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AUTHOR	Judd, Wilson A.
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ABSTRACT

Research on which aspects of the instructional process are most appropriately placed under learner control is reviewed. The review covers representative experiments from the 1960's in brief and experiments at the University of Texas from 1970 to 1973 in more detail. Although it appears that learner control can be helpful in mainline computer-assisted instruction (CAI), the characteristics of its role have not yet been well defined. The research in general has been inconclusive, and further research should focus on individual differences in learner control. Few studies found the expected conclusion that learner control improves student attitudes; however, one study found that learner-control students have lower scores on a state anxiety scale. Future research will hopefully determine the conditions under which learner control would reduce student anxiety. Since learner control is not as simple an instructional treatment as was first imagined; well controlled laboratory tests, rather than extensive instructional sequences seem appropriate for the study of conditions under which learner control is appropriate in CAI. (JK)

THE UNIVERSITY OF TEXAS AT AUSTIN

Computer Assisted Instruction Laboratory

AUSTIN

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Learner-Controlled

Computer-Assisted Instruction

by

Wilson A. Judd

The University of Texas at Austin

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In conventional classroom instruction, the teacher may be viewed as an interface between the student and the information he is to learn. Unfortunately, because of the many constraints on the classroom teacher, she is often considered to be a very poor interface. Nelson (1970) has symbolized the role of the teacher as a brick wall between the student and the subject matter, preventing the student from having more than very limited access to the subject and only minute control over the means by which information is presented.

The computer is viewed by many educators as a powerful tool for individualizing instruction and thus alleviating this problem. However, the degree to which computer-based instruction can be adapted to individual students is limited by the program author's ability to determine the current, momentary state of the student's level of knowledge and interest. In my own work as an instructional designer, I have been frustrated by my limited ability to predict which stimulus to present at any given moment, given the very tenuous data available regarding the student's current learning state. A second, perhaps more serious, limitation concerns motivation. While a student may be very interested in exploring a particular topic in depth at some given moment, the sequence of instruction, derived from generalized instructional design considerations, may dictate that the topic not be covered until much later in the program. The program author cannot anticipate a particular student's interest with any degree of accuracy, nor is the student normally provided with a means of requesting more information on a subsequent topic. By the time the topic is treated, in the normal course of the program, the student's interest may well have been extinguished. In addressing this problem, Nelson (1970) claims that conventional computer-assisted instruction (CAI) provides no improvement at all over the regular classroom situation. He symbolizes the computer as playing a role identical to that of the classroom teacher: a brick wall between the student and the subject matter.

As a result of such considerations, considerable interest in the possibilities of learner-controlled or student-controlled CAI has developed. Many instructional applications of computers exist in which the student is in complete control of the computer, or at least in control of the information presented him. Instructional simulations, problem solving, and information retrieval systems are examples. Most of these situations occur, however, in what may be termed <u>adjunct</u> as opposed to <u>mainline</u> CAI: situations in which the computer program does not bear the primary responsibility for instruction. This paper's concern will be with learner-controlled CAI in situations in which the computer provides the primary or the only source of instruction. As is the case for conventional mainline CAI, the program author assumes that the student knows relatively little about the subject matter and there are specific objectives which the student is expected to master. Learner control differs from conventional CAI in that the student is given some degree of control over the means by which he is to learn the subject matter.

The question of interest concerns which aspects of the instructional process are most appropriately placed under learner control. The purpose of this paper is to review some of the research pertaining to this question. A number of earlier, representative studies will be described briefly and then experiments conducted at The University of Texas at Austin will be discussed in greater detail.

A Brief History of Research on Learner Control

Systematic research on learner-controlled instruction can be traced to two non-computer based studies by Mager (1961) and Mager and McCann (1961). Mager (1961) explored the effect of allowing the learner complete control over the sequence of instruction in a course in electronics. His six subjects had no previous training in electronics. They selected the materials to be studied and allocated time to each specific activity. Instructors were always available but they functioned only as information sources. Mager found that the students defined organizational patterns which were quite different from those imposed by previous instructors and which placed more emphasis on functional relationships.

The second study (Mager & McCann, 1961) attempted empirically to determine the relative efficiency of learner-controlled instructional sequencing as compared to instructor-defined sequencing. Six engineering trainees were given total control over the curriculum. They completed their training in three months, only half the time required for the instructor-controlled program. In a second phase of this study, six more engineering trainees were provided with a list of the terminal objectives for the course. When given the objectives and the freedom to control their curriculum, these students required only 7 1/2 weeks to complete their training. The authors concluded that the use of behavioral objectives and learner control greatly facilitated attainment of the terminal behavior. These results should be interpreted with some caution, however. The authors note that prior to the experiment, the training course was apparently quite poor. Both the instructor and the students were bored with the course. The students' proficiency was evaluated subjectively by the experimenter. Finally, the students, being new trainees, were in a highly-motivating environment.

Given the dramatic results reported, however, it is not surprising that learner control of sequence should be investigated in the context of CAI. One of the first CAI learner-control studies was conducted by Grubb (1969) in a context quite similar to that of Mager and McCann. His subjects were fifty mature, well-motivated IBM employees. The subject matter consisted of two topics in an elementary statistics course: measures of central tendency and measures of dispersion. Two versions of the course were created: a learner-control version which allowed the student to control the sequence in which material was presented, and a linear version with a single inflexible sequence. Subjects were randomly assigned to five experimental conditions: linear presentation in both units, linear presentation in the first unit and learner control in the second, learner control in the first and linear in the second, learner control in both units, and learner control in both units as well as control over the sequence of units.

Analysis of posttest results indicated that groups with learner control in both units scored significantly higher than did any of the groups administered one or more linear sequences. The two learner-control groups did not differ between themselves.

Dean (1969) contrasted learner control with a linear sequence in a computerized arithmetic practice module. Seventy-two different arithmetic practice problems in addition, subtraction, and multiplication were arranged in increasing order of difficulty. The subjects were 120 fourth, fifth, and sixth grade students. The group studying under linear or program control was presented a new problem type only after they completed five successful trials with the current problem type. The group studying under learner control determined the amount of practice for each problem type themselves. Averaging across all three grades, the learner-control subjects scored slightly higher on both the posttest and a retention test but the statistical significance of these differences, if any, was not reported. Performance within individual grades was also investigated. A significant difference favoring learner control ($p < .01$) was found between the retention test scores of the two groups of fourth graders. No differences were found for the fifth or sixth grade classes. The sixth graders, however, required much less time to complete the program under learner control than under the linear condition and did so without any reduction in posttest score.

Dean postulated that motivation differences were responsible for the different results obtained at the various grade levels. It was hypothesized that the fourth grade subjects were excited and eager at the prospect of a new experience while for the sixth grade subjects, such material was redundant and probably boring.

Newkirk (undated) used two versions of a computer program to teach the rudiments of the structure and language of the hypothetical CLIP computer. Her subjects were 26 volunteer computer science students. Half of the subjects proceeded through the content on a fixed, linear path, i.e., the program did not adapt in any way to the subject's performance or allow him to make any choices in relation to what material was presented. The other half of the subjects studied under learner control, i.e., they had complete freedom to select their own path through the material within each block. The subject studied only those frames which he considered necessary to master the topic. The learner-control group only had control within a block of instruction. The order of the blocks was fixed and the subject was required to pass a criterion question for each block. Upon completion of the program each subject completed a posttest and an attitude questionnaire. Two weeks later a retention test was administered.

Analysis of variance of the data from both the posttest and the retention test revealed no significant differences between the two groups with respect to posttest performance or responses to the attitude questionnaire. Paired t tests were also computed for each group to determine if there was a decrement between the posttest scores and the retention scores. No differences were found for the learner-control students but retention test scores were significantly lower than posttest scores for students who studied under the linear program ($p < .005$). Thus, although there was no difference in immediate recall, the learner-controlled strategies appeared to yield better retention.

Brown, Hansen, Thomas, and King (1970) investigated a variety of control conditions of which two are of particular interest: subject selection of the instructional media or sensory input device, and selection of instructional information load. Fifty-five university-level students were administered instruction in "patterns of curriculum organization." Under the learner-control conditions, three devices were available for presenting instructional materials: CRT terminals requiring light pen responses, typewriter terminals requiring keyboard responses, and a manually-operated audio tape player. The latter required written responses. After being familiarized with all devices, the learner-control subjects were allowed to select one device for their instruction.

The instructional materials for all devices were programmed at three levels of information load: terse, medium, and redundant. Again, the learner-control subjects were familiarized with the nature of the three levels and allowed to select the level which they preferred. Under the program-control condition, the instructional materials were presented on the CRT terminal at the medium level of redundancy.

Significant pre- to posttest improvement was observed for all groups but there were no significant differences between the learner- and program-control groups. No particular combination of conditions was significantly better than any other combination. The pattern of choices of information level which subjects made under learner control did indicate that they tended to select levels of information load which reduced the memory requirements for the particular instructional device which they were using. The authors suggested that the amount of information provided the student to guide his decisions may well be a critical variable and one which should be investigated in more detail.

Barnes (1970) used 214 students from grades eight to thirteen to study the effect of learner control on student performance in multiplication. Two variables were investigated: problem type, and the nature of the remedial feedback. Five problem types were created, differing in the number of digits in the multiplier and multiplicand (the range was 1 - 4). One-half of the subjects were assigned to a program-control group which received problems randomly selected from the five available types. Subjects in the learner-control group determined the problem type they wished to study by specifying the number of digits. The feedback provided for correct responses was constant for all subjects and consisted of a positive reinforcement such as "good" or "correct." The remedial feedback provided for incorrect responses was either active or passive. One-third of the subjects were assigned to active remediation which required the subject to respond by correctly solving the problem under the tutorial direction of the program. A second third of the subjects were assigned to passive remediation which merely presented the correct solution. The remaining subjects were allowed to determine the type of feedback they received on each problem.

Gain scores were computed for all subjects. An analysis of variance of the data indicated that neither problem type, type of remedial feedback, nor their interaction resulted in significant differences in gain scores. Barnes postulated that lack of readiness was an important confounding variable in this study. Subjects must be capable of making decisions which affect their learning if learner control is to be of value. Again, the importance of motivational factors was discussed.

Although not directly concerned with learner-controlled CAI, a series of experiments reported by Pask (1969) raises questions related to the potential effectiveness of student control over instruction. Pask has suggested that students are not aware of their own particular pattern of competencies and that when given a choice the student is not likely to select an instructional strategy which is consistent with his abilities. Pask studied a difficult problem-solving situation in which subjects were presented with a sequence of four variable visual signals, and asked to solve each problem by making an appropriately-coded, four-component response.

Following a sequence of experiments in which problems were solved in a free learning situation, four distinct learning strategies were identified. Of these four strategies, only two resulted in successful learning. Furthermore, these two strategies placed demands on very different abilities. It was found that subjects who were adept at one strategy were unlikely to be successful employing the other. Of the twenty-six subjects run in the free learning situation, few were able to learn to solve the problems. Those who did learn required a mean of 575 trials. For the most part, subjects selected one of the two inappropriate strategies or, if they selected one of the two appropriate strategies, failed to select the strategy consistent with their abilities. Pask then developed a conversational instructional program which attempted to match the appropriate instructional strategy to the subject's abilities. Under these conditions subjects learned to solve the problems in approximately half the number of trials required by those few subjects who did reach solution under the free learning conditions.

Learner-Control Research at The University of Texas at Austin CAI Laboratory

Learner Control Over Sequence

At The University of Texas at Austin, the investigation of learner control began with a study of control over sequence of instruction (Olivier, 1971). The learning task selected for the experiment was an artificial science. This task provided a means of employing relatively meaningful materials while maintaining experimental control. The task was easy to learn and the subjects had no previous experience with the materials. University students were assigned to six treatment conditions. For the purposes of this paper, only three of the groups, each containing 52 subjects, will be considered. These were (1) a forced group, who were directed through the materials in the sequence dictated by a task analysis of the subject matter; (2) a learner-control group, who determined their own sequence through the material; and (3) a yoked group, the members of which were randomly paired with subjects in the learner-control group and given the sequence selected by those subjects.

Posttest performance was evaluated with respect to the degree to which subjects deviated from the presumably optimal sequence defined by the task analysis. It had been hypothesized that posttest performance would be reduced as the subject's actual sequence deviated from the optimal sequence and that the performance of the learner-control subjects would exceed that of the subjects yoked to them. No obvious decrement in performance was found, however, as a subject's path deviated from the optimal sequence and the performance level of the learner-control subjects was actually found to be inferior to that of the yoked subjects. It was also hypothesized that learner control would result in more favorable responses on an interest questionnaire. Again, this was not found to be the case. It was concluded that since learner control of sequence failed to produce any increase in either performance or stated interest, it had no obvious advantage over a predetermined sequence.

The second and third learner-control studies conducted by the CAI Laboratory were done in the context of a program of instruction in precalculus mathematics designed to include a number of learner-control options (Smith & Gregory, 1970). The program, entitled MATH-S, treats three topics in a sequence of 29 modules: 12 in Exponents, 12 in Logarithms, and 5 in Dimensional Analysis. When a student begins the program, he is presented with a Table of Contents on the cathode ray tube (CRT) display which allows him to make increasingly specific selections of course material. For instance, his first choice is between the areas of Exponents, Logarithms, and Dimensional Analysis. If he selects Exponents, he can then choose between segments concerning the Definition of Exponents, the Definition of Scientific Notation, and the Laws of Exponents. After making his selection, he is shown the list of skills assumed to be prerequisite to that segment. If, after seeing the prerequisites, the student does not believe that he is adequately prepared, he may select another segment or another area from the Table of Contents. If the student decides to continue and has selected the segment on the Definition of Exponents, he then indicates which of the following modules he wishes to study: Positive Integral Exponents, Zero Exponents, or Rational Number Exponents.

On beginning a specific module, Positive Integral Exponents, for example, the student is given a five-item diagnostic pretest over the concepts in the module. After completing the test, he is given his score. If the student answers all test items correctly, he is told that he has demonstrated proficiency in that area. If he did not answer all of the items correctly, the student is advised that his score indicates a weakness in the area. Whether or not he studies the instructional material, however, is the student's decision.

Within instructional modules, the rules, concepts and corresponding examples are presented on the CRT and supplemented by displays on the image projector. Following each expository segment, the student is given a number of practice problems, where each problem contains one or more questions pertaining to a particular numeric expression. The numeric values in the expressions are selected or generated and a student can repeat each problem a number of times with different values and, hence, different solutions.

In the first of the two experiments conducted in the context of this program (Judd, Bunderson, & Bessent, 1970), alternate versions of the control routines were written to systematically eliminate the various learner-control options to allow experimental comparisons. Only one of these comparisons, that of learner versus program control over sequence and selection of material, will be discussed here since the other options were treated more systematically in a subsequent experiment, to be reported next. Under program control, the Table of Contents was eliminated and the subject's sequence through the material was fixed in what was considered to be the optimal order.

Subjects given learner control over the sequence and selection of instruction made significantly ($p < .02$) lower posttest scores than did program-control subjects in one of the three areas--Logarithms. Only trivial differences were found in the other two areas. It was noted that the learner-control subjects spent only one-half as much time working in the Logarithms area as did the program-control subjects (116 as opposed to 217 minutes). In contrast, learner-control subjects spent more time on the other two areas than did the program-control subjects. Logarithms was the most difficult area of study in the program and the area with which the students were the least familiar. The speculative conclusion was that subjects given control over the sequence and selection of material used that option to avoid the difficult material rather than to pursue it.

The results of examining the other variables considered in this experiment (learner control over the amount of practice within modules and over the decision of whether or not to study a particular topic, given a score on the diagnostic pretest) did not lead to any definite conclusions. Allowing learner control over the sequence of instruction made it impossible to maintain the desired degree of experimental control over the subject's actions with respect to these variables. Therefore, a modified replication of the experiment was run the following year using the same instructional program.

Learner Control vs. Response Sensitive Branching

In this second experiment (Judd, Bunderson, & Collier, in preparation) the order of presentation was fixed in the assumed optimal order for all treatments. Program and learner control were compared with respect to two specific instructional decisions, both concerning a subject's ability to evaluate his own performance. The two methods were evaluated in terms of student decisions and performance during the course of the program, posttest scores and responses on an attitude scale.

The first learner-control option investigated concerned the action taken following a diagnostic test with regard to whether or not the student studied the corresponding instructional module. Students with learner control on this variable were given their score on the test and advised as to whether they had or had not met the objective of that module. The student was then free to enter or skip the module, as he wished. Students under program control on this variable were routed into the module if they demonstrated less than perfect performance on the test. Otherwise, they were routed to the next test. On the assumption that subjects would be more tolerant of their own errors on the diagnostic test than would the program-control decision function, it was hypothesized that subjects given control over the number of modules studied would select fewer modules than would be assigned to the program-control subjects. No specific hypotheses were formed concerning posttest scores or responses to the attitude scale.

The second option investigated concerned the number of times students repeated each practice problem (with different numeric values) within the instructional modules. For students with learner control on this variable, each practice problem was repeated until the student indicated that he was ready to proceed to the next problem. Subjects under program control were required to make two errorless passes through a problem, answering all questions in the problem correctly. It was hypothesized that subjects would consider themselves to have mastered a problem prior to having completed two errorless solutions and that, therefore, subjects given learner control over the amount of practice would make fewer responses to each problem than would the program-control subjects. Again, no specific hypotheses were formed regarding posttest scores or responses to the attitude scale.

It was assumed that, in general, subjects would view program control as being more aversive than learner control. If this was the case, then subjects who were given the choice would be expected to avoid program-controlled instruction. Therefore, it was hypothesized that, given learner control over the selection of instructional modules, subjects who were given learner control within modules would select more modules for study than would subjects under program control within modules.

Finally, it was anticipated that subjects might need to learn to use the learner-control options appropriately and that, if so, differences in the students' use of the control options would be expected between the earlier and later parts of the program.

Subjects were drawn from introductory physics classes on the basis of pretest scores indicating deficiencies in the topics covered by the instruction. The Logarithms area was deleted from the program at the request of the course instructors. The complete experiment consisted of a two by two design: learner and program control in the diagnostic tests, and learner and program control within the instructional modules. Due to the fact that many of the subjects who completed the instruction on Exponents did not complete Dimensional Analysis, the two topics were treated separately statistically. Complete data were available for 97 subjects completing Exponents and 72 completing Exponents and Dimensional Analysis.

All subjects were administered a 43-item, multiple-choice pretest during a regular class period. Two parallel forms of the test were available and subjects were randomly assigned to Form A or B. At the time of the posttest, each subject was administered the alternative of his pretest form. Those scoring less than 85% on the pretest were strongly advised to take the program. Pretest scores were also used as a covariable in the data analysis. Subjects were randomly assigned to one of the four experimental treatments when they came to the laboratory for their first study session. When a subject completed his last work session, he filled out an attitude questionnaire. Group posttests were scheduled just prior to the end of the semester.

The dependent variable selected to evaluate within-program performance for the diagnostic test option was the number of modules which each student studied. The two groups did not differ in number of modules studied in the Exponents topic. As a supplemental analysis, the number of diagnostic tests failed by the two groups was contrasted. Learner-control subjects failed slightly more tests than did program-control students (3.96 as opposed to 3.45) but the difference was not significant. In Dimensional Analysis, following more experience with the control options, learner-control subjects elected to study significantly fewer modules than were assigned program-control subjects (1.67 as opposed to 2.89, $p < .0001$). This was despite the fact that learner-control subjects continued to fail at least as many diagnostic tests as did the program-control subjects (3.45 and 2.92, respectively, $p > .10$). Considering the analyses from both sections of the program, one sees that the learner-control subjects selected fewer failed modules for study. Although slight at first, this tendency increased with experience with the program.

Posttest scores were insensitive to the diagnostic test variable. There was no main effect in either Exponents (21.79 for learner control and 22.29 for program control) or Dimensional Analysis (9.13 and 8.95).

Only one of the 13 items on the attitude scale even tended to differentiate between diagnostic test learner- and program-control subjects. This item noted that different subjects had been given different degrees of control over the program and asked if the subject would rather have had more or less control. A chi-square test for the 84 students who completed the questionnaire indicated slightly more learner-control than program-control students wanted more control over the program ($p < .10$).

The dependent variable selected to evaluate within-program performance in the practice option was the student's mean number of responses per question. Learner-control subjects were found to have a somewhat higher number of responses per question (9.07) than program-control subjects (5.78) in Exponents. This difference approached significance ($p < .10$). The trend was much more pronounced in Dimensional Analysis with learner-control subjects having a mean of 10.75 responses per question as contrasted with a mean of 5.31 for the program-control subjects ($p = .0001$). Again, posttest scores were insensitive to these performance differences: 21.19 for learner control and 22.88 for program control in Exponents; 9.03 and 9.06 in Dimensional Analysis.

Only one item on the attitude scale differentiated between instructional learner- and program-control subjects. This item pointed out that the computer could "understand" the subject's answers only if they were entered in the correct form and asked if he found the program to be too restrictive. A chi-square test indicated that more learner-control than program-control students found the program to be too restrictive ($p < .02$).

It had been hypothesized that due to the relative aversiveness of program-controlled instruction, given learner control in diagnostic tests, subjects who also had learner control in instruction would select more modules for study than would subjects who had program control in instruction. Analysis of the data from these two groups found small differences in the anticipated direction in both Exponents (4.04 for learner control and 3.08 for program control) and Dimensional Analysis (1.79 and 1.53) but in neither case were the differences significant. It must be concluded that the assumed aversiveness of program-controlled instruction did not result in program-control students selecting fewer modules for study than their learner-control counterparts.

In the context of this particular program, learner control would appear to be a mixed blessing. After some experience with the program, subjects' decisions were apparently more efficient than decisions made by the branching algorithm with respect to whether or not to study instructional modules. Learner-control subjects studied fewer modules in Dimensional Analysis than were assigned to program-control subjects but had posttest scores which were just as high. Contrary to expectation, the prospect of being under program control in an instructional sequence did not deter subjects from selecting as many modules for study as were selected by subjects with learner control in instruction. With respect to decisions regarding the amount of practice in instructional modules, however, students were less efficient than the corresponding algorithm. Learner-control subjects expended significantly more effort in practice than did program-control subjects but posttest scores did not differ between groups. None of the presumed affective advantages of learner control were supported by subject responses to the attitude scale.

A consistent problem with this type of learner-control research concerns the limitations on attempting to generalize to other instructional programs. While learner control may prove to be more efficient than a particular branching algorithm, the difference may be due to the use of a poor algorithm rather than to any real advantages for learner control. A related problem concerns whether or not the variable over which the subject is given control is of any real instructional consequence. Finally, experience with the three studies described above indicated that research in the context of extensive instructional sequences raises serious problems of experimental control. The last experiment to be described represents an attempt to resolve these methodological problems.

Investigation of Learner Control in a Laboratory Task

The dependent variable of major interest in this experiment (Collier, Poynor, O'Neil, & Judd, 1973) concerned the affective advantages of learner control rather than performance differences. Specifically, state anxiety was measured by means of the five-item form of the state anxiety scale of the State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970).

The learning task consisted of a series of three multi-category conjunctive concept learning problems of increasing difficulty. In each problem, the subject was shown a series of stimuli on the CRT in which each stimulus consisted of four abstract symbols. He was told that each stimulus belonged to either class "A" or class "B" and that he was to determine the rule by which stimuli were assigned to classes. He responded to each stimulus by typing either "A" or "B" and was immediately told the correct classification. A subject was assumed to have learned the rule once he completed a long series of errorless trials--ten trials for each of the first two problems and sixteen trials for the third problem. On the basis of previous experience with such tasks, it was hypothesized that a subject's performance would be improved by providing him with memory support. In this instance, memory support consisted of displaying the two previous stimuli and their correct classifications while the current stimulus was present on the CRT.

Fifty-eight subjects drawn from an undergraduate education course were randomly assigned to one of three groups: an experimental group and two control groups. Subjects in the experimental group (LC-MS) were given learner control over memory support. That is the two previous stimuli and their correct classifications were displayed if the subject requested them. Two control groups were employed in order to demonstrate that memory support was a critical variable and to isolate the influence of learner control *per se*. The first control group (NMS) had no access to memory support, while memory support was always presented for the second (MS) control group.

Prior to being seated at the terminal, all subjects were administered the MA 3, a paper and pencil test of associative memory (French, Ekstrom, & Price, 1963). After being shown how to operate the terminal, but prior to the presentation of the first problem, subjects were administered an on-line version of the five-item state anxiety scale. The same scale was also administered following the completion of each problem. Performance was measured in terms of trials to criterion on each of the three problems.

It was hypothesized that if memory support was critical to the learning task, the performance of the MS subjects would exceed that of the NMS subjects. It was also anticipated that the performance of the LC-MS subjects would at least approach that of the MS group. If this was found to be the case, it was further hypothesized that, if learner control did indeed have affective advantages over program control, then the experimental group (LC-MS) would demonstrate lower state anxiety than would either of the two control groups.

No differences were found between the scores of the three groups on the memory ability test, the means being 20.6, 18.2, and 20.9 for the NMS, MS, and LC-MS subjects, respectively. Similarly, no differences were found between groups with respect to their scores on the first, pre-experimental anxiety test, the mean scores being 9.4, 11.0, and 10.2. The number of trials required to reach criterion for each of the three groups is shown in Table 1. The performance data were analyzed by means of linear regression (Bottenberg & Ward, 1963) in which memory ability was used as a co-variable.

TABLE 1

MEAN TRIALS TO CRITERION REQUIRED UNDER THE THREE EXPERIMENTAL CONDITIONS

	Concept Learning Problem Number		
	1	2	3
No Memory Support (NMS)	30.2	30.6	77.8
Memory Support (MS)	18.5	14.2	51.4
Learner-Controlled Memory Support (LC-MS)	19.1	11.0	41.1

Significant differences in performance were found between groups on all three problems (p = .003, .002, and .013 for problems 1, 2, and 3, respectively). It is obvious from the data that memory support did facilitate performance. Subjects in the MS group required substantially fewer trials to reach criterion than did the NMS group on each problem. It may be concluded, therefore, that the experimental group did have control over a relevant instructional variable. In addition, learner-control subjects learned the concepts in as few or fewer trials than were required by the MS group. Differences among these three groups were not significant.

The mean anxiety scores across the three problems were 10.6 for the NMS subjects, 10.4 for the MS subjects, and 8.3 for the LC-MS subjects. These scores were found to be significantly different by analysis of variance ($p = .046$).

As had been hypothesized, while memory support had a pronounced facilitating effect on performance, it did not, by itself, reduce the subjects' anxiety concerning the task. Giving subjects control over that same memory support did reduce their anxiety.

This experiment yielded another result of some interest. There has been a question as to whether students require extensive practice to learn to use learner control effectively. Data from this experiment suggests that this is not always the case. When a learner-control subject requested memory support, there was a one- or two-second delay before the previous stimuli were displayed. Thus, it cost the subject some time to ask for memory support. In examining the data of the experimental, LC-MS group, it was noted that subjects requested memory support much less often once they began the series of errorless trials which defined problem solution. Examining the data from the third problem more closely, it was found that prior to a subject's trial of last error, the probability of requesting memory support was .61. Following the trial of last error, when subjects thought that they had learned the rule, the probability of memory support requests dropped to .13. It would appear that subjects quickly learned to discriminate between the conditions under which it was appropriate or inappropriate to request memory support.

Conclusions

It would appear that learner control can have a definite facilitating role in mainline CAI but the characteristics of that role have not yet been well defined. The research, in general, has been quite inconclusive. Individual differences in student response to learner control may be a critical factor. Specific training in the use of the control functions may well be required in many instances, although some students appear able to use learner control effectively with only a minimum of instruction. Further research should be directed toward individual differences in response to learner control and to the effects of instruction in the use of the control options.

Many of the authors cited have indicated that learner control was expected to result in more positive student motivation and attitudes. This would appear to be a logical expectation, and the greatest advantage of learner control may well be motivational. Few studies reported, however, have found attitudinal differences favoring learner control. The last experiment reported (Collier, et al., 1973) is an exception in that learner-control subjects were found to have lower scores on a state anxiety scale. It is noteworthy that this is the first reported use of a state anxiety measure as opposed to the usual use of an attitude scale. An obvious next step for research concerns the determination of the conditions under which learner control would be expected to reduce student anxiety. A related question concerns whether reduced anxiety could actually be expected to improve performance under these conditions.

Finally, it should be realized that learner control is not as simple an instructional treatment as was first imagined. A considerable amount of additional research will be required to determine the conditions under which learner control is appropriate in CAI, and well-controlled laboratory tasks would appear to be a more appropriate context for investigation than extensive instructional sequences.

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