EXPERIMENTAL STUDIES IN CUE PROBABILITY LEARNING

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The dissertation consists of this summary and the following nine papers:


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To LILLEMOR

AXEL, OSKAR, KAROLINA, and JOHAN
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EXPERIMENTAL STUDIES IN CUE PROBABILITY LEARNING

Lars-Åke Lindberg

The purpose of this summary is to outline an explanatory frame of reference in retrospect, consistent with results from the present studies, rather than to recapitulate the experimental findings in full detail.

The problems investigated in the present thesis concern human judgment under uncertainty. Specifically, the thesis is concerned with cue probability learning (CPL), as studied within the Regression-correlation paradigm (Slovic & Lichtenstein, 1971). This paradigm combines the basic concepts of Brunswik's probabilistic functionalism (e.g., Brunswik, 1952) and the techniques of regression analysis and correlation methods. It makes it possible to analyze the interaction between two systems, the environment with which the subject copes, and the inference strategy of the subject, respectively, and to describe these systems in the same terms. The paradigm has recently been further formalized and developed in Social Judgment Theory (Hammond, Stewart, Brehmer, & Steinman, 1975). From here on, this paradigm will be labeled "the normative model".

In a cue probability learning experiment, the subject learns the task through repeated trials. On each trial he is given a set of cues and asked to make a quantitative prediction of a criterion variable. He is then informed about the correct criterion value (outcome feedback).

The learning task is constructed as a regression system, and uncertainty is introduced in the separate cue-criterion relations and/or in the multiple cue-criterion relation. In the present single-cue probability learning (SPL) studies, the criterion is a positive linear function of the cue. In the multiple-cue probability learning (MPL) studies, two-cue tasks are used, with two
linear cues, or with one linear and one quadratic cue. The cue variables are orthogonal.

According to the present model, the best estimate of the criterion, \( \hat{E}_c \), given the cue values, is a sum of weighted cue values, where the weights are determined according to the least squares criterion. This "linear model" is then also used to model the predicted subject response (\( \hat{E}_s \)) as a function of the cues. The interaction between the two systems is further analyzed by means of Eq. 1: the Lens Model Equation, Hammond, et al., 1975.

\[
r_a = G \times R_e \times R_s
\]  

(1)

where \( r_a \), achievement or task control, is the linear correlation between the subject's responses (predictions, inferences) and the criterion values; \( G \), the index of "matching", is the linear correlation between \( \hat{E}_e \) and \( \hat{E}_s \); \( R_e \), the predictability of the task, is the multiple correlation between the cues and the criterion; \( R_s \), consistency, is the multiple correlation between the cues and the responses.

Eq. 1 applies when all of the systematic variance in the criterion can be accounted for by a linear function of the cues. For the non-linear MPL tasks, a non-linear, additive polynomial model was applied. For a description of the response measures used in the present experiments, see Study I (Brehmer & Lindberg, 1970a) and Study VII (Lindberg & Brehmer, 1977a).

In the paper by Hammond, et al., (1975) it is stated that Social Judgment Theory "is not aimed at finding the laws of human judgment; rather it is intended to be descriptive". (p. 276). On the other hand, Social Judgment Theory incorporates the regression model which, in turn, presupposes certain assumptions with respect to the nature of the cognitive processes involved in human judgment. In the light of recent empirical findings, the regression model has received increasing criticism as a "process" model of inference.
behavior. For example, experiments by Brehmer (1972) and by Armelius & Armelius (1976) show that subjects violate the model in that they use different inference strategies for different subsets of cue combinations. Therefore, it is not surprising that assumptions made by Social Judgment Theory do not conform to the subjects' actual performance; The present studies contradict the assumptions of this model that subjects mirror the systematic aspects of the task in their inferences and that they minimize the mean prediction error.

In stead, the main objectives of Social Judgment Theory is to be "life relevant" (p. 276) and to create "cognitive aids for human judgment" (p. 276). On the basis of this theory, it has been possible to develop technical aids, which enable the human judge to reach more optimal judgments in specific situations. The efficiency of these aids determines the ultimate validity of this theory. As a consequence of the focusing on these "technological" objectives, Social Judgment Theory offers no explanations of the original psychological problem how the unaided subject copes with a probabilistic environment.

According to Social Judgment Theory, optimal performance for the present kind of inference tasks is defined as a perfectly consistent strategy on part of the subject \( R_s = 1.0, \) cf. Eq. 1. Furthermore, the subject is assumed to mirror the systematic aspects of the task system in his inference strategy, while he minimizes the mean squared predictive error. When interpreting the subject's performance, the theory also assumes, more or less implicitly, (1) that the subject bases his inferences solely on what he learns from the task, (2) that the subject's only objective is to maximize his level of task control, \( r_a \), and (3) that the structure of the task does not prevent the subject from reaching the "maximal possible" level of consistency, \( R_s = 1.0. \) Consequently, (4) learning is an inductive process, characterized by the subject's gradual and passive adaptation to the structure of the task, in which process the main function of feedback is to transmit task information.
As a consequence, the subject's less than optimal performance in CPL is typically interpreted to mean that he lacks the cognitive capacity required to cope with this kind of tasks. The basic assumptions on which this interpretation rests, are seldom questioned, however. In reinterpreting the results from the present studies, this summary will focus on the validity of these assumptions. The main objective here is not to evaluate Social Judgment Theory. This theory will serve only as a point of departure for the analyses, since this theory did provide the point of departure for the research problems originally selected for investigation in the present experiments. Nor does the present summary aim at a comprehensive presentation of results from the area of CPL. Instead, the purpose is to try to explain the results from the present studies by means of a critical analysis of the following questions, related to basic assumptions held by the normative model: (1) What kind of knowledge determines the subject's inference strategy in CPL? (2) Which are the subject's objectives in CPL? (3) To what extent does the structure of the task permit the subject to fulfill his objectives? (4) How do the subject's knowledge, his objectives, and the task structure interact in determining his inference strategy?

COGNITIVE DISPOSITIONS AND HYPOTHESES

In the present section, the nature of the subject's preexperimentally established experience will be discussed, as well as the possible effects of this experience on his inference strategy.

In Study I (Brehmer & Lindberg, 1970a) it was shown that at the final level of performance in SPL, the slope of the regression line relating the subject's inferences to the cue values, \( b_{CR} \), exceeds the slope of the regression line relating the criterion values to the cue values, \( b_{CE} \), i.e., the subject is extreme in his inferences in that he changes his inference more than he should when the cue value changes. The degree of extremeness is an inverse function of cue validity, \( r_{CE} \), and/or a monotone function of task error variance, \( s_{CE}^2 \), since in the SPL studies, cue validity was manipulated by means of a variation in the task error variance. These
results contradict predictions based on the normative model. In particular, this model assumes that $b_{CR} = b_{CF}$. Therefore, the extremeness effect will be chosen as the point of departure for the following discussion.

It is here assumed, that this effect reflects a compromise between the subject's preexperimentally established cognitive dispositions and the task structure, and that outcome feedback has a regulative function in balancing those two behavior determinants, not only initially, but throughout the subject's interaction with the learning task.

Recent empirical findings strongly indicate that the subject actualizes preexperimentally established cognitive dispositions when he learns to cope with probabilistic inference tasks. These dispositions reveal themselves as simple "hypotheses" (Brehmer, 1974), or "heuristics" (Tversky & Kahneman, 1973), which may be quite resistant to change in the laboratory setting. In particular, the Hypothesis Testing Model (Brehmer, 1974) assumes that the subject initially generates positive linear hypotheses with respect to the form of the cue-criterion function in SPL. This assumption is, for the present tasks, consistent with the "representativeness" heuristic detected by Tversky & Kahneman (1973), according to which the subject has a strong bias to select that output or inference which is most "similar" to the input, e.g., when making inferences about population parameters from sample information. Tversky & Kahneman have also demonstrated that the subject is insensitive to "the regression effect", which effect occurs in the present tasks.

On the basis of these results, it is here assumed that the subject in SPL initially executes an inference strategy according to which the highest prediction value goes with the highest cue value, and so on, where the cue values and the inferences are matched with respect to similarity on subjective standard scales, and where outcome feedback determines the range of the inferences. The use of this strategy implies that $b_{CR}$ will exceed $b_{CE}$, since the latter
measure, but not the former measure, reflects the "regression effect". Outcome feedback affects the subject's inference strategy in the direction of greater isomorphy with the task \( b_{CR} = b_{CE} \), and for the present positive linear tasks, learning amounts to a successive adjustment of the parameter \( b_{CR} \).

In Study II and Study III (Brehmer & Lindberg, 1970b, 1971) it was observed that the degree of extremeness increases when outcome feedback is removed. This result is consistent with the present assumptions, indicating that the subject tends to change his inference strategy towards the initial structure when the regulative effect of outcome feedback is no longer present. Since there was no non-feedback block preceding the first feedback-block, this hypothesis could not be tested on the basis of these experiments. It is, however, consistent with results obtained by Brehmer (1974) which show that the subjects make most frequent use of linear rules and classification rules when they are instructed to assign numbers to cue values without receiving feedback information.

The transfer studies, Study V and Study VI (Lindberg & Brehmer, 1976a, 1976b) show that although the subject quickly responds to a change in the task structure \( s_{CE}^2 \), he does not passively adjust to the new task. Instead, transfer effects occur. The hypothesis that the subject simply adjusts to the totality of the transfer task and the learning task was rejected. Although these results do not confirm the assumption that the subject is able to use pre-experimental experience, they do indicate the existence of one necessary condition for this, namely that the subject is able to use task-independent knowledge.

Effects of preexperimental experience on the subject's performance are, however, indicated by results from Study II and Study IV (Brehmer & Lindberg, 1970b, 1973), in that the subject's retention of SPL was not affected by the length of the retention interval (retention measures immediately after the completion of the learning stage, and after one week). That is, what is learned in SPL, i.e., the execution of a positive linear inference strategy, is
extremely resistant to forgetting, indicating the existence of well established operative cognitive structures. It is assumed that these structures are of the kind arising out of what Piaget (1973) defines as "logico-mathematical experience", as compared to "physical experience", in the following quotation:

"On the one hand, there is what may be called in the widest meaning of the term physical experience, i.e., experience that involves contact with objects and the gaining of knowledge by abstraction from the object itself (colours, weights, and so on). It is this kind we commonly think of and which alone is taken into account by empiricism. On the other hand, however, there is what may be called logico-mathematical experience, which play an important part before the appearance of deductive processes. It too involves contact with objects, but by obtaining knowledge of these actions themselves, and not from the object as such" (Piaget, 1973, p. 45).

Logico-mathematical experience expresses itself, and is defined by, a cognitive operative pattern, or a schema, and is, thus, less susceptible to "forgetting" than is physical experience; "There is therefore no memory of patterns, for the memory of patterns is nothing more than the pattern itself" (Piaget, 1973, p. 40-41).

The concept of a logico-mathematical cognitive schema implies that the subject is able to execute a certain level of task control without basing his strategy solely on what he learns from the task per se. Furthermore, the subject's use of this kind of schema implies that he also, to a certain extent, focuses on his own inference strategy rather than on the task. On the other hand, the cognitive schema is not fully available for conscious interpretation on the part of the individual. This would explain why subjects sometimes give less adequate descriptions both of their strategies and of the task (Brehmer, Kuylenstierna, & Liljergren, 1974).

Some of the basic concepts in the present approach have been formalized in Brehmer's (1974) Hypothesis Testing Model. One purpose
of the SPL experiments was to test predictions from this model, which, so far, has been developed only for the single-cue case.

The Hypothesis Testing Model describes the subject's cognitive dispositions as a hierarchy of hypotheses about the form of the cue-criterion function. Hypotheses are generated one at a time in accordance to their sampling probabilities in this hierarchy (independent of the task), and linear hypotheses are more probable than are non-linear hypotheses. Each hypothesis is then tested against the feedback information from the task. In the second stage, the subject finds the parameters of the cue-criterion function, and he learns to use the resulting inference rule consistently.

Results from Study VII and Study VIII (Lindberg & Brehmer, 1977a, 1977b) support the predictions from the Hypothesis Testing Model that the subject increases his task control by testing hypotheses about the cue-criterion function form for each cue separately, and that he tries linear hypotheses before he tries non-linear hypotheses. Study VIII and Study IX (Lindberg & Brehmer, 1977b, 1977c), taken together, support the prediction that non-linear inference rules are more difficult to apply than are linear rules.

In the latter two studies it was also demonstrated that the subject increases his task control if he is permitted to select feedback instances in free order (active feedback control), and that he in part selects feedback instances in the order predicted by the model. These results support the general assumption that the subject tests hypotheses based on a preexperimentally established cognitive structure, which also contains an operative schema which requires active interaction with the task (active feedback control), to be tested and adequately adjusted to the task.

However, although the present MPL results support some of the predictions from the Hypothesis Testing Model, there are also results which are inconsistent with this model in its present form. First, this model does not account for the extremeness effect in SPL.
Second, results from the last MPL study, Study IX (Lindberg & Brehmer, 1977c) suggest that, initially the subject does not generate hypotheses related to separate cue-criterion functions, although the frequency of such hypotheses increases with practice. These latter results imply that some kind of inductive thought may precede deductive thought, and that the functional hypotheses predicted by the model are not task-independent. This of course, is not a surprising conclusion with respect to the present kind of tasks; whatever the structure of the subject's cognitive dispositions, they do not inform him about the numerical definition or the range of the criterion variable. Thus, it is necessary for the subject to find "anchoring points" in the task structure, from which he can proceed with his hypothesis testing activity. The above suggestion that the subject's hypotheses might not be task-independent is consistent with recent SPL studies which indicate that the subject is able to construct new hypotheses which are not present in his initial cognitive hierarchy (Brehmer, 1976a).

In summary, the above discussion supports the assumption that the subject's inference strategy in SPL is affected by his preexperimental experience, i.e., cognitive dispositions. In part, these effects are accounted for by the Hypothesis Testing Model. For further developments of the Hypothesis Testing Model, the following distinctions should be considered: (1) Hypotheses which focus on the inference strategy vs. hypotheses which focus on the task; (2) Hypotheses about the systematic aspects of the strategy (the task) vs. hypotheses about the unsystematic aspects; (3) Criteria of acceptance and rejection of hypotheses vs. those of operative schemata.

MOTIVATION AND COGNITIVE CAPACITY

In the normative model (Hammond, et al., 1975) the $r_a$ measure is explicitly used as a criterion of achievement. According to Brunswik, however, the $r_a$ measure is also a criterion of intentionality, since the subject is assumed to try to reach a stable relation to that
distal event with which his responses have the highest correlation (Smedslund, 1966). This latter interpretation of \( r_a \) is not made explicit in the normative model. It will be assumed here, that the subject has two objectives in CPL, and that the \( r_a \) measure is of direct relevance only for one of these objectives.

Specifically, the subject is first assumed to try to reduce the difference between his operative schema and the task, in the direction of greater "structural" isomorphy. Second, the subject is assumed also to try to maximize his task control, as defined by the \( r_a \) measure. These objectives are not wholly independent and they have conflicting behavioral consequences. In part these objectives are consistent with a "problem solving attitude" and a "gambling attitude", as defined by Bruner, Goodnow, & Austin (1956). In contrast to these authors, the present approach assumes that the subject adopts both objectives simultaneously, although their relative importance may change over conditions and as a function of learning.

In CPL, the subject does not reach the maximal level of task control, \( r_a \) (see, e.g., Study I (Brehmer & Lindberg, 1970a) with respect to SPL, and Study VIII (Lindberg & Brehmer, 1977b) with respect to MPL). The subject does, however, reach a stable level of task control. If we adopt Piaget's criterion, as interpreted by Smedslund (1966), that "it is reasonable to infer that when a pattern of activity is repeated a second time without any modification, the intention was fulfilled the first time" (p. 386), we may conclude that this stable level of task control also represents an "optimal" level of task control according to the subject's internal performance criteria.

On this stable level of task control, the subject may change the structure of his inference strategy. This fact is demonstrated in the transfer studies, Study V and Study VI (Lindberg & Brehmer, 1976a, 1976b), in that transfer effects occurred with respect to \( b_{CR} \) and \( s^2_{CR} \) but not for \( r_{CR} \), under the high-low validity conditions.

On the other hand, the subject may also change his task control
without changing his inference rules, as shown for the maximal information condition in Study VIII (Lindberg & Brehmer, 1977b). These results are interpreted to support the assumption of two, partly independent, objectives on part of the subject.

A different kind of evidence stems from those studies in which the relative importance of the two objectives may be assumed to change, due to the experimental design. First, in Study II and Study III (Brehmer & Lindberg, 1970a, 1971), the relative importance of the two objectives was changed by means of the omission of outcome feedback. An omission of feedback will increase the relative importance of the objective to increase the task control, since in this condition there is nothing more to learn about the structure of the task. Results support this assumption in that the subject decreased the isomorphy between the strategy and the task (b^ - b^) in favour of an increase in task control (r^).

Second, in Study VIII and Study IX (Lindberg & Brehmer, 1977b, 1977c), the relative importance of the two objectives was changed from the learning stages to the test stages in that the subject was required to control the task, i.e., make predictions, only in the test stages. In these experiments, results indicate that the subject focusses on different aspects of the task in the learning stages as compared to the test stages.

Third, in these latter experiments, the subject was informed about the values of the optimal predictions, under the maximal information condition, in which case he does not need to learn the structure of the task in order to reach the maximal level of task control. Nevertheless, under this condition the subject did focus on this latter objective, indicated by the facts that he did not reach the maximal level of task control, and that he searched for the structural aspects of the task in the same way as did subjects who were not informed about the values of the optimal predictions.
Of particular interest is the question of how the subject copes with the error variance of the task. In SPL (see, e.g., Study I, Brehmer & Lindberg, 1970a) the subject's active control of the task error variance is indicated by the fact that the $s_{CR}^2/s_{CE}^2$ ratio (relative consistency) remains invariant over different levels of task error variance, $s_{CE}^2$. The subject's active control of $s_{CE}^2$ in SPL is also evidenced by the transfer studies, Study V and Study VI (Lindberg & Brehmer, 1976a, 1976b). The subject's active control of the task error variance is also consistent with Brehmer's (1976a) suggestion that he learns correlations rather than functional relations. The results from Study VIII (Lindberg & Brehmer, 1977b), indicate that the subjects in the maximal information condition are inconsistent in spite of the fact that they were given the information required to execute a perfectly consistent strategy without difficulties, i.e., they chose to be inconsistent. All these results agree with the assumption that the subject tries to reflect at least part of the task error variance in his inferences. In this respect, the subject gives priority to the first hypothesized objective, which, as a consequence, decreases his task control, $r_a$.

On the other hand, most hypotheses put forward so far explain inconsistency ($R_s < 1.0$) in terms of a lack of cognitive capacity on part of the subject (see Brehmer, 1976b), e.g., lack of "cognitive control" (Hammond & Summers, 1972), lack of "cognitive skill" (Brehmer, 1974), and lack of "response reliability" (Brehmer, 1976b). All these hypotheses presume, as does the normative model, that the subject tries to be consistent (and that the task permits him to be consistent, see next section), but that he is not capable of fulfilling this objective. The criterion of consistency is not, it should be noted, deducible from the structure of the task per se, and the subject is free to select alternative performance criteria, as well as alternative objectives. In particular, the hypothesis that the subject does not try to be consistent remains to be rejected on the basis of empirical tests.
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In summary, the above arguments are consistent with the assumption that the subject tries to reach two objectives simultaneously in CPL, and that the fulfillment of the objective to increase the structural isomorphy between the task and the inference strategy may explain why the second objective to increase the task control, i.e., to be consistent, is not reached. Furthermore, the validity of the assumption that the subject lacks the cognitive capacity required in CPL could not be inferred from empirical results so far obtained.

The present assumptions, however, compete with those suggested in the previous section. For instance, the extremeness effect in SPL may be interpreted to reflect the subject's initial cognitive dispositions, as well as the relative importance of his objectives. The same holds true with respect to the effects of a omission of outcome feedback. The fact that the subject under the minimum information condition in Study VIII (Lindberg & Brehmer, 1977b) controls the task mainly by means of the linear cue in the test stages may, in the same way, be alternatively interpreted in terms of the accessibility of the linear hypothesis or in terms of his objectives, respectively. Thus, in future studies it will be necessary to try to separate the effects of the subject's operative schemata from those reflecting his objectives.

THE STRUCTURE OF THE LEARNING TASK

The normative model (Hammond, et al., 1975) holds that the formal structure of the task is an important regulator of the subject's behavior in cue probability learning. This general assumption has received substantial empirical support, and results from the present experiments agree with those obtained in other studies. We are now able to predict with fair accuracy the effects on the subject's achievement of a number of variations in the structure of the task. For a recent overview of SPL results, the reader is referred to Brehmer (1977).
Second, the model assumes that the "system characteristics" of the task, i.e., the nature of the cue-criterion relation, rather than the "surface characteristics", e.g., number of cues, determine the structure of the subject's inference strategy. This assumption was supported in the first MPL study, Study VII (Lindberg & Brehmer, 1977a). Results from this study also show, however, that even if the system characteristics of the task are the more important ones, the content aspects of the task as well as temporal relations in the presentation of task information should also be considered.

Third, the model also assumes that the deterministic or "systematic" aspects of the task are mirrored in the subject's inference strategy, while the error variance of the task is reduced to zero by means of a perfectly consistent strategy ($R_s = 1.0$). Both parts of this assumption are contradicted by the present results; Subjects do not match the systematic aspects of the task, and they are not consistent in their inferences. See, e.g., Study I (Brehmer & Lindberg, 1970a) for SPL, and Study VIII (Lindberg & Brehmer, 1977b) for MPL. The present studies also replicate the finding from previous studies that consistency ($R_s$) is a monotone function of task predictability ($R_e$).

These results refer to the subject's final level of performance, and the problem here is to explain why the subject does not reach the "maximal possible" level of task control, that is, why he is inconsistent ($R_s < 1.0$). Rate of learning is characterized by the fact that the subject increases his task control and reaches a stable level of performance within two hundred trials or less. The problem here is to explain how this could be achieved, considering the fact that the task may contain a hundred different cue values, with a number of criterion values for each cue value (as in Study I, where subjects in fact reach a stable level of performance within about one hundred trials). In this section, these problems will be discussed mainly with reference to the structure of the task.
The normative model assumes that the subject bases his inferences on the task information only, mainly the feedback instances, and that he progresses by means of inductive thought. Optimal performance is achieved when the subject (1) learns the criterion mean for each cue value (combination of cue values), and (2) makes consistent use of these values as his predictions.

If it is assumed, for the moment, that inductive knowledge is possible in principle, which could be doubted on theoretical grounds (Popper, 1969), the subject would need a great number of trials for each cue value (combination of cue values) to be able to infer the criterion mean with any accuracy. The hypothesis that a considerable increase in the number of trials will affect subjects' performance was, however, contradicted in Study IV (Brehmer & Lindberg, 1973).

From a deductive point of view, although the power functions for tests of separate criterion means have not been calculated, it seems safe to state that the power of such tests is extremely low for these tasks, within the number of trials usually provided.

These arguments indicate that the subject has no rational tools at his disposal to determine from the task information alone what the optimal inferences are. Therefore, the value $R_s = 1.0$ represents an overestimation of the maximal possible level of consistency, given the assumption of the normative model, that he bases his inferences on the task information only.

With respect to the question of rate of learning, it should first be noticed that the learning task is typically constructed as a formal regression system with artificial cue and criterion variables. One argument for this has been that such "content-less" tasks will, presumably, minimize the effects of the subject's preexperimental experience on his thinking in the experiment. This argument seems reasonable if we think of "physical experience" (i.e., knowledge about the task per se), but is less convincing if we also consider the possibility of "logico-mathematical" experience on part of the subject (see p. 7 , for definitions).
The present tasks may be well suited for the subject to express his preexperimentally established logico-mathematical experience. Furthermore, if the subject's logico-mathematical schema is isomorphic with certain aspects of the task structure, this would enable the subject to reach operative control of the task within a few trials, perhaps after minor adjustments of his strategy. That is, he does not have to base his inferences only on what he learns about the task structure per se. The possible existence of a structural isomorphy between the scientific model and the cognitive processes of the human being has been pointed out by Piaget (1973) and others. For the present tasks, this assumed isomorphy is supported also by empirical results obtained by Brehmer (1974). In short, when interpreting the subject's rapid improvement observed in CPL, the possibility that the task "is adjusted" to the subject should be considered.

In conclusion, the present discussion indicates that the analysis of the task provided by the normative model is not quite adequate, especially with respect to the definition of "maximal possible" level of consistency ($R_s$). On the other hand, the subject performs better with respect to rate of learning, than could be expected from the assumption that he is not familiar with the task. This fact could be explained by the assumption that the task in certain respects is isomorphic with subject's cognitive schema.

Therefore, in addition to the effects of the subject's cognitive dispositions and of his objectives on his inferences, we might now add certain effects of the task structure, not accounted for by the normative model. Together, these factors provide an explanation for the subject's inconsistency in CPL, which contradicts the assumption of the normative model that the subject lacks the cognitive capacity required for this kind of tasks.

**THE FUNCTIONS OF OUTCOME FEEDBACK**

The assumptions given above imply a "structuralistic" frame of refe-
rence for CPL: The subject's inferences reflect a compromise, or a dynamic balance, between his cognitive dispositions, his objectives, and the task structure. According to this view, outcome feedback has a regulative function with respect to the subject's cognitive schemata, as well as an information mediating function with respect to the task characteristics per se. In the normative model, the latter function is given priority, while in the present approach, the former function is the most important one.

The Theory of Cognitive Control (Hammond & Summers, 1972), a close relative of the normative model, the essential assumptions of which have, in fact, been incorporated in the normative model, also admits a regulative function of outcome feedback. According to this theory, outcome feedback prevents the subject from applying his cognitive dispositions into a consistent inference strategy. The reason for this is that outcome feedback contains an "error" component since it reflects the unsystematic aspects of the task. This theory, however, differs from the present approach in the important respect that it defines the subject's cognitive dispositions in terms of what he has learned from the task, while neglecting his task-independent experience.

The Theory of Cognitive Control also predicts the effect observed in Study II and Study III (Brehmer & Lindberg, 1970b, 1971) that the cue-response correlation, $r_{CR}$, increases as a function of the removal of outcome feedback. On the other hand, this increase in $r_{CR}$ is due to a parallel increase in $b_{CR}$, and it is thus not a genuine decrease in inconsistency ($s_{CR}^2$); (It should be noticed, however, that in this theory, "consistency" is defined by the measure $r_{CR}$, while in the present SPL experiments, "consistency" is defined by the measure $s_{CR}^2$). Independent of the definition of "consistency", the fact that the structural isomorphy between the subject's inference strategy and the task (inversely related to $(b_{CR} - b_{CE})$) decreases when feedback is removed, favours the present approach.
In particular, these results indicate that the presence of outcome feedback has the effect of adjusting the subject's inference strategy towards that of the task, and away from that of his initial strategy. Advocates of the Theory of Cognitive Control, on the other hand, express the opposite point of view, in suggesting that outcome feedback should not be present in CPL since it forces the subject to become "inconsistent" and thus "nonoptimal" (see, e.g., Hammond, Summers, & Dean, 1973). Instead, according to the Theory of Cognitive Control, the subject should be given cognitive feed-forward (pictorial information about the statistical properties of the task) and/or cognitive feedback (pictorial information about the statistical properties of the inference strategy). This suggestion, however, seems to neglect the following important points: (1) If outcome feedback is not present in the learning stage, the task is no longer a probabilistic task, from the point of view of the subject, although it may still be a complex task, in the sense that the subject is required to integrate information from a number of cues of different validities, cue-criterion function forms, etc.; (2) Nor would this task be an inference task in the original sense of this term, since the subject is informed about exactly those parts of the task or his strategy (e.g., cue weights) which he should infer on the basis of the cue information. (3) Accordingly, the suggested shift of task information would change the basic structure of the task, from the point of view of the subject. According to the present approach, this shift would, presumably, affect the subject's relative focusing on his objectives, so that he would give priority to the objective of mirroring those task aspects of which he is informed, in his inference strategy.

The present approach also indicates that the relative importance of the functions of outcome feedback changes as a function training. As has been mentioned above, the structure of the subject's inference strategy seems to change with practice. These results contradict predictions based on the normative model, according to which the structure of the subject's inference strategy will not change as a function of training, except for a gradual adjustment to the
structure of the task. Therefore, learning seems to be a "stage-wise" process, the nature of which is still mainly unknown, rather than a single process.

CONCLUSIONS

The results of the present discussion indicate that in order to increase our understanding of the experimental results in CPL, it would be necessary to take the subject's preexperimentally established cognitive dispositions and his objectives into account, and also to reanalyze the task structure and its information content. The present analyses also suggest that the subject's inference strategy reflects a joint effect of these factors, and that the main function of feedback is to regulate the subject's cognitive schemata with respect to the demands put on him by the task. The normative model was contradicted with respect to its assumptions that the subject makes use only of task-dependent experience, that his only objective is to increase his task control in terms of $r_a$, that the task structure permits the subject to be perfectly consistent, and that learning is mainly an inductive process, characterized by the subject's gradual adjustment to the systematic aspects of the task.

Important problems for future experiments within the present paradigm are, with respect to the subject's experience, to study the effects of a systematically introduced task-independent knowledge; with respect to the subject's objectives, to investigate the too long neglected question how the subject tries to cope with the task error variance, and to define independent criteria of achievement and intentionality, respectively; With respect to the structure of the task, to calculate the power functions for different kind of hypotheses; Finally, with respect to feedback, to study the effects of an addition of outcome feedback on the subject's inference strategy as developed on the basis of cognitive feedforward/feedback.

However, it seems necessary to consider also the problem of the main direction of future research. Two principal directions suggest
themselves from the above discussions: (1) Research focusing on the subject's logico-mathematical knowledge and his development and use of operative schemata, and (2) Research focusing on inference behavior in life-relevant situations with a specific substantial content. The (necessary) choice between these objectives, both of which are called for in the development of the basic Brunswikian approach, will have consequences with respect to methods of analysis as well as the choice of experimental tasks.
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