion values, $\bar{r}_a$, and the average correlation between the linearly predictable variance of the task, and that of the subject's judgments, $\bar{G}$, are shown in Table 2 for each group.

Table 2. Average achievement, $\bar{r}_a$, and matching of regression weights, $\bar{G}$, for the last block of the Learning stage in each of the ten groups.

Group	1	2	3	4	5	6	7	8	9	10
$\bar{r}_a$	.52	.34	.75	.39	.43	.27	.67	.47	.53	.33
$\bar{G}$	.94	.91	.93	.93	.86	.77	.96	.98	.94	.94

In the Test stage the subjective intercorrelation, r_{ij}' , was computed with the strictest possible criterion for each subject. In order to get at least 6 observations for the computation of r_{ij}' , it was necessary to use criterion 4 and 5 for 69 subjects, while for the remaining 31 subjects there were enough observations in category 5. There was no relation between the number of subjects in each category and the values of the independent variables of the experiment, and there were no differences among the groups with respect to the number of observations on which r_{ij}' was computed. To investigate the degree of matching of r_{ij}' to r_{ij} a polynomial regression analysis was performed. The analysis showed a significant linear trend ($F_{1/98} = 38.48$, $p < .001$) with a correlation of .53 between r_{ij}' and r_{ij} . No other significant trends were found. The intercept was .02 and the regression coefficient was .43. This means that the matching of r_{ij} was similar for the positive and the negative values of r_{ij} and that, in general, the values of r_{ij} were underestimated by a little more than 50%. In Figure 1 the subjective intercorrelations of the present experiment as well as those of previous experiments on detection of r_{ij} with the recognition method are plotted against the actual intercorrelations. An inspection of Figure 1 gives support to a hypothesis of a general bias in the detection of r_{ij} . The subjects tend to underestimate the values of r_{ij} regardless of whether they are positive or negative.

Since the values of the cue intercorrelation in the task differed among conditions and the subjective intercorrelations were linearly related to the intercorrelations of the tasks, the ratio of the subjective intercorrelation to the task intercorrelation, r_{ij}' / r_{ij} , was computed for each subject and used for comparisons among groups. In order to ascertain the effects of r_{ei} and R_e^2 on the detection of r_{ij} a $2 (r_{ei}) \times 2 (R_e^2) \times 2 (\text{Sign of } r_{ij})$ ANOVA was performed on the ratio scores. There were no significant effects for any of the factors.

One reason for the interest in subjective intercorrelation is that detection of r_{ij} may be regarded as a necessary, although not sufficient, requirement for optimal performance. This implies a positive correlation between the detection of r_{ij} and performance. A direct test of this

Figure 1. Average subjective intercorrelations, r_{ij} , plotted against the intercorrelations of the tasks, r_{ij} , for the present and previous experiments with the recognition method.

hypothesis may be achieved by correlating the ratio, r_{ij}' / r_{ij} , and an index of relative achievement r_a / R_e for all subjects. This correlation is $-.04$, which indicates that subjects' achievement in MCPL-tasks with intercorrelated cues is not dependent on how well they detect the cue intercorrelation.

Discussion

The results of the present experiment clearly show that subjects detect the cue intercorrelation when they learn a MCPL-task. There is no doubt that they notice the sign of the intercorrelation, but the magnitudes are greatly underestimated. When the results of previous experiments on the detection of cue intercorrelation are pooled with the results of the present experiment it is evident that there is a weak but positive relation between the subjective and the objective values of r_{ij} .

The results of the present experiment also throw some light on the question of what the subjects do when they learn MCPL-tasks. Detection of r_{ij} was unrelated to the subjects performance. Furthermore, detection of r_{ij} was unrelated to the task parameters r_{ei} , R_e^2 and the sign of r_{ij} . All these parameters have, however, been found to influence performance in MCPL-tasks (Armeliu and Armeliu, 1975c). Thus, there is strong evidence against the hypothesis that the suboptimality of the subjects performance in MCPL-tasks is due to poor learning of r_{ij} . These results suggest that the statistical model of inference behavior should be abandoned as an explanation for what the subjects do when they learn a MCPL-task. That is, it is unlikely that the subjects assess the validities of the cues from what they learn about the cue-criterion correlations and the cue intercorrelations. If this model were correct, there should have been positive relation between performance and the learning of r_{ij} . The results of the present study, however, indicate that detection of r_{ij} and performance are independent.

A more fruitful approach may be to consider MCPL as a hypothesis testing activity (Brehmer 1974). Support for this approach is found in a recent experiment by Armeliu and Armeliu (1975a), which showed that the subjects may adopt a variety of strategies when they make their predictions. Almost

all of these strategies were based on a combination of the two cues rather than on separate learning of the cue-criterion correlations and the cue intercorrelation, thus giving further evidence against the statistical model.

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