Psyke & Logos, 1984, *5*, 288-301

INDUCTIVE AND DEDUCTIVE APPROACHES TO MODELLING OF HUMAN DECISION MAKING

Erik Hollnagel
Institute for Energy Technology
Halden, Norway

This paper presents the two conventional approaches to modelling of human decision making. The inductive approach emphasises the anchoring in empirical data. The deductive approach is based on accepted assumtions from formal decision theory. A comparison of the resulting models show that the outcome is very similar. It is argued that this is because modelling of decision making basically is a hermeneutical exercise, hence neither purely inductive or deductive. An adequate model of decision making in man-machine systems must be based on a description that captures the complexity of both man and machine, such as Cognitive Systems Engineering. This leads to two essential assumptions about decision making systems, that they must be both causal and intentional. An alternate cybernetic approach to modelling of decision making, which includes both of these assumptions, is briefly described.

Introduction

One of the current interests in the investigation of operator performance appears to be in the aspect of decision making. This is so for a number of reasons. First of all it is generally found that serious incidents and/or accidents occur because the decision making has been deficient, either because an incorrect decision has been taken or because no decision has been taken when one was required. In addition to that any theory of human performance must contain an element of decision making, since it is the decisions the person makes which shape the performance -- unless, of course, one agrees with the simplified view that performance is completely determined by stimulus-response connections, hence beyond the control of consciousness. And finally, decision making seems to have attained a status as the most important type of activity in almost any situation. There seems at present to be a trend to focus on decisions in every aspect of life, whether it be politics or private occupations.

Decision making has also become a focal point in work on the so-called expert systems. Here one often tries to provide an "intelligent" computer system that can support an operator's decision making, e.g. by providing expert knowledge or advice. These systematic attempts at practical applications have been very useful, though less by their success than by showing how little is still known about the fundamental psychological processes in human decision making, thereby contributing to a more precise definition of research problems. This paper will consider some of the problems related to defining or specifying models of human decision making.

Decision Making and Levels of Behavior

It must be noted from the start that it is possible to talk about decisions on many levels, and thereby also to misuse the concept of decision making. A reasonable position will be to reserve the term decision making to those decisions which are made consciously by the person.

The different categories of human decision making and action can be defined in several ways. A recently used description has the following three categories: (1) decisions in situations that are familiar and frequent, (2) decisions in situations that are familiar but infrequent, and (3) decisions in situations that are unfamiliar and infrequent (e.g. Rouse et al., 1984). Psychologically, the person's behavior can be characterised as to whether alternative solutions are known or can be found, and whether attention is required in making and implementing the decision (cf. Note 1). In relation to man-machine process control systems the terms skill-based, rule-based, and knowledge-based performance are often used (cf. Rasmussen, 1979).

According to this, the term *decision* should be used for the level of knowledge-based behavior, i.e. the cases where the activity requires the attention of the person, hence is conscious. At the level of rule-based behavior, the term *choice* is preferred, since at this level a rule or a familiar principle can be employed, hence making conscious deliberations unnecessary. Since the interest in this paper is mostly on the decisions rather than the choices, we shall prefer to use the former term. Something akin to decisions and choices does, of course, also takes place at the level fof skill-based behavior, since skill-based behavior essentially is the smooth and automatic version of sequences of activities that were once knowledge-based and rule-based. However, since the selections between alternative paths in skill-based behavior are made automatically, without involving the person's attention, they are not decisions in any reasonable sense of the word. There has been a tradition to talk about decision-making in other cases as well, e.g. decision processes in perception (Swets, Tanner & Birdsall, 1968), referring to the selections which are implied by an information processing theory of perception. But this is in my opinion a misuse of the term, even more so because the "decisions" in this case by definition are unavailable to consciousness.

Theories and models for decision making

A theory for decision making is a systematic description of how people make decisions, including a set of explanatory principles that refer to interfering, hypothetical variables. It is thus an explanation of the overt behavior in terms of covert processes. Theories have traditionally been of either the inductive type, based on generalizations made from empirical observations, or of the deductive type, based on some assumptions or axioms about decision making or about humans (cf. Edwards, 1954; Lee, 1971; Suppes, 1967). The former type is represented e.g. by the Step-ladder model (Rasmussen, 1979) which we will discuss in the following, while the latter is represented e.g. by the traditional normative theories of decision making and the concept of the *homo economicus.* A model is formally speaking a part of the theory. It is an expression of the essential principles or functional relationships of the theory using an analogy from another scientific discipline (which presumably is better understood). In the behavioral sciences the models are normally expressed in terms of information processing and/or control structures. Strictly speaking a model is something different from a theory, byt it is common practice to use the two terms interchangeably, and we shall do the same here.

A theory or a model for decision making is necessary for several reasons, as already mentioned. First of all it is necessary to determine what one should observe when empirical investigations of decision making are made. This need not be in the sense that a specific hypothesis is developed, from which one then derives a particular set of variables which must be observed or measured to decide (statistically) whether the hypothesis is false or not, i.e. the traditional experimental approach. It is rather in the sense that the theory, by indicating the essential functional relationships of the various parts of the decision, specifies which aspects of behavior that one should pay attention to. The theory thus defines the aspects of behavior which are meaningful under the circumstances. If the purpose of the investigation was different, e.g. studying the operators' use of body language rather than decision making, this would call for completely different set of observations.

Secondly, the theory is necessary for the analysis of the observations which have been made. The theory supplies the conceptual background from which the analysis is made. In terms of the general model for analysis (Hollnagel et al., 1981), the theory corresponds to the description at the level of competence, which is used to produce the prototypical description from the actual data. This is so whether the purpose is the test of specific hypothesis, or the more general articulation of empirical regularities. In the present paper we shall be concerned mainly with the first of these aspects, i.e. the way in which a model for decision making may be used as a basis for making observations of decision making, although the aspect of analysis will partly be anticipated by the very observational categories which are used.

The inductive or empirical model for decision making

The model is the Step-ladder model described by Rasmussen (1979) and

shown in Figure 1. The model describes eight functions or steps of processing in the sequence from activation to execution, which may be summarized as follows:

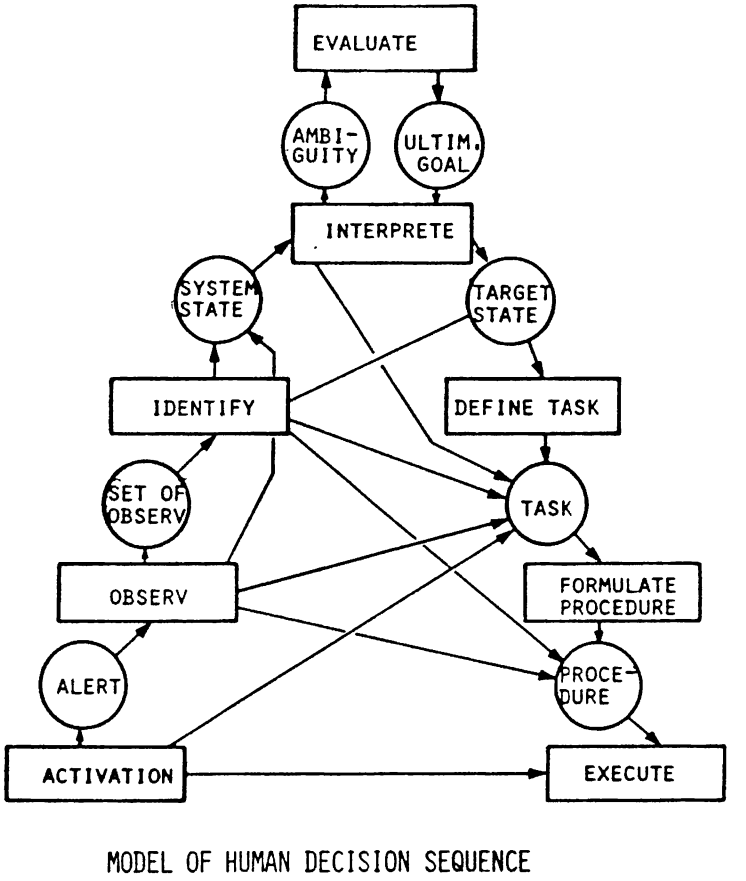

Figure 1: The Step-Ladder model of Decision Making.

1. *Activation* – Detection of need for data processing.
2. *Observation* – Gathering of information and data.
3. *Identification* – Naming the present state of the system.
4. *Evaluation* – Evaluating the alternatives in relation to the chosen performance criteria.
5. *Interpretation* – Considering the consequences for current task, safety, efficiency, etc.
6. *Definition of Task* – Selecting the appropriate change of system conditions.
7. *Formulation of Procedure* – Planning the sequence of actions.
8. *Execution* – Carrying out the planned actions and coordinating them.

One characteristic of the Step-ladder model is that the actual decision making is split into a number of decisions. These correspond roughly to the right leg of the step-ladder. First, as a result of the Evaluation-Interpretation a goal is chosen. This represents the overall purpose of the activity, i.e. the future state of the system which fulfills the criteria for performance which the operator considers adequate for the situation. However, this is not the choice of an alternative but rather the choice of the definite criteria for the later selection of an alternative. In a way it is also the indication of which set of alternatives that will be acceptable, since surely several alternatives may be expected to match the criteria, i.e. be functionally equivalent, while others definitely will not do that. The choice of the goal determines the boundaries for what is normally called the subjective set of alternatives, i.e. it functions as the first filter for the set of alternatives.

The next decision concerns the target state. This occurs as a result of the interpretation. The interpretation is the assessment of the expected consequences for each alternative considered. The alternatives are not yet as specific as alternatives for the action, but are rather alternative end states or target states. The criteria which resulted from the selection of the goal specify the acceptable conditions for the goal, hence also the desirable range of expected consequences. The selection of the target state can therefore be made with reference to this, in the sense that each target state can be evaluated vis-a-vis the goal (the criterion), and then accepted or rejected. In this way a narrowing and a specifications is made of the subjective set of alternatives. As a result of specifying the target state a limited number of alternatives remain, but each alternative is better specified than it was after the first decision, the selection of the goal.

The next decision concerns the task, i.e. the more specific set of changes which have to be made in the system. It is a specification of *what* should be done to obtain the target state, but not yet a specification of *how* it should be done. In a certain sense, the "real" decision has been taken in the previous step. By selecting and accepting the target state, the operator has decided what he wants to do, but not how he is going to do it. In normative decision theory it is assumed that these two are parts of the same, i.e. that an alternative which specifies *what* also specifies *how*. But in the Step-ladder model, the two aspects are considered separately.

The selection of the proper task indicates what should be done in order to reach the selected target, and the final decision concerns the procedure, i.e. the *how*. This, then, is the specification of the concrete activities and the way in which they are to be organized, to bring about the desired target state. It may be the specification of the individual activities, or it may just be the naming of a procedure which will lead to the desired results, at least according to the experience of the operator. The procedure is that which can be acted upon and is thus the concretization of the target state, i.e. the concrete form of the alternative which was chosen at a higher level. Obviously, the choise of the alternative in the form of the target state may have implied the use of a specific procedure, especially if the operator is familiar with the situation. But in the case of an unfamiliar situation – either because the opera-

tor is a novice or because it is a rare event – it may be appropriate to consider the intermediate steps.

One of the advantages of the Step-ladder model is that it not only specifies the correct and complete way of reaching and executing the procedure which will lead to the target state, but that it also gives an account of the various ways in which shortcuts or shunts may be made. It is thus a basis for a description of the novice as well as the expert. Normally, one should not expect that all the functions may be observed in an actual case, simply because the operator may make the decision in various ways. It has been suggested (Note 2) that explicit models of decision making only are relevant for the novice, and that the expert decision maker behaves quite differently. But even if that is the case, the Step-ladder model can be used because it makes explicit allowance for this. However, when planning to make observations of operator performance and decision making, one should strive for as many details as possible, hence assume that the operator will go through the decision making according to the chosen model. The observations of the actual performance may then be used to note differences between the model and reality, hence to make inferences about the "mechanisms" which account for the discrepancies.

A deductive decision making model

In contrast to the inductive theory or model of decision making which is represented by the Step-ladder model, the most common models are deductive models. This means that they are based on a set of theoretical principles and axioms rather than on empirical data. From these axioms it is deduced how decision making should occur, and this is then presented as a model. In several cases the model may be supported by empirical data. However, the data usually come after the model, which is why it may be called deductive rather than inductive. Even in the cases of the so-called descriptive models of decision making, which according to their name should be inductive models, one can always find a strong influence from some of the basic normative principles, which reveals that the models by nature are deductive rather than inductive. This is the case for some of the better known models, such as the Conflict Resolution Model (Janis & Mann, 1977), Schrenk's model for diagnostic decisions (Schrenk, 1969), or the Elimination-by-aspects model (Tversky, 1972).

In the following we shall briefly describe a generic, deductive model for decision making. It is generic because it summarizes the common features which may be found in various deductive models. However, since each deductive model generally emphasizes a specific part of the decision making or a specific rule for decision making it is misleading to consider just one or two of them. A more useful approach is to produce a generic description which will cover practically all of the deductive models that one may come across. This description is a further development of a previous model (Hollnagel, 1977).

A decision involves the selection of one alternative out of two or more

alternatives. To decide means originally to cut off, probably in the sense that the alternatives for action are cut off or deleted until just one remains. So a decision involves the actual selection or preference of one alternative from a number of alternatives. (Note that if only one possibility for action exists, it is meaningless to talk about a decision. However, there will normally be at least two possibilities, i.e. the action and its opposite of not doing anything.)

Preceding the selection or decision there must have been some evaluation and comparison of the alternatives, however incomplete and deficient, since otherwise the selection of an alternative will be random. From a psychological point of view the person *must* have considered the alternatives together in order to be able to select one of them. However, nothing is supposed about the way this considering or comparison is made. It is specifically not required that it conforms to some the many rules or principles for comparison which have been producted by normative and descriptive decision theory. cf. Montgomery & Svenson, 1976.

Preceding the comparison there must also have been some kind of evaluation of the alternatives. This is necessary since one cannot compare something unless there is some basis for the comparison. That basis is usually described as an assignment of a value to each alternative, even if it is only a subjective assessment of the alternative in a context dependent way. There are many theoretical principles and rules by means of which this assignment of values can be made (cf. Edwards, 1954 & 1961), but it is not necessary at the moment to make any assumptions about how the persons does it. It may even be so that the assignment of values is entirely subjective and implicit, thus hard to observe or register or even report introspectively. Nevertheless, it is logically necessary for the comparison, so it has to be included in the deductive model.

A part of the assignment af values must be the determination or demarcation of the alternatives that are possible, i.e. a definition of the so-called subjective set of alternatives, cf. Lehtinen, 1971 & 1974. This may also be a separate function, preceding the assignment. Yet for our purpose it is equally convenient to assume that the demarcation of the alternatives takes place intermingled with the assignment. In many cases it is reasonable to assume that the assignment of values to some alternatives may lead to the detection of further alternatives, so that there is a coupling between the two functions. Again, the demarcation of alternatives may be something which is made automatically, e.g. in the sense that the person takes some alternatives for given and does not consider explicitly whether others also are possible. But although it may be difficult to observe the demarcation, it is logically necessary as a separate part of the decision making.

A final event which must precede the decision is the apprehension or realization that a decision is necessary. The person must accept the role of a decision maker, rather than of e.g. an observer or a performer (e.g. Schrenk, 1969). This is, of course, a crucial event since if it is missed, the decision will also be missed. In many cases the need to make a decision is part of a larger context, e.g. an ongoing procedure or a task. In those cases apprehending that a decision is necessary may not have the same flavour of becoming aware of some-

thing, that may be characteristic in other cases. As with the other functions we have mentioned, it may be performed either automatically or consciously. But from the point of view of this analysis, it is a necessary function.

In addition to the events preceding the decision, there must also be an event after the decision, the carrying out of the chosen alternative. The execution of the chosen alternative is important in several ways. As concerns the decision as such, it may be the place where an error occurs. Therefore, a decision is not correctly concluded until the chosen alternative has been properly executed. Concerning other decisions, the execution of the chosen alternative changes the state of the world, thus bringing about a specific (although not always anticipated) set of conditions for the following decision. It is furthermore the only way in which the person can ascertain whether his decision was correct, in the sense that the actual consequences correspond to the expected consequences. Seen over a longer period of time this provides the basis for the world, his development of new criteria and decision rules, etc.

To summarize the development so far, we have shown that there are a number of functions which analytically are necessary as parts of making a decision. They are the following, cf. Figure 2:

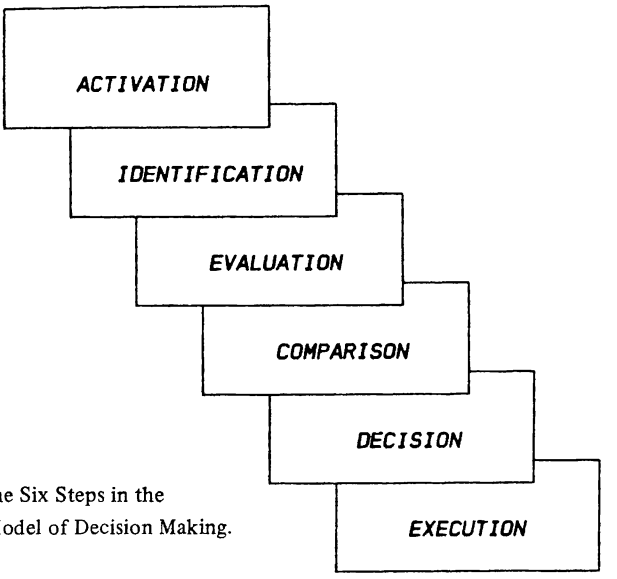

Figure 2: The Six Steps in the Deductive Model of Decision Making.

1. *Activation* or *Apprehension,* where the person realizes that he has to make af decision, and thus embarks on the decision making process.
2. *Identification* or *Demarcation of alternatives,* where the person makes a selection of the subjective set of alternatives among which he is going to make the decision.
3. *Evaluation* or *Assignment of values to alternatives,* where the person considers each alternative in turn in relation to his criteria for the decision.

4. *Comparison of alternatives,* where the person relates the alternatives to each other and to the decision criteria and determines which one is the most acceptable under the circumstances.
5. *Decision,* where the person as a result of the comparison selects an alternative and accepts that as the chosen alternative.
6. *Execution,* where the person executes the selected alternative and thereby brings the decision to an end.

Note that this division into six different functions is a theoretical result. Logically, making a decision must include these functions. But it does not mean that a person actually goes through all these functions, either in the sense that he is aware of it or in the sense that it may be observed or concluded from an analysis of the decision making. The purpose of the six functions mentioned here is not to put down any requirements about what the person *must* do, but rather to provide a background for making systematic observations and analyses. It is in a way the theoretical structure by means of which the actual decision making may be observed and examined.

A comparison of the inductive and the deductive models of decision making

Comparing the two different models which we have described so far does not serve the purpose of deciding which one is the best or most correct. The mere fact that the inductive model has an empirical basis assures that, at least within that domain, it will be superior to the deductive model. A comparison may rather serve the purpose of indicating the relative advantages of each of the models, thereby contributing to a better overall understanding of decision making.

One obvious way of making the comparison is to juxtapose the two models. If this is related to the descriptions given of the various functions, we find a number of differences. First of all, the deductive model puts much emphasis on the way in which the alternatives are demarcated, assigned values, and compared. Generally, the normative and descriptive decision making models tend to emphasize the assigning of values, using such terms as subjective protabilities and utilities, multi-attribute utilities, maximization principles, etc. This is a result of the influence from economic decision theory, which to a considerable extent has been taken over by behavioral decision theory. Consequently, the identification of the situation and the establishing of the goal is of less importance. It is rather assumed that the person in his attempt to reach some goal has come across a situation where several alternatives are available. His task is therefore to make a decision among the alternatives, rather than to identify the situation and specify the goal. Both of these are simply taken for given. Traditional decision theories thus work on the assumption that the situation is well-defined, and proceeds from that. However, note that this does not imply that the alternatives also are well-defined.

In contrast to that, the inductive decision making model describes an ill-defined situation. The person, whom we shall call an operator to indicate that we are talking about the inductive model, knows that he has to do something, which presumably includes making a decision. But apart from that not much is given. The model therefore describes in considerable detail how the operator makes the identification of the situation, how he establishes his goal, and how he through a number of seperate decisions reaches the point where he can begin to execute the chosen alternative. Since this form of decision is worlds apart from the economic type of decision making, there is very little concern for the details of e.g. decision rules, principles of maximization or combination of multiattribute alternatives, etc. Quite likely, the homo economicus, or even Herbert Simon's decision maker with limited rationality, would be a disaster in a control room.

Yet there are some resemblances in the overall structure of the two models, and these may be highlighted by referring to a general division of the decision making into four phases, which we shall call Activation, Preparation, Decision, and Execution. This is shown in Figure 3.

This figure shows more clearly what the differences between the two models are. The deductive model assumes that the specification of the alternatives takes place during the preparations for the decision, hence coincides with the gathering of information and identification of the state of the system. While the inductive model assumed that the decision is not a simple selection of one alternative among many, but rather a gradual narrowing down of the alternatives to just one, and then a specification of the chosen alternative. The decision rule is thus a form of iteration, such as e.g. the elimination-by-aspects rule (Tversky, 1972), or a similar procedure. Another possibility is a form of satisficing (Simon & Stedry, 1969) where possible target states are examined one by one with respect to the specified goal (criteria) and the search stopped when an acceptable target state has been found. This would be an example of a non-exhaustive procedure. The following specification of the details related to the target state, i.e. the specification of the task and the procedure, would then correspond to the operator's acceptance of the chosen alternative and his preparations for implementing it. Obviously, if the operator has not accepted his decision, he would not start to implement it by selecting the more detailed activities which are necessary to bring about the desired target.

Comparing the merits of the two models it is obvious that they differ, particularly in the emphasis they put on various parts of the decision making. Still, the two models are related and the lack of agreement is in the details rather than in the overall perspective. Yet neither seems fully to capture the essentials of human decision making in task environments. It is obvious that a purely deductive model, based on the predominantly economic and mathematical decision theory, is inadequate for purposes of man-machine systems. It is probably less obvious that the inductive model is inadequate as well. But a little reflection will clearly show that to be the case.

	INDUCTIVE MODEL	DEDUCTIVE MODEL
ACTIVATION:	ACTIVATION	ACTIVATION
PREPARATION:	OBSERVATION IDENTIFICATION	IDENTIFICATION EVALUATION COMPARISON
DECISION:	EVALUATION INTERPRETATION	DECISION
EXECUTION:	DEFINITION OF TASK FORMULATION OF PROCEDURE EXECUTION	EXECUTION

Figure 3: A Comparison between the Steps of the Inductive and Deductive Decision Making Models.

Towards a cybernetic approach to modelling

The virtue of the inductive model is the basis in empirical data, i.e. analysis of think-aloud protocols, observations of decision making in fault diagnosis, etc. The fact that a purpose of decision making models is to support data collection and analysis should, however, make it clear that the situation is less

ideal. The way we observe and analyse decision making in the first place must depend on some assumptions about the nature of decision making. Accordingly, the inductive model is not based on empirical data alone. This is hardly surprising to anyone who is familiar with the basis philosophy of psychology or with hermeneutics. It may be less obvious for persons with a predominantly technological background, since the academic world traditionally makes an unfortunate distinction between human and technical sciences.

The implications of this are that the inductive model is as influenced by its underlying assumptions as the deductive model. The underlying assumptions are furthermore essentially the same. In both cases they are a mixture of knowledge of decision making as described in philosophy and literary fiction, of our privileged (introspective) knowledge of how decision are made, and the fragments of formal decision theory that have been absorbed in common sense knowledge. There is little need to argue that we have a tacit knowledge of what decision making is, and that it influences how we reason about it as well as how empirical data are interpreted. The lesson is that there is no such thing as an exclusively inductive or deductive approach to modelling decision making. In the inductive apporach one starts with the data but has the theory as an underlying assumption. In the deductive approach one does the opposite. The main advantage of the deductive apporach is that the underlying assumptions are more obvious, hence easier to guard against.

Both the inductive and the deductive model are expressed in terms of separate steps and information processes, and both thereby imply that the operator can be described in those terms. Partly because of this neither of them is adequate. The modelling of human decision making in man-machine systems may preferably start from a consideration of how the model will be used, taking the nature of the task environment into account. The perennial problem in research on man-machine systems is whether the man or the machine should provide the basis for description (cf. Hollnagel, 1983). So far the machine point of view has been dominating (also in cognitive psychology, I might add) but it is gradually becoming clear that this has serious limitations for real world applications. A proposed solution has been to use a mode of description that treats man and machine on equal terms as functionally equivalent cognitive systems (Hollnagel & Woods, 1983). From that two assumptions can be derived. Firstly, that the decision maker (be it man or machine) is causal, although not necesarily rational. The decision maker is causal in the sense that events (consequences) can be related to earlier events (causes) in a consistent manner, and that the decision maker itself uses causality as a basis for reasoning. Secondly, that the decision maker is an intentional system, i.e. that the decisions serve to bring about a certain intended state of the world. The inductive and deductive models each implies one of these assumptions. Intentionality is essential for the forward striving analysis of the inductive model, and causality is the basis for the top-down analysis of the deductive model. What is needed is a model that implies both intentionality and causality.

Since such a model would emphasise how decision making is controlled, we may call it a *cybernetic* model. It will probably not be radically different from the models we have considered in this paper since it refers to the same

basic functions in decision making. But it will deal more explicitly with the internal and external control functions in decision making. This aspect, which is essential for understanding decision making in man-machine systems, is completely missing in the conventional approaches, hence from the conventional models. This is probably the main reason why expert systems focus on reasoning rather than decision making. Yet if we do not have adequate models of decision making it is next to impossible to design a machine, expert or otherwise, that can support the operator. The cybernetic aspects of man-machine systems, the concept of reciprocal control achieved through communication, the steering of the system towards its goal, must be an integral part of a decision making model. Otherwise we shall find it hard to progress beyond the rudimentary description of elementary information processes.

REFERENCE NOTES

Note 1. Hollnagel, E. *A framework for the description of operator behavior.* Roskilde, Denmark: Risø National Laboratory, Electronics Department N-35-79 (NKA/KRU-P2(79)24).

Note 2. Dreyfus, S. E. *Formal models vs. human situational understanding: Inherent limitations on the modelling of business experience.* Berkeley, California: University of California at Berkeley, Operations Research Center, 1980.

REFERENCES

EDWARDS, W. (1954). The theory of decision making. *Psychological Bulletin, 54*(4), 380-417.

EDWARDS, E. (1961). Behavioral decision theory. *Annual Review of Psychology, 12,* 473-498.

HOLLNAGEL, E. (1977). Cognitive functions in decision making. In H. Jungermann & G. de Zeeuw (Eds.). *Decision making and change in human affairs.* Amsterdam: D. Reidel.

HOLLNAGEL, E. (1983). What we do not know about man-machine systems. *International Journal of Man-Machine Studies, 18,* 135-143.

HOLLNAGEL, E., PEDERSEN, O. M. & RASMUSSEN, J. (1981). *Notes on human performance measurement* (Risø-M-2285). Risø National Laboratory, Roskilde Denmark: Electronics Department.

HOLLNAGEL, E. & WOODS, D. D. (1983). Cognitive systems engineering: New wine in new bootles. *International Journal of Man-Machine Studies, 18,* 583-600.

JANIS, I. L. & MANN, L. (1977). *Decision making.* New York: The Free Press.

LEE, W. (1971). *Decision theory and human behavior.* New York: John Wiley & Sons, Inc.

LEHTINEN, U. (1972). A model describing consumer brand choice. *The Finnish Journal of Business Economics, 21*(3), 200-221.

LEHTINEN, U. (1974). A brand choice model-theoretical framework and empirical results. *European Research, 2*(2), 51-68, 83.

MONTGOMERY, H. & SVENSON, O. (1976). On decision rules and information processing strategies for choices among multiattribute alternatives. *Scandinavian Journal of Psychology, 17,* 283-291.

RASMUSSEN, J. (1979). *On the structure of knowledge – A morphology of mental models in a man-machine system context* (Risø-M-2192). Risø National Laboratory, Roskilde, Denmark: Electronics Department.

ROUSE, W. B., KISNER, R. A., FREY, P. R. & ROUSE, S. H. (1984). *A method for analytical evaluation of computer-based decision aids.* Oak Ridge, Tennessee: Oak Ridge National Laboratory (NUREG/CR-3655, ORNL/TM-9068).

SCHRENK, L. P. (1969). Aiding the decision maker – A decision process model. IEEE Transactions on Man-Machine Systems, *MMS-10,* 204-218.

SIMON, H. A. & STEDRY, A. C. Psychology and economics. In G. Lindzey & E. Aronson (Eds.). *The handbook of social psychology* (2nd ed.). Reading, Massachusetts: Addison-Wesley Publishing Company.

SUPPES, P. (1967). Decision theory. In P. Edwards (Ed.). *The encyclopedia of philosophy* (Vol. 2). New York: The Macmillan Company & The Free Press.

SWETS, J. A., TANNER, W. P. & BIRDSALL, T. G. (1968). Decision processes in perception. In R. N. Haber (Ed.). *Contemporary theory and research in visual perception.* New York: Holt, Rinehart and Winston.

TVERSKY, A. (1972). Elimination by aspects: A theory of choice. *Psychological Review, 79*(4), 281-299.