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EFFECTS OF TASK INFORMATION AND ACTIVE FEEDBACK CONTROL
IN INDUCTIVE INFERENCE

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CONTROL IN INDUCTIVE INFERENCE

Lindberg, L-Å., and Brehmer, B. Effects of task information and active feedback control in inductive inference. Umeå Psychological Reports No. 123, 1977. - Learning of an inductive task with one linear and one quadratic cue was investigated in a 2 (levels of task information: maximum vs. minimum) x 2 (control of outcome feedback: active vs. passive) x 4 (blocks of trials) factorial experiment. In the maximum information condition subjects were given the criterion distribution, including the mean, for each combination of cue values. Under the active feedback condition subjects selected cue combinations and feedback instances in whatever order they wanted. Positive effects of all three factors were obtained with respect to subjects' selection of inference rules and level of task control. It was concluded that subjects' inconsistency under ordinary outcome feedback conditions is due in part to lack of memory capacity and in part to the fact that subjects are prevented from active hypothesis testing. However, these factors do not fully explain the lack of consistency as shown by the fact that subjects under the present maximal information/active feedback condition did not reach the maximal level of task control, although they used the optimal inference rules.

In a recent experiment, Lindberg and Brehmer (1977a) investigated learning in a two-cue inference task as a function of (1) relative cue complexity, (2) relative cue validity, (3) task predictability, and (4) cue-criterion function form. The results contradicted the Progression hypothesis (Fitts, Bahrick, Noble, & Briggs, 1961) in that relative cue complexity did not affect subjects' performance. Instead subjects' progression to a higher level of task control was determined by the system characteristics of the task, i.e., relative cue validity, task predictability, and cue-criterion function form, rather than by the surface characteristics of relative complexity as defined by

Fuchs (1962). Furthermore subjects' increased task control was achieved by means of a more appropriate selection of inference rules for each one of the cues, a result consistent with Brehmer's (1974) hypothesis testing model.

Even though the subjects in Lindberg and Brehmers (1977a) experiment improved by training, they did not manage to reach the maximal possible level of task control under any of the four conditions. This was true also for the condition under which the criterion variable was perfectly predictable from the cues, i.e., where there was no error variance in the task. In the present study, we will test two explanations of the suboptimal performance. These hypotheses will be discussed in turn.

Information about the formal characteristics of the task. The standard task in studies of inference behavior according to the Social Judgment Theory (Hammond, Stewart, Brehmer & Steinman, 1975) consists of a set of correlated metric variables, where subjects have to learn to predict the value of one variable (the criterion) from those given on the remaining variables (cues). Usually, the subject receives immediate information about the correct criterion value (outcome feedback) after he has made his prediction. Alternatively, the subject may be given information about the statistical properties of the task in advance (feed-forward) and he can, as well, after a set of trials receive information about statistical characteristics (e.g., cue weights) of his inference strategy (cognitive feedback). For this kind of tasks, the normative model within the Social Judgment Theory holds that the subject should apply statistical inference rules, i.e., that he should base his inferences on the cue-criterion functions and that he should minimize the unsystematic variance in his response system. That is, the subject should be consistent, and he should not try to match the error variance of the task.

Typically, in studies using outcome feedback as the principal way of informing the subject about the task and his achievement, subjects are found to be inconsistent in their inference strategies. The amount of inconsistency is a positive function of the amount of error variance of the task (e.g., Brehmer, 1976).

According to a hypothesis put forward by Brehmer, Kylenstierna, and Liljergren (1974) the inconsistency might be due to the subjects interpreting the task as having a deterministic rather than a statistical structure, i.e., that he tries to control the task by means of deterministic inference rules. Since there exist no rules that enable the subject to hit the correct criterion value in each trial for this kind of tasks, he is forced to change his rules and, thus, to become inconsistent. From this hypothesis it was predicted by Brehmer and his collaboratorsthat subjects' inconsistency would decrease when they get information about the statistical nature of the inference task. This prediction was tested in a series of experiments, in which subjects where given different kinds of task information (Brehmer, Kylenstierna, & Liljergren, 1975, 1976; Brehmer, & Kylenstierna, 1976). However, in these experiments subjects' inconsistency was not affected by the variations in task information. Brehmer and Kylenstierna (1976) concluded that it is possible that the subjects actually made use of statistical hypotheses about the task structure, but that they did fail to test these hypotheses in a proper manner, i.e., by means of statistical criteria of optimality due to lack of memory capacity.

The assumption that subjects lack the capacity required to store the amount of data necessary to learn to use the optimal statistical inference rules implies that subjects would be able to become more consistent if they were provided not only with information about the nature of the task but also with memory aids by means of which they could record and keep track of the information given, and thus, reduce the memory strain. This implication will be put to test in the present experiment.

Active control of outcome feedback. As compared to feedforward information and cognitive feedback, outcome feedback is detrimental to performance in that it makes subjects inconsistent (see Steinman, 1975, for an overview of results). From this fact some authors (e.g., Hammond, 1971; Hammond & Summers, 1972), conclude that subjects should not be provided with outcome feedback, which, due to the probabilistic nature of the task includes a disturbing "error" component. This error component prevents the subject from gaining perfect control of the inference task.

In the opinion of the present authors, however, outcome feedback is an indispensable feature of the subject-task interaction, provided that our principal concern is with the question how subjects use uncertain cues to reach stable relations to distal environmental goals. Therefore an important question seems to be under which conditions outcome feedback could be used more efficiently than it has been under the conditions investigated so far.

The hypothesis testing model suggested by Brehmer (1974) provides one suggestion with respect to this problem. According to this model, the subject makes use of feedback information to test hypotheses about the structure of the task, i.e., the form of the cue-criterion function. If so, the subject would be able to perform his hypothesis testing more efficiently if he could select exactly those feedback instances which provide the most direct test of the hypothesis which he has in mind. Studies on concept formation (Bruner, Goodnow, & Austin, 1956), indicate that subjects improve their hypothesis testing when they are allowed to select cue values and feedback instances in free order.

According to the hypothesis testing model, then, also active feedback control will reduce the memory load on part of the subject, since it enables him to test one hypothesis at a time, and, thus, does not have to store several hypothesis in memory.

In previous experiments on effects of outcome feedback, the order of feedback instances has been out of the subject's control. Instead, cue presentation and feedback has been determined in advance and executed by the experimenter. It is thus possible that the negative effects of outcome feedback are, in part, due to the subject's passive role in this respect, and that the subject could improve by means of active feedback control. This hypothesis will be tested in the present experiment.

In the present experiment, then, inference behavior is investigated as a function of two experimental variables, both of which are assumed to reduce memory strain on part of the subject and enable him to find and make use of the optimal inference rules. Specifically, subjects learn a two-cue task with one linear and one quadratic cue, and the experimental conditions are varied along two orthogonal factors: (1) Maximal vs. minimal information about the task, the former condition including aids for data recording, and (2) active, subject controlled vs. passive, experimenter controlled, outcome feedback. Only the results from the test stage will be reported here. Results from the learning stage under the active feedback condition are presented elsewhere (Lindberg & Brehmer, 1977b).

Hypotheses

For single-cue learning the hypothesis testing model (Brehmer, 1974) assumes that the subject learn the inference task in two stages where he (1) generates and test hypotheses about the form of the cue-criterion function, and (2) learn to apply the resulting inference rule consistently, i.e., that he learns the parameters of the function. Linear hypotheses have a greater sampling probability than quadratic hypotheses, and linear rules are easier to apply than are quadratic rules (Brehmer, Kylenstierna, & Liljergren, 1974). That is, with respect to the present task, subjects will have less difficulty in learning the linear cue than the quadratic cue.

Although the model assumes that hypotheses are ordered, it does not predict the order in which subjects will attend to different cues in a two-cue task: When the subject has detected that one cue is non-linear he may either give priority to this cue, in order to detect the form of the cue-criterion function, or he may focus on the linear cue in order to increase his control of this cue through a determination of the parameters of the cue-criterion function. It is predicted here, in consistency with the single-cue case, that subjects will learn the form of both cue-criterion functions before they focus on the parameters of either function. If so, they initially give a higher weight to the linear cue, and the relative weighting of the

quadratic cue will increase with practice when linear rules are omitted in favour of quadratic rules.

It is further assumed that subjects have to store a greater amount of data to determine the form and the parameters of the quadratic cue as compared to the linear cue. Therefore, the main effect of task information and of active feedback control will be on subjects' utilization of the quadratic cue. The effects of active feedback control are not, however, expected to occur under the maximum information condition, under which condition subjects are provided with all the information necessary to execute an optimal prediction strategy according to the normative model (Hammond, et al., 1975). For the minimum information condition, although active feedback control is assumed to reduce memory strain, it is not assumed to reduce it completely. Under this condition, therefore, subjects are expected to improve with practice but they will not reach the maximal level of task control.

In summary, the following predictions are suggested:

Effects of task information

Under the minimum information condition, subjects perform less optimally than under the maximum information condition with respect to

- (1) level of task control,
- (2) relative utilization of the quadratic cue, and
- (3) selection of inference rule for the quadratic cue.
- (4) Under the maximum information condition, subjects will perform optimally from the very beginning.
- (5) Under the minimum information condition, subjects will improve their task control with practice in that they
- (6) start out with linear rules for both cues, then
- (7) increase the proportion of quadratic rules for the quadratic cue, and
- (8) increase their relative control of the quadratic cue.

Effects of active feedback control

- (9) There will be no effects of the feedback factor under the maximum information condition.

Under the minimum information condition, subjects who receive active feedback control will perform more optimally than subjects who receive passive feedback control with respect to:.

- (10) level of task control,
- (11) relative utilization of the quadratic cue,
- (12) selection of inference rule for the quadratic cue.

Method

Subjects

Thirty-two undergraduates from the University of Umeå participated as paid volunteers. Subjects were randomly assigned to the four experimental groups.

Design

Subjects went through the experiment individually in a series of alternating learning blocks with outcome feedback and test blocks without feedback. The learning stage as well as the test stage consisted of four blocks of trials. Each learning block included twenty-five trials, while each test block included fifty trials, with one replicate of each one of twenty-five different cue combinations.

In the learning stage, two factors were varied orthogonally in two steps: Factor I: Maximal vs. minimal task information, and Factor II: Active vs. passive feedback control. The learning stage, then, follows a 2 (maximum-minimum) x 2 (active-passive) x 4 (blocks) factorial design.

Learning task

The learning task was a two-cue task with metric cue and criterion variables. Cue values, from 1 to 5, were presented on cards as bars of different height, each card containing one value for each cue. On the back side of each card, the criterion value was given as a number, which could take on values from 5 through 43. Cue 1 was linearly related to the criterion while cue 2 was related to the criterion through a quadratic function. The criterion variable was an additive function of the two cue variables, cues were uncorrelated, and the cues were given equal validities (weights). The statistical charac-

teristics of the task are given in Figure 1 and Tables 1-2.

Figure 1. The criterion variable (E) as a function of the linear cue (C_1) and the quadratic cue (C_2) respectively.

Table 1. Statistical characteristics of the task.

Criterion variable (E), numbers from 5 to 43

Linear cue (C_1), bar varying in height from 1 to 5

Quadratic cue (C_2), bar varying in height from 1 to 5

$$E = .60 (C_1 - \bar{C}_1) + .60 (C_2 - \bar{C}_2)^2$$

$r_e = .85 \pm .05$ (multiple correlation for the cue-criterion relation)

$$r_{C_1 C_2} = .0 \pm .05$$

$$r_{C_1 E} = r_{C_2 E} = .60 \pm .05$$

Table 2. The cue-criterion matrix.

		C_2					$\bar{E}$
C_1	1	23	14	11	14	23	17
	2	26	17	14	17	26	20
	3	30	21	18	21	30	24
	4	34	25	22	25	34	28
	5	37	28	25	28	37	
		30	21	18	21	30	$\bar{E}$

Experimental conditions

Group 1: Minimum task information/active feedback control. Subjects were instructed that their task was to learn to predict numbers on the back side of the cards from the values of the two bars on the front side of the cards. They were informed that there was a systematic relation between each bar and the number, that they could not expect to hit the correct number on every trial but that they could improve by training, and that the experiment consisted of alternating training blocks and test blocks.

The cards used in the learning blocks were placed on a table in front of the subject in a 5 x 5 matrix, with eight cards in each cell. The subject was asked to select cards, one at a time, from any cell and in which order he wanted, and to check the number on the back side. He was informed that each learning block consisted of 25 selections, after which there would come a test block of 50 trials, and that he was free to distribute his selection as he wished over the total of 25 x 4 training trials, but that he would not be given any new cards

if one of more cells became empty. For each learning trial the subject (1) selected a card, (2) checked the criterion number, (3) put the card aside (no replacement), and (4) drew a new card, and so on. In the test blocks, the subject was given a deck of cards by the experimenter, consisting of 50 cards, with each cue combination occurring twice. These test cards did not have criterion numbers, and were given in a different order for each subject. For each test trial, the subject (1) looked at the cue values, (2) wrote down his prediction of the criterion value on an answer sheet, and (3) looked at the next card in the deck, and so on.

Group 2: Minimum task information)passive feedback control. This condition differed from condition 1 above in that the cards in the training blocks were presented by the experimenter, one at a time in a predetermined order which was varied among subjects. In each training block, each subject was given one card from each of the 25 cells.

Group 3: Maximum task information)active feedback control. This condition differed from condition 1 in that subjects were provided with the following task information and aids for data recording: (1) Throughout the experiment, subjects could inspect an information sheet which gave the information in Table 2, and where also all criterion values in each cell were given; (2) For the learning blocks, subjects received a recording sheet, in the form of the cue-criterion matrix, on which they recorded each feedback (criterion) value.

Group 4: Maximum task information/passive feedback control. This group was treated as group 2 with respect to procedure, and as group 3 with respect to task information and recording aids.

Under all conditions, subjects finished the experiment within two hours.

Response measures

For each subject and block in the test stage, measures indicating (1) task control, (2) relative cue weighting, and (3) type of inference rules, were calculated. These measures were analyzed by means of 2 (maximum-minimum) x 2 (active-passive) x 4 (blocks) analyses of variance (ANOVAs) with repeated measures on the last factor.

Task control, r_{RE} . As an index of task control, the correlation r_{RE} between the subject's responses and the criterion cell means were calculated. Since there were no criterion values given in the test blocks, the response-criterion correlation, r_a , could not be calculated (see Equation 1).

$$r_a = G \times r_s \times r_e \quad (1)$$

where

G is the correlation between the predictions derived from the linear model of the task with the predictions derived from the linear model of the judge; G measures the extent to which the subject's weights on the cues are proportional to the weights of the cues in the task; r_s is the consistency of the judge (the multiple correlation between the cues and the predictions); r_e is the predictability of the task (the multiple correlation between the cues and the criterion values).

As could be seen from Equation 1 (Tucker's, 1964, representation of the so called Lens Model Equation), task predictability, r_e , sets an upper limit with respect to achievement, r_a . This is not the case for the measure r_{RE} used here, which relates to the measure r_a according to the following Equation (Equation 2).

$$r_{RE} = r_a / r_e = G \times r_s \quad (2)$$

The maximal possible value of r_{RE} is 1.0, which is also the optimal level of task control, according to the normative statistical model implicits in the Social Judgment Theory (Hammond, et al., 1975).

Relative cue weighting, $(\omega_1^2 - \omega_2^2)$. The subject's utilization of each cue was defined by the measures ω_1^2 and ω_2^2 , for the linear cue and the quadratic cue, respectively. The measure ω^2 indicates the extent to which the subject's response variance is systematically related to the cue variable (Vaughan & Corballis, 1969). The difference $(\omega_1^2 - \omega_2^2)$ defines, accordingly, the subject's relative weighting of the two cues.

Inference rules, ω_{1LIN}^2 , ω_{2LIN}^2 , ω_{2QUAD}^2 . To define the subject's inference rules, a trend analysis was performed for each cue. For each cue-response relation, the linear component (LIN), the quadratic component (QUAD), the cubic component, and higher order components, were calculated. For each component, the measure ω^2 was then calculated. In the following, only the results with respect to ω_{1LIN}^2 , ω_{2LIN}^2 , and ω_{2QUAD}^2 , are reported, since these rules account for the dominant part of the subjects' cue utilization.

Before the ANOVAs, the measure r_{RE} was transformed into Fisher's Z scores, and negative ω^2 -values were set equal to zero.

Results

Task control, r_{RE} . The effects of task information, feedback control and blocks are illustrated in Figures 2-3.

The maximum information groups perform better than the minimum information groups ($F_{1/28} = 56.83$, $p < .001$). Active feedback groups perform better than passive feedback groups (nonsignificant $F_{1/28} = 2.56$, $p > .05$) and in all groups subjects increase their task control as a function of training ($F_{3/84} = 3.26$, $p < .05$). Under no condition do the subjects reach the maximal possible value $r_{RE} = 1.0$.

Relative cue weighting, $(\omega_1^2 - \omega_2^2)$. As could be seen from Figure 4, subjects increase their task control by different means under the maximum information condition as compared to the minimum information condition.

While under the maximum information condition subjects learn by practice to give about the same weight to both cues, under the minimum information condition subjects increase their relative utilization of the linear cue. For the measure $(\omega_1^2 - \omega_2^2)$ ANOVA yielded a significant main effect of the information factor ($F_{1/28} = 8.45$, $p < .01$) as well as a significant information x blocks interaction ($F_{3/84} = 3.14$, $p < .05$).

Figure 2. Level of task control, r_{RE} as a function of information level and blocks of trials in the test stage.

Figure 3. Level of task control, r_{RE} as a function of feedback condition and blocks of trials in the test stage.

Fig.4. Relative cue weighting ($w_1^2 - w_2^2$) as a function of information level and blocks of trials in the test stage.

Inference rules, ω_{1LIN}^2 , ω_{2LIN}^2 , ω_{2QUAD}^2 . Results with respect to subjects' rule selection are illustrated in Figures 5-7.

Figure 5. ω_{1LIN}^2 , as a function of experimental conditions and blocks of trials in the test stage.

Figure 6. ω_{2LIN}^2 , as a function of experimental conditions and blocks of trials in the test stage.

The group means for all three measures indicate positive effects of active feedback control under both information conditions. However, these effects do not reach statistical significance ($p > .05$).

Finally, a comparison between the measures $\omega_{2\text{LIN}}^2$ and $\omega_{2\text{QUAD}}^2$ indicate that subjects under the minimum information condition initially use linear rules to a greater extent than quadratic rules, a difference which is reduced over blocks.

Discussion

In contrast to what has been found in previous experiments on single-cue probability learning (Brehmer, et al., 1975, 1976, Brehmer & Kuylenstierna, 1976), the present results provide strong support for the hypothesis that subjects are able to use information about the task to improve their inference strategies (prediction 1). However, in the earlier experiments the subjects were not given information about the rule, but only about the general nature of the task. In the present experiment, subjects were given the criterion distribution, including the mean, for each combination of cue values. Subjects' improvement was accomplished when they were provided with aids for registration of data, that is, memory aids, in addition to this information. It is concluded that subjects' ordinarily less than optimal performance in this kind of tasks in part is due to lack of memory capacity, thus supporting a suggestion put forward by Brehmer and Kuylenstierna (1976).

An alternative interpretation of the effects of extended task information might be that subjects simply use the given criterion cell means as their predictions and that they do not solve the prediction problem in the same way as do subjects under the ordinary information condition. This interpretation is, however, less probable since the subjects under the maximum information condition did not reach the maximal level of task control and that they improved both with practice and as a function of active feedback control (contradicting predictions 4 and 9). In these respects, subjects under the maximum information condition behave in the way predicted from the hypothesis testing model for the

minimum information condition. The fact that subjects under the maximum information condition did not reach the maximal level of task control also indicate that lack of memory capacity with respect to storing of feedback information is not the only reason why subjects are inconsistent under ordinary information conditions.

The effects of task information were in the direction predicted from Brehmer's (1974) hypothesis testing model in that subjects under the maximum information condition reached a higher level of task control than subjects under the minimum information condition by means of a more optimal utilization of the quadratic cue (prediction 3). This model was also supported in that subjects under the minimum information condition weighted the cues according to the form of the cue-criterion functions (prediction 2), they started out with linear rules for both cues (prediction 6), and they increased their relative utilization of quadratic rules for the quadratic cue (prediction 7), as well as their task control (prediction 5), with practice.

However, prediction 8 that subjects under the minimum information condition would increase their relative utilization of the quadratic cue as a function of blocks was contradicted. Instead, the subjects increased their relative utilization of the linear cue. This result could be explained in two ways. First, it is possible that subjects deliberately gave priority to the linear cue in order to increase their task control. Second, it may be that subjects did try to use also the quadratic cue but that they were unable to apply the quadratic rule consistently. (The third possibility, that subjects did not detect the quadratic rule, is not consistent with the present results.)

The present results indicate positive effects also of active feedback control (nonsignificant, however), for both levels of task information. For the minimum information condition, these effects are consistent with the hypothesis testing model (predictions 10 and 12), although subjects also made use of active feedback control to increase their relative utilization of the linear cue (contradicts prediction 11). These results indicate that the negative effects of outcome feedback which have been obtained in previous experiments (see, e.g., Steinman, 1975) in part may be attributable to an experimental procedure which, in fact, prevents subjects from active hypothesis testing.

In summary, the way in which the present results do not support the predictions give rise to the following questions: (1) To which extent do subjects under the maximum information condition learn the task through a hypothesis testing activity similar to that assumed for the minimum information condition? (2) Is the relative overweighting of the linear cue under the minimum information condition attributable to subjects' hypothesis testing activity and/or to their rule application? These problems will be further investigated by means of analyses of subjects' selection of feedback instances in the learning stage of the active feedback control condition. Results from these analyses are presented in the next report from the present project (Lindberg & Brehmer, 1977b).

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