THE PSYCHOLOGY OF RATIONAL DECISIONS

A Cognitive Process-model Approach

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ABSTRACT

The purpose of the present project is to perform a cognitive psychological analysis of the decision-making process. The basis of the analysis is a division of the decision process into four functions one of which, called *estimation*, is in particular supposed to be the factor that limits the complexity of the decisions one can make. The decision process itself is defined as a conscious, sequential, purposive line of thought. It is assumed that this can be adequately described by a cognitive information-processing system of limited complexity. On a broader scale the purpose is to describe characteristics of conscious thinking in general, e.g. problem-solving, attention, short-term memory, etc.

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The cognitive approach.

It is a common observation that decision-making among alternatives, each of which consists of a number of subjectively disparate attributes, is usually subjectively and objectively non-optimal or even irrational. The aim of the present paper is to try to describe a cognitive psychological process-model for decision-making that can explain this non-optimality or irrationality. The initial assumption is accordingly that decision-making can be made the subject of an analysis in cognitive psychological terms (in the following only called cognitive). This means that the label decision will be restricted to situations where a decision-maker (DM) makes a *deliberate* choice between two or more alternatives. Consequently, behavior in situations where a subject "chooses" an alternative without being fully aware of the reason why, or without considering other alternatives, will *not* be labelled decision-making. It may instead be called selection, intuitive behavior, performance of skills, drive reductive behavior, acting, etc., where the label applied will depend on the type of situation as well as on the level of description chosen. This, however, is beyond the scope of the present paper.

One implication of the cognitive approach is that only individual decision-making will be taken into consideration. Although there is a tradition for making a distinction between individual decision-making and decision-making by groups, witnessed by e.g. the "risky-shift"-phenomenon (Blank, 1968), the restriction to only individual decision-making is not regarded as a serious limitation. That is because the differences found between decisions made by an individual DM and by a group are believed not to reflect differences in the underlying cognitive processes, but rather differences in the nature of the factors that influence the decision, as well as in the kind of alternatives available. It is thus assumed

that an adequate explanation of group decision-making will be contingent on an analysis and explanation of the behavior of the individual DM.

Another implication of the cognitive approach is that decision-making will be considered in a *descriptive* rather than in a *normative* way. It is, of course, a natural thing in psychology that one should try to describe human behavior rather than to prescribe it. This seems, however, to be less natural in decision theory. Although a strictly normative approach has been abandoned in general, the spirit of it is still remaining in the preoccupation with questions concerning *what* the DM chooses and *why* he choooses it, as e.g. in the theories of consumer behavior, rather than with questions as to *how* the decision is made. As the aim of the cognitive approach taken here is to describe only in what way the decision is made, without considering what the alternatives might be, it is hoped that the ensuing model will be of a quite general nature. In fact, the purpose of the project may be described as making an analysis of the cognitive information-processing system, using the process of decision-making as a basis for the analysis. By describing the cognitive system one also makes it possible to describe the way in which decisions are made.

On a larger scale this project may be seen as a contribution to the research on man-machine interaction in decision-making (e.g. Yntema & Torgerson, 1961; Shepard, 1964), in particular concerning the structure of the cognitive interface. This application is, however, not accounted for explicitely in the present paper.

Thinking and decision-making.

The cognitive approach implies in general that decision-making is regarded as a kind of thinking. One major feature of the cognitive system is that it is made up of two larger subsystem: A *representational* system which organizes and interprets information about the state of the environment, and an *executive* system which guides the flow of thought. The ex-

ecutive system may in turn be described as being organized at at least two levels: one that may be called the *superordinate* executive system, and one that may be called the *subordinate* system (Anderson, 1975). Corresponding to these two levels, one may distinguish between two kinds of thinking. One kind is conscious, straightforward, predictable, and rather pedestrian; the other is confused, rich, productive of novelty, emotionally charged, and generally beyond consciousness.

> "My thesis is that human thinking is a multiple activity. Awake or asleep, a number of more or less independent trains of thought usually co-exist. Ordinarily, however, there is a 'main sequence' in progress, dealing with some particular material in step-by-step fashion. The main sequence corresponds to the ordinary course of consciousness. It may or may not be directly influenced by the other processes going on simultaneously. The concurrent operations are not conscious, because consciousness is intrinsically single: one is aware of *a* train of thought, but not of the details of several."
> (Neisser, 1963, p. 8)

Of the two kinds of thought, the latter is known only by its products, which may enter into consciousness spontaneously. Examples of this are associations, in words or images, or names that have been at the tip of the tongue and which are *suddenly* remembered (e.g., Brown & McNeill, 1966). The former kind of thinking is known not only by its products, but also by the process itself; we experience that we are thinking. This kind of thinking may also be termed *reasoning*, or *analytical* or *directed thinking* in contrast to more *intuitive* or *undirected* kinds of thinking.

> "Analytical thinking characteristically proceeds a step at a time. Steps are explicit and usually can be adequately reported by the thinker to another individual. Such thinking proceeds with relatively full awareness of the information and operations involved. It may involve careful and deductive reasoning, often using mathematics or logic and an explicit plan of attack...Intuitive thinking characteristically does not advance in carefull, well-planned steps. Indeed, it tends to involve manoeuvres based seemingly on an implicit perception of the total problem. The thinker arrives at an answer, which may be right or wrong, with little if any awareness of the process by which he reached it."
> (Bruner, 1960, p. 57-58)

If one looks upon decision-making as a kind of thinking, it is being characterized precisely by being a conscious, sequential, and directed line of thought. It has an explicit purpose for the DM, and may thus in a way be described as rational. It is, however, not the traditional concept of rationality, but rather what might be termed 'cognitive rationality'. It is rational in the sense that the person who makes the decision can explain the basis of his judgement, to himself or to another person. The decision made is not the result of unconscious motives, needs, etc., but the result of deliberate thinking and contemplations. Still, this does not in any way preclude that the directed thinking that constitutes the decision may be influenced by the undirected thinking, that exists independently at the subordinate level. Neither does it mean that the values assigned to the alternatives may not have their origin in psychological factors of an unconscious nature. We all know that even the most concentrated and directed kind of thinking contains an element of unpredictability, and may be temporarily thrown off the track by a sudden impulse or association. These influences from the undirected thinking must, however, not be so pervasive, that directed and conscious thinking is made impossible in effect. If this happens, the individual will generally be maladaptive in his way of thinking, and at times even crossing the border of pathology.

One might believe that this influence from the undirected thinking would be the reason why decision-making could never be rational in a normative sense of the word. This is, however, not likely to be the case. Instead, the main obstacle to rational decision-making is assumed to be that the information-processing capacity of the cognitive system is too small, even for slightly complicated decisions; i.e. even if the directed thinking could exist undisturbed, there would be another, more narrow limit that would preclude rationality.

In conclusion, decision-making may be defined as a kind of conscious, sequential,and directed thinking. It is also rational in a cognitive sense, i.e. that the DM is able to ex-

plain the basis of it and is aware of the step-by-step process followed in making it.

Functions in the decision process.

In the preceding section decision-making was described as a step-by-step process. This is not something that is peculiar to decision-making; most, if not all, of the information-processing that constitutes thinking, e.g. problem-solving, concept identification, etc. is described in this way. The description of thinking as a series of distinct, interconnected functions has the advantage of highlighting the basic functions and structures that form a necessary part of the process in question. The number and nature of the functions may, of course, vary. In this project a description in four functions has been chosen. The functions are 1) an initial *structuring* which selects a limited number of alternatives for the DM, 2) an *evaluation*, where a subjective value on one or more dimensions is assigned to each alternative, 3) a function of *estimation* or judgement, where each alternative is compared to the others, resulting in either a complete ordering of the alternatives or an unambiguous selection of the alternative with the highest value, and 4) an *action* which carries out the consequences connected to the alternative chosen. The four functions and the relation between them is shown in Figure 1.

Insert Figure 1 about here

The primary connection between the functions is shown by the full line. This corresponds to what one might call the time path of an idealized decision process (DP). It may normally be necessary to assume that the relation may be more complicated, so that the DP involved loops among the functions. This has been shown by the dashed lines. The to-

tal network may be seen as an expression of the fact that it may be quite possible to specify the *functions* that make up a DP without being able to specify a particular *course of action* that will invariably take place.

Function 1: Structuring.

By structuring is meant that part of the DP where the DM tries to identify and select the alternatives acceptable to him. Other names that have been used for this function are *decomposition* (Shepard, 1964) and *choice limitation* (Lethinen, 1974). (From a psychological point of view it is evident that this function cannot be the first stage in the DP. Before this, the DM must have realized in some way that it is necessary for him to make a decision, i.e. he has psychologically accepted that he has to make a decision, and has by that become a DM.)

It is important to include this function in the DP, because the DM will seldom know in advance what alternatives are, in fact, possible for him. From an analytical point of view, there exists some set of alternatives M^u which is in some sense universal, i.e. common to all DMs. Of these alternatives the DM will only know some subset $M^k \subseteq M^u$; the factors influencing the selection of M^k are of course very important, but only rarely included in theories of decision. They will be factors pertaining to the individual as well as factors pertaining to the particular situation where the decision takes place. There will also be some set of alternatives $M^a \subseteq M^u$, that are acceptable to the DM. Again, the factors that determine what is acceptable and what is not are to a large extent unknown. Many preference-models assume that attitudes play an important role, but do not explain why and how. (This task is supposedly left for the psychologists to do.) Together this will make up a set of alternatives that are both known and acceptable to the DM, and which may be termed the set of available alternatives: $M^* = M^k \cap M^a$.

It is assumed that even in the same 'objective' situation, e.g. in buying a car, the set M^* will be particular to each individual DM. Thus, it will be attributes of M^* and not

of M^u, or M^k, or M^a, that will be of importance for the DM. Factors that determine the compositon of M* in real life may be attitudes, values, needs, social norms, personality traits, habits, expectations of role, level af aspiration, etc., etc.; the list is seemingly endless. In laboratory experiments this function is bypassed by presenting to the DM a set of alternatives among which he has to choose. One may be tempted to question the pertinence of such a set for the DM.

This selection of the set M* is in a way a judgement or estimation of the alternatives on the part of the DM. It is, on the other hand, different from a decision and may better be called a filtering or a screening. The essential difference is that it is not necessary for the DM to compare the alternatives to each other, but only to some criterion of subjective acceptability. This process may easily take place as a *sequential process*, thus making only small demands to the cognitive system. As shown by Lethinen (1974) this selection of the available alternatives may even take place by using only one criterion of selection, thus being a rather uncomplicated process.

Function 2: Evaluation.

By evaluation is meant that part of the DP where the DM assigns a value to each of the available alternatives. As a result of the first function, one may assume that at some point of time there exists for the DM a number of alternatives that he can consider *his*, i.e. he has selected them. It is therefore fair to assume that he will be able to evaluate each alternative in some way, and also that he will be able to assign a value to each of them.

The concept of value naturally includes the concept of dimensions and scales, i.e. the value is a value on some dimension or other. Much effort has been invested in trying to describe a particular dimension, that of *utility*. The present suggestion is that this may be a fundamentally wrong approach. From the psychological point of view, each alternative can be described by the DM on several dimensions and by a value for

each dimension, e.g. a car may be fast, a girl may be beautiful and bright, a painting may be abstract, small and very expensive, etc., and usually it is also possible to describe alternatives in relation to each other. There will typically be more than one dimension, and although some of them may be common to two or more alternatives, it should not be assumed that they may be condensed into one single dimension. Thus the alternatives may normally be evaluated in an adequate way only by means of multidimensional attributes, and it may be considered very doubtful whether the dimension called utility exists as a psychological reality for the DM. How many of us have, in fact, ever used it in our own decisions?

Fortunately it is not important for the descriptive analysis employed here to assume the existence of a single dimension applicable for all the alternatives. It is sufficient to assume that a value (which may be multidimensional) can be assigned to each alternative by the DM. It is of considerably greater interest to try to analyze the way in which this value is assigned. In some cases the DM may be able to assign the value on the basis of experience only, e.g. when the alternative is well-known to him. In many situations, however, this is not the case, i.e. the consequences of choosing an alternative will be unknown or known with only a certain degree of certainty or probability. In cases like this, the DM will often resort to trying to imagine what the consequences, and thereby the value, of choosing a specific alternative, might be. This kind of strategy is well-known from other areas, e.g. game-theory, or AI, and is known as an *n-step look ahead strategy* (e.g. Hunt, 1975, p. 246). The advantages of the strategy are many, but, alas, mostly on a theoretical level. In practive, there are many obstacles which severely limit the number of steps that may be taken into consideration. One major problem is that the number of possibilities increases at an exponential rate; another is that there must be some effective way of keeping track of what has been tried and what remains. This may be suggested as an area where man-machine interaction may come to play a significant role!

In spite of these limitations, which may lead to a somewhat 'fuzzy' result, the strategy may be considered commonly used. One way of doing this, suggested by Shepard (1964, p. 277), is to 'try out' various frames of mind until the DM finds one which gives the least dissatisfaction. This is in effect a sort of backwards application of Festinger's (1957) principle of cognitive dissonance. The method is by nature rather vague, but may be used in cases where more deductive methods are unavailable.

Again, as was the case with the structuring, this evaluation and assignment of values is different from a proper decision in that 1) it does not result in one alternative being the best and 2) it can be carried out as a sequential process, without involving the comparison of one alternative to another. It may thus be seen as a natural continuation of the function of structuring, and may in fact be somewhat indistinguishable from it. Even so, for the purpose of analysis, it is considered important to isolate it as a function in its own right.

Function 3: Estimation.

This function is in the present approach considered to be the most important. By estimation is meant the mutual comparison of the alternatives by means of the values assigned to them resulting in a clear preference of one alternative over the others. It is thus by definition assumed, that the alternative actually chosen was the one with the highest value.

The fact that the comparison must be mutual implies, that at some time, some or all of the alternatives must be dealt with simultaneously. This, however, comes into conflict with the limited capacity of the cognitive information-processing system. This limit has come to be known as the magical number 7±2 (Miller, 1956), although the exact nature of this limitation is rather much more complex, as will be evident from a following section. It is not possible to avoid this need for simultaneity by using a serial comparison, because

this would demand something in the nature of an algorithm which could guarantee that the comparisons were effective (i.e. avoiding repeated comparisons) as well as exhaustive. Not even with the help of an external memory device, e.g. paper and pencil, would this be a feasible course of action. And even if it could be employed, it would not completely make a simultaneous comparison superfluous. This is shown by the following example: Assume that the DM has to choose between a set of alternatives $M^*=(m_1, m_2, m_3,\ldots,m_n)$ and that there have to these alternatives been assigned values on three dimensions *A*, *B*, and *C*, denoted by $A(m_i)=\alpha_i$, $B(m_i)=\beta_i$, and $C(m_i)=\gamma_i$. Thus, the value *V* of alternative m_i may be expressed as $V_i=(\alpha_i, \beta_i, \gamma_i)$, and the value of alternative m_j will be $V_j=(\alpha_j, \beta_j, \gamma_j)$.

In keeping with the assumption stated earlier, that the three dimensions cannot be condensed into a single one, it is a necessary condition for the comparison to be possible, that the DM is at the same time conscious of these six values, and is able to compare them to each other. This condition is aggravated by the fact that the values of the alternatives will not be easy to remember, because they are not easily recallable, like e.g. the letters of the alphabet are. On the contrary, they are values that must be kept in the part of the memory called STM (Short-term memory) which has a very limited capacity. It is well-known, that there is no simpel way of voluntarily transmitting the contents of STM into the permanent LTM. You cannot remember something just because you want to. The DM therefore will have to keep them all 'in the head' at the same time, so to speak, to be able to make the comparison. If this is not possible, and one may assume that this is often the case, the DM will be unable to perform the comparison as intended, and will thus be unable to reach the proper decision. This means, that the decision will not be optimal, not even by the standards of the DM.

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> (Shepard, 1964, p. 257)

The analysis of the limits of the cognitive system that has to carry ot the function of evaluation will therefore be the focus of this project. It is, however, also of great importance to consider what courses of action (strategies) the DM may resort to, to get out of the conflict. The general aim of these strategies will be to simplify the situation in some way, hopefully without loosing important information. It is, however, very little that is known in connection with this, although a similar phenomenon, called *information overload* may be of some relevance here (Miller, 1960). It will be of great importance for any descriptive theory of decision to be able to account for the behavior of the DM in this situation, as this may be the cause of the 'irrationality' of the decision.

Fucntion 4: Action.

The concept of action is often left out of theories of decision, presumable because it takes place *after* the decision has been made. It is, however, very important to include the action in the DP, because a decision must, almost by definition result in an action on the part of the DM.

Of direct importance is the fact that the action will lead to a *post hoc* evaluation of the alternative chosen, and thus be of relevance for future decisions. If the DM realizes that he has made the wrong decision, he may either do it all over again, using the new information, or try to explain it away by 'sweet lemon thinking', as assumed by the theories of cognitive dissonance (e.g. Abelson, 1968). This may be of considerable importance in the long run, as it may lead

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to a change in the personality of the DM. Cognitive dissonance has been a field of intense psychological interest, and much research has taken place, yet only rarely connected to decision theory. In this project it assumes a minor role only, although the importance of it is not denied. It is generally considered more a subject for social psychology than for cognitive psychology.

Memory requirements in decision-making.

As has been obvious from the preceding sections, a point of major importance to the cognitive analysis is to what extent the DP is dependent on memory. It is here necessary to refer to a distinction between two types of memory. The first type is STM (Short-term memory) which is a transient memory of very limited capacity; information in STM is kept alive by an active rehearsal and would else decay in about ½ minute. The capacity of STM is usually taken to be 7-10 units (often called 'chunks'). The other type is LTM (Long-term memory) which is of virtually unlimited capacity and of a much more permanent character. Material may usually be transferred from LTD to STM at will, provided that is is stored appropriately, which is in phenomenological terms equivalent to saying that it is known to us. Material cannot be transferred from STM to LTM in a similar easy way, and the rate of transfer is usually rather slow. (You may compare the time it takes to memorize a poem with the time it takes to recite it.) In addition to STM and LTM one may also distinguish a specific receptor VSTM (Very-Short-term memory) and an EM (External memory) as e.g. paper and pencil (Anderson, 1975). These last two kinds of memory are not considered in the present analysis.

In decision-making, one may assume that the set of available alternatives M* is accessible to the DM from the LTM, i.e. he does not have to keep it in mind all the time, but may recall it at will. The values of the alternatives are, however, less readily accessible. As they are depending upon individual as well as on situational factors, one cannot assume that the values are pre-existing, but they arise from

the situation. It is thus possible for the DM to *construct* the values at any time; this construction will typically take some time and puts a load on the cognitive information-processing system.

The last part of the data entering the DP, the relative value of the alternatives among each other, is someting that is wholly generated in the situation on basis of the values of the alternatives. Thus this mutual ordering cannot in any way be assumed to be accessible from a permanent memory, but must be created and remembered during the DP. Due to the fact that transmission from STM to LTM does not take place at will, the alternatives will have to be remembered in the STM-system. As this system is also the one that carries out the comparisons, it is easy to understand, that the bottle-neck of the whole decision-making system will be here. Consequently, a more detailed understanding of the functions of the STM-system is of vital importance for a cognitive analysis of the DP.

Models of human information-processing.

In a previous section, the DP was defined as a conscious, sequential, directed line of thought, and rational in the sense that the DM was able to explain the basis of his judgement, to himself and to others. A consequence of this definition is that the DP is assumed to be performed by an information-processing system of limited capacity. It is the more precise specification of the structure and functioning of this system that is hoped to be accomplished by this project.

The concept of an information-processing system of a limited capacity is quite general in present-day cognitive psychology. Examples are most notably found in the field of attention (e.g. Broadbent, 1958; Moray, 1969; Norman, 1969), as well as in thinking in general (e.g. Thomas, 1962; Shallice, 1972; Pollio, 1974; Anderson, 1975). The limited capacity has been attributed to either a *limited channel capacity* or a *limited processing capacity*. The last view which seems to be more generally accepted will be the one taken here, mainly because the focus is on information-processing and not on

information transmission. In the following sections a very brief review of some of the more prominent models will be given, concluded by a more detailed exposition of the model used in the present project. (A basic introduction to this area may be found in e.g. Lindsay & Norman, 1972.)

The Sperling model.

One of the first models to appear, was the one formulated by George Sperling based on his results of experiments on the recognition of tachistoscopically presented visual stimuli (Sperling, 1963, 1967). His purpose was to describe the processes that took place from the time an S saw the stimulus, till he was able to report it, e.g. by writing it down. Sperling formulated several models of the information-processing system involved, the last of which is shown in Figure 2.

Insert Figure 2 about here

The important point in this model for the present purpose is that the visual stimulus ('light pattern') was transformed into a verbal representation (called 'a program of motor-instructions') which was of a more permanent nature than the visual image. This verbal representation could be remembered temporarily by means of rehearsing it and thus be kept available for the recognition process to work. The actual process was the *scan* which was relatively slow, and thus demanded that the material was remembered in some way. The STM was the function performed by the rehearsal, and the capacity limit of the whole system was determined partly by the STM and partly by the process (the scan) that was to be performed. Sperling also suggested that consciousness was restricted to the scan-component, i.e. only those matters that were being processes, were conscious.

It is obvious that the model is insufficient at some very important points. First of all, it was a model for a specific process, and thus not generally applicable right away. Secondly, it contained no suggestion as to how the LTM was connected to the STM-system. In spite of its primitive level, it contained the basic elements of the superordinate and the subordinate executive systems and has been very influential on the later research.

The Posner model.

One of the later models have been formulated by Michael I. Posner (Posner, 1967, 1974). The structure of the model is shown in Figure 3, adapted from Reitman (1970).

Insert Figure 3 about here

Even though it is much more general in nature and is usefull over a wider range of functions, its structure is simpler than that of the Sperling model. One major advantage is the distinction between external and internal information. The external information enters the system by way of the STM, which has a rehearsal function connected to it that temporarily keeps the information available while it is processed in the STM. The internal information, i.e. information remembered by the S, resides in the LTM and is entered into the conscious information-processing system by means of the operational memory (OM). There is no rehearsal connected with the OM, because material that might be forgotten can be recovered from the LTM. The internal information may be exemplified by a problem-solving situation where the S tries to recall knowledge and recombine it to find a new solution, or by a decision situation where the DM tries to use his knowledge of the alternatives in the evaluation of them. Although Posner thus made a distinction between the STM and

the OM in terms of the kind of information they handled, he nevertheless underlined that the operational characteristics (e.g. information capacity, information-processing rate, rate of forgetting) of the two systems were essentially identical.

The Posner model was thus not designed with one specific application in mind, but was intended to be a rather general description of human information-processing. The limitations of the processing capacity are primarily a limitation of the number of objects (or chunks) that the STM/OM can hold at any one time.

One major objection to this model is, that the need for two separate systems (STM and OM) seems to be based on a distinction between external and internal information only. This distinction is not one that is experienced by the S, and considering that the performance characteristics of the two systems are assumed to be identical, the distinction may safely be dropped. Another objection which is shared by many cognitive information-processing models is that they are in fact very little concerned with information-processing and rather more concerned with the short-term memory function. Even though the interest for the processing aspect has been increasing (e.g. Sternberg, 1970; Posner, 1974), the memory function has still been considered the primary one. This may seem to be a bit of a paradox, because memory might really be considered a 'side-effect' of processing of information. If e.g. you add two numbers in your head, you remember them as a result of having added them and not as a result of a separate process. It is thus a general weakness of the cognitive information-processing models, that they are very unspecific as to how information-processing takes place and *where* it may take place. It is also of general importance to elucidate the role of consciousness in cognitive information-processing.

The CPS model.

The model used as a basis for the present object, has been formulated to take all these aspects into consideration. The model is shown in Figure 4, and is based on some previous experiments (Hollnagel, 1974).

Insert Figure 4 about here

Its main component is a superordinate process-component called the CPS (Central or Conscious Processing System). This process-component is divided into two parts, a set of registers and a processor. Each register can hold one psychological unit of information, e.g. a chunk. The processor can carry out the necessary basic processes. These may be rehearsal, comparison, transfer, adding, etc. The basic processes may be specified much as the basic repertoire of a computer. It may, however, be more advantageous at the present time to look upon them at a psychological level, e.g. as *plans* (Miller, Galanter & Pribram, 1960), or sequences of operations. They can then be specified more *ad hoc*, assuming that some finite set of basic operations can be specified at a later time. It is assumed in the model that the capacity limit is connected to the CPS, and also that consciousness is sited there, i.e. for something to become conscious, it has to be transferred to the CPS.

The access to the CPS is by way of a subordinate controller. This controller is again connected to the 'external' world by means of the different kinds of modal memories and receptors. It is also connected to the 'internal' world by the LTM. By giving the controller a status of its own, one takes account of the fact that information may enter the system without becoming conscious (e.g. when we suddenly remember having seen something before) and may also leave the system in the same way (as e.g. in well-learned, automated behavior). That it is not conscious is, of course, not the same as saying that it is not controlled. It should, however, be kept in mind that the model can be used only for cognitive information-processing that is based on verbally coded material. This is of course a limitation to the generality, but on the other hand a large part of our conscious thinking is in fact of a verbal nature.

The purpose of the experiments carried out under this project is to supply experimental data that can be used in assessing the correctness of the model and in specifying the details of it. The experiments are basically a series of rank-ordering tasks where the S has to produce a rank-ordering of a number of names on the basis of some information consisting of binary relations among the names. The independent variables are the number of names, the number and type of relations, and the degree of control of the S over the selection and presentation of information. Also varied in the experiment is the extent of the rank-ordering, i.e. whether it must contain all the names or only the first one. The experimental data have not been fully analyzed yet, but will be reported at a later date. The initial analysis of the data seem to suggest that the limit of the CPS is around seven items, i.e. a decision can comprise at most seven single-attribute alternatives.

In conclusion one may say that theories of decision-making in general would seem to be benefited bu including, to a much larger extent, elements of cognitive as well as social psychology. Decision-making is a *human* performance, and a thorough understanding of the psychological characteristics of man must be a necessary condition for the formulation of adequate theories of decision-making.

REFERENCES

Abelson, R. P. et al. (Eds.) (1968) *Theories of Cognitive Consistency: A sourcebook*. Chicago: Rand McNally and Company.

Anderson, B. F. (1975) *Cognitive Psychology*. New York: Academic Press.

Blank, A. D. (1968) Effect of group and individual conditions on choice behavior. *J. Person. Soc. Psychol. 8*, 294-298.

Broadbent, D. E. (1958) *Perception and Communication*. London: Pergamon Press.

Brown, R. & McNeill, D. (1966) The "tip of the tongue" phenomenon. *J. Verb. Learn. Verb. Behav. 5*, 325-337.

Bruner, J. S. (1960) *The Process of Education*. Cambridge, Massachusetts: Harvard University Press.

Festinger, L. (1957) *A Theory of Cognitive Dissonance*. Stanford, California: Stanford University Press.

Hollnagel, E. (1974) Human information processing capacity in counting several things simultaneously. *Scand. J. Psychol. 15*, 43-49.

Hunt, E. B. (1975) *Artificial Intelligence*. New York: Academic Press, Inc.

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

Lindsay, P. M. & Norman, D. A. (1972) *Human Information Processing*. New York: Academic Press.

Miller, G. A. (1956) The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychol. Rev. 63*, 81-97.

Miller, G. A., Galanter, E. & Pribram, K. H. (1960) *Plans and the Structure of Behavior*. New York: Holt, Rinehart and Winston, Inc.

Miller, J. G. (1960) Information input overload and psychopathology. *American J. Psychiatry 116*, 695-704.

Moray, N. (1969) *Listening and Attention*. Harmondsworth: Penguin Books Ltd.

Neisser, U. (1963) The multiplicity of thought. *Brit. J. Psychol. (54(1)*, 1-14.

Norman, D. A. (1969) *Memory and Attention*. New York: John Wiley & Sons, Inc.

Pollio, H. R. (1974) *The Psychology of Symbolic Activity*. Reading, Massachusetts: Addison-Wesley Publishing Company.

Posner, M. I. (1967) Short term memory systems in human information processing. In A. F. Sanders (Ed.) *Attention and Performance I*, 267-284. Amsterdam: North-Holland Publishing Company.

Posner, M. I. (1974) *Cognition: An Introduction*. Glenview, Illinois: Scott, Foresman and Company.

Reitman, J. S. (1970) Computer simulation of an information-processing model of short-term memory. In D. A. Norman (Ed.) *Models of Human Memory*, 117-148. New York: Academic Press.

Shallice, T. (1972) Dual functions of consciousness. *Psychol. Rev. 79(5)*, 383-393.

Shepard, R. N. (1964) On subjective optimum selection among multiattribute alternatives. In M. W. Shelley & G. L. Bryan (Eds.) *Human Judgement and Optimality*, 257-281. New York: John Wiley & Sons, Inc.

Sperling, G. (1963) A model for visual memory tasks. *Hum. Factors 5*, 19-31.

Sperling, G. (1967) Successive approximations to a model for short term memory. In A. F. Sanders (Ed.) *Attention and Performance I*, 285-292. Amsterdam: North-Holland Publishing Company.

Sternberg, S. (1970) Memory-scanning: Mental processes revealed by reaction-time experiments. In J. S. Antrobus (Ed.) *Cognition and Affect*, 13-58. Boston: Little, Brown and Company.

Thomas, H. B. G. (1962) The "supervisor" - A hyphotetical mental function impaired by brain damage. *J. mental Sci. 108*, 329-346.

Yntema, D. B., & Torgerson, W. S. (1967) Man-computer cooperation in decision requiring common sense. In W. Edwards & A. Tversky (Eds.) *Decision Making*, 300-312. Harmondsworth: Penguin Books Ltd.

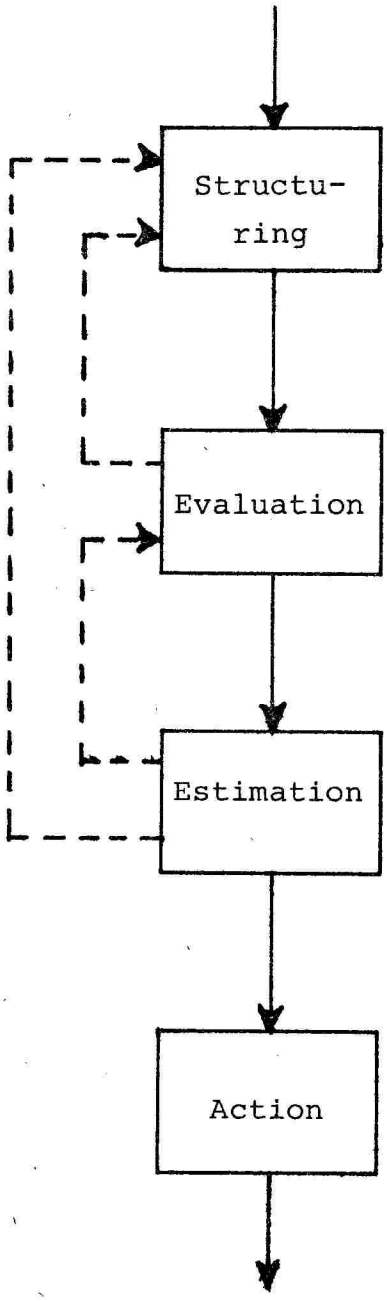
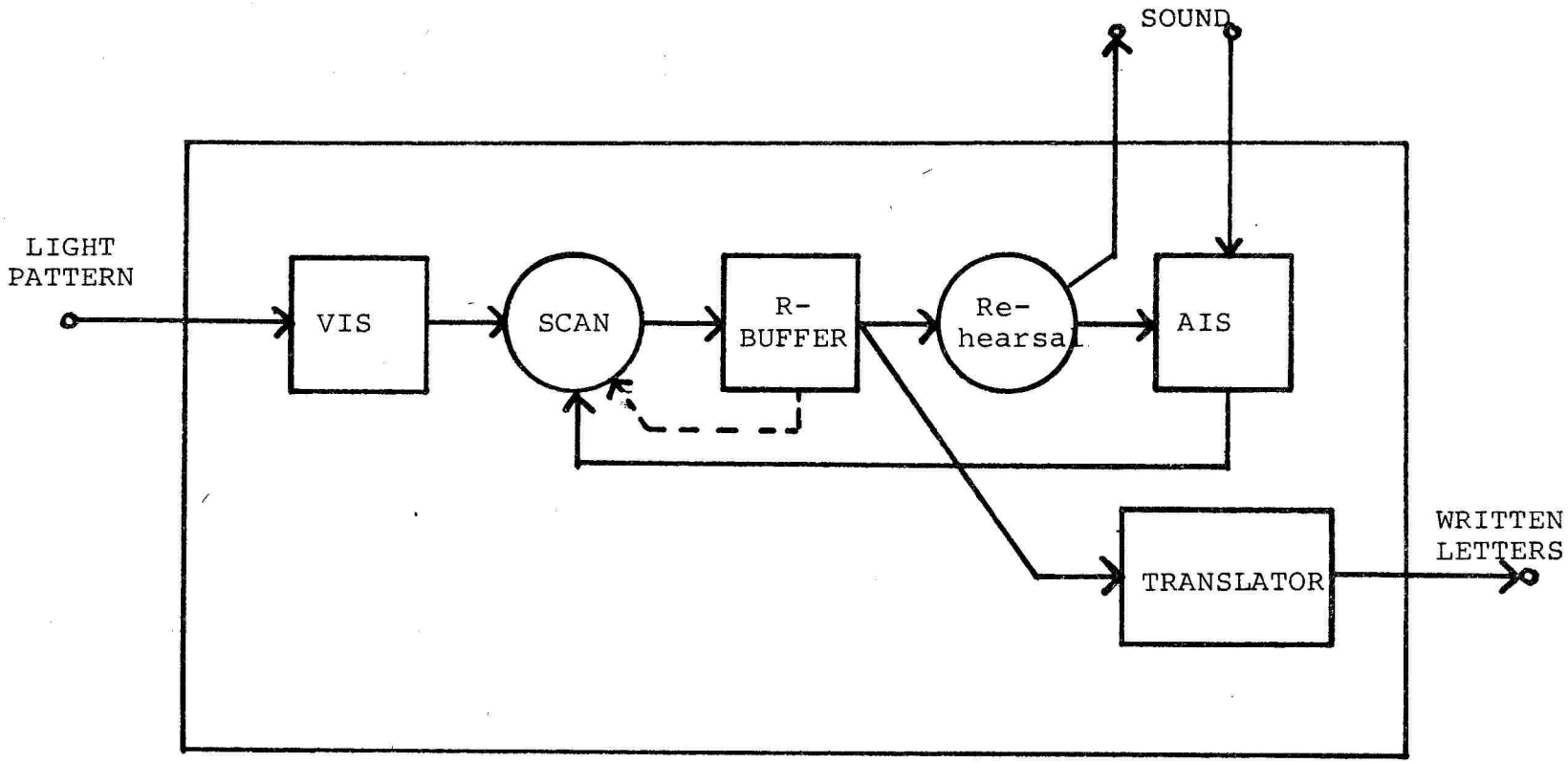
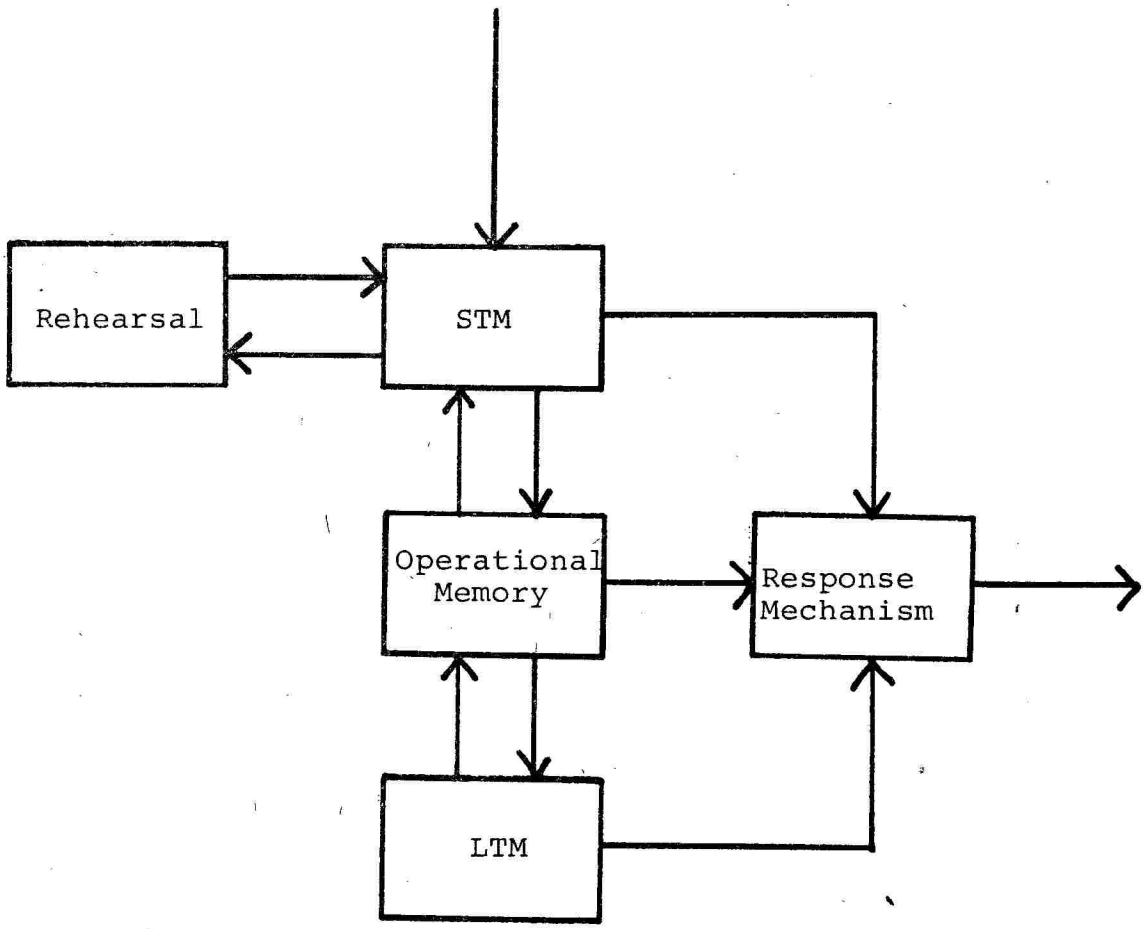


Figure 1.


SOUND
LIGHT
PATTERN
VIS
SCAN
R-
BUFFER
Re-
hearsal
AIS
TRANSLATOR
WRITTEN
LETTERS

Figur 2



Figur 3

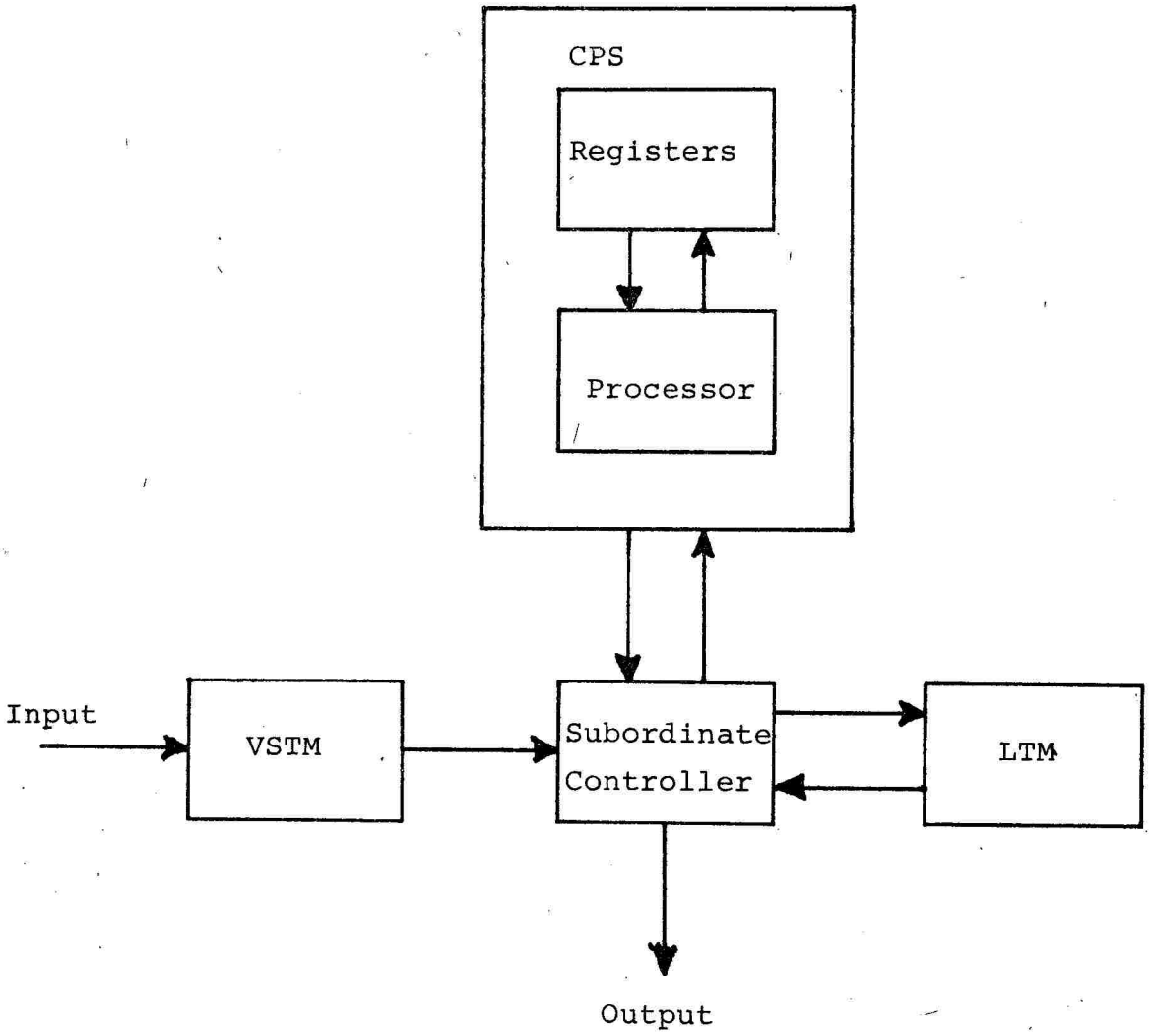

CPS
Registers
Processor
Input
VSTM
Subordinate
Controller
LTM
Output

Figure 4.