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ABSTRACT

A description is provided of a computer-based simulation of an instructional system which adapts the learning environment to the individual's unique attributes for processing information and for being motivated. The main purposes of the simulation are: 1) to introduce, as attributes for individualizing instruction, information processing variables with their associated reinforcement contingencies; 2) to model the learning environment resulting from the adaptation of instruction based on such attributes; and 3) to specify a computer-based adaptive instructional model which selects treatments dimensioned on the attributes of information processing variables and which provides for the control and monitoring of learning. The simulation is part of an overall effort to apply the results of psychological research to educational needs. Phase one of this effort simulates a learning environment based on knowledge gathered from 1) cognitive psychology and 2) from the experimental analysis of behavior. The second stage will involve a review of the relationship of these two areas and of individual differences useful in adaptive instruction, while the final phase will attempt an empirical evaluation of the simulation. (Author/PB)

ABSTRACT

A computer-based simulation of adaptive instruction was generated. The simulation was a method of problem construction with three main purposes. The first purpose was to introduce, as attributes for individualizing instruction, information processing variables with their associated reinforcement contingencies. The second purpose was to model the learning environment resulting from the adaption of instruction based on such attributes. For this purpose, EDR 537 was simulated. The simulation included student performance, alternative treatments, and selection of treatments. The third purpose was the preliminary specification of a computer-based adaptive instructional model, which selects treatments dimensioned on the attributes of information process variables, and provides for controlling and monitoring of the learning. The model utilizes linear regression techniques in treatment selection.

NEW APTITUDES FOR ADAPTIVE INSTRUCTION: A COMPUTER SIMULATION OF A LEARNING ENVIRONMENT INDIVIDUALIZED BY HUMAN INFORMATION PROCESSES AND REINFORCEMENT CONTINGENCIES

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This paper describes a computer simulation of an instructional system which adapts the learning environment to each student's unique attributes for processing information and being motivated. The simulation has three main purposes. The first purpose is to introduce the combination of human information processing and the associated contingencies of reinforcement as attributes for individualizing instruction. While each of these areas has separately produced research and generated practices in the educational realm there has not been any attempt to utilize the combined research results. Only in the last few years have basic theories been developed to synthesize these two seemingly divergent schools of psychology.

The second purpose is to model the learning environment that would result from the adaption of instruction based on attributes of processes and their reinforcement contingencies. Whereas the first purpose or goal of the simulation allowed a visibility of measures which might be useful in individualizing instruction, the second purpose provides for operationalism in an educational environment.

The third purpose of the simulation is the preliminary specification of a computer-based adaptive instructional model based on these aptitudes.

The model specified can actually be considered the decision system which utilizes the measures to assign learning environment parameters. The measures, the learning environment, and the model are all grounded in the theories and research of human learning and reinforcement. Section 1, Information Processes and Their Reinforcement Contingencies; Section 2, Learning Environment; and Section 3, A Computer-Based Adaptive Instructional Model, respectively address the three purposes in this paper. These sections in effect are the results of the simulation effort.

The simulation described in this paper is part of an overall effort to apply knowledge gained in psychological research to educational needs. More specifically, it appears to the investigator that the two most cohesive and continuous schools of research and theory in psychology today are those termed cognitive psychology and the experimental analysis of behavior. That these two areas are epistemologically divorced seems unwarranted considering the problems which must be solved by the applied psychology fields.

The overall program is separated into three phases. The first phase is the simulation of a learning environment which demonstrates the utilization of knowledge in the two areas for adaptive instruction. The simulation is an effort to avoid the pitfalls of speculation upon which many educational claims are made. It allows concrete conceptualization of the usefulness and operations of the psychological body of knowledge in question. The simulation does not provide a formal theoretical structure, but rather an application framework which says, "If the two schools are in consonance then they may be useful in this way."

The second phase of the program will be a critical review of both areas within the context of the relationship and to individual differences which are useful in adaptive instruction. The phase one effort actually begins this task and has helped to shape the direction of the phase two effort. That direction is to utilize reinforcers with both informational and motivational value to gain attention, storage, and retrieval of the informational environment.

The third phase will attempt empirical validation of simulation and critical review conclusions. It is expected that the phase three experiments will determine the need for utilizing measures of information processes and their reinforcement contingencies to individualize instructional design.

Glaser (1972) has recently discussed instruction with an analogy to evolution and defined two educational modes, selective and adaptive. The selective mode of education is characterized by minimal variation in learning conditions, and is the educational mode under which most formal education operates today. The term selective is used because the fixed learning conditions of the instructional environment require particular student abilities, therefore, these are the abilities a student must have for success.

The educational application of the psychological principles, which is the subject of this paper, is called adaptive instruction. The adaptive mode of education assumes that the environment can be structured to individual characteristics, and that it is not necessary to identify students as inadequate by virtue of an artificial evolutionary process. The adaptive mode attempts to provide alternative learning conditions which are matched to information about each individual. While a selective mode of education emphasizes measures of a student that predict success in a fixed or limited environment, the adaptive instructional mode attempts to measure individual differences which can be used to define alternative environmental conditions.

Using Glaser's evolution analogy it can be stated that in any educational mode, the individual measures of importance are those that have ecological validity. As expressed by Glaser, and in such diverse theories as that of Piaget and Skinner, psychological functioning is a continuous bidirectional interaction between behavior and the controlling conditions of the environment. Behavior partially creates the environment and the resulting environment influences the behavior. The behavioral measures considered in the simulation are process variables interacting with the environment. The particular aspects of the environment to be considered are those fitting a reinforcement paradigm. By the term reinforcement is meant the behavior-influencing factors of the environment that are also contingencies of the behavior.

SECTION 1

INFORMATION PROCESSES AND THEIR REINFORCEMENT CONTINGENCIES AS DETERMINANTS OF INDIVIDUAL DIFFERENCES

In general the concern is with memory and motivation. Each of these terms are abstract and will be defined by the theories and research described in this section. The concern with memory is not only in retention, but also in sensory selection, information processing during learning, and processing subsequent to permanent storage of information. The concern with memory includes all influences on the processing which takes place, especially the motivational factors. By motivational factors is meant a paradigm of reinforcement such that all information processing has contingencies of reinforcement. These contingencies include the reinforcing events. Reinforcement and motivation are used synomonously to mean all events which influence information processing and the more observable behaviors.

In reviewing the literature the prime interests were threefold. The first was to search for evidence of linkage between information processing research and reinforcement research. The second was to determine the relevance of these process variables and their reinforcement contingencies as individual difference indicators. The third interest was to examine the use of these individual difference indicators for the purpose of instructional design which optimizes the educational process within individuals. This section describes the literature which is the basis for the simulation with the three interests as guides.

Roles of Reinforcement in Human Learning

An implicit assumption here is that by reinforcement is meant secondary or conditioned reinforcement. As reviewed recently by Hendry (1969), Honig (1969), and Katz (1972) there are several alternatives to classifying secondary reinforcers. The differences in the alternatives lie in the necessary conditions which are hypothesized to allow the reinforcing event to acquire control of behavior. Three alternatives frequently mentioned are the discrimination hypothesis, the discriminative-stimulus hypothesis, and the information hypothesis. The discrimination hypothesis (Mowrer & Jones, 1945) stated that behavior is a function of the similarity between the acquisition conditions and the test conditions. The discriminative-stimulus hypothesis (Keller & Shoenfeld, 1950) differed in that a stimulus must be discriminative for some response in order to act as a secondary reinforcer. The information hypothesis (Berlyne, 1957; Egger & Miller, 1963; Hendry, 1969) suggested that the usual emphasis on close temporal relationship of a stimulus and primary reinforcer is in error, and that it is the information gain in reducing uncertainty which is the necessary condition for secondary reinforcement. It is assumed that all of the above hypotheses may be correct depending on the task conditions and state of the learner. What is of most importance in the simulation is not the general correctness of any given hypothesis, but the affect on information processing, whether the reinforcer itself does or does not carry information.

Atkinson and Wickens (1971) have recently presented a theory of reinforcement effects on human learning. More specifically, the theory is concerned with the influence of reinforcers on memory storage and retrieval. Learning is defined by Atkinson and Wickens as the storage and retrieval of information. While the theory does not exclude any of the alternative hypotheses of reinforcement, the primary concern is with the roles of reinforcement as it affects the storage and retrieval of information. These roles are the primary emphases of the simulation.

As represented in Figure 1 a theoretical memory system is proposed (Atkinson & Shiffrin, 1968) that consists of three memory components. These are a sensory register (SR), a short term storage (STS), and a long term storage (LTS). It is assumed that the SR takes information in from the sensory receptors. Information is then transferred from the SR to STS, which can hold information for a short period of time before the information begins a fairly rapid process of decay. Both the SR and the STS are limited in the amount of information which can be held at any one time, and current information can be lost through displacement as well as decay. Ultimately the information must be transferred to the more permanent LTS in order for learning to occur.

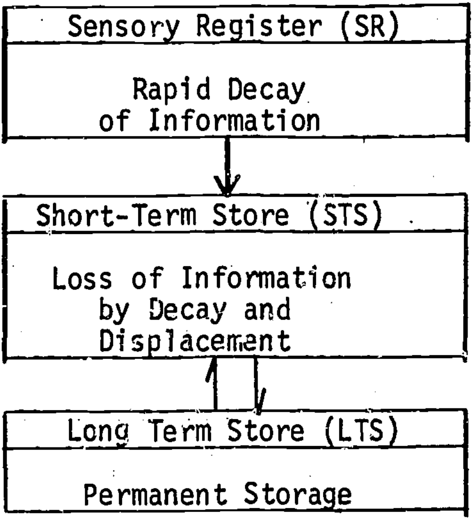

Figure 1.--The Structure of Memory (Based on Atkinson & Shiffrin, 1968)

The structural factors of the memory system are the limits on the amount of information which can be stored in a memory component and the information loss in SR and STS. These factors require people to select information out of the total information environment for storage in the SR, transfer to STS, and eventually to store it permanently in LTS. Furthermore, a search of LTS for relevance to information in STS and the decision to transfer from STS to LTS must be performed. Each of these processing functions must occur if information is to be stored permanently and learning to occur.

The Atkinson and Wickins theory suggested that the role of reinforcement is to modulate these transfer and storage functions by indicating "when" and "what" should be stored or transferred. That is, the information to be transferred and stored is a function of reinforcing what is to be transferred or stored. Although the Atkinson and Wickens theory does not address any specific hypotheses on the source of secondary reinforcement, it is assumed that whether the reinforcer is informative, associative, or discriminative it will nevertheless function as a modulator of storage and retrieval. This concept of reinforcement is very close to a concept of attention in that the reinforcer is viewed as causing the person to attend to certain information over other information. Because of the memory structural limits, some information will be retained in any given instance while other information may be lost.

The Atkinson and Wickins theory of the role of reinforcement as modulator between memory system components provides the theoretical framework for the simulation of the adaptive instructional system. As will be seen in later sections detailing the learning environment and the adaptive model, the simulation revolves around a concept of reinforcer as it affects transfer, storage, and retrieval of information from memory.

While the general roles of reinforcers and the structural limits of memory systems are assumed to be constants for all individuals, there is also variance in the individual's differences which are needed for adaptive instruction. Three categories of individual difference sources are used. These are: (a) control and strategy, (b) information availability and organization, and (c) contingencies of reinforcement. An example of control and strategy would be: If STS is filled with information, and the current task of the person requires more information to be stored in STS, it is possible to code or group the information so that it takes up less storage than was initially needed. This requires the person to have coding strategies in order to control the amount of information that may be transferred from the SR into the STS. One may wish to hold large amounts of information in the STS, because time limitations do not permit transfers into LTS, or the decision cannot be made at the time for which information should be transferred into LTS. These differences are termed as control and strategy functions, and are presumed to provide a large amount of the variation among individuals because the functions must be learned.

Information also varies as to its availability and organization. Within permanent memory is stored the information about the individual's world and includes information about reinforcing events. The Atkinson and Wickins theory assumes that information cannot be transferred from STS to LTS, or at least it is more difficult, without information in LTS which can be matched with information in STS. This is an expectancy hypothesis which states that information in STS must be related to information in LTS to determine its usefulness and storage location. The matching will also determine the strategy for holding information in STS and the strategy used for transfering to LTS in relation to other information. Thus, the information currently available in LTS is another individual difference. Several studies have noted that while information may be in LTS it is not always available for retrieval. The Atkinson and Shiffrin model of memory assumed that information stored in LTS is permanent (without decay or displacement), but that retrieval schemes and control of transfer from LTS to STS may not always be available or complete. This is in part a function of the organization of information. A second category of individual difference measures is therefore the availability and organization of information.

The third and final category of individual differences is the contingencies of reinforcement. This includes the time factors of reinforcement such as delay of reinforcement, the value of the reinforcer both in terms of information and motivation, and the conditions surrounding the reinforcing event, which may make the reinforcer more or less effective. While the structural limitations of memory provide limits on the reinforcers' effectiveness, the history of reinforcement also plays a part in the individual's memory/reinforcement system. This source of individual differences is also taken into account in this simulation. The remainder of this section discusses in detail the factors found in research within each of these three categories.

Control and Strategy

In the Atkinson and Shiffrin (1968) model of memory a distinction was made between the structural components and control processes of memory. The structural components, as described previously, are the sensory register, short-term storage, and long-term storage. The limitations resulting from these structural components provide the invariate factors of memory. However, control processes are factors which function to provide individual differences. The control processes regulate what information is selected from the external environment and what is transfered among memory components to result in learning. Furthermore, there are control processes which allow retrieval from LTS to STS, and ultimately result in observable behavior.

Three types of control processes for short-term storage can be described in order to clarify the meaning of control processes. When information is required to be used immediately, and need not be learned permanently, the person may use a strategy of maintaining as much as possible in STS through rehearsal without attempting to transfer information to LTS. By rehearsal is meant repeated passage through the same limited capacity channel. Using such a strategy the person can be highly accurate with short lags (amount of activity between events, e.g. number of intervening items), but performance can be expected to drop rapidly for long lags. A second type of strategy also requires a person to maintain information in STS through rehearsal, but to maintain less information in STS so that an attempt can be made to transfer it to LTS. This strategy will also allow good performance at short lags, but only with lesser information will items tested at long lags or delays not experience a large drop in performance. A third strategy may be used when a person wishes to store information more permanently. The strategy is to code the information in STS and store it in LTS as it is presented without maintaining it in STS for any appreciable length of time. This strategy is possible only when enough time is available to transfer to LTS without need to buffer larger amounts of information in STS. The determination of which control process will be used is a function of the nature of material presented and the task environment. These factors include the contingencies of reinforcement.

Of particular interest is the effect of reinforcement, both in terms of information and motivation, on such control processes. While the relationship between motivation and memory is not completely clear, several research projects over the last five years have demonstrated some functional relationships. Weiner (1966a, 1966b) demonstrated that the introduction of a motivational variable, such as statement of the reward value, during trace storage enhanced performance on a test later. However, no effects were found in several studies (Bourne, 1955; Weiner, 1966a, 1966b) for motivation by monetary incentive when the reinforcement was introduced during retention test rather than during the acquisition phase.

More recently, Loftus and Wickens (1970) found that presenting the value of an item at the time the item was studied as well as at the time the item was tested effected the probability of a correct response at test. Thus, the motivational effects of reinforcement were found both for reinforcement at acquisition time and at test time. While the effect of reinforcement at test time was smaller, it was nevertheless significant. The Loftus and Wickens experiments were different from those of Weiner and Bourne. The critical difference is that Loftus and Wickens used a within-subjects design rather than a between-subjects design. The within-subjects design provided that for each subject items were assigned either a high or low value for their reinforcement. Loftus and Wickens suggested that the psychological values of reinforcers are relative rather than absolute, and that providing for relativity within subjects allowed the effects of motivation on retrieval to be observed. The relativity effect of the reward was reflected in the different strategies used by a subject to store and retrieve information. The interpretation was that a high value item under consideration was given a greater amount of a subjects limited information processing capacity than low valued items. The Atkinson and Wickens theory of motivation and memory stated that control processes available during storage are greater than those available at retrieval time. By providing subjects with relative reinforcing values it was assumed that subjects may use the more limited control processes of retrieval by devoting less processing capacity to the lower valued items.

Not only is reinforcement effectiveness based on relative values rather than absolute, but what is regarded by some persons as reinforcement may be differently perceived and acted on by others. Rotter (1966) suggested that one of the determinants of reinforcement effectiveness was the degree to which the individual perceived that the reward follows from, or is contingent upon, his own behavior, as opposed to outside forces which act independently of his behavior. Rotter proposed that the effect of the reinforcement is not a simple stamping in process, but a function of whether or not the person perceives a causal relationship between his own behavior and the reward. This supposition resulted in the development of concepts of external and internal control. External control is an interpretation by an individual that reinforcement follows the person's action, but is not, at least entirely, contingent upon his action, and is under the control of others or the result of chance. Internal control is a subject's perception that an event is contingent upon his own behavior and therefore under his control.

To test these concepts, scales of individual differences in a generalized belief in internal-external control were developed. One of the findings in this research was that for people who perceived internal control in a task, 100 percent reinforcement took longer to extinguish than did 50 percent reinforcement . This finding is quite different from what would be expected based on usual operant research findings. It seems apparent that individual differences in reinforcement laws become more important as information processing variables are considered. Although Rotter and his associates did not interpret these results in terms of memory, it may be that this is another example of the effects of reinforcement on control processes. One would expect internal control perception to cause greater use of the control processes available to an individual than would external control. The role of reinforcers as modulators of information transfer and storage should be dependent upon a person's perception of his control of those events. In the case of this particular finding one would expect the internal control perception to be stronger in a 100 percent reinforcement schedule, and the behavior to be more persistent than in a 50 percent partial reinforcement schedule.

The categorization of people by their expectancy of control over reinforcement contingencies is one example of a learner type which influences the modulating function of a reinforcer. Other learner types are visible in the literature which might also be relevant within the theoretical framework of reinforcers as modulators of information processing. Generally, these types may be considered as classifying learners by personality variables and learner strategies. Typically, such variables are studied without regard to the effects of reinforcement contingencies so that it is difficult to state on an empirical basis which measures might be useful within the context of reinforcement modulation of information processing.

Several such variables may be identified as examples. These are:

1. Subjective organization index. Mandler (1967) has suggested that the memory limits for verbal information require organization for permanent storage and recall. The organizing strategy a person freely uses (rather than that strictly defined by another source) is defined as subjective organization. Measures of such control processes have been developed by Bousfield (1964), James (1972), and Tulving (1962). It is possible that these measures can be used to classify subjects as high, medium, and low subjective organizers, thus providing an indication of storage control processes.

2. Cognitive style. Frequent mention of a learner's "style" of information processing was apparent in the educational research literature. Kagan (1965) studied a classification of impulsive versus reflective learners. These styles are defined by the dimensions of time

still do occur, however, and for the purpose of this paper these retrieval problems are classified under the term, availability. The hypothesis in the literature is that information may be available (in memory) but not accessible (retrievable).

Tulving and Pearlstone (1966) found that subjects given recall cues had greatly facilitated recall over subjects not given recall cues. The indication from this study was that items of information were in memory, but subjects needed help before the items could be retrieved. The Tulving and Pearlstone study used categories of word lists, and it was found that this category organization of material played a part in the cued recall. If at least one word from a category was recalled by the subject the same proportion of remaining words was recalled in a no-cue condition as with a cue condition. Thus, the organization of information seemed to greatly facilitate the accessibility and retrieval from long-term memory.

Retrieval cues would only appear to help if information is organized appropriately at the time of storage. Tulving and Osler (1968) demonstrated this by a study in which training conditions consisted of cues being presented during acquisition for some subjects while not for others. The results indicated that retrieval cues facilitated free recall if they were present both at the time of storage and at the time of recall. Cues which were presented only at the time of storage or recall did not improve performance.

The roles of reinforcement for storage and retrieval control processes indicated that reinforcers, by provoking discriminative attention, influence both the storage and retrieval processes as indicated in the findings of Loftus and Wickens (1970). Informative reinforcers may act as information organizers, as well as attention influences, such that they allow the viewing of memory for storage and retrieval. By providing information, the reinforcer may act to organize information by categories, associations, and hierarchies. One can speculate that both discrimination and generalization might, depending on the task and learner, effect control processes. In particular, the operant conditioning concepts of stimulus discrimination and generalization may be relevant.

The role of reinforcement in the encoding process is exemplified by a study (Zinnes & Kurtz, 1968) concerned with discrimination and generalization of light patterns. In the discrimination experiment two light patterns, one a standard pattern consisting of nine lights, and another a comparison consisting of ten, eleven, or twelve lights (S_1, S_2, and S_3 respectively) were presented successively and the subject had to identify the standard. In the generalization experiment, a stimulus pair was presented on each trial which would be two standards (S_{oo}), two comparison patterns (S_{jj}), or a standard-comparison pair (S_{oj} or S_{jo}). Differential payoffs were used as follows:

		Response	
		same	different
Stimulus Pair	Ss (S_{oo} or S_{jj})	o	-1, -5, -10
	Sd (S_{oj} or S_{jo})	-1	0

Calling a "same" stimulus (S_s) different cost subjects one, five, or ten points in each of three conditions. For the other response stimuli conditions the reinforcement values remained unchanged. Zinnes and Kurtz interpreted the results in terms of inducing response biases. That is, they found that the asymetric payoff conditions resulted in a greater tendency to respond "same." Even under the conditions where discrimination was almost perfect, generalization readily occurred. In fact, the greater the loss for a miss, the more pronounced was the tendency to generalize. The "response bias" can also be interpreted in terms of memory components. The asymetric payoffs modulated the information processing such that comparisons of stimuli within STS resulted in the classification of different stimuli as the same to avoid penalty. The stimuli were encoded or organized as a function of the payoff.

In the previous discussion on control processes, subjective organization was suggested as a control variable. Mandler (1967) suggested that organization was required because the limitations of the memory system may result in exceeding the span of imediate memory. Postman (1972) labeled this stance as a strong principle of limited mnemonic capacity. The weak principle states the development of higher order information units increases mnemonic capacity but makes no firm assumptions about the limits of memory. Evidence reviewed by Postman indicated that findings are consistent with the weak form of the principle but provided no conclusive support for the strong version.

Regardless of whether or not organization is necessitated by memory limits an assumption of this paper is that reinforcing events act as both cues for attention and organizing. To consider individual characteristics in a learning task means that the amount, type, and organization of the student's memory must be measured. Such measures would include not only the traditional pretests, but also organization measures such as Mandler's (1967) Q-sort and Quillan's (1969) retrieval time or latencies. In addition, it would be of interest to determine individual cues which would be useful for organizing, adding, and retrieving information. Such cues would be considered as part of the reinforcement contingencies.

Contingencies of Reinforcement

While the two previous categories of individual difference sources are oriented toward the internal environment of a person, this category is concerned with the external events which occur and the relationships among them. Skinner (1969) originally stated a definition of "contingencies of reinforcement" as the formulation of the interaction between an organism and its environment which specifies the interrelationships among: (a) the occasion or condition upon which a response occurs, (b) the response itself, and (c) the reinforcing consequences. The interrelationships are frequently specified in such terms as rate of responding, latencies, delay of reinforcement, and interresponse times. Information processing experimental studies frequently use such measures of interrelationships between events as speed of response, delay of feedback, delay between trials, delay between study and test events, and numbers and types of intervening task. There is at least an intuitive correspondence between the measures of the two tyeps of experimental paradigms.

This possible consonance is further strengthened by noting that since reinforcing events must play a role in the information processing operations which will occur, and thus in part determine what is learned, it should be possible to formulate a paradigm which includes information processing functional relationships and contingency of reinforcement functional relationships. It should be noted that information hypotheses of reinforcement expressed by Berlyne (1957), Egger and Miller (1963), and Hendry (1969) are in a sense attempts to provide a paradigm which takes into account both information processing and reinforcement (by viewing reinforcement as information). The formulation suggested, however, is not concerned with whether reinforcement has solely informative properties, associative properties, or any others. The emphasis is on reinforcement as a modulator of information storage and transfer, informative or not. While such a formulation will not be attempted here, several of the possible interrelationships in such a formulation will be discussed.

It appears that there are actually two levels at which reinforcement might be applied in an instructional situation. One of these is a long-term reinforcement system in which payoff is expected to motivate a learner to enter a line of instruction or continue through a series of tasks. Use of this reinforcement scheme does not usually consider more micro-measures such as latencies or interresponse times. Much behavioral modification research and technique seems to fall in this category even where reinforcement is applied after every response and task. There is usually little consideration given to contingencies of reinforcement other than rate of responding. This is characteristic of research found in the Journal of Applied Behavioral Analysis. An information processing view of this form of reinforcement scheme suggests that students would have to form long-term strategies for payoff.

The second level of reinforcement system is more closely allied with research reported in the Journal of Experimental Analysis of Behavior in that greater attention to more contingencies is given in the reports.

Thus, rather than only the reinforcing event being a variable of interest, the contingencies of the reinforcement are studied in greater depth. This latter form of research is of more immediate relevance when considering an information processing approach to human behavior, because human learning research typically takes into account similar micro-measures. For example, if feedback were provided for responses, such variables as delay of feedback, intertrial times, noise conditions, intervening tasks, and retention test intervals would also be of interest in determining functional interrelationships.

While the long-term reinforcement seems necessary in an instructional system, particular attention in this paper is given to the more detailed analysis of reinforcement contingencies to provide a better basis for a linkage to information processing variables. This is particularly required in order to specify instructional variables or dimensions which take into account memory processes. It will be noted in Section two, Learning Environment, and Section three, Computer-Based Adaptive Instructional Model, that the simulation actually uses incentives based on total test performance of an instructional task, but in addition provides for the dimensioning of treatments on contingencies which are particularly time dependent. Examples would include such variables as delay of reinforcement and intertrial times. The remainder of this section discusses some of these possible dimensions and measures.

<u>Delay of reward</u>. In animal learning studies it has been found that effectiveness of reinforcement is usually inversely related to delay

of reward following the response undergoing acquisition. This relationship in human learning appears not to be as simple. Depending on the task and material content considerable delays, as much as 30 seconds to a minute can be of benefit before presentation of the reinforcer or feedback (Atkinson & Wickens, 1971; Brackbill, Brovos, & Starr, 1962). In addition some studies find a delay in reinforcement will impair learning (Greenspoon & Forman, 1956). Atkinson (1969) performed a study in which conditions allowed observations of impairment, facilitation, and no effect. By providing an irrelevant intermediate task between stimulus presentation and response, observations of both deliterious and no effect could be made depending on whether reinforcement was either in the form of information feedback only, or presentation of the stimulus and feedback together. In a condition without the intermediate task, Atkinson found that longer delays of reinforcement allowed a greater proportion of correct responses. The critical factor appeared to be whether an intermediate task was involved that could prevent rehearsal of information in STS, thereby providing a loss of information in STS and no opportunity for transfer to LTS.

Response latencies. While studies of human learning utilizing operant techiques typically record rates of responding, the analysis of human learning and conditioning has found latency data useful to obtain information about contingencies. This has included studies of response latency in relation to reward frequency (Straughan, 1956) and reward magnitude (Stelleng, Allen, & Estes, 1968) in recent studies of human learning. It seems reasonable to speculate that response latencies therefore seem a likely candidate for discussing information processing contingencies of reinforcement.

Magnitude of reinforcement. It is typical to hear reward values spoken of in terms of an absolute scale, but current research and theoretical concepts would seems to indicate otherwise. Premack (1971) in particular regarded reinforcements as having relative values to an individual. In fact, Premack suggested the definition of both positive and negative reinforcement as a function of the relative incidence of responding of a reinforcing event versus the event or response to be reinforced. Thus, positive reinforcement is defined as the opportunity to perform a response of higher frequency to a response of relatively less frequency. A negative reinforcer is defined as the necessary response of relatively less probability to a response of relatively higher probability. Studies in which concurrent tasks are reinforced with differential reward values show that performance of items can be manipulated simply by manipulating the incentive values assigned to the item (Harley, 1965, 1968). When items with different reward values are presented to an individual they would therefore seem to receive different treatments. This suggests that absolute reinforcement values are not of significance. Furthermore, in the Harley studies it was found that the effects of reward conditions are significant only when observations are made within subjects as opposed to between subjects. The Loftus and Wickens studies described previously also studied the relative values of reinforcement within subjects and arrived at similar conclusions. The interpretation was that Ss used more of the control process capacity for higher value items.

Intertrial times. Studies of the time delay between reinforcement and presentation of the next trial stimulus (Bourne & Bunderson, 1963) indicated that it may be desirable to delay the time between trials. An information processing interpretation of this data is that the time is needed for rehearsal of STS information and transfer to LTS. While no explicit formulation of intertrial times relationship to interresponse times as used in operant studies was suggested, there would appear to be some correspondence.

Schedules of reinforcement. An experiment performed by Brelsford, Schiffren, and Atkinson (1968) illustrated an interpretation of how a series of reinforcements can act to build the strength of representation in LTS through successive storage of information. Reinforcements in the form of knowledge of correctness of response were employed in a paired associates task with lags between study and test trials distributed geometrically. By lag is meant the number of irrelevant intervening items. Since the lag determines the frequency of presentation of an item, the number of reinforcements can also be varied. In this study, either one, two, or three reinforcements per item were presented. As might be expected the greater the number of reinforcements the greater the subject's learning ability increased. This was interpreted to mean that a series of consecutive trials without lag tends to cause the information to be entered in through the STS rehearsal buffer without further disruption of other items in STS. In addition, transfer to LTS is further facilitated. However, if a series of items is presented which are different, disruption of the information currently in STS can occur causing some loss of information. The same loss might also be expected with simply passage of time, since information does decay in STS and will be lost unless transferred to LTS.

SECTION 2

LEARNING ENVIRONMENT

The learning environment of the adaptive instructional system is quite different from a traditional learning environment. The traditional environment uses selective instruction rather than adaptive instruction. The type and quantity of data used for decision-making in the traditional environment is also different from the adaptive environment. These differences have been detailed through the simulation effort and are the subject of this section. Four general categories of changes have become visible and are subsumed under the following subsections:

1. Treatments
2. Reinforcement
3. Computer-Based Environment
4. Student and Teacher Roles

Perhaps of most importance is the fact that the instructional alternatives available will be designed according to dimensions of students which allow near optimum acquisition and performance for mastery and time. The instructional design must include analysis of the contingencies of reinforcement. A fully adaptive system will most likely require a computer for assistance in measurement, instructional control, and decision-making. Finally, the interaction among students and between students and teachers will be different both in quality and quantity.

This section describes what is conjectured to be the structure of such a learning environment. While there could be variations, the general structure of the system is seen to be necessary as presented here. It is important to describe a learning environment such as this so that the utility of information processing and contingencies of reinforcement for educational purposes are not speculated upon without attention being called to the operationalism of the total education environment. The value of the simulation has been, as it is in the case of most simulations, to provide a vehicle for modeling the real world before attempting to manipulate it.

Course Simulation

To further detail the resulting learning environment, a specific course was chosen for the simulation. EDR 537, Techniques of Programmed Instruction, was selected because it is a course currently presented under computer management and is designed modularly with instructional objectives. The course consists of twelve "cognitive" units followed by "productive" units. The cognitive units consist of readings and tests on the readings administered in an interactive mode via computer terminals. After the cognitive units are completed students enter a production mode and proceed to develop programmed instruction utilizing the information acquired in the cognitive units. During this time students correct misinterpretations and acquire new information.

The first five cognitive units of the course were chosen for the simulation to represent how this course would be developed utilizing the adaptive measures and model presented in this paper. These units are listed in Table 1. Also associated with each unit are times designated as TAT and TACT. TAT is an acronym for Targeted Average Time and refers to the average time a student is expected to spend on that particular instructional unit. TACT is an acronym for Target Average Course Time and refers to the average time expected for completion of all previous units plus the current one. For example, as reflected in Table 1, Units 1, 2, and 3 should take 2, 3, and 4 days respectively to complete because these are the TATs associated with them. In addition, the student is expected to have completed Unit 3 at the end of nine days (TACT=9) regardless of whether all TATs were achieved. It is assumed that students had been presented these targeted units (TAT) and targeted course (TACT) completion times along with a scheme for obtaining tokens for completion ahead of the targeted times. The rules for obtaining

TABLE 1

Simulated Units of EDR 537
with TAT and TACT Times

UNIT	TAT	TACT
1. Systems Approach	2 days	2 days
2. Documentation	3 days	5 days
3. Problem Identification	4 days	9 days
4. Task Analysis	3 days	12 days
5. Entry Behavior	4 days	16 days

incentive tokens for time savings will be discussed shortly in the section on reinforcement.

For the purpose of the simulation, the instruction is seen as criterion-referenced as opposed to norm-referenced. This means that objectives of instruction are stated in terms of expected student performance with specified conditions of performance. The goals of the instructional system are to provide all students with mastery of objectives. The student is rated on how well he or she performs according to these criteria rather than relative to other students. Each instructional objective has a set of conditions and a criterion level of performance associated with the specified behaviors. Because of this the criterion-referenced system lends itself more readily to a precise statement of reinforcement contingencies.

Treatments

The explicit assumption for adaptive instruction is that instruction should be designed according to the interaction of student attributes and treatment dimensions. The treatments in the simulation are designed according to some of the variables discussed in the first section of this paper entitled Information Processes and their Reinforcement Contingencies as Determinants of Individual Differences (p.5). For each instructional unit in the simulation five alternative instructional treatments were conceptualized.

One of the considerations in design was that some students do not need as much of the learning task controlled as other students. The treatments may in fact be viewed along a continuum of instructional control. Treatments one and two allow the greatest learner control. Thus, it was assumed that a category of students, probably those who have in the past "learned to learn," would achieve mastery of the instructional materials within reasonable amounts of time with only a minimum control of their information processing and contingencies of reinforcement. While these students were assigned specific readings or activities to be performed, the treatments assigned left the control of processing and contingency functions to the students. In treatment one, readings or other resources were only suggested, allowing the student to choose from the list. In treatment two resources were assigned.

The students (Treatments 1 and 2) received reinforcement in terms of token incentives during their testing of a unit, which was done in an interactive mode at a computer terminal. Thus, reinforcement was used to influence performance on a test period and was not considered necessary during acquisition for these students. These students were considered to know in advanje that they would receive tokens during the test period for their performance. The incentive values of specific information items were considered to be individualized based on pretests of information availability and organization. Those items which the student did not do well received the higher relative values.

For students in which the adaptive model predicted more need for external control of information processes and contingencies of reinforcement, treatments three, four, and five were conceptualized to be dimensioned by such attributes. The dimensioning of all five treatments is presented in Table 2 for the treatment attributes across control and strategy processes, availability, and organization of information, and contingencies of reinforcement. Treatments three, four, and five all have the presentation of learning materials via computer control. The material is interactive and responses are collected by the computer system along with measures of time contingencies such as latencies. By providing computer control of the learning task several dimensions of the treatment can be controlled.

For all three treatments, reinforcement is provided both for information and payoff during both the acquisition and test period. During the acquisition phase the values of items, according to incentive tokens which may be acquired by success on an item, are presented with the item. Furthermore, the values for any particular item may change dynamically for individual students according to pretest scores which indicate prelesson information availability and organization on the topic. In this way, a student is given higher reward values for items in which the most learning is required. More precisely, after preassessment of a student's information availability and organization, the instructional objectives of which there are three, are weighted to provide the relative payoff values for a student.

The delay of reinforcement and intertrial times are also controlled by the computer. It is assumed that both of these would have standards associated with them for a given task based on an empirical derivation. Deviations from the standard for a given student could depend on previous history of latencies to determine the initial delay and intertrial times. As a lesson proceeded, the current latencies

TABLE 2

Treatment Dimensions

TREATMENTS	CONTROL AND STRATEGY PROCESSES	AVAILABILITY AND ORGANIZATION	CONTINGENCIES OF REINFORCEMENT
1. Reading Assignments* Suggested with Learner Choice	(a) Incentives during Test Only	(a) Information Resources under Learner Control	(a) Mastery Incentive Magnitudes as Differential Values for Items (b) Time Savings Incentives
2. Reading Assignments* Required	(a) Incentives during Test Only	(a) Information Resources Assigned	(a) Mastery Incentive Magnitudes as Differential Values for Items (b) Time Savings Incentives
3. Computer-Controlled Interactive Media Such as Slide/Tapes, Films, and CAI*	(a) Incentives during Acquisition and Test (b) Use of Standard Lag with Dynamically Updated Lag Proportions	(a) All Information Resources Computer-Controlled and Managed	(a) Mastery Incentive Magnitudes as Differential Values for Items - Both Acquisition and Test (b) Time Savings Incentives (c) Control of Reinforcement Delays (d) Control of Intertrial Times
4. Same as Treatment 3*	(a) and (b) as in Treatment 3	(a) As in Treatment 3 (b) Organizers (c) Remedial Diagnosis	(a), (b), (c), and (d) as in Treatment 3
5. Same as Treatment 3*	(a) and (b) as in Treatment 3	(a), (b), and (c) as in Treatment 4	(a), (b), (c) and (d) as in Treatment 3.
	Participation in Group Discussions and Exercises with Students and Instructor		

*All treatments provide access to supporting resources consisting of abstracted readings, slide/tapes, films, and CAI. These are available at student option.

would provide information on whether times should increase or decrease. Presumably longer latencies would mean a student should have longer delays and intertrial times, but this would be an empirical question as in any given task with specific sets of materials.

In addition, the lag is also controlled. Lag is the number of intervening items between two presentations of a same or similar item. The lag also would be initialized by a standard, and would be changed dynamically during the lesson as students mastered previous items and items that were dropped from the lesson to lower the lag proportions. Thus, instructional presentation would be modularized according to the number of intervening items which are determined to be acceptable for a student's learning without detriments to the individual's control processes.

Treatment four differs from treatments three and five in that it is dimensioned to aid the learner who scores low on preassessment measures for information availability and organization. Dimensions of this treatment include a preliminary organizer which suggests to the student ways in which the material can be organized. In addition, remedial diagnosis is performed on-line to determine more explicit weaknesses in the student's information structure of the material and instruction. Instruction, including review, can be provided if needed for remedial purposes before proceeding to the base line instruction. It will be demonstrated later with the simulation data that the organization attributes of a student having learning problems may be updated so that these measures reflect the student's current state.

Treatment five differs from three and four in that, in addition to the base-line computer-controlled material, an assignment is made to the student to participate in group discussions and exercises relevant to the material. This treatment dimension is seen as providing aid to both control and strategy processes and the information availability and organization for an individual student. It provides for human interaction with possible social reinforcements, imitative learning, and allows the instructor to diagnose any serious motivational problems. It should be noted that while the group is assigned especially to students having the greatest amount of learning problems, the group sessions would be available as an option to all students.

In addition to the prescribed treatment resources the simulation takes into account the availability to the student of supporting materials. Supporting resources would consist of additional or alternative readings, slide/tapes, films, and CAI. All such resources would be abstracted for the student so that information concerning relevance and importance of the resource could be obtained.

Reinforcements

While the treatment dimensions specify most of the contingencies of reinforcement, the actual reinforcers used have not been discussed as yet. The reinforcement used in the treatments is based on a token incentive economy. In keeping with the goals of the instructional system, incentive tokens could be obtained both for saving time during instruction and achieving mastery of the material. More specifically, tokens were given to students on the basis of: (a) the time saved on an instructional unit relative to a Targeted Average Time (TAT), (b) course time saved on the overall course according to a Targeted Average Course Time (TACT), (c) meeting criterion for an objective, and (d) demonstrating long-term retention of previous material. In addition, tokens were given for scores over the criterion on both the mastery and retention tests. The actual token formulas are presented in Table 3.

TABLE 3

Incentive Token Formulas

Mastery	Time
1 token for each quarter day saved on TAT	50 tokens for reaching criterion 1 token for each percentage point above criterion
2 tokens for each hour saved on TACT	25 tokens for retention criterion 1 token for each percentage point above retention criterion

If all or any part of the time a student saved on an instructional module also happened to be the course time savings, he received tokens for both categories. However, the reason for having tokens for both types of time savings is that when a student was behind in a course, even to a point of little hope for recouping, it would still be possible to gain tokens by saving time on individual instructional modules. Since savings in the course time was the ultimate goal, twice as many tokens were provided for saving time in the course as opposed to modules.

Twice as many tokens could also be obtained for reaching criterion on mastery as opposed to retention. It was assumed that this would require a student to utilize a strategy for more initial learning, than if an equal number of tokens were provided for mastery and rention or retention received more tokens. The retention test was given for all material previous to the current lesson, and followed the current lesson. Measurement of retention in the simulation therefore covered days or even weeks of intervening learning activities in a course as well as a student's general life. For any given instructional module seventy tokens could be gained maximum for mastery. As students were presented items either in acquisition or test phases, the values of the items presented totaled seventy tokens. The actual number of tokens for an information item was determined according to an individual student's pretest scores. Three performance objectives were allowed for each instructional module and each objective was weighted according to the student's component score for the objective on a pretest. For example, if each of the three objectives had equal weight according to the instructor's goals, and the student answered correctly twenty percent, thirty percent, and fifty percent of the three test components, then the weights for the objectives could be determined by $.8x + .7x + .5x = 70$. The tokens for the first objective item set would be $.8x$; $.7x$ for the second item set; and .5x for the third. This assumes an equal number of items (x/3) in each objective set. Other weighting techniques could be used with this method only meant to be exemplary. The items for each objective item set would then be distributed token units weighted on an objective. In addition, if a student was assigned treatment four he would receive remedial diagnosis, for which further breakdown of the appropriate values for items was determined and related to the student during the instruction to follow. This allowed the use of relative reinforcement in modulating the student's attention and acquisition processes, such that control processes would be more available to those information items most needed by the student.

The incentive menu list did not directly influence the simulation. The list could consist of any items. For purposes of conceptualization at least the following were considered to be part of the menu:

1. grade of A, B, C, or I
2. number of credits for the course
   (basic course = 4 credits; 1 extra credit could be obtained)
3. entry into EDR 539, <u>Advanced Topics in Computers in Education</u>.

A student would have to acquire various predetermined levels of incentive tokens to achieve any of these menu items and these levels would be part of the menu list.

The reinforcers are most typically described as incentives or motivators in the sense of the association hypothesis of reinforcement. As noted earlier in this section (p.25), it was not a direct concern of this paper to discuss whether the source of control for secondary reinforcement was a conditioning process or better fit under another hypothesis. However, in addition to the token values of items being presented with the items, it was considered that feedback was also presented. Feedback is usually considered an information reinforcer, thus two types of reinforcers may be within the simulation, both playing the same role as modulators of information storage and transfer.

Computer-Based Learning Environment

The learning environment for the adaptive instructional system is computer based. In order to acquire and analyze measurement information with which to select alternative instructional treatments, and to allow, where appropriate, control of the information processing and contingencies of reinforcement embedded in the treatments, the rapid processing of computers is required. Figure 2 represents the functions for such a computer-based system. The functions include: (a) acquisition of measurement data, (b) analysis of measurement data, (c) decision-making, (d) presentation and control of learning tasks, and (e) test and evaluation.

The use of these computers to perform functions stated above is generally termed computer-managed instruction (CMI). CMI is differentiated from computer-assisted instruction (CAI) in that in CMI the computer is used to make decisions about a student's instructional progress and to manage the instructional sequence for the student. CAI, on the other hand, is used to actually present instructional material and acquire student responses to that material. CMI is the diagnosis and prescription of instruction, whereas CAI may actually be the instruction prescribed.

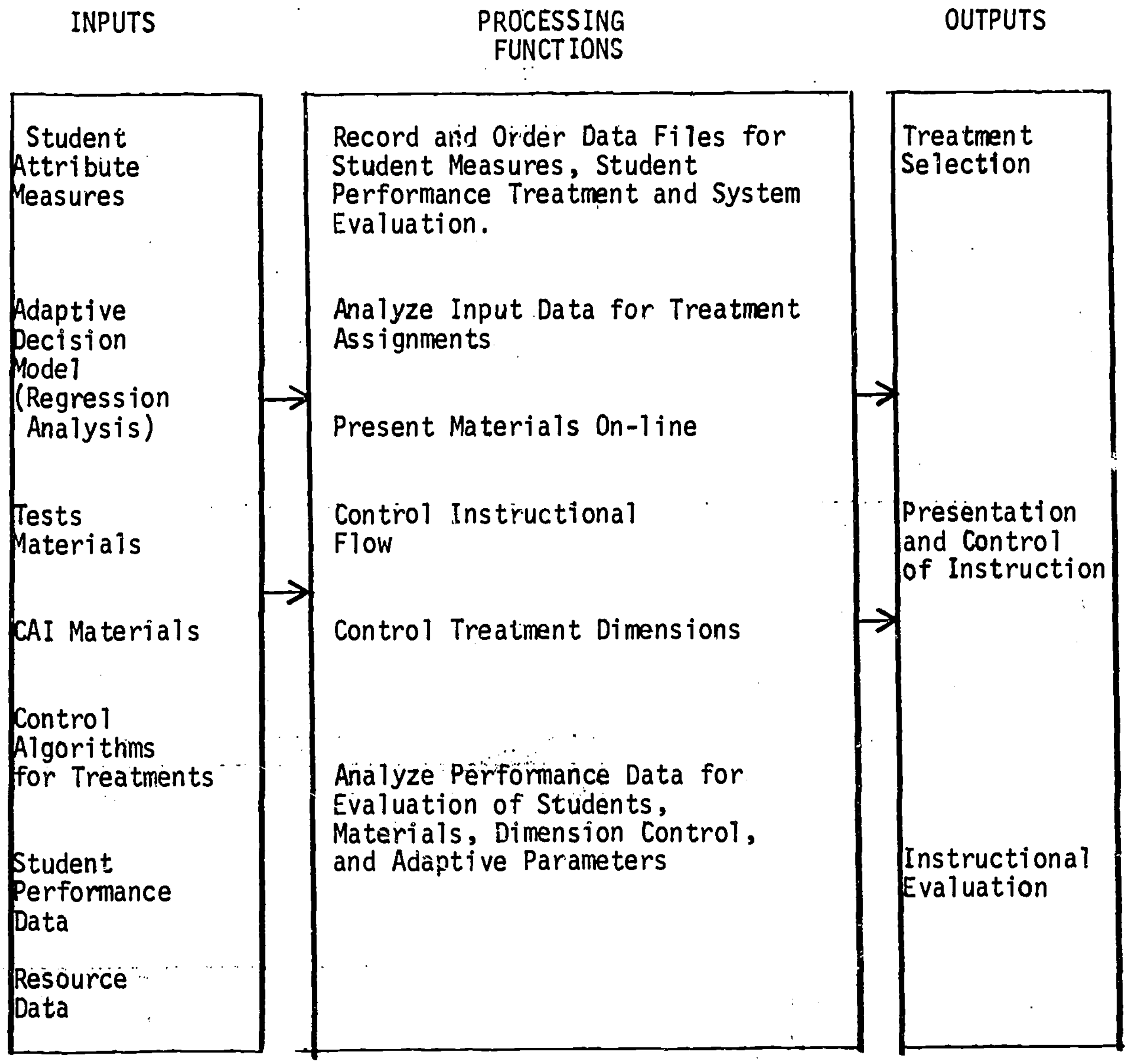

Figure 2.--Computer-Based Function for Adaptive Instruction

In this simulation much of the material is considered CAI, but all instruction is considreed under CMI control.

Learning environment interactions. Much of the learning environment described may be difficult to conceptualize operationally without more concrete demonstration. The visible results of the simulation (the results which directly accrue from execution of the computer programs) are reports. These reports represent the interactions of students to: (a) other students, (b) instructors, and (c) the adaptive instructional system. The reports also provide visibility of instructor interactions with the learning environment. Finally, the reports demonstrate the considerations of those who must monitor and evaluate the learning environment such as curriculum designers, researchers, and learning resource managers.

Student interactions and reports. Since the student, in the course described, would encounter an instructional system quite different from the usual, an orientation session would be necessary. The orientation would include discussion of student/computer interactions such as the expected use of computer prescriptions to the student and the use of computer terminals for testing and instruction. In addition, the instructor would describe the self-paced structure of the course, the variability of instruction assigned to students, and the availability of incentives.

The first encounter of the student with the computer system would probably be on-line interactive testing to acquire measures for use in the computer-based adaptive model. Such measures would include pretests, organization measures, and internal/external reinforcement control measures. Since these tests can be performed on-line, the results would immediately be available to the computer data files and the student could begin instruction.

The first prescription in the simulation came to the student as represented in Figure 3. Four parts of this report to the student are evident. The first part, the heading, identifies the student, course, instructional unit, instructor, and date. The second component of the report is a plot of TATs and TACTs which is designed to provide the student with a visual representation of the targeted times which must be bettered to gain incentive tokens. The graph also shows the student's progress in meeting the targeted times. The dotted line in the graph represents the start and stop times for each unit attempted. All five units are represented in this manner along the ordinate axis with time shown along the abscissa. Note that while incentives were acquired by hours saved, it was necessary to plot the graph in half days because of limited printing device space.

Since the prescription report in Figure 3 is for Unit 1, the student has not yet completed any instruction and no progress is shown. In addition, the TATs and TACTs for each unit are at the exact same points. This is because TATs are plotted from the point of the expected completion of the previous unit or its actual completion, whichever is appropriate, and TACTs are merely cumulative TATs. As the student progressed, TACTs remained the same on the plot but TATs, in most cases, change position since the completion date for a unit by its TAT is relative to the completion date of the previous unit.

```
    NAME        SECURITY    COURSE      UNIT        INSTRUCTOR      DATE
Curles, J.S.     250557     EDR537        1     EDR. Instructor    1/5/73

    PROGRESS TO DATE

U   5                           ---------
N   4                   -------
I   3            ------
T   2       -----
    1   ----
        0   5   10   15  20   25   30   35   40
                    TIME (HALF DAYS)
TAT=X       TACT=0

                    TOKENS OBTAINED TO DATE

    BY TIME                 BY TIME                 MASTERY     RETENTION
SAVING IN COURSE       SAVINGS IN UNITS
       0                       0                   0            0

                    DIAGNOSIS AND PRESCRIPTION

FOR THIS UNIT YOU SHOULD SIGN ON A TERMINAL WHERE FURTHER

INSTRUCTIONS WILL BE PROVIDED.  YOUR INSTRUCTIONS WILL

ALL BE COMPUTER DIRECTED.  THE TARGETED TIME FOR COMPLE-

TION OF UNIT 1 IS EIGHT QUARTER DAYS.
```

Figure 3.--Student Report Prior to Unit 1

The next section of the report assigns the student to a particular treatment. In this case it was treatment 3. The student is also told the TAT for the unit. For purposes of the simulation the prescriptions were stated as:

1. Treatment 1 - YOU MAY CHOOSE ANY OF THE PRIMARY RESOURCES FOR STUDY IN THIS UNIT. THE TARGETED TIME FOR UNIT X IS YY.
2. Treatment 1 - READ THE PRIMARY REFERENCE FOR THIS UNIT. THE TARGETED TIME...
3. Treatment 3 and 4 - FOR THIS UNIT YOU SHOULD SIGN ON AT A TERMINAL WHERE FURTHER INSTRUCTIONS WILL BE PROVIDED. YOUR INSTRUCTION WILL BE ALL COMPUTER DIRECTED. THE TARGETED TIME IS...
4. Treatment 5 - FOR THIS UNIT YOU SHOULD SIGN ON TO A TERMINAL FOR INSTRUCTIONS. YOU MAY DO THIS NOW BY TYPING "N", OR ANY TIME LATER. YOU SHOULD START THE LESSON BEFORE YOUR ASSIGNED GROUP DISCUSSION. THE TARGETED TIME...

Immediately after completion of a lesson the student was provided with a diagnosis of success or failure as in Figure 4 and with a new prescription as in Figure 3. The new prescription had updated "progress to date" and "tokens obtained" sections. Treatment 3 was successful for student J. S. Curles. As seen in Figure 4 student Curles obtained incentive tokens for saving time in the unit and course, as well as passing the criterion on the mastery and retention tests. The numbers for incentive tokens obtained indicate 4 hours were saved both in the course and the unit resulting in 8 and 4 tokens respectively.

```
    NAME        SECURITY          COURSE      UNIT    INSTRUCTOR       DATE
CURLES,J.S.      250557           EDR537       1   ED R.INSTRUCTOR   1/5/73
STRATEGY BULLETIN
     (none)
DIAGNOSIS AND PRESCRIPTION
    YOU HAVE SUCCESSFULLY COMPLETED THIS UNIT
    YOUR INCENTIVE TOKENS ON THIS UNIT ARE:
        BY TIME                 BY TIME
    SAVINGS IN COURSE       SAVINGS IN UNIT     MASTERY    RETENTION    TOTAL
           8                       4             50/2       25/11        100
```

Figure 4.--Student Report After Unit 1

In addition, criterion was passed on both the mastery and retention tests. These were worth 50 and 25 tokens respectively. Finally, since the student scored over criterion on both tests, 1 token was acquired for each percentage point over criterion (2 and 11 tokens respectively).

For cases in the simulation where students did not pass, the diagnosis was as in the following example:

```
YOU WERE UNSUCCESSFUL ON THIS ATTEMPT.  YOUR SCORES WERE:

MASTERY     OBJECTIVE 1     OBJECTIVE 2     OBJECTIVE 3
  78%           76%             82%             76%
```

This message should provide a student with information as to where study is needed. In addition, a redistribution of the differential reinforcement magnitudes for objective item sets could be made. This was not realized at the time the simulation was developed and, therefore, was not done. It is assumed that such updating of reinforcement values would be more useful than the pretests scores. When students did fail, they would be expected to study in any way available to them and then to be retested. Thus, they could rerun the assigned treatment, utilize any primary or secondary resources, join the group discussions, or talk to the instructor. The simulation programs did not actually simulate what the student did after a failure except for generation of new mastery scores and times without regard to student activity.

In this particular example no strategy bulletins were issued. A strategy bulletin was intended to demonstrate how messages could be sent to the student to suggest different learning strategies or allow revision of teaching strategies. Such bulletins did occur throughout the simulation. The representative messages chosen and the associated conditions were as in Figure 5.

CONDITIONS	MESSAGE
Last attempt unsuccessful (Presented not more than 2 times per student)	You may need to reevaluate your strategy for saving time. Strive for mastery first.
Last two attempts unsuccessful	Please see the proctor to answer some questionnaires. This will take only ten minutes. You may need to take more time in your initial study.
Last three attempts unsuccessful	Please see the instructor for guidance on this unit
Over YAT (Once only per student)	The graph in the student report is meant to assist you in recording the results of your learning strategies. Note that the longer the time to complete a unit, the less tokens you receive in several categories.
Over TACT (Once only per student)	Your "progress to date" record shows you behind the course schedule and therefore losing incentive tokens. Try a strategy of arranging a block of time for study and test. Utilize any of the secondary resources which you might think helpful. The incentive token attainment is structured so that you are not penalized by your past performance. Only the current lesson counts.

Figure 5.--Strategy Bulletin Messages and Conditions

Figure 6 represents the reports to student Curles on unit 4 of the course. The prescription on this unit was treatment 1. This is the treatment allowing the most learner control. To be assigned this treatment at this point, it would be expected that the student had performed well previously. Such is the case as seen by the "progress to date" graph and the "tokens obtained" summary. Student Curles was saving time in the course, mastering the material, and retaining his mastery. Incentive tokens were provided for all of these. Further, it was not necessary at this point to control this student's information processing and reinforcement contingencies to the level of treatments 3, 4, or 5.

Instructional manager interaction and reports. The teacher in the adaptive learning environment is more appropriately called an instructional manager. The teacher no longer lectures all class members three times a week, tests all students on the same day, or evaluates each student relative to the others. Instead, some students in the simulation were considered to be provided instructor time as a result of a treatment 5 prescription, or unsuccessful attempts on any treatment; while others could have completed the course without ever seeing the instructor. The variability of needs for the instructor's intervention and pacing in the course, means that the instructor must manage student progress carefully.

Figure 7 represents results of the simulation on the last unit simulated. This report was generated for an instructor when all students had completed a unit. In reality, it would be desirable to initiate

```
    NAME       SECURITY    COURSE    UNIT      INSTRUCTOR     DATE
CURLES, J.S.     250557   EDR 537     4     EDR. INSTRUCTOR   1/23/73

DIAGNOSIS AND PRESCRIPTION (BEFORE LESSON)

YOU MAY CHOOSE ANY OF THE PRIMARY RESOURCES FOR STUDY IN

THIS UNIT.  THE TARGETED TIME FOR UNIT 4

QUARTER DAYS.

DIAGNOSIS AND PRESCRIPTION (AFTER LESSON)

YOU HAVE SUCCESSFULLY COMPLETED THIS UNIT.  YOUR INCENTIVE

TOKENS ON THIS UNIT ARE:

    BY TIME             BY TIME     MASTERY     RETENTION   TOTAL
SAVINGS IN COURSE SAVINGS IN UNITS
         26              13           50/4        25/19       137


PROGRESS TO DATE

5                                   X 0
4                   -----X 0
3             -----XO
2       -----X
1   ----X

    0    5    10    15    20    25    30    35    40    45    50
                        TIME (HALF DAYS)

TAT=X   TACT=0

TOKENS OBTAINED

     BY TIME                BY TIME     MASTERY   RETENTION  TOTAL
SAVINGS IN COURSE   SAVINGS IN UNITS
         66                   33        200/24      75/36     434
```

Figure 6.--Report to Student Curles on Unit 4

```
  INSTRUCTOR              COURSE              UNIT            DATE
EDR INSTRUCTOR           EDR 537               5             2/1/73

UNIT EVENTS

   SUMMARY

      TOTAL NUMBER STUDENTS = 20    MEAN CRITERION SCORE = 85.7 (RANGE= 80-90)
               PASS 1 FAILS =  4    MEAN RETENTION SCORE = 83.3 (RANGE= 75-97)
               PASS 2 FAILS =  1    MEAN TAT SCORE       = 15   (RANGE= 12-20)
                INCOMPLETES =  0    MEAN TACT SCORE      = 82   (RRANGE= 56-124)

   INDIVIDUAL RECORD
                                                                 INCENTIVE GAINS
NAME       TREATMENTS    TAT     TACT    MASTERY  RETENTION  TAT   TACT  MASTERY  RETENTION
                       SAVINGS  SAVINGS   SCORE     SCORE
PEARSON, M.    3          4        4        80        90      4      8     50/0     25/10
LOVE, U.L.     1          0        0        83        76      0      0     50/3      0/0
DALE, F.O.     4          0        0        87        87      0      0     50/7     25/7
   .           .          .        .         .         .      .      .      .         .
   .           .          .        .         .         .      .      .      .         .
   .           .          .        .         .         .      .      .      .         .
CURLES, J.S.   1          0        0        81        76      0      0     50/1      0/0

   CUMULATIVE EVENTS
                               MEAN         MEAN               INCENTIVE GAINS
  NAME       TAT     TACT    MASTERY     RETENTION   TAT     TACT     MASTERY     RETENTION
           SAVINGS SAVINGS    SCORE        SCORE
PEARSON,M.    25      25        92           86       25      50      250/58       100/33
LOVE, U.L.     0       0        87           90        0       0      250/35       100/52
DALE, F.O.     0       0        88           84        8       0      250/42       100/25
   .           .       .         .            .        .       .        .            .
   .           .       .         .            .        .       .        .            .
   .           .       .         .            .        .       .        .            .
CURLES, J.S.  33      33        87           87       33      52      250/37       100/39
```

FIGURE 7.--Instructional Manager Report for Unit 5

this report more often, especially when a student made an unsuccessful pass or took a large amount of time. There are four parts to the report. The first part identifies the instructor, the course, the unit and the date the report was generated. The second part summarizes the unit by identifying unsuccessful attempts and identifying the four performance types which are reinforced: mastery, retention, unit time (TAT), and course time (TACT). In the simulation, students were allowed three attempts at unit completion. If the third attempt was unsuccessful (labeled "incomplete" on the report) the student was directed to meet with the instructor. The student's name appeared on the instructional manager report directly under the number of incompletes occurred (none occurred in the example). It was considered that the instructor would, at this point, have to make a decision as to whether the student should go on in the course, be given an incomplete, or be given remediation. For the simulation, if a student failed three times to pass a unit, he was given fifty incentive tokens for mastery and allowed to proceed to the next unit.

The third part provides more information on the unit by giving details of each student's performance. For each student the prescribed treatment was identified. Associated with that prescription were the performance indices of time saved (in hours) and test scores on both mastery and retention scores. In addition, the number of incentive tokens for each reinforced behavior was listed. For mastery and retention the scores were shown by xx/yy to indicate the criterion tokens and over criterion tokens obtained, respectively.

While the second and third parts of the report describe the unit events, the last part details the cumulative performance. For each student the total time saved (in hours) and mean test scores are listed. The accumulated tokens for time and test performance are listed also.

Monitor and control reports. The third report type assumes that the environment will require specialists such as curriculum designers, media specialists, or environmental contingency designers. Of course, any or all of the functions may be carried out by the instructional manager. The information required for such functions must allow evaluation and accountability of the instructional system. Figure 8, Monitor and Control Report is derived from the simulation to demonstrate the information usage. The report has four parts. The first two parts are similar to the first two parts of the instructional managers report. They consist of headings identifying the course, unit, date, and instructor, and also a student summary of success or nonsuccess along with mean performance scores. The third and fourth parts are oriented toward treatment evaluation. Part 3, treatment selection summary, identifies the following information items for each treatment:

1. % prescribed - the percent of times the treatment was selected over all other treatments. In the example of unit 5, 20 treatment selections were made. Since treatment 1 was chosen three times it was prescribed 15% of the time.

2. % unavailable - the learning resources may receive highly variable usage in this instructional system, and it is important to know when a treatment was prescribed but would not be made available to a student

```
COURSE   UNIT    DATE    INSTRUCTOR
EDR 537   5     2/1/73  EDR. INSTRUCTOR

STUDENT SUMMARY

  TOTAL STUDENT=20         MEAN CRITERION SCORE = 85.7 (RANGE=80-95)
      PASS 1 FAILS= 4      MEAN RETENTION SCORE = 83.3 (RANGE=75-97)
      PASS 2 FAILS= 1      MEAN TAT SCORES      = 15   (RANGE=12-20)
      INCOMPLETES = 0      MEAN TACT SCORES     = 82   (RANGE=56-124)

TREATMENT SELECTION SUMMARY
                                                           MEAN            MEAN
  TREATMENT        % PRESCRIBED   % UNAVAILABLE   % MASTERY   TAT SAVINGS      RETENTION
      1                 15              0            33           0              85
      2                 10              0            50           2              76
      3                 35              0           100           2              86
      4                 25              0            80           1              90
      5                 15              0           100           1              92

SECONDARY RESOURCE UTILIZATION
             1-3    12-1    41-3    64-11    91-1    113-5    131-6   199-3
             2-7    13-1    43-1    65-8     92-3    114-1    142-5   201-1
             5-1    14-2    44-4    77-1     98-13   115-2    140-4
            10-3    22-7    50-1    86-1    111-4    119-1    182-2

TREATMENT ADAPTION SUMMARY
                                                                INCENTIVE GAINS
  TREATMENT   OBJECTIVE   DELAY    INTERTRIAL   LAG   TAT    TACT    MASTERY     RETENTION
               WEIGHTS
     1        25 35 10                               0      0        53          30
     2        25 30 15                               4      1        56           0
     3        20 31 19     12          6        9    4      8        50          35
     4        30 13 27     15          8        5    0      0        57          32
     5        15 26 29     15          9        6    3      0        58          39
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Figure 8.--Monitor and Control Report on Unit 5

because it was in use or inoperable (as in the case of audio/visual devices). In unit 5 no treatments were found to be unavailable. The rules used in the simulation provided that the next ranking treatment be selected when a higher selection was unavailable.

3. % mastery - percent mastery refers to the proportion of successful completions on the first pass. For example, on treatment 1 only one out of three students successfully completed the first pass. The other two students passed but on a second or third attempt, and may have used resources other than treatment 1 (e.g. secondary resources or other treatments).

4. Mean TAT savings - the mean time savings, in hours, for the treatment in the unit is listed.

5. Mean retention - the mean retention score received on a retention test after the treatment is listed. The score reflects retention of all previous instruction rather than the unit alone.

6. Secondary resource utilization - in the previous description of treatments, availability of secondary learning resources to augment the treatments was discussed. This section of the report details that usage. The number pairs on the report indicate the number assigned to the resources and the number of times a student checked it out for usage.

The last part of the report provides information about the adaption to individual students on the treatment dimensions. Each of the five treatments is listed and within each treatment the dimension values for each student assigned that treatment is detailed. Note that treatments 1 and 2 do not have the computer controlled dimensions. The dimensions represented on the unit 5 report are as follows:

1. Objective Weights- the "objective weights" columns indicate the number of incentive tokens distributed to each of the three behavioral objective item sets. The determination of these weights was described previously in the subsection on reinforcement. The values listed represent the differential reinforcement of the information units to be processed by the student.

2. Delay- the final delay of reinforcement is indicated in seconds. Initially this is considered to be determined by a baseline value for all students and would be updated by measures of latency, errors, or some other empirically relevant measure.

3. Intertrial- the final intertrial times are indicated in seconds on the report. As with delay of reinforcement, this is considered to be determined by a baseline value for all students and updated by measures taken on the student during instruction.

4. Lag- the lag, the number of intervening items between presentation of an information unit, is also considered to be set by a standard and updated on the basis of the student's performance. The final lag value was printed on the report. For all four of the above dimensions the simulated values were generated randomly since there is at present no data available on which to base them. They were programmed as part of the reports to illustrate the evaluation process of the learning environment. That is, the treatment dimension values would need to be monitored, evaluated, and possibly modified or replaced.

Finally, the report provides information related to the incentive token acquisition for time savings and meeting criterion on both the mastery and retention tests. Since these values are grouped by treatment they provide data on which to evaluate these variable dimensions.

SECTION 3

A COMPUTER-BASED ADAPTIVE INSTRUCTIONAL MODEL

A model is a representation of some aspect of real world events, event relationships, and processes. Models of teaching and learning have been in existence as long as man has been interested in the subject, and have usually taken the form of verbal statements called theories. The model presented here is quantitative. It allows the prediction of a student's performance on a specific task if given measures of the student's capacity for information processing and characteristics of reinforcement contingencies. The methods of treatment selection and treatment control, based on the student characteristics, defines the adaptive instructional model (AIM). The AIM used in the simulation is actually a two phase model in that one phase selects a treatment and a second phase controls treatment dimensions such as delay of reinforcement, lag, or intertrial times. This section describes the phase 1 AIM simulation method for selecting treatments. Discussion of Phase 2 simulation for controlling treatments follows that of Phase 1.

Ideally, it would be possible to so completely specify the functional relationships between the relevant, independent variables and student performance that the AIM would consist of deterministic statements of these relationships. Unfortunately, such completeness is not available at the present and it is necessary to turn to probabilistic models. In particular multiple linear regression lends techniques which are suitable for the operations of the adaptive instruction system.

Multiple linear regression techniques allow the definition of the straight line to best fit multiple variables. That is, the error of prediction (the distance between actual scores and predicted scores) of the equation is at a minimum. Regression techniques utilize least squares methods to regress actual scores toward central points along the best fit line.

It is of particular interest to examine the use of regression for multiple measures of information processing and associated reinforcement contingencies to predict an individual's performance on treatments. The treatments are considered to be designed on dimensions related to these measures. To illustrate, assume that a situation exists in which three treatments are available by which to instruct a student. The treatments vary on four dimensions: (a) delay of feedback, (b) delay of intertrial times, (c) reinforcement schedule, and (d) organization of materials. The treatment dimensions would, of course, have been studied empirically to determine appropriate types and ranges. When a new student enters the instruction his measures are input as data values to the regression equations generated for each of the three treatments. The coefficients in the regression equations (beta coefficients) would have been previously obtained by analysis of all previous students.

Figure 9 represents the procedures by which this hypothetical case would operate. The first stage is analysis and would determine the relevant measures pertaining to individualization of instruction. Stage

STAGE 1

ANALYSIS

Literature
Reviews

Pilot
Studies

Analysis

Determine
Relevant
Measures

STAGE 2

TREATMENT DESIGN

Equate
Measures to
Dimensions

Determine
Dimension Values

Determine
Dimension Controls

Design Treatments
Dimensioned on
Measures

STAGE 3

REGRESSION ANALYSIS

Gather Target
Population Samples

Develop Treatments

Generate Beta Weights
Weights With Target
Samples and Treatments

Generate Initial
Equations

Figure 9.--Development and Operation of a Regression-Based Adaptive Instructional Model

(continued)

(Figure 9 continued)

STAGE 4

OPERATIONS

Predict Treatments
Mastery and Time
Using Individual Scores

Rank Treatments
by Mastery and Time

Select Treatment
Over Criterion with Best Time
If Mastery Not Predicted
Pick Best Criterion Treatment

Select "Best"
Treatment
for Individual

STAGE 5

EVALUATION AND UPDATE

Evaluate Treatment
Effectiveness

Modify
as Needed

Evaluate Selection
Effectiveness

Modify
as Needed

Update
Equations

Reiterate
Instructional Design

Figure 9.--Development and Operation of a Regression-Based
Adaptive Instructional Model

two would be to design treatments dimensioned on these measures. The next stage would be to obtain a sample of the targeted population to obtain both attribute measures and performance measures on the treatments. The purpose of this sampling is to generate regression equations with beta coefficients for the target population. At this point the instruction can become fully operational and the regression equations may be used as adaptors of instruction.

During the operational stage each student's measures would be input to the regression equations for each of the treatments. Two equations would be developed for each treatment in order to predict criterion values for both mastery scores on tests and the time taken on instruction. If more than one treatment was predicted to achieve mastery then the one with the fastest predicted time would be chosen. If no treatments predicted mastery then the one with the highest predicted score would be selected. The actual performance results would of course be recorded and saved for stage five.

Stage five is the evaluation and update phase. The validity of the selections must be determined by success of prediction in order to modify the selection procedure, predictor variables or measures, and treatments. In addition, the beta weights for the regression equations must be updated with the new student data in order to add greater confidence and predictive power to the model.

The model used in the simulation is conceptualized to follow this same form. For each treatment two equations were generated, one for prediction of the mastery score on tests and one for time on instruction.

Fourteen predictor variables were used in addition to these two criterion variables. The predictor variables were:

Control and Strategy

1. Expectancy of Incentives
2. Subjective Organization Index
3. Anxiety
4. Cognitive Style Class
5. Epistemic Curiosity

Information Availability and Organization

6. Pretests on Content
7. Organization Tests
8. Score on Last Lesson
9. Retention Score
10. Average Scores on Previous Lessons

Contingencies of Reinforcement

11. Latencies History
12. Lag History
13. Intertrial History
14. Delay History

The predictors were drawn from the three categories used in the literature review earlier: (a) control and strategy, (b) information availability and organization, and (c) contingencies of reinforcement. These categories represent relevant courses of individual differences for instruction based on the student's information processing attributes and the reinforcement contingencies which may influence those processes.

The values of these variables were simulated in this project as were the regression equations themselves. While the simulation effort followed the procedures of Figure 9, in general, none of the empirical derivations indicated in that diagram were made. The regression equations were derived in the simulation by generating the basic form of equations for a specified number of predictor variables. Beta weights were generated by inputting the distribution characteristics of the data to a regression analysis. Similarly, student data were generated by specifying distribution characteristics to a regression analysis using the previously generated beta weights.

Phase 2 of the AIM controls dimensions within treatments. In the simulation this includes differential values of items (magnitude of reinforcement), lag (schedules of reinforcement), delay of reinforcement, and intertrial times. These are dimensions controlled in treatments 3, 4, or 5. For the purpose of the simulation these values were generated with normal distributions for input to treatments. In an actual system they must be empirically based to obtain baseline values. They must also be updated dynamically by some scheme which describes the relationship of each variable to student behavior in the given learning task.

It is this realm, determining relationships of treatment dimensions, that is the most critical to the adaptive instructional system. It is also where the research effort must be placed to achieve an AIM based on information processes and their contingencies of reinforcement.

The systems for controlling treatment dimensions must actually be one of the considerations in building the selection model. Specifically, stage two in Figure 9 cannot proceed without this information. The simulation passed over this step by simply generating scores on a treatment without regard to the treatment dimensions. Obviously, this part of the simulation does not model real life. The treatment dimensions represented in the simulation are only seen to be suggestive as to what may be useful.

Another aspect of the treatment controls is that the measures and dimensions are linked to student attributes which can be modified. That is, the student can learn to perform in certain ways during the treatment and this behavior so modified may be useful in other situations. Such might be the case in pacing a learner by controlling delay and intertrial times with positive contingencies such that he or she is no longer an "impulsive" learner as defined by Kagan (1965), and discussed as a learner measure earlier. The result may be that the dimension controls not only provide for more likelihood of succeeding on the specific treatment, but also provide adaptive modification of the learner's basic control processes.

SUMMARY AND CONCLUSIONS

The computer-based simulation of adaptive instruction was a method of problem construction with three main purposes. The first purpose was to introduce, as attributes for individualizing instruction, information processing variables with reinforcement contingencies. The second purpose was to model the learning environment resulting from the adaption of instruction based on such attributes. The third purpose was the preliminary specification of a computer-based adaptive instructional model. The results of the simulation, according to each purpose, are represented respectively in the three major sections of the paper.

One of the problems with much current instructional design utilizing the reinforcement paradigm is the epistemological lack of consideration of the capability of people to utilize plans and information. In so doing, a major source of individual differences is neglected. Recent articles in the Experimental Analysis of Behavior (EAB) literature have proposed such consideration of process variables be a subject of study in the EAB on a behavioral level (Kantor, 1970; Salzinger, 1973). Kantor has suggested that the EAB has such a reflex-generated interpretation of all psychological events that it has stopped short of studying "complex human behavior" such as remembering and thinking because of lack of techniques.

Salzinger, a major figure in behavioral modification, stated, "It behooves us, as good citizens of the science of psychology, to shirk no area of psychology as long as we can apply scientific method to it. The research in cognitive psychology is certainly interesting, on the whole well executed, and very challenging. It is well within the scope of a behavioristic approach. It merely awaits more attention from behaviorists." Salzinger questioned, however, whether the theoretical trip inside the organism is necessary. The approach in this paper relies heavily on a model of the internal environment of human memory. Whether it is necessary is a respectable question. It has been helpful in this case. It is also a fact that, despite the remarks of Kantor and Salzinger, radical behaviorists have not, at this point, found methods to conceptualize the same problems.

Cognitive psychology has, in turn, neglected EAB concerns until recently. These attempts by cognitive psychology to study reinforcement are the prime sources for the new aptitudes of the proposed adaptive system simulation. One of the long standing issues of reinforcement has been its definition by a law of effect via Thorndike versus a law of contiguity via Guthrie. As an offshoot of this, the recent attempts have been to view reinforcement as having both motivation and information components. Much of this research had its impetus in the issue of information effect versus a reward or incentive effect and has generated some useful r uggestive parts of the literature can be described at this time. Further, the simulation has not been professed as fully empirically grounded, but rather as a conceptual framework in which measures of information processing and reinforcement become relevant to instruction.

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