UMEÅ PSYCHOLOGICAL REPORTS

No. 46 1971

Department of Psychology
University of Umeå

OMISSION OF FEEDBACK IN SINGLE-CUE PROBABILITY LEARNING

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Brehmer, B., and Lindberg, L. Omission of feedback in single-cue probability learning. Umeå Psychological Reports, No. 46, 1971. - The effects of the omission of feedback in single-cue probability learning was studied as a function of the sign and magnitude of the correlation between cue and criterion variables, the magnitude of the slope relating the criterion values to the cue values, and the magnitude of the unaccounted for variance in the task in three experiments. Replicating earlier findings, the results of these experiments show that the omission of feedback results in an increase in the correlations between cues and judgments. This increase in correlations is due to an increase in the slopes of the regression lines relating the subjects' judgments to the cue values.

In an experiment designed to study the retention of single-cue probability learning (SPL) tasks with scaled cue and criterion variables, Brehmer and Lindberg (1970a) found that omission of feedback resulted in an increase in the correlation, r_{CR} , between the cue values and the subjects' judgments. Similar results had previously been obtained by Azuma and Cronbach (1966) for multiple-cue probability learning and by Björkman (1969) for a cue probability learning task with nonmetric cue and criterion variables.

The increase in r_{CR} in the Brehmer and Lindberg study was due, (a) to a decrease in the unaccounted for variance in the subjects' response system, s_{CR}^2 , and, (b) to an increase in the slope of the regression lines relating the subjects' judgments to the cue values, b_{CR} . The increase in b_{CR} was interpreted to indicate that the omission of feedback made the subjects more extreme in the sense that they changed their

judgments more when the cue values changed in the nonfeedback stage than they did in the feedback stage.

These results were, however, obtained under rather restricted conditions. First, Brehmer and Lindberg used only positive cue-criterion relations. There is evidence that the learning of negative cue-criterion relations may proceed in a way different from that of positive cue-criterion relations (Naylor & Clark, 1968). Thus, nonfeedback performance for positive and negative cue-criterion relations may differ also.

Second, Brehmer and Lindberg manipulated the correlation between cue and criterion variables by varying the amount of unaccounted for variance in the task system, s_{CE}^2 , while holding the slope of the regression line relating criterion values to cue values, b_{CE} , constant. This, of course, limits the generality of their results; the correlation between cue and criterion in a SPL task may also be manipulated by a variation of b_{CE} , holding s_{CE}^2 constant.

Third, Brehmer and Lindberg not only held b_{CE} constant across tasks, they also used a b_{CE} value which was below unity. Their tasks required the subjects to learn to infer the value of a criterion variable, which was presented in the form of numbers ranging from 1 through 300, from the length of a cue line which varied from 3 through 300 millimetres. This suggests a simple explanation for their results, namely that the subjects, in the nonfeedback stage, regressed towards giving the length of the line in millimetres, instead of the criterion value, i.e., the subjects regressed towards a b_{CR} value of unity. Since b_{CE} was below unity, and since the b_{CR} values were fairly close to the b_{CE} value at the end of training, such behavior would lead to an increase in the slope of the subjects' regression lines.

The purpose of the present study, then, is to investigate the effects of the omission of feedback in SPL over a wider variety of task conditions in order to assess the generality of the original Brehmer and Lindberg results, and to test the hypothesis that the increase in the slope of the subjects' regression lines was due to a tendency to regress towards a slope of unity.

Method

Subjects. The subjects were 96 High School students aged around 18. They were randomly assigned to 12 groups with 8 subjects in each group.

Design. SPL tasks may vary with respect to the sign and magnitude of the correlation between cue and criterion variables, r_{CE} . The magnitude of the correlation, in turn, may be varied, either by manipulation of the amount of unaccounted for variance in the task, s_{CE}^2 , holding the slope of the regression line relating criterion values to cue values, b_{CE} , constant across tasks, or by a manipulation of b_{CE} , holding s_{CE}^2 constant across tasks.

The present study is an attempt to study the effects of the above factors, i.e., r_{CE} , b_{CE} , s_{CE}^2 , and the sign of r_{CE} . Obviously, r_{CE} , b_{CE} , and s_{CE}^2 cannot be varied independently in an orthogonal design, since when the values of two of these factors, e.g. r_{CE} and s_{CE}^2 , have been decided upon, the value of the third, b_{CE} in this case, is not free to vary. Thus, three experiments had to be run to evaluate the effects of the above factors.

The first experiment employed a 2 (Signs of r_{CE} : positive and negative) by 2 (Levels of r_{CE} : .40 and .80) by 2 (Levels of b_{CE} : .50 and 1.50) by 2 (Blocks of trials: the last block in the learning stage and a test block without feedback) factorial design with repeated measures on the fourth factor. This experiment evaluates the effects of the sign and magnitude of r_{CE} and b_{CE} . The unaccounted for variance, on the other hand, is left free to vary to produce the desired combinations of values of b_{CE} and r_{CE} .

In the second experiment, the design was a 2 (Signs of r_{CE} : positive and negative) by 2 (Levels of r_{CE} : .40 and .80) by 2 (Levels of s_{CE}^2) by 2 (Blocks of trials) factorial design with repeated measures on the fourth factor. This experiment evaluates the effects of sign and magnitude of r_{CE} and of the magnitude of s_{CE}^2 . The slope of the regression line relating criterion values to cue values was left free to vary to produce the desired combinations of values of r_{CE} and s_{CE}^2 .

The third experiment, finally, evaluated the effects of s_{CE}^2 and b_{CE} , with r_{CE} left free to vary. Thus the design was a 2 (Signs of b_{CE} : positive and negative) by 2 (Levels of b_{CE} : .50 and 1.50) by 2 (Levels of s_{CE}^2) by 2 (Blocks of trials) design with repeated measures on the fourth factor. The characteristics of the SPL tasks in the three experiments are given in Table 1. As can be seen from this table, there is partial overlap among experiments with respects to combinations of values of r_{CE} , b_{CE} , and s_{CE}^2 . Thus, the total number of groups could be reduced from 24 to 12.

Learning tasks. The cue values were represented in the form of lines varying in length from 3 to 300 mm. The criterion values were numbers varying from 1 to 300. Seven blocks, consisting of 50 pairs of cue-criterion values, were constructed for each condition by random sampling by means of a specially designed computer program from distributions with the desired values of r_{CE} , b_{CE} , and s_{CE}^2 . This sampling involved only criterion values. The cue values were the same in all conditions.

The learning tasks were presented in booklets. Each booklet contained one block of 50 trials.

Procedure. The experiment was conducted in two stages, a Learning stage and a Test stage. The Learning stage consisted of six blocks of 50 trials each. As shown by earlier studies (Brehmer & Lindberg, 1970b; Naylor & Clark, 1968) this is an adequate amount of training to bring the subjects to a stable performance level. On every trial in the Learning stage, the subjects, (a) observed the cue value, (b) recorded their prediction of the criterion value on an answer sheet, and (c) observed the correct criterion value for the trial. The procedure in the Test stage was identical to that in the Learning stage with the exception that no feedback was given.

Before the Learning stage, the subjects were instructed that they would be shown pairs of lines and numbers and that their task was to learn the relation between lines and numbers so that they could predict the numbers from the lines. They were not informed of the nature of the relation between cue and criterion variables, nor of the fact that a test stage was to follow.

Table 1. Characteristics of the SPL tasks in the various conditions of the three experiments.

Exp. I		Exp. II		Exp. III	
b_{CE}		s_{CE}^2		s_{CE}^2	
1.50	.50	6600	730	6600	730
r_{CE}	.80	$b_{CE} =$	$b_{CE} =$	$r_{CE} =$	$r_{CE} =$
		6600	730	6600	730
		6600	730	6600	730
		6600	730	6600	730
r_{CE}	.40	$b_{CE} =$	$b_{CE} =$	$r_{CE} =$	$r_{CE} =$
		61500	6600	6600	730
		61500	6600	6600	730
		61500	6600	6600	730
r_{CE}	-.40	$b_{CE} =$	$b_{CE} =$	$r_{CE} =$	$r_{CE} =$
		61500	6600	6600	730
		61500	6600	6600	730
		61500	6600	6600	730
r_{CE}	-.80	$b_{CE} =$	$b_{CE} =$	$r_{CE} =$	$r_{CE} =$
		6600	730	6600	730
		6600	730	6600	730
		6600	730	6600	730

Before the Test stage, the subjects were told that the next block was a test block. During this stage, they should apply whatever they had learned about the relation between lines and numbers, but they would not receive information about the correct answers.

Response measures. For every block and subject, the following indices were computed: (a) the correlation between the subject's judgments and the cue values, r_{CR} , (b) the slope, b_{CR} , of the regression line relating the subject's judgments to the cue values, and s_{CR}^2 , the variance unaccounted for by the regression line relating judgments to cue values. To facilitate comparisons among conditions, the ratio of b_{CR} to b_{CE} and the ratio of s_{CR}^2 to s_{CE}^2 were used in the analyses. The population values of b_{CE} and s_{CE}^2 were used as denominators when computing these ratios. The signs of r_{CR} , b_{CR} , and b_{CE} were reversed in the negative task slope conditions so that all conditions could be compared directly with respect to the magnitude of r_{CR} and b_{CR}/b_{CE} .

In SPL studies the cue-judgment correlation, r_{CR} , is a standard index of the subject's consistency in using the linear prediction strategy required by the task. The b_{CR}/b_{CE} ratio shows the extent to which the systematic characteristics of this strategy match the systematic characteristics of the task. This ratio also gives an index of the degree of conservatism of the subject's inference behavior (Brehmer & Lindberg, 1970b). If $b_{CR}/b_{CE} < 1.00$, the subjects may be considered conservative, since they change their judgments less than they should do when the cue values change. If, on the other hand, b_{CR}/b_{CE} exceeds unity, the subjects are extreme, since they change their judgments more than they should do.

The ratio of s_{CR}^2 to s_{CE}^2 , finally, shows the subject's tendency to match the distribution of his judgments to the distribution of the criterion values. If this ratio approaches unity, the subjects may be said to employ a probability matching strategy, and if the ratio approaches zero, they may be said to maximize. The s_{CR}^2/s_{CE}^2 ratio also provides a more useful index of response consistency than r_{CR} . The latter measure is influenced, not only by the amount of unaccounted for variance in the subject's response system, s_{CR}^2 , but also by the extremeness or conservatism of his judgments, b_{CR} .

Results

r_{CR} . The cue-judgment correlations were transformed to Fisher's Z scores and analyzed for each experiment according to the design of the experiment. The results of these analyses showed that there were reliable increases in r_{CR} from the last feedback block to the test block for Experiments I and II ($F_{1/56} = 7.21$, $p < .01$, and $F_{1/56} = 5.02$, $p < .05$, respectively). For Experiment III, the increase did not reach significance. The Blocks factor did not interact with any of the other factors in the experiments.

For Experiments I and II, which had cue-criterion correlation, r_{CE} , as a systematic independent variable, r_{CR} was a positive function of r_{CE} ($F_{1/56} = 27.98$, $p < .01$, and $F_{1/56} = 42.15$, $p < .01$, respectively). For Experiment III, r_{CR} was a positive function of b_{CE} ($F_{1/56} = 22.26$, $p < .01$) and a negative function of s_{CE}^2 ($F_{1/56} = 15.56$, $p < .01$). These factors did not interact, indicating that r_{CR} was an additive function of b_{CE} and s_{CE}^2 . This means that r_{CR} is dependent on r_{CE} , rather than on b_{CE} or s_{CE}^2 . Thus, the results of Experiment III are consistent with those of Experiments I and II, which also show r_{CR} is affected by r_{CE} , but not by b_{CE} or s_{CE}^2 . The results are shown in Figure 1.

There were no reliable effects in any of the three experiments of the sign of r_{CE} . That is, the results were the same for positive and negative cue-criterion relations.

b_{CR}/b_{CE} . The results of the analyses performed on the b_{CR}/b_{CE} ratios yielded only two significant effects, namely those of blocks in Experiments I and II ($F_{1/56} = 5.18$, $p < .05$, and $F_{1/56} = 5.75$, $p < .05$, respectively). For Experiment III, the difference between the two blocks did not reach significance. In accordance with the original Brehmer and Lindberg (1970a) results, the b_{CR}/b_{CE} ratios in these experiments were higher for low values of r_{CE} than for high values. The effect did not quite reach significance in any of the three experiments, however.

The results with respect to the b_{CR}/b_{CE} ratios are illustrated in Figure 2.

Fig. 1. Cue-judgment correlations, r_{CR} , as a function of r_{CE} for the last block in the learning stage and the nonfeedback test block.

Fig. 2. The ratio of b_{CR} to b_{CE} as a function of r_{CE} for the last blocks in the learning stage and the nonfeedback test block.

There were no reliable Magnitude of b_{CE} by Blocks interactions, indicating that b_{CR}/b_{CE} increased regardless of whether b_{CE} was above or below unity. Thus, the hypothesis that the increase in b_{CR} in the Brehmer and Lindberg (1970a) study was due to a regression towards a tendency to give the length of the cue line in millimetres instead of predicting the criterion values, is not supported.

s^2_{CR}/s^2_{CE} . For the ratio of s^2_{CR} to s^2_{CE} , the analyses yielded no significant effects for Experiment I and II. For Experiment III, there were reliable ($p < .01$) effects of b_{CE} ($F_{1/56} = 12.34$) and of s^2_{CE} ($F_{1/56} = 18.33$), as well as an interaction between b_{CE} and s^2_{CE} ($F_{1/56} = 5.13$, $p < .05$). The

interaction is illustrated in Figure 3.

Fig. 3. The b_{CE} by s_{CE}^2 interaction in Experiment III.

As can be seen from this figure, the interaction stems from the fact that the high b_{CE} , low s_{CE}^2 condition has a higher s_{CR}^2/s_{CE}^2 ratio than the other groups. This is presumably due to the fact that when correlations get as high as they do in this condition ($r = .97$), subjects cannot make s_{CR}^2 lower than s_{CE}^2 because of their inability to follow linear rules perfectly (see Brehmer, 1971). Except for the high b_{CE} , low s_{CE}^2 groups, the s_{CR}^2/s_{CE}^2 ratios

were less than unity in all conditions. This explains why r_{CR} exceeds r_{CE} in these conditions (see Fig. 1).

Discussion

These results replicate those of the original Brehmer and Lindberg (1970a) study in that they show that the omission of feedback in SPL leads to an increase in cue-response correlations. However, in the original study, this increase in correlations was due to two factors: (a) an increase in b_{CR} , i.e., the subjects were more extreme when there was no feedback, and (b) a decrease in s_{CR}^2 , the unaccounted for variance in the subjects' response system. In the present study, the increase in b_{CR} is obtained, but not the decrease in s_{CR}^2 . This is not due to a lack of statistical power. In fact, s_{CR}^2 increased for six of the 12 groups, and decreased for the other 6 groups. There was no relation between any of the independent variables in the study and the direction of change from the last feedback block to the nonfeedback block. In view of the fact that the present study is more extensive than the original study, it seems more reasonable to consider the rejection of the null hypothesis in the original study to be a Type I error than to consider our failure to reject the hypothesis in this study to be a Type II error. Thus, we would conclude that the increase in r_{CR} after the omission of feedback is due solely to an increase in b_{CR} , and that no reliable decrease in unaccounted for variance occurs. That is, the increase in cue-response correlations following the omission of feedback is due to the fact that the subjects become more extreme in the sense that they change their responses more when cue values change in the nonfeedback stage of the experiment than in the feedback stage.

The analyses on the b_{CR}/b_{CE} ratios yielded no Magnitude of b_{CE} by Blocks interactions. This shows that the b_{CR}/b_{CE} ratios changed in the same manner regardless of whether b_{CE} was above or below unity. Thus, the hypothesis that the increase in b_{CR} in the original Brehmer and Lindberg (1970a) study was due to a regression towards a b_{CR} value of unity is not supported. That is, the present data give no evidence that the increase in b_{CR} with the omission of feedback is due to a tendency to give the length of the cue variable in millimetres instead of the criterion values. Furthermore, the results show that the increase in b_{CR} occurs

regardless of the sign and magnitude of r_{CE} , and regardless of the magnitude of s_{CE}^2 . Thus, the increase in b_{CR} seems to be a stable result of the omission of feedback in SPL. Unfortunately, neither the present results, nor those of the previous study, suggest any explanation for this effect. Such an explanation will probably have to wait until a better understanding of SPL phenomena has been reached. This will require far more data than are currently available.

This study was supported by a grant from the Swedish Council for Social Science Research. The authors are indebted to Kent-Åke Enström for assistance in the experimental and computational work.

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