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ABSTRACT

Lawrence University in Wisconsin has developed a means whereby time-shared terminals may be effectively used in a small college. The manner in which the terminals are employed in an introductory psychology course is indicative of their general usefulness. The time-sharing system consists of a PDP-11/20 computer (RSTS system) with 8K of core storage and nine terminals. From 50 to 60 undergraduates can take the course in human learning at one time. The time-sharing system is used primarily in the laboratory portion of the course, performing the functions of 1) generating stimuli, 2) running experiments, and 3) running computer simulations for experiments dealing with visual searching, concept learning, continuous memory, and paired-associate learning. Evaluation shows that students feel the computerized labs are enjoyable and that they learned more because of the simulation models and the combination of data collection and simulation. Due to the absence of a suitable control group it is unknown if students actually learn better in these labs. (PB)

THE USE OF TIME-SHARED TERMINALS IN A HUMAN-LEARNING COURSE

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In a recent paper, Bert Green [1] has pointed out the great potential of time-shared terminals for psychology, particularly at relatively small institutions. The purpose of this paper is to describe the use of time-shared terminals at such an institution in an introductory level psychology course.

Lawrence University is a liberal arts college located in northeastern Wisconsin. The total enrollment is about 1500 undergraduate students. The Lawrence time-sharing system consists of a PDP-11/20 computer (RSTS system) with 8K cf core available to each user and nine terminals scattered about the campus. The psychology department has recently dropped the traditional introductory course from its curriculum and now offers introductory level courses in each of seven content areas; human learning, physiological psychology, conditioning, social psychology, history of psychology, perception, and personality. The human learning course has so far made the heaviest use of the time-sharing system, and it is this course which will be described.

The human learning course is a laboratory course having an enrollment of from 50 to 60 students. About half of these students have not had a prior psychology course and practically none of them have had prior computer experience. The time-sharing system is used primarily in the laboratory portion of the course, performing functions involved in the execution of four different lab experiments. The system has performed three main functions; it generates stimuli, it runs experiments, and it runs computer simulations. Each of these functions is described below in relation to the four lab experiments.

Stimulus Generation

The first experiment is a partial replication of the visual search study of Neisser [2,3]. Each student is shown 20 lists of letters, one list at a time. Each list is composed of 50 lines, 6 letters per line. The student's task is to scan the list from top to bottom searching for a particular target. There are two independent variables: the target to be found and the context in which it is embedded. The five targets are Q, Z, not Q, not Z, and Q or Z. The context in which the target is embedded is either angular or round. With the angular context, the non-target letters are drawn from the set E, I, M, V, W, X. With the round context, the non-target letters are drawn from the set C, D, G, O, R, U. The lists used in this experiment are generated and printed on a time-sharing terminal using a BASIC program which allows specification of the target and context desired. The program then prints the target location in each of 20 lists, and prints each of the 20 lists. Target lines and letter positions within a line are generated by a random process. When all 20 lists have been generated, they can easily be prepared for whatever display device is available.

Running Experiments

The second experiment is run on a time-shared terminal. This experiment is a partial replication of the concept-learning experiment of Levine [4]. Class members serve as subjects (Ss). Each S is first given a practice problem consisting of the presentation of a series of 8 stimulus pairs. Each stimulus in a pair is composed of a letter of the alphabet (K or T) which has a particular size (large or small), color (black or white), and position (left or right). A stimulus is thus defined by values on four dimensions: letter, size, color, and position. The stimuli in a pair differ on all four dimensions; e.g., if the stimulus LARGE BLACK T is located at the left, the stimulus at the right would be SMALL WHITE X. One of the dimension values (e.g., LARGE) is arbitrarily designated as the concept. S's task is to indicate which of the two stimuli presented on each trial is a positive instance of the concept. If it is the stimulus at the left, S types 1. If it is the stimulus at the right, S types 2. As an example, in the stimulus pair described above (LARGE BLACK T at the left, SMALL WHITE X at the right) if the concept is LARGE the correct response is 1. During the practice problem, each response is followed by feedback indicating whether the response was correct or wrong. When all trials of the practice problem have been completed, S is

asked to identify the concept by typing one of the eight dimension values. If the wrong dimension value is chosen, S is required to respond again. This is continued until the concept is correctly identified.

Following the practice problem, S receives a series of eight concept-learning problems. Each problem involves the presentation of 16 trials, each trial consisting of the presentation of stimulus pairs followed by S's response. The stimulus pairs are those used in the practice problem. Unlike the practice problem, however, feedback is not given after every response nor is S asked to identify the concept. The pattern of S's responses on non-feedback trials (blank trials) is used to indicate S's current hypothesis (H) about the identity of the concept. Figure 1 shows a sample sequence of four blank trials and illustrates the use of response patterns to identify S's hypothesis. The position of the dot indicates which of the two stimuli was designated a positive instance of the concept, the one on the left or the one on the right. The stimuli shown in Figure 1 are pictorial representations of stimuli which are presented in words (e.g. LARGE BLACK X) in the present experiment.

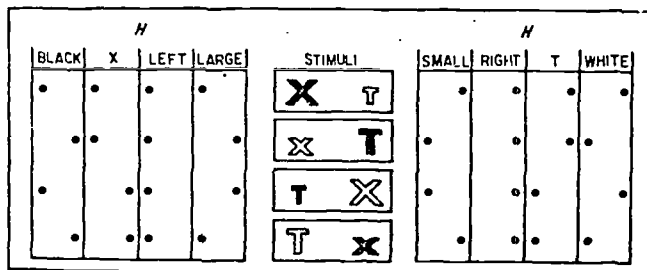


Figure 1. Eight patterns of choices corresponding to each of the eight Hs when the four stimulus pairs are presented on consecutive blank trials.

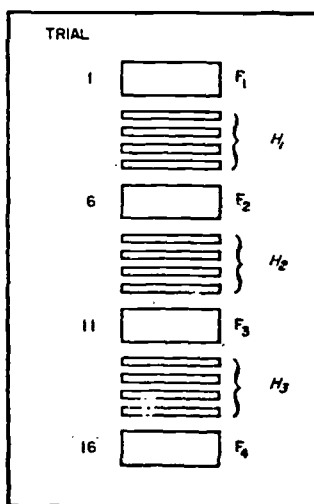


Figure 2. Schema of a 16-trial problem showing the feedback trials (F₁) on which E says "right" or "wrong" and the blank trials from which the Hs are inferred.

Figure 2 shows the arrangement of feedback and blank trials in a sixteen-trial problem. Trials 1, 6, 11, and 16 are feedback trials. Blank trials occur in four-trial groups at trials 2-5, 7-10, and 12-15. Each blank-trial group identifies S's hypothesis at a particular stage of learning the concept: H₁ is the hypothesis following the first feedback trial; H₂ is the hypothesis following the second feedback trial; H₃ is the hypothesis following the third feedback trial. The nature of the feedback on each feedback trial for each of the eight problems is predetermined and is shown in Figure 3. A "+" means that "CORRECT" is printed following S's response, and a "-" means that "WRONG" is printed following S's response.

When all 8 concept-learning problems have been completed, data describing S's performance and theoretical predictions are printed.

<u>Feedback</u> <u>Trial</u>	1	2	3	<u>Problem</u>		6	7	8
				4	5			
1	+	-	+	-	+	-	+	-
2	+	+	-	-	+	+	-	-
3	+	+	+	+	-	-	-	-
4	+	+	+	+	+	+	+	+

Figure. 3. Predetermined feedback on each feedback trial for each of the 8 problems. + = "CORRECT", - = "WRONG".

Computer Simulation

The time-sharing system performs two functions in the experiments described in this section. The first function is running the experiment. As in the experiment described in the preceding section, the system collects and reduces data from the student as S. The second function is the running of a computer simulation. A BASIC program is written which is intended to simulate human behavior, and the system collects and reduces data from the simulation program as S.

Two experiments are described in this section, each involving a different simulation. The first experiment to be described runs the student and a simulation of the buffer model of Atkinson and Shiffrin [5] on a continuous-memory task. The second experiment runs the student and a simulation of the SAL model of Hintzman [6] on a paired-associate task. Each experiment is described in detail below.

The continuous memory experiment

Class members serve as Ss, data being collected from each student by the computer time-sharing system. Stimuli are printed on the teletype and responses are made on the teletype keyboard. Each S is given 48 trials on a continuous-memory task. Each trial consists of a test phase and a study phase. In the test phase, which occurs before the study phase in a particular trial, the word "TEST" is printed above a two-digit number and a question mark. In the study phase, the word "STUDY" is printed above the same two-digit number and a letter of the alphabet. A sample sequence of trials is shown in Figure 4. The S's task is to try to remember the letter most recently paired with each of six two-digit numbers so that the correct letter can be typed following the question mark in the test phase of each trial. As an example, the letter "Q" should be typed in the test phase of Trial 3 of the trial sequence shown in Figure 4.

	TEST		TEST
	20?		31?
Trial 1		Trial 3	
	STUDY		STUDY
	20-P		31-G
	TEST		TEST
	31?		20?
Trial 2		Trial 4	
	STUDY		STUDY
	31-Q		20-T

Figure 4. A sample sequence of trials from the continuous-memory experiment.

The independent variable is the "lag" or the number of trials intervening between study and test of a particular number-letter pair. In the sample sequence of Figure 4, the lag for the test at Trial 3 is 0 and the lag for the test at Trial 4 is 2. The trial sequence used in this experiment is constructed such that 6 lags occur; 0, 2, 4, 6, 8, and 10. Each of these lags occur 6 times. The dependent variable is the probability of a correct response at each lag.

The buffer model of Atkinson and Shiffrin [5] postulates three components of the memory system; a sensory register (iconic storage), a short-term store (primary memory), and a long-term store (secondary memory).

All items (number-letter pairs) entering the system are assumed to enter through the sensory register. Decay of information from the sensory register is extremely rapid, total loss of stored information occurring in a second or less.

The contents of the short-term store are items which were taken from the sensory register (through an attention process) before they were lost. Once in the short-term store, items may enter the rehearsal buffer, a subcomponent of the short-term store. No information in the buffer is lost. Information is lost from the short-term store only when it is not in the rehearsal buffer. Whether or not a number-letter pair enters the buffer depends primarily on whether or not a number-letter pair with the same number is already in the buffer. If such is the case (e.g., 31-Q is the incoming item and 31-B is in the buffer), the incoming item will replace the similar item in the buffer (e.g., 31-Q will replace 31-B). If an item with the same number as the incoming number-letter pair is not in the buffer, the incoming item enters the buffer with probability α . If an item enters the buffer under this circumstance, it replaces an item already in the buffer. The particular item replaced is chosen at random. When an item fails to enter the buffer or is replaced, it is lost from the short-term store during the current trial.

It is assumed that information concerning an item is transferred from the short-term store to the long-term store at rate θ during every trial an item is in the rehearsal buffer. If an item is in the buffer for 5 trials, the amount of information in the long-term store would be 5θ . It is further assumed that information in the long-term store begins to decay on every trial when the item is not in the buffer. The rate of decay is such that information decreases by a constant proportion γ on each trial. If the item had been in the buffer for 5 trials and had been dropped from the buffer 3 trials before the test, the amount of information in the long-term store regarding the item would be $5\theta\gamma^3$.

So far three parameters of the buffer model have been defined; α , the probability of an item entering the buffer; θ , the rate of transfer of information to the long-term store; and γ , the proportion by which information decreases in the long-term store. A final parameter to be defined is r , the size of the buffer. The values of these four parameters determine the probability of a correct response at each lag. An item can be recalled from each of the three components of the memory system. It is assumed that because of the extremely rapid rate of decay, an item can be recalled from the sensory register only at lag 0. Recall from short-term store depends entirely on the item being in the rehearsal buffer. The probability of an item being in the buffer depends on the parameters r and α . If an item is not in the sensory register or in the short-term store, it can be recalled only from the long-term store. The probability of correct recall from long-term store is a function of all four parameters.

While the task is being presented to S , it is also being presented to a simulation of the Atkinson and Shiffrin [5] model. When the task is completed, data for both S and the model are printed, allowing a comparison of S 's performance with the predictions of the model. Atkinson and Shiffrin [5] estimate the following values for the four parameters: $r = 2$, $\alpha = .39$, $\theta = .40$, $\gamma = .93$. These are the parameter values used initially. When the student finishes the continuous memory task, he may change these values and rerun the simulation to see how the performance of the model is changed. In order to help the student understand what the simulation is doing, the contents of the buffer and the probability of retrieval from the long-term store are printed following the test phase of each trial.

The paired-associate learning experiment

This experiment serves two functions: (1) it demonstrates an experimental analogy of the learning of morphological rules [7]; and (2) it demonstrates the discrimination-net model for paired-associate learning [6].

Class members serve as S s, data being collected from each student by the computer time-sharing system. Each S is given trials of practice on a paired-associate list in which two-digit numbers are stimuli and two-letter bigrams are responses. Each trial consists of a study phase and a test phase. In the study phase, the word "STUDY" is printed followed by the successive presentation of number-letter pairs. Each pair is presented for three seconds. In the test phase, the word "TEST" is printed followed by the successive presentation of number stimuli. Upon the presentation of each stimulus, the S is required to type the response associated with the stimulus.

stimuli are paired with responses according to a rule which is best understood through reference to Table 1. Stimuli are the numbers 61 to 64, 71 to 74, 81 to 84, and 91 to 94. As can be seen in the table, if the first digit of the stimulus is 6, 7, 8, or 9, the first letter in the response is V, H, R, or X, respectively. If the second digit of the stimulus is 1, 2, 3, or 4, the second letter of the response is M, F, G, or K, respectively.

Table 1

Stimulus-Response Pairings

Stimuli (1st digit)	Stimuli (2nd digit)			
	1	2	3	4
6	VM	VF	VG	VK
7	HM	HF (PC)	HG	HK
8	RM	RF	RG	RK
9	XM	XF	XG	XK (WS)

Fourteen of the 16 stimulus-response pairings used in this experiment follow the rule described above. These 14 pairs are designated "regular" pairs. The two pairs which do not follow this rule, designated "irregular" pairs, are 72-PC and 94-WS. Only 12 of the 14 pairs are presented during the study phase. These 12 are designated "presented regular" pairs. The two pairs which are not presented during the study phase (61-VM and 83-RG) are designated "omitted regular" pairs. The two irregular pairs are each presented twice during the study phase. With the 12 presented regular pairs and the double presentation of the 2 irregular pairs, 16 stimulus-response pairs are presented during the study phase. All 16 stimuli are presented during the test phase. Trials continue until a correct response is made to each of the 16 stimuli presented during the test phase of a trial. When this criterion is met, the machine attempts to learn the list using a simulation based on the Hintzman [6] discrimination-net model.

Morphological Rule learning.--Ervin [8] has found that children's acquisition of past tense inflections for verbs goes through a very peculiar series of stages. The first verbs which are correctly inflected are the irregular verbs, verbs for which no general rule can be used to produce the correct past-tense form (e.g., "came", "ran", "did"). The child then learns the correct inflections for regular verbs, verbs for which there is a general rule which produces the correct inflection (e.g., "kissed", "hugged", "loved"). At this point, the child begins to apply regular inflections to the irregular verbs (e.g., "comed", "runned", "doed"). The child is apparently overgeneralizing the regular rule to irregular verbs.

The present experiment attempts to produce the same type of behavior in adults using a paired-associate list in which a rule can be used to generate the response from the stimulus for some pairs (regular pairs) but not for others (irregular pairs). The irregular pairs are presented more frequently than the regular pairs (irregular verbs occur with greater frequency than regular verbs) and should, therefore, be learned more quickly. As the presented regular pairs are learned, the rule relating stimuli to responses will eventually be noticed. When this rule is noticed, correct responses should begin to be made to the stimuli of the omitted regular pairs. Overgeneralization errors should then be made on the irregular pairs (e.g., 72-HF, 94-XK).

The discrimination-net model.--Hintzman [6] describes a model for paired-associate learning in which the primary process in learning is stimulus discrimination. This process is represented in the model by a discrimination net consisting of a hierarchy of binary choice points or test nodes. The test nodes contain tests for the presence of a particular item in a particular position of the input stimulus. A sample discrimination net is shown in Figure 5. The first test node tests for the presence of "X" in the first position of the stimulus. If the result of this test is positive ("X" is present), the next test is for the presence of "F" at the second position of the stimulus. If the result is positive, a terminal or end node is reached which contains the response to the input stimulus. The net shown in Figure 5 would make no errors on the paired-associate list: XBN-1, RGP-2, XFM-3, XQL-4. The model learns by adding new test nodes. If the net shown in Figure 5 received the pair LCS-5, the existing net would produce "2" as a response. Since this response is incorrect, a new node must be added. The terminal node containing "2" is replaced by a test node looking for the presence of "L" in the first position of the stimulus. A positive outcome for this test leads to a terminal node containing "5". A negative outcome leads to a terminal node containing "2". The new net is shown in Figure 6. The choice of letters for

new tests proceeds from left to right. If a test of the first letter does not lead to the correct response, a test is made on the second letter. If this test does not lead to the correct response, a test node is added which tests for the presence of the third letter.

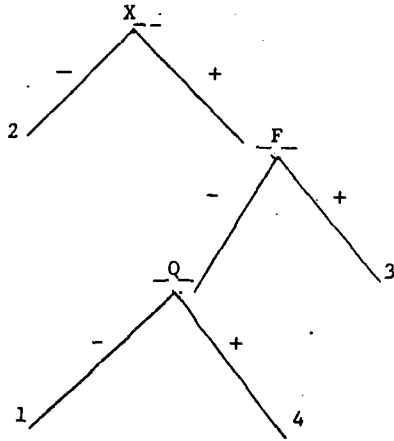


Figure 5. A discrimination net which performs without error on the list: XBN-1, RGP-2, XGM-3, XQL-4.

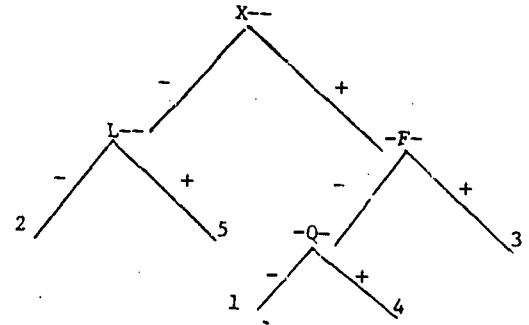


Figure 6. A discrimination net which performs without error on the list: XMN-1, RGP-2, XFM-3, XQL-4, LCS-5.

When the machine attempts to learn the list in this experiment the study and test phases are printed just as they were when the student was learning the list. The responses in the test phase are, of course, made by the machine. During the study phase, the machine builds a discrimination net, adding and changing nodes as needed with the presentation of each new pair. When the study phase is completed, the machine prints its net in the format shown in Figure 7. The net is organized according to lines. At each line is either a test node or a terminal node. A line contains a test node if the entries in the "Pos'n", "Pos.", and "Neg." columns contain non-zero values. A line contains a terminal node if the entries in those columns are zero. The first line of Figure 7 contains a test node which tests for the presence of "X" at position ("Pos'n") 1. If the outcome is positive ("Pos.") we go to line 2. If the outcome is negative ("Neg.") we go to line 3. As can be seen, the net in Figure 7 is identical to that in figure 5. Only the format is different. The machine uses the net formed during the study phase to respond during the test phase.

Line	S/R	Pos'n	Pos.	Neg.
1	X	1	2	3
2	F	2	4	5
3	2	0	0	0
4	3	0	0	0
5	Q	2	6	7
6	4	0	0	0
7	1	0	0	0

Figure 7. The discrimination net produced by program PAL which performs without error on the list: XBN-1, RGP-2, XFM-3, XQL-4.

Evaluation

At the end of the course, each student was asked to evaluate the lab experiments by completing a four-item questionnaire. Each item of the questionnaire consisted of a statement regarding the use of the time-shared terminals in the course, and each student indicated whether he strongly agreed, agreed, disagreed, or strongly disagreed with the

statements. The statements and their response distributions are shown below. The data are percentages based on the responses of 56 students.

1. Using the computer to collect data probably helped me enjoy the labs a little more.

$\frac{SA}{25}$	$\frac{A}{57}$	$\frac{D}{11}$	$\frac{SD}{7}$
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2. Using the computer to demonstrate simulation models helped me understand the experiments.

$\frac{SA}{14}$	$\frac{A}{72}$	$\frac{D}{14}$	$\frac{SD}{0}$
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3. Combining data collection and generation of predicted data helped me understand the experiments.

$\frac{SA}{36}$	$\frac{A}{64}$	$\frac{D}{0}$	$\frac{SD}{0}$
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4. As a result of my lab experience I would like to learn more about computers and their uses.

$\frac{SA}{36}$	$\frac{A}{40}$	$\frac{D}{21}$	$\frac{SD}{3}$
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These results seem to indicate that the students enjoyed the computerized labs, and that they believed they learned more because of the simulation models and the combination of data collection and simulation. Whether the students actually do learn more from these labs is impossible to determine because of the absence of a suitable control group.

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