A THEORY OF EMOTIONAL BEHAVIOR

Herbert A. Simon

Much progress has been made in building and testing an information processing theory of human thinking and problem solving [4]. The program called the General Problem Solver (GPS) has been successful in explaining a range of simple human problem-solving behaviors in terms of the processes of means-end analysis. Other programs, including several theories of concept formation, and the Elementary Perceiver and Memorizer (EPAM), have extended the information processing explanation to other aspects of cognition.

There has been less progress toward providing information processing explanations of affective behavior, or of the interaction of cognition with affect. Motivation is represented in only rudimentary ways in existing information processing theories. Yet it cannot be gainsaid that in actual human behavior the influences of affect upon cognition (as well as the influences in the opposite direction) are often of fundamental importance in determining the course of behavior. A more general theory of thinking and problem solving must incorporate such influences. It cannot be entirely independent of a motivation and emotion.

Ulric Neisser [3, pp. 193-4], whose views on computer simulation of thinking are sophisticated and informed, asserts that although computers can be programmed to behave in impressively intelligent ways; machines can

* Discussions with my colleague, Walter R. Reitman, about the relations of serial and parallel processing provided much of the motivation for the approach of this paper. I alone accept responsibility for the particular form of the theory of emotional behavior proposed here. Professor Reitman has described part of his own theory in [7]. An earlier version of this paper provided the basis for one of my William James Lectures at Harvard University, March 1963.
create yet "the view that machines will think as man does reveals mis-
understanding of human thought." He concludes [3, p. 195] that:

Three fundamental and interrelated characteristics of human thought . . . are conspicuously absent from exist-
ing or contemplated computer programs:

1) human thinking always takes place in, and contributes to, a cumulative process of growth and development;

2) human thinking begins in an intimate association with emotions and feelings which is never entirely lost;

3) almost all human activity, including thinking, serves not one but a multiplicity of motives at the same time.

We need not debate at length whether Professor Neisser is entirely correct in his assessment of the present— or future— state of the art of computer simulation. The first of his three "absent" characteristics can be found in existing programs— learning programs in general; EPIAN [4, pp. 408-9], with its recursive, hierarchic structure; and the Logic Theorist, the earliest theorem prover, with its provision for storage and subsequent use of proved theorems, in particular. However, even if we were to argue that the differences along the three dimensions he mentions, between the programs of human beings and the programs of computers, are quantita-
tive rather than qualitative differences, they are nonetheless conspicuous enough. Developmental processes play a small role in existing simulation programs, emotions play almost no role, and most such programs are apparent-
ly driven by a single top-level goal, or motive. Progress in theory con-
struction will require us to remove these differences.
In seeking to account for motive and emotion, we must avoid giving up what we have already learned about the organization of human cognitive processes. One of the important postulates built into the existing information processing theories of thinking is that the central nervous system is basically organized to operate in serial fashion.

It is not easy to state rigorously what is meant by a "serial" as contrasted with a "parallel" processor. A serial processor, of course, is one in which many things go on at a time. But this distinction is meaningless until we specify how we are to count "things"--how we are to recognize a unitary process or object. Most existing digital computers, for example, are said to be serial processors. Yet when they add ten digit numbers, all ten pairs of digits are added simultaneously--or "almost" simultaneously. Thus they really are parallel in the small--i.e., in handling the contents of single words--but serial in the large--i.e., in performing complex operations on groups of words. If it is not strictly accurate to say they do only one thing at a time, it is accurate, if vague, to say that they do only a little at a time.

The ambiguity of the distinction between serial and parallel extends not only to the definition of the symbolic units, but to the definition of the time units as well. Any serial system, given enough time, can do many things. Hence, a serial system can be used to simulate a parallel system. If we only look at its behavior periodically, we cannot tell whether the processes that have been executed during a single period have been carried out in serial or parallel fashion.
When we say that the human central nervous system is organized as a serial processor, we must have in mind some notion of an "elementary" symbol and an "indivisible" time unit. Since the simplest reflex actions take time of the order of 100 milliseconds, we may think of a tenth of a second as the relevant time interval. Since in some memory experiments, the "chunk"--i.e., a single familiar symbol, like a familiar nonsense syllable, a digit, or a familiar short word--appears to be the significant processing unit, we may consider it the elementary symbol.

Then the postulate that the human central nervous system is serial can be rendered roughly as follows: The processes that operate during a tenth of a second affect only a few chunks (at most about seven, according to G. A. Miller) among all those in temporary and permanent memory. More macroscopic processes are synthesized from sequences of elementary processes, organized to operate over longer time intervals. For anything "interesting" to happen in the C.N.S. may require quite long times--for example, about 30 seconds to memorize a nonsense syllable of low association value. During a relatively short interval of time during which one such process is going on, not much else can or does go on.

The plausibility of this postulate rests on several kinds of evidence. First, there is a large mass of behavioral evidence, both from everyday observation and from laboratory experiments, for a phenomenon called "attention", and evidence that the span of attention--the number of things that can be attended to simultaneously--is only a few chunks. To be sure, not everything that happens in the C.N.S. goes on at the level of consciousness. Nevertheless, certain cognitive processes, at least, require attention; and the number that can be within the scope of attention at one time is very
limited. I think I would go so far as to say that I am not familiar with
a single piece of behavioral evidence that is inconsistent with an hypothe­
sis of essentially serial processing, taking a tenth of a second as the
unit time, except for evidence about motivation and emotion that I shall
consider in this paper.

A second kind of argument for serial processing is of a more a priori
character. There have been a number of serious endeavors to design digital
computers that would be parallel in important aspects of their processing.
These endeavors have encountered great difficulties of a fundamental, con­
ceptual sort.

The basic difficulty is this. Suppose a computer, C, has two com­
ponents, C₁ and C₂, operating in parallel. If the operations of the compon­
ents are entirely independent, there is, of course, no difficulty--they are
simply separate organisms. Suppose, however, that they interact. From
time to time the behavior of C₁ depends on the current state of C₂, and
vice versa. In a simple case, we might have two memories, M₁ and M₂, for
communication between the two components. At certain times, C₁ would store
outputs in M₁, and C₂ in M₂; likewise, from time to time, C₁ would take in­
puts from M₂, and C₂ from M₁.

Under these conditions, in order to obtain coherent behavior from
the computer, there would have to be a certain measure of temporal coordin­
ation between its components. If C₁ takes inputs from M₂, which have been
placed there by C₂, then C₁ must, in some sense "know" how recently the
contents of M₂ have been updated. The higher the frequency of resort to
the memories--of interaction--the more precise the requirement of temporal
coordination. One could, of course, conceive of all sorts of special tasks.
in which the coordination could be quite rough; but if the two components were, e.g., cooperating in planning an intricate structure, the coordination might have to be very precise.

Without going into this issue in detail, we can say in general terms that if the components of a parallel system are to operate with a high degree of interdependence, there must be a correspondingly adequate system of coordination or synchronization among them. And then the coordinating or synchronizing system will itself be a serially organized system. In the case of an organism like a human being, the requirements for coordination are fairly obvious. Most behaviors call upon a considerable part of the whole sensory and motor system for their successful performance. Hence, patting one's head while rubbing one's stomach becomes feasible only under the guidance of a supervisory synchronizing program. Even extreme cases of schizophrenia take the form of alternation, rather than parallelism, of personality. At any given moment somebody must be in charge. 1/

The obvious way to govern the behavior of a serial processor is by means of a program organized as a hierarchy of subroutines, with an interpreter capable of executing the program instructions in the proper order. [4, pp. 380-84]. For example, the program, "Walk the length of a block," could consist of a list of instructions, to be executed in sequence:

Walk the length of a block
1 Step with left foot, then 2.
2 Step with right foot, then 3.
3 If end of block, do 4; if not, do 1.
4 Terminate.

1/ One of Mark Twain's short stories tells of a pair of Siamese twins, Antonio and Luigi, who, for reasons similar to those discussed here, agreed to take turns in command of the joint enterprise. The twin(s) were accused of a murder that occurred at a time when Luigi was in charge. The last line of the story reads: "And so they hanged Luigi."
A similar sequence of instructions could correspond to the program "Cross an intersection." Now by combining these two programs in a larger one, we could construct, "Walk to the 1400 block" thus:

Walk to the 1400 block
1 Walk the length of a block, then 2.
2 Cross an intersection, then 3.
3 If "1400" reached, do 4; if not, do 1.
4 Terminate.

The interpreter in such a system starts to execute the executive program—the program at the highest level in the hierarchy. Each instruction in this program will be, in general, a subprogram to be executed in the same way. Thus the interpreter must proceed downward through the hierarchy of subprograms, or subroutines, until it reaches an "elementary" process that can be executed immediately. While it is doing this, it must keep its place in the routine it is executing at each level of the hierarchy—must keep in memory the equivalent of a list (pushdown list) of these locations, one for each level of the hierarchy.

Subroutine hierarchies are a familiar and important feature of modern computer programming languages. The interpreter for IPL-V, the programming language that has been most often used for building information processing theories, has precisely this structure [4, pp. 421-2]. No grossly different schemes of organization for interpreters have been proposed that would appear to handle the same range of information processing performances.

Now a program organized in a simple, straightforward way to make use of an interpreter of this kind is likely to reveal, in its behavior, a considerable single-mindedness and unity of purpose. Whatever elementary task it is performing at a given instance was assigned to it by a subroutine which was itself, in turn, called for by a higher level subroutine. Thus, every-
thing that is done, is done in the service of the highest level executive program, through successive levels of delegation. It is very difficult to say in what sense the delegation process admits discretion for the subroutines, but even to the extent it does, the discretion is still exercised in the "interest" of the higher level program.

It is this single-minded, single-purpose character of the behavior of most existing information processing programs that provides the striking contrast with human behavior to which Professor Neisser refers. Under many circumstances, human behavior can be interrupted by imperative demands entirely unrelated to the goal hierarchy in current control—by hunger, fear, the noticing of sudden motion, or what not. Moreover, even when not actually interrupted, human behavior appears to be responsive not just to one, but to a multiplicity of goals. A speaker not only attends to the content of what he is saying, but responds in many gross and subtle ways to the feedback he gets from the facial expressions and postures of his listeners. While he is seeking to inform, he may also be seeking to please, to impress, or to earn love.

Thus the evidence, cited earlier, that man is a serial processor must be reconciled with the evidence that he is a parallel processor—that the process of attaining particular goals may be interrupted by the imperious claims of other goals, and that each goal is sought with at least peripheral attention to independent goals that are simultaneously affected (or effected). Moreover, those aspects of behavior that are most tinged with parallelism appear to be the aspects in which emotion and affect play their largest roles. We must account for the elements of parallel processing in our serial processor, and we must account for the association between affect and multiplicity of goals.
In succeeding section I shall undertake to describe a processor that fits this description, and I shall base upon this description a theory of emotional behavior.

THE GOAL HIERARCHY

We begin with a serial processing system, having a hierarchically organized program, and proceed to introduce specifications and modifications to account for parallelism, or apparent parallelism, in its operation. Even in a purely serial system, there must be some way in which a particular program or subroutine can be terminated and control returned, at the next higher program level, to the program that called for its execution. For simplicity, let us think of the hierarchy of subroutines as being essentially a hierarchy of goals. Routine A, say, is aimed at achieving goal a. To achieve goal a, we must achieve, in sequence, subgoals b, c, d. But these, we suppose, correspond, respectively, to the subroutines, B, C, D, of which A is comprised.

When work on a subgoal is complete, then, the interpreter "pops up" to the next level of the program. What are the criteria of completeness of a subgoal that might initiate this termination? There are a number of possible alternatives:

1. A subroutine may terminate when its subgoal has been achieved. In many cases, achievement is an all-or-none matter. The subgoal may be, for example, to discover a proof for a certain theorem; or to discover a move in a chess game that leads to checkmate; or to transform one expression into another.
2. A subroutine may terminate when its subgoal has been achieved "well enough." A subroutine may search for a course of action that will yield at least \( k \) dollars profit; or for a chess move that will win at least a pawn. The criterion that defines "well enough" turns achievement that may be a question of degree into an all-or-none matter.

3. A subroutine may terminate when a certain amount of time has been used up in trying to achieve it. This termination rule may be combined with a procedure that keeps, at all times, the achievement which is "best so far."

4. A subroutine may terminate after a certain set of processes for attaining the subgoal have been tried and have failed.

Thus, aspiration levels, satisficing criteria, impatience, and discouragement constitute mechanisms for terminating subroutines. These mechanisms can be combined in a variety of ways. One arrangement that is probably of some significance for human behavior uses a combination of a satisficing criterion with a time limitation. The initial aspiration for subgoal attainment is set at a relatively high level, and is progressively reduced as the search for a solution continues. The solution that is best so far is retained. When the aspiration has been lowered to the point where the "best so far" equals it, search is terminated. Search may also be terminated earlier through interruption or by exhaustion of a fixed time period. The mechanism allows a rough equating of marginal returns of search with time costs (without the need for elaborate computations), and adjusts aspirations over time to the generosity of the environment. 2/

2/ Schemes of this general kind are described in [5], Chapters 1 and 15.
MULTIPLE GOALS

The fact that a processor is organized in the serial, hierarchic fashion we have described does not imply, however, that it is capable of responding to only a single goal, or even that it cannot respond to several goals simultaneously. There are at least two ways in which multiple goals can be introduced into such a system without altering its serial character. The first is by queuing—attending to several goals in sequence. The second involves generalizing the notion of goal to encompass complex multi-faceted criteria against which possible problem solutions are tested. We shall consider these in order.

Queuing of Goals

At a minimum, a living organism like a human being has to take care, periodically of its biological needs. We may take food and water as typical of such needs, and hunger and thirst as the corresponding drives. A goal (seeking food or water) is then evoked by a drive. If the organism is quiescent at the time a new goal is evoked, a program appropriate to a goal of this kind is put into execution. If the organism is occupied with achieving a goal when another goal is evoked, the new goal is put on a "waiting list" and activated when the program associated with the earlier goal has been terminated. 3/

This scheme will accommodate any number of needs provided the total processing time required to execute the programs that are evoked is, on the average, a small fraction of the total processing time available to the organism. It is necessary, also, that the drives be so designed that the goals are evoked

3/ For further discussion, see [5], Chapter 15
a sufficient time before their achievement becomes essential for survival. That is, the hunger mechanism must be adapted to the organism's storage capacity for food and the expected length of search to find food once the goal has been evoked.

Many industrial scheduling systems for multi-product factories operate on a queuing system of this general kind. This does not prove that human beings operate in the same way, but it shows the feasibility of systems of this sort for handling multiple goals.

If goals are evoked more or less periodically (e.g., the need for sleep), then the queuing system can be supplemented or replaced by a time allocation system. There is a fixed cycle of processing, and each phase of the cycle is assigned to the program associated with a particular goal. Again, a system of this kind will work successfully only if the total processing time required for each of the goals is less than the time available in its phase of the cycle.

Observation of everyday behavior makes it pretty clear that the techniques we have just described—queuing and allocation—are widely employed by human beings to reconcile the competing claims upon their processing capacities of the multiple needs they must satisfy. This applies, of course, not only to the kinds of biological needs used for purposes of illustration but the whole range of goals that characterize adult human existence.

Multi-faceted Criteria

Our analysis up to this point has been oversimplified in a crucial respect. We have used the phrase "goal achievement" as though a goal were a unitary thing. In actual fact, it need not be and seldom is. Consider the
goal of satisfying hunger. Except in extreme circumstances, the only behaviors a human being regards as suitable for accomplishing this goal are behaviors that lead to ingesting foods of culturally acceptable kinds in a cultural acceptable manner. Gentlemen dress for dinner, and eat with knife and fork roast beef that has been obtained in a legal way—e.g., by purchase—and subjected to heating at high temperatures.

Achievement of a goal, then, characteristically calls for behavior that meets a whole set of criteria. In fact, there is no real need to treat these criteria asymmetrically—to single one of them out and call it "the goal." We could as well say that the gentleman's goal is to dine in his dinner jacket as to say that his goal is to satisfy his hunger. The hierarchy of programs that is associated with the goal will be responsive to the whole set of criteria.

There is no reason, therefore, why a hierarchically organized serial system need single-mindedly pursue a simple goal. The chess programs constructed by Newell, Shaw and Simon [4, p. 402], though a serial program, takes into account protection of pieces, development of pieces, and control of the center in selecting a move. It limits itself, of course, to consideration only of legal moves, and there is no reason why it could not take into account additional criteria—even esthetic ones.

4/ This is not to say that the set of criteria that specify goal achievement may not change from one situation to another, or that there is not some sense in which "satisfying hunger" is a more fundamental goal than "dining in one's dinner jacket." We are considering here only short-run considerations: the set of criteria that are applied by the goal achievement program to determine when processing should terminate.
If the programs that are commonly used with digital computers give an impression of single-mindedness, this is only because they have been written in terms of relatively simple criteria of goal achievement, and with far fewer side conditions than is characteristic of human goal-oriented activity. The difference is one of degree, not of kind, and has nothing to do, fundamentally, with the serial organization of the system executing the program.

The mathematical procedure known as linear programming provides an instructive formal model for multi-faceted goal systems. A linear programming system includes one or more criterion variables, one or more decision variables, and a number of constraints, in the form of linear inequalities that must be satisfied by the variables. The problem is to find the set of values of the decision variables that maximizes a specified function of the criterion variables subject to the constraints.

Any set of values of the decision variables that satisfies all the constraints is called a feasible set. Now suppose that we add to the constraints the requirement that the criterion function must not fall below a specified level--this is simply a new constraint, symmetrical with the others. If this constraint is stringent enough, the feasible set will be small, and we might be willing to call any decision satisfactory that falls within it. But now we are treating the criterion symmetrically with the other constraints. In fact, we can select any constraint and, reversing the process, convert it into a criterion function to be maximized, subject to the remaining constraints. By repeating this process for each constraint in turn, we select out of the set of feasible decisions the several members of that set which are optimal from the standpoint of the several constraints, respectively.
For example, let the decision variables be quantities of various kinds of food, the criterion variable the total cost of food, and the constraints the minimum number (and possibly maximum number) of calories, vitamins, and other nutritional requirements for a healthful diet. Then a linear programming problem would be to find the least-cost diet satisfying all the nutritional requirements. Alternatively, we could find the maximum-calory (or minimum-calory) diet that satisfied all the remaining requirements and did not cost more than a specified amount.

Since powerful algorithms exist for solving quite large linear programming problems with serial programs, the linear programming model shows, with great clarity, that simple goals and single-mindedness are not essential characteristics of serial systems.

INTERRUPT SYSTEMS

We have now described a variety of ways in which a serial processor can respond to multiple needs and goals. In doing so, we have not had to introduce any special mechanisms to represent affect or emotion. We can use the term motivation, in systems like those described, simply to designate that which controls attention at any given time. The motivation may be directed toward a single goal, or, more commonly, toward multiple goals.

But this is not the whole story. The mechanisms we have considered are not adequate to handle all the problems that multiple goals pose for an organism like a human being. In particular, they are inadequate to deal with the fact that, if the organism is to survive, certain goals must be achieved by certain specified times. The environment places important, and sometimes severe, real-time demands upon the system.
In a queuing system, for example, if a new goal is evoked, it is placed on a waiting list until current goal programs have been terminated. No process is provided that allows one goal to take priority over another, or to adjudicate the claims of two conflicting goals. In a mild, benign environment, a leisurely response of this kind is adequate. In the real world, it sometimes is not.

If real time needs are to be met, then some modification must be made in the strict hierarchical organization of programs and in the serial character of the system. Provision must be made for an interrupt system. Such a system sets two requirements:

1. A certain amount of processing must go on continuously, or almost continuously, to enable the system to notice when conditions have arisen that require a new goal to be achieved in real time, and hence require ongoing programs to be interrupted. The noticing processes will be substantially in parallel with the ongoing goal-attaining programs of the total system, although this parallelism may be realized, in fact, by high frequency time sharing of a single serial processor.

2. The noticing program must have the capability of interrupting and setting aside ongoing programs when real-time needs of high priority are encountered. The programs thus set aside may simply be abandoned, or they may be resumed after the real-time need has been met. In either case, there must be provision for interruption of hierarchic control.

Simple noticing and interruption programs of this general kind are already incorporated in some information-processing theories. EPAM, for example, notices the turning of the memory drum, and is capable of interrupting its learning processes to attend to the new syllable that has appeared on the drum. In this case, the interrupted activities are simply abandoned, and not later resumed.
A somewhat different kind of interrupt system can be described in terms of the hunger-thirst example introduced earlier. For each of these drives, we could have a drive level, an increasing function of the number of hours of deprivation. The gradient of this function would depend on the number of hours of food or water storage, respectively, available to the organism. The need with the smaller storage, in hours, would have the higher gradient. Further, a threshold for each drive would determine at what drive level the goal would become "urgent" and would interrupt the ongoing program. (We would need a double threshold, the lower to place the drive on the waiting list of goals, the higher to interrupt an ongoing program.) The threshold level would be related to the amount of uncertainty in the time required to achieve the goal once it was evoked--high uncertainty would call for early interruption. 

Real-Time Needs

What are the principal kinds of real-time needs that the interruption system will serve in human beings? We can distinguish three classes:

1. Needs arising from uncertain environmental events--"loud" stimuli, auditory, visual, or other, that warn of danger.

2. Physiological needs--internal stimuli, usually warning of the impending exhaustion of a physiological inventory.

3. Cognitive associations--"loud" stimuli evoked not by sensory events but by associations in memory--for example, anxiety arousal.

The capacity of stimuli from these sources to interrupt attention is a commonplace of daily experience. With respect to the first class of stimuli, it is especially clear that they will be more likely noticed to the extent that they are both intense and unexpected.

A system of this kind is described in [5], Chapter 15. More recently, in [8], Sylvan S. Tomkins has described a system with some similar characteristics.
Sudden, intense stimuli have easily observable effects on behavior. They also have well-substantiated effects on the central nervous system. These are described at length, for example, by Donald D. Lindsley, in his chapter on emotion in the Stevens Handbook [6, Chapter 14]. These effects produce substantial disruption of the EEG pattern [6, pp. 496-500]. A plausible, and not novel, interpretation of these C.N.S. effects is that they amount to an interruption of the interpreter that manages the goal hierarchy—i.e., that they supplant the present goals with a new hierarchy. This interpretation has become increasingly popular as more has been learned of the role of the lower brain centers in motivation.

Second, sudden intense stimuli often produce large effects on the automatic nervous system, commonly of an "arousal" and "energy marshalling" nature. It is to these effects that the label "emotion" is generally attached. The weight of evidence today is that the effects result from, rather than cause, the changes in the C.N.S. described in the previous paragraph. Thus, substantial destruction of the connections of C.N.S. with the autonomic nervous system does not prevent normal displays of emotional behavior in animals. 6/

Third, in human beings sudden, intense stimuli are commonly associated with reports of the subjective feelings that typically accompany emotional behavior. We shall not be particularly concerned here with these reports, but shall assume, perhaps not implausibly, that the feelings reported are produced, in turn, by internal stimuli resulting from the arousal of the autonomic system.

6/ Lindsley [6, pp. 484-5].
Emotional Behavior

We see that all the evidence points to a close connection between the operation of the interrupt system and what is usually called emotional behavior. Further, the interrupting stimulus has a whole range of effects, including (a) interruption of program control in the C.N.S. and initiation of new programs, producing, inter alia, emotional behavior; (b) arousal of the autonomic nervous system; (c) production of "feelings" of emotion. We will be concerned with the first of these effects, and will largely ignore the others. The diagram of Figure 1 illustrates the hypothesized relations in emotional behavior.

![Diagram of Emotional Behavior](Figure 1)

Principal Mechanisms Involved in Emotional Behavior

This system comprises both performance and learning processes. In the performance system, emotion is aroused (the interrupt mechanism is activated) by sensory stimuli, memory images, and drives. What response program will replace the interrupted program will also depend on the nature of the interrupting stimulus. The response program may, and often will, activate the autonomic nervous system, producing a feeling of emotion.
As Hebb [1, pp. 238-40, 250-8] and others have emphasized, the emotional stimulus is to be regarded as more often interrupting rather than disrupting behavior. We might expect the responses to interruption to be largely adaptive, either because they are genetically determined or because the adaptation has been learned. Thus, there have been many efforts to explain the adaptive character of the autonomic responses in terms of evolutionary processes. With respect to the learning of adaptive responses we shall have more to say in a moment. For the present, we simply observe that interruption is not limited to simple responses like "startle," but may evoke an elaborate goal-oriented chain of activity—e.g., the reactions of a trained soldier to the sound of approaching aircraft.

When the emotion-producing stimuli are persistent as well as intense, they may well become disruptive and produce nonadaptive behavior. This will occur if the stimuli continue to interrupt, repeatedly, the evoked response program, and hence to prevent an organized behavioral response to the original interrupting stimulus.

Learning of Emotional Behavior

We would expect two kinds of learning to occur in relation to an interrupt system:

(1) Changes in the efficacy of particular stimuli in activating the interrupt system. New associations could be acquired, allowing stimuli not previously effective to interrupt ongoing behavior. Stimuli, on the other hand, that previously had the capacity to interrupt could lose their efficacy.

(2) The acquisition of new or modified response programs associated with the various interrupting stimuli.
In general, we would expect the tendency of a particular stimulus to evoke emotional behavior through interruption of ongoing behavior to decrease with repetition. For we may regard the interruptions (at least "minor" interruptions) to have the function of guaranteeing that certain side conditions are met while current goals are being achieved. Through learning, the goal structure associated with the ongoing programs can be elaborated to incorporate these side conditions as constraints. When they have been so incorporated, there is no longer any need to interrupt in order to guarantee that they are satisfied.

For example, a relatively unskillful bicycle rider who tries to carry on a conversation while he is cycling finds it necessary frequently to interrupt his conversation to attend to the road. With greater skill, he develops a program that time-shares between the conversation and the cycling in such a way that the latter can be attended to as far as is necessary without often interrupting the former. In effect—we have little detailed knowledge as to exactly how the processing is organized—the earlier single-purpose program, with frequent interruption, has been replaced with a program having the goal: "carry on the conversation while keeping your balance." Everyday observation confirms that, as learning in such situations proceeds, not only does the amount of interruption decrease but evidences of emotional behavior become less and less frequent and intense, as well.

Similarly, if we restrict ourselves to the response after interruption itself, we find that this response usually becomes more and more adaptive with repetition. The bicycling example illustrates this also. The feeling of losing balance initiates the interrupt. In the early stages of practice, the interrupting response is generally a rather vigorous one that overcorrects, causes new feelings of losing balance and produces a new interrupt. The interruption
cycle is often undamped and unstable. As practice proceeds, the response to a feeling of loss of balance is more adequately controlled, and usually restores balance without initiating a new interruption.

In two ways, then, we may expect learning to reduce the emotionality of response as a situation becomes more familiar: (1) the need for interruption is reduced by incorporation of more elaborate side conditions in the programs associated with ongoing goals; (2) the response to interruption becomes more successfully adaptive, thus forestalling new interruptions. Hence, emotionality will be associated with meeting real-time needs, but particularly with meeting those needs that arise unexpectedly and in unfamiliar circumstances.

Of course learning need not be successful here, as in any other learning situation. If interruption occurs and real-time needs are not met, the painful consequences may lead to more precipitous, less adaptive responses when the situation recurs. Since by its nature--unexpected presentation of a real-time need--avoidance behaviors are not generally feasible, a situation that is productive of emotional behavior should be an effective one--if learning can be prevented--for producing frustration and consequent neurotic responses. Indeed, the classical paradigms for producing neurosis experimentally place real-time demands on the organism.

EMOTION AND SOCIAL INTERACTION

In human behavior, situations involving interaction with other human beings are characteristically more heavily laden with emotion than are other situations. A theory of emotional behavior, to be satisfactory, must explain this connection of emotion with social interaction. The present theory provides such an explanation.
In general, real-time needs to respond to the environment arise when the environment can change rapidly and unpredictably. We have seen, in our discussion of learning, that where the situation is stable and predictable, employment of the interruption mechanism can be largely avoided. What are the most active and unpredictable parts of the human environment—and particularly, the parts whose change has most consequences for goal attainment?

Suddenly-appearing, rapidly-moving objects are one important class of events calling for interruption—flying sticks and stones. Their capacity to attract attention and produce interruption is well known. Changes of environment through one's own relative motion—slipping or falling—are another.

But the most active part of the environment of man, and the part most consequential to him as well, consists of living organisms, and particularly other men. Hence, a large part of the complexity of goals arises from the need, while accomplishing tasks, to attend to the responses of other human beings, and to do this in real time. Most contemporary theories of social interaction take quite explicit account of this requirement. Thus, the behavior of problem-solving groups is commonly described as taking place at the two "levels": "task-oriented" behavior, and behavior directed toward the group's social-emotional needs.

The degree to which a person exhibits emotional behavior in social interaction will vary with the progress of the two kinds of learning that may modify the interrupt system. We would expect a human being, in the course of development and socialization, to acquire an increasingly sophisticated
set of cues to indicate those responses of another person that call for interruption of his own ongoing program. As the set of interrupting social stimuli grows, the emotionality of social systems should increase.

On the other hand, the maturing individual also learns programs for anticipating (hence forestalling) interrupting stimuli, and for responding to them adaptively when they occur. As the behavior of other actors becomes more predictable, ego's behavior can be more readily planned, and the emotionality of the situation decreases. Thus, the experienced salesman finds his interaction with the customer less stressful as his ability to predict responses to his own behavior improves.

Since the one type of learning tends to increase the emotionality of social situations, the other to decrease it; and since both types of learning can be expected to be going on simultaneously, the theory leads to no definite prediction of whether, netting these two effects, emotionality of social interaction will tend to grow or decline for the individual. Common observation suggests that it typically grows through adolescence, then gradually declines throughout adult life.

The theory does suggest, however, that certain characteristic pathologies should appear if the first form of learning proceeds much more rapidly than the second, or if the first proceeds very slowly. In the former case, the individual would find social interaction progressively more anxiety-producing, as his sensitivity to the reactions of others outgrew his skill in responding adaptively. In the latter case, the individual would remain highly insensitive to cues indicative of social responses, and would have periodic large disappointments in his expectations of other people--when the signals grew so "loud" that they were no longer inaudible to him.
We conclude that for human beings living in a culture like our own, the most common occasions for activating the interruption mechanism will arise in social interaction with other human beings. For it is the environment of those other human beings that has the most momentous and most unpredictable consequences for us, and their reactions must be handled in real time.

MOTIVATION AND LEARNING

In this section we shall discuss one final topic on which the theory of emotional behavior proposed here casts some light. Learning theories differ widely in the role they assign to motivation in the learning process. These differences were central to the controversy, in the 1930's and '40's, about latent learning. The issue, in its simplest form is: does the organism learn anything about aspects of its environment that are not directly relevant to its currently evoked goal system. For labelling purposes only, let us call the affirmative and negative views on this question Tolmanian and Hullian, respectively.

The theory proposed here gives a qualified Tolmanian answer to the question, and makes some predictions about the circumstances under which latent learning will occur. If we try to make order out of the chaos of latent learning experiments, as Kimble, Hilgard, and Marquis have done [2, pp. 226-234], we discover that they are reasonably consistent with the two following generalizations:

(1) Learning only occurs when there is knowledge of results, but may proceed in the absence of anything clearly identifiable as reward or punishment; and punishment is often as effective in giving knowledge of results as is reward;
Learning without obvious punishment or reward occurs principally under conditions of low irrelevant drive.

The simplest explanation of these facts, consistent with the rest of our knowledge about human behavior is that motivation is effective primarily in determining *what* goal hierarchy will be activated at any given time, hence, in determining what aspects of the environment will be relevant to the organism for performance of learning. Stated otherwise, motivation controls attention, hence influences learning only through its influence on program control. *Given* the focus of attention and the established goal hierarchy, learning still requires knowledge of results, but does not call for reward or punishment mechanisms. Reward and punishment—and motivation generally—are mechanisms that install and replace goal systems.

This explanation leads to three predictions of circumstances under which "latent" learning will occur. First, if in the course of achieving a particular goal that has been evoked, the organism encounters an interrupting stimulus, it may learn things about the environment that are irrelevant to the original goal, but relevant to the response program activated by the interruption. Thus, a hungry rat can learn where it will receive an electric shock in the maze. Since punishment is present in this situation, it has not usually been thought to be related to the phenomenon of latent learning. But by increasing the intensity of the original drive, we should be able to reduce sensitivity to interruption, hence the amount of learning producible by potentially interrupting stimuli. The fact that the interrupting stimulus does or doesn't have punishment associated with it is irrelevant.
Second, as goals are elaborated by the incorporation of side constraints, the organism will learn about aspects of the environment that are relevant to meeting the side constraints, as well as aspects relevant to the original goal. Thus, as a novice chess player begins to learn that he must protect his own men while attacking his opponent's, he learns to attend to his opponent's as well as his own threats.

Third—really a generalization of the first two points—the organism may learn about any aspect of the environment that "happens" to attract its attention. Aspects of the environment with which negligible, or no, rewards and punishments are associated, will generally attract attention only when other, more pressing, needs are absent. Hence—consistent with the evidence—latent learning should occur principally under conditions of low irrelevant drive.

CONCLUSION

In this paper we have proposed a theory of motivation and emotional behavior that appears to provide reasonable explanation of the relation of these phenomena to man's information processing behavior. In its broadest terms, the theory explains how a basically serial information processor endowed with multiple needs can behave adaptively and survive in an environment that presents unpredictable threats and opportunities. The explanation is built on two central mechanisms:

1. An aspiration-level mechanism permits the processor to satisfy, dealing generally with one goal (albeit perhaps a complex one) at a goal, and terminating action when a satisfactory situation has been achieved;

2. An interruption mechanism—that is, emotion—allowing the processor to respond to urgent needs in real time.
Rudimentary mechanisms of these kinds have already been incorporated in some of the current information processing theories of human cognition. Elaboration of the mechanisms, and assignment to them of a larger and more crucial role in the simulated behavior will permit these theories to be extended to the explanation of wider ranges of human behavior. Thus, information processing theories must be endowed with, and can readily be endowed with, precisely the properties that Professor Neisser lists as characterizing human thinking: intimate association of cognitive processes with emotions and feelings; and determination of behavior by the operation of a multiplicity of motivations operating simultaneously.
REFERENCES


