Influence of Instructional Control and Learner Characteristics on Factual Recall and Procedural Learning from Interactive Video

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Abstract: This study examined the extent to which different levels of Instructional control and varied learner characteristics affected performance and time on task, using Interactive video materials to teach a biochemistry laboratory procedure. Subjects (n = 46) were randomly assigned to one of three treatment conditions. In the first (linear control), subjects proceeded through the instruction according to a pre-determined sequence, but were able to control pacing. The second condition (designer) had moderate levels of control and also Included the provision for pacing. In the final condition (learner) a complete array of sequence and pacing options were provided. Subjects were blocked as either high or low in academic ability according to their scores on the vocabulary section of the Nelson Denny Reading Test. A prbr knowledge test and Rotter's Internal-External Locus of Control Scale were administered as additional Indices of learner characteristics. A multrvariate analysis of variance established significant main effects for instructional control and academic ability, The results further indicated that linear control significantly outperformed learner control In facilitating recall of facts. Subjects in the linear conditbn, however, took significantly more time to complete the Instruction than those In the learner controlled treatment. No other significant differences were observed.

R6sum«: Dans cette etude, on a examine I'etendue sur laquelle dIfferents nlveaux de la direction educative et des divers caracteristiques de l'apprenant ont eu un effet sur la performance et le temps d'une tache, en utilisant du materiel video interactlf pour enselgner une procedure de laboratoire en biochimie. Les sujets (n=46) avaient ete assignes au hasard d une des trote conditions de traitement. Dans la premiere condition (le contrdle llnealre), les sujets ont accompli I'lnstruction selon une sequence predetermlnee, tout en etant capabtes de contrdler le rythme. La deuxieme condition (concepteur) avalt des niveaux de contrdle moderes disposal! aussl des moyens de controler le rythme. Dans la dernlere condition (apprenant), une gamme complete d'opttons de sequences et de regulations etalt fournle, L'aptltude academique des sujets fut classee, soit elevee ou basse, selon les points accordes lors du test Nelson Denny Reading Test dans la section vocabulalre. Un test anterteur sur les connalssances et un examen d I'echelle Rotter's Internal-External Locus of Control Scale furent dispenses pour connaitre davantage les caracterisitques des apprenants. Une analyse multlvarlee de variances demontra significatlvement les principaux effets d'une direction educative et d'une competence academique. Les resultats demontrerent en plus que le controle llneaire sur classe de facon significative Le controle de I'apprenant en faclIltant le rappel des faits. Cependent, les sujets en condition linealre prlrent consIderablement plus de temps 6 completer I'lnstruction que ceux qul etalent dans le traitement controle de I'apprenant. Aucune autre difference en importance fut observee.

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Currently among the most touted of the emerging instructional technologies, one which will undergo rapid development leading into the twenty-first century, is interactive video. It is held to be especially promising since it permits the convenient union of the modern microcomputer with its interactive capabilities and the visual expository features of video, while at the same time providing the opportunity to exploit a vast array of instructional designs and strategies. To date, and perhaps understandable because of its novelty, most of the emphasis in interactive video has been on refining its technical development, rather than on empirically validating strategies to improve its instructional effectiveness.

Where research has been conducted, as with the "standard" experimental design that pits a new technology against more traditional forms, much of it has been devoted to comparing interactive video with other methods of instruction, and particularly computer-aided instruction (Dalton, 1986; Henderson & Landesman, 1988-89; Holmgren, Dyer, Hilligoss, & Hillel, 1979-1980; Ketner, 1982; Lawrence & Price, 1987; Schroeder, 1982; Soled, Schore, Clark, Dunn & Oilman, 1989). The practical residue from these studies which might be of immediate use to instructional designers has been limited since the typical finding has been one of no significant differences. The underlying theme of this criticism suggests that research needs to be conducted within instructional innovations, and not between them (Reeves, 1986).

Particularly germane to interactive video is the issue of instructional control, and how design strategies can best be applied that are fully cognizant of individual learner characteristics and the particulars of the material to be taught. Instructional control refers to the degree to which a learner can control his or her path through a particular lesson. Design strategies can range from complete learner control at one extreme to complete program control at the other (Pawley, 1983). Learner characteristics are attributes such as age, academic ability, and prior knowledge which might have a discernable effect on the type of design strategy chosen. The immediate and most compelling rationale for undertaking this type of research is to provide some prescriptive guidelines as to who would best profit from what type of control strategy for which type of instructional task. This is further supported by Ross and Morrison (1989) who insist that research is needed that identifies learner control variables that are relevant and appropriate for different learners and tasks.

Most of the background literature on aspects relating to instructional control is derived from research into computer assisted instruction. And while much of it endorses the inclusion of mechanisms for learner control, the empirical evidence is mixed. In an earlier review, Steinberg (1977) noted that those studies examining learner control either found no differences or found learner-controlled subjects to be the poorest performers. Our current sense of the literature is that positive or negative findings with respect to learner versus program control is very much bound up with student ability and type of instruction. For example, several studies have found program control strategies to be significantly superior to learner controlled treatments in learning mathematical skills (Fisher, Blackwell, Garcia & Greene, 1975; Judd,1972; Ross & Rakow, 1981), and parts and operations of the heart (Belland, Taylor, Canelos, Dwyer & Baker, 1985). Conversely, learner control treatments were significantly superior to program control treatments in mastering computer assisted instruction (Campanizzi, 1978), science education (Kinzie, Sullivan, Beyard, Berdel & Haas, 1987), and cardiopulmonary resuscitation (Hannafin & Colamaio, 1987). And no significant differences were noted between the two strategies in acquiring advertising concepts (Klein & Keller, 1990) nor in preparing and administering intramuscular injections (Balson, Manning, Ebner & Brooks (1984-85).

Research on learner characteristics, by and large, has tended to concentrate on three areas of inquiry. One is concerned with the ability of students and the interaction of aptitude-by-treatment (Carrier, 1984; Clark, 1984; Corno & Snow, 1986). The findings suggest that the higher the academic ability of a student, the better s/he would perform in a learner controlled situation. Another area has dealt with subjects' internal locus of control (Clark, 1984; Copeland, 1988; Hannafin, 1984,1985; Merrill, 1980). This latter focus has examined the degree to which an individual perceives events to be under his/her ability to master and its subsequent effect on performance with respect to program or learner control. Rotter (1966) suggested that learners who load high on external locus of control scales believe that their performance is a function of fate, and they are not motivated to seek reinforcement. Internal learners on the other hand, perceive their own success or failure in terms of the effort that they exert. In a study that examined the interaction between learner control and subjects' locus of control, Holloway (1978) found that high internality subjects performed better when they were able to control their own learning. Clark (1984) proposes that "internally controlled learners may be more able to make effective instructional control decisions than externally controlled learners" (p. 238). In a variation to this trend, Fry (1972) reported that the level of inquisitiveness which students brought to a computer-aided instructional task was directly related to performance on learner controlled programs. Contrastingevidence is provided by Burwell (1991) who found that learner control generated significantly higher recall scores for field dependent students and significantly lower recall scores for field independent students than programmed controlled IV.

The third area of investigation, amount of prior knowledge, has produced the more stable results. High prior knowledge students consistently perform better under learner control conditions than students who enter an instructional task with little or low prior knowledge (Carrier, 1984; Gay, 1986; Hannafin, 1984; Milheim & Azbell, 1988; Steinberg, 1977). Learner controlled subjects as a rule, however, took longer to complete instruction than their counterparts in program controlled environments.

Research examining locus of instructional control and interactions between the learner characteristics noted earlier has not been abundant, and, for the most part, findings have been either inconclusive or mixed. As a result, no general prescription exists with respect to when and how learner control should be deployed, and notably so in interactive video since most of the research background is in related, but less complex media. Taken altogether, some studies have found that performance is improved with learner control, while others have observed opposite effects or no difference across treatments. It is clear, however, that the characteristics which an individual brings to a learning task are meaningful, if not critical, factors and need to be addressed in the design of instruction. In this spirit, the present study examined the influence of learner control in an interactive video environment in order to answer the following questions and test the ensuing hypotheses:

Research Questions

1) Is there a difference on posttest performance between learning groups that are provided with different levels of instructional control (program control, limited learner control, full learner control)?
2) Is there a difference in time spent on the instruction between the three levels of instructional control?
3) Is there a relationship between posttest performance and learner characteristics (prior knowledge, internality/externality)?
4) Is there an interaction between learner ability and instructional control?

Hypotheses

An aptitude-by-treatment interaction was predicted. It was hypothesized that high ability subjects would perform best under conditions of full learner control, and subjects with low ability would perform best under conditions of program control. It was further hypothesized that high internality subjects, and subjects with high prior knowledge, would perform best when allowed to control their own learning.

METHOD

Subjects

Forty six students enrolled at Concordia University (45 undergraduate, 1 graduate) participated in the study. Forty-three were following programs leading to a major in a science discipline (chemistry, biochemistry, biology, or exercise science). The remaining three were pursuing studies in arts-related fields. There were 23 males and 23 females. Subjects volunteered to participate and were each paid a stipend of $ 15.00.

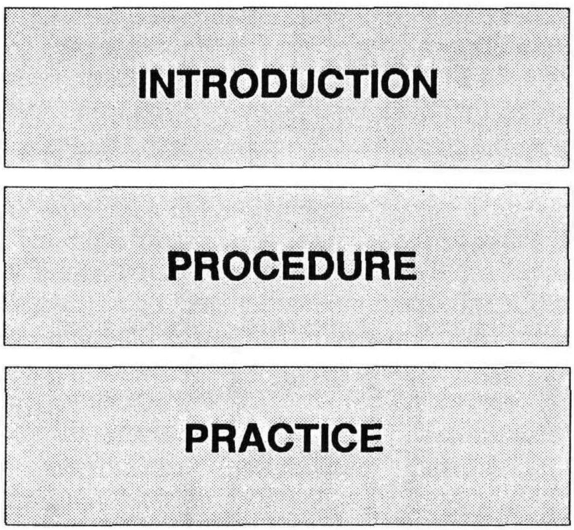
Materials

The materials were created by the authors using a videodisc that had been produced by Doiron (1990), and evaluated by a target audience of undergraduate biochemistry students at Concordia University. The instructional module teaches the materials that are required, and the steps needed, to conduct a biochemistry procedure called the "Swipe Check". Briefly, the Swipe Check is a process whereby suspected areas of radioisotope contamination are detected, recorded, and effectively eliminated. Typically, biochemistry students must be able to demonstrate proficiency with this procedure as they are likely to come into contact with radioactive substances, and must be aware of the potential hazards. Interactive video is a particularly appropriate medium for teaching this topic since it allows effective simulation of a procedure which might otherwise involve exposure to radioactive areas.

Three interactive video programs were produced that provided identical instruction on how to perform a Swipe Check, but differed to the extent to which learner control options were present. These three conditions, similar to Hannafin and Colamaio (1987), were labelled linear control (program control), designer control (limited learner control), and learner control (full learner control).

The instruction was divided into three major sections that formed the basis for either providing or removing instructional control. These three sections were presented in a menu structure comprising introduction, procedure, and practice. Figure 1 presents a facsimile of the menu structure as it appeared to the learner for all experimental conditions.

Figure 1.
Main Menu



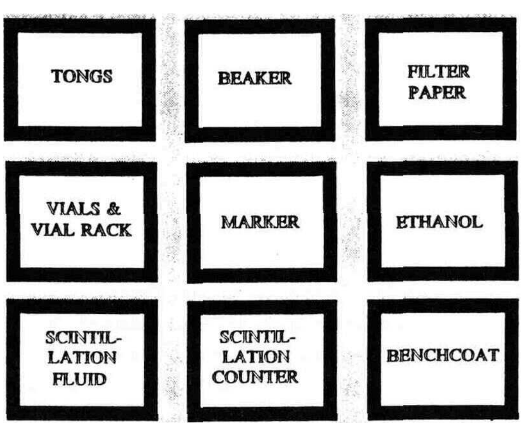
The first section, introduction, presented the learner with two separate video segments appearing in a menu structure. One discussed the hazards of radioactive materials and their implications in the context of the Chernobyl nuclear power plant meltdown; the other introduced the Swipe Check method and explained when and why it should be conducted.

Due to the length and nature of the Swipe Check, the procedure section was further subdivided into six components and was presented in a menu structure as shown in Figure 2. Two of the components presented instruction in terms of the tools and materials that were required. In the first subsection, a still frame video image of each tool was presented in a predetermined order and had a textual description superimposed on it. An additional "chart of tools" subsection presented a text screen that listed all of the tools in a random order as shown in Figure 3.

Figure 2.
Procedure Menu

TOOLS & MATERIALS	A VIDEO PRESENTATION
CHART OF TOOLS	BROKEN DOWN INTO COMPONENT STEPS
A LIST OF THE 14 STEPS	A DIAGRAM OF THE STEPS

Figure 3.
Chart of Tools



The other components provided four ways to learn about the fourteen steps that comprise the actual procedure. One provided a video segment which presented a lab technician carrying out the Swipe Check, with a narrator's voice-over describing each step as he went along. In another component, each step was broken down into individual segments which included a textual description of the step superimposed on the video, and presented in the order in which it should be carried out. The learner's response triggered the video segment to be played as the textual information disappeared from the screen. The third method of instruction provided a textual list of the fourteen steps and simply presented, in order, a written description of each step. Finally, the last component represented the procedure as a diagram, again showing the steps in the correct sequence.

In the last section, practice, the learner was presented with a video segment which displayed a step and had a textual description superimposed on it. The learner could respond by indicating that the step was correct or incorrect; if deemed incorrect s/he was required to supply the step by typing it on the keyboard. If the typed response was correct, a message to that effect was displayed on the screen and a description of the step was provided as reinforcement. If the typed response was incorrect, an appropriate message was issued and the same reinforcement that appeared for correct responses was displayed. There were a total of 14 practice questions (one for each step). A grid showing the status of the practice (those steps that were answered correctly or incorrectly, and in the case of learner control, those steps that were not attempted) was displayed upon completion of the exercise.

The treatments were developed on a Pioneer LD/VS 1 configuration consisting of a videodisc player, a monitor, and an 8-bit computer that was bundled with a keyboard, a mouse, and a touch screen. The interactive video lesson was designed so as to maximize the use of touch screen interface and minimize keyboard entry. In order to make a selection or to control pacing, the learner could touch that part of the screen that corresponded to his desired action. Alien and Carter (1988), Baggett (1988), and Bijlstra and Jelsma (1988) have endorsed the use of touch screen interfaces within interactive video lessons. Keyboard interaction was limited to the practice section, and was only used in the event of an incorrect step to allow the learner to supply the answer. The details of the treatments are discussed below.

Linear control. Of the three experimental conditions, linear control provided no options for selection other than for pacing and subjects were under complete control of the program. The lesson began with the presentation of the menu structure as shown in Figure 1. To initiate the lesson, the learner touched any part of the screen which triggered the start of the introduction section. When the screen was touched, the colour of the introduction box changed so that the learner would perceive the event that was about to occur. The learner was forced to view both components of the introduction section (video on hazards of radioactive materials, and when and why Swipe Check method should be used). At the conclusion of the introduction, the main menu structure was re-displayed and the procedure section began with the menu structure appearing in Figure 2. All six components were presented in order from left to right, starting from the top of the screen. Within a component, subjects could neither go back, nor exit. Similarly, once a section had been completed, it could not be re-initiated.

In the practice section the learner was presented with two screens of instructions and directed to complete all fourteen practice exercises. In responding to a question, if the answer was correct, *a/he* would touch a box labelled continue. If it was incorrect, s/he would touch a box labelled make the correction and then, in his/her own words, type the correct response at the[1] keyboard. Feedback and reinforcement were provided at each step, described earlier. There were no provisions to allow the learner to re-attempt a question and the practice could not be terminated prematurely. When the learner finished the practice, a status grid displayed the correctness/incorrectness of each question. The learner was then forced to re-view each step that s/he had answered incorrectly.

Designer control. In addition to providing control over pacing, this condition offered a limited degree of instructional control. Control options were available at the main menu structure but not within the introduction and procedure subsections. The learner could, in effect, choose introduction, procedure, or practice, in any order, by touching the box that corresponded to his/her choice. However, once introduction or procedure had been selected, individual choices, vis-a-vis any of the components that comprised the section, could not be made. The instruction was presented in the same order and used the same touch/ colour protocol as the linear control treatment. Additionally, any one of the three sections could be selected as often as desired but the sequence of the section was always the same.

There was, however, a certain amount of control offered within some of the procedure subsections. In the tools and materials component, the learner could advance to the next, or go back to the previous frame, by touchingan appropriately labelled box on the screen, but could not exit the component. The ability to terminate the broken down into component steps subsection was provided, and was initiated by touching an exit box. This subsection also included the option of interrupting the video segment by touching any part of the screen, which advanced the instruction to the next component step. Furthermore, the learner could go back to a previous component step by touching the appropriately labelled box. A list of the 14 steps contained two text screens of information, and allowed the learner to go back and forth between the screens, and to exit the subsection by touching the appropriately labelled box. The three remaining subsections did not differ from the linear control condition with respect to options.

The practice section differed from linear control to the extent that an exit option was included with each question. The status grid was displayed when the learner had either completed the practice or used the exit option. In the case of the latter, two control options were then available. The learner could either re-select a question s/he had attempted by touching the appropriate part of the grid, or s/he could exit the practice and return to the main menu.

Learner control. This treatment condition offered a full range of pacing and sequence options and used the same touch/colour protocol. At the highest level of control, each section in the main menu could be repeatedly selected in any order. And within sections (specifically introduction and procedure), the subsections could also be repeatedly selected, in any order, by touching the appropriate box. Video segments in the introductory sequence could be terminated at any time by touching any part of the screen. Those components that contained video segments were preceded with a text screen that described this control option.

In a similar vein, the six subsections that comprised the procedure could be chosen at will. Of these subsections, four of them contained additional control options that were not available in designer or linear control. A video presentation could be terminated by touching any part of the screen, tools & materials included an exit option, and individual tools in chart of tools could be viewed by touching the appropriate box on the screen (see Figure 3). Finally, in a diagram of the 14 steps, any step could be played by touching the corresponding part of the diagram. The other two subsections contained the same control options that were present in designer control.

With the exception of the status grid, the practice section was identical to the designer control treatment. In addition to providing an opportunity to re-view attempted questions or exit, the facility to view questions not previously tried was also included.

Design and Analysis

The study employed a completely randomized 3 X 2 factorial design. There were two independent variables, three dependent variables, and two covariates. The first independent variable featured three levels, linear control, designer control, and learner control. In the second independent measure, subjects were blocked as either high or low in academic ability (median point split) as determined by the vocabulary section of the Nelson-Denny Reading Test which has shown good potential for estimating students' academic aptitude (Gabriel & Richards, 1988).

Of the three dependent measures, two were derived from the posttest recall of basic facts and recall of procedure. The third dependent measure was time on task. Rotter's Internal-External Locus of Control Scale and the pretest knowledge scores were both used as covariates. Two independent judges rated both components of the posttest, which consisted of unit ideas. The recall of basic facts measure consisted of 25 items, each worth 1 point. The recall of procedure measure required that the subject identify in the correct sequence, the 14 steps. Each step carried a maximum weight of 2 points, 1 for identifying the step and 1 for specifying it in the correct order. Correlation procedures were conducted to establish consistency among the scoring. The pathways which subjects in the learner control condition navigated through the instruction were recorded by the computer program, and examined descriptively. All effects were analyzed using MANOVA procedures and multivariate post hoc comparisons.

Procedure

Four instruments were used in the study, namely, *a* pretest for establishing prior knowledge levels, the Nelson-Denny Reading Test (Form E), Rotter's Internal-External Locus of Control Scale, and a posttest. The posttest consisted of two parts, namely recall of basic facts and recall of procedure.

Two Pioneer LD/VS 1 systems had been installed in different locations for the purpose of testing. Subjects were recruited from intact biochemistry classrooms and through a student university newspaper advertisement, and were randomly assigned to one of the three treatment conditions when they arrived for their previously scheduled testing session. The subjects did not know in advance that they were going to learn about the Swipe Check, nor did they know which treatment they had been assigned to; they had been advised that they would be participating in an experiment in which they would learn about laboratory safety procedures using interactive video.

Experimentation began with the administration of the pretest, which was designed to measure prior knowledge of the Swipe Check method. Following its completion, subjects began the vocabulary section of the Nelson-Denny Reading Test. This is a 100 item timed-test, and subjects had up to 15 minutes to complete it. Next, the Rotter scale was administered with no time limit.

Before starting the lesson, the testing monitor initiated a computer program that was designed to acquaint the learner with the touch screen interface. The assigned treatment was then started; the subject was told that s/he could take as much time as desired and to simply tell the monitor when s/he had finished. The monitor recorded the time that the subject began and ended the treatment. Upon completion, passages six and seven of the comprehension section of the Nelson-Denny Reading Test were administered as an interpolated task designed to eliminate treatment immediacy effects. The test requires that the subject read a short passage and answer multiple choice questions in a ten minute time frame. Finally, the subject completed the written, open-ended posttest, was thanked for his/her involvement, and asked not to reveal any details of the session to future participants,

Results

A preliminary scan of the pretest data revealed that none of the subjects possessed the facts required to perform the Swipe Check method. Consequently, as the distribution of scores was too homogeneous to be used as an effective discriminator of prior knowledge, the pretest was not included in any analysis.

Similarly, it was expected that the Rotter Internal-External Locus of Control Scale would have provided an appropriate level of discrimination between groups on posttest performance. However, a multivariate analysis of covariance established that the Rotter scale was not, in fact, a significant predictor when regressed on each dependent measure, and it was dropped from subsequent analyses. This lack of predictive ability of the Rotter scale might be explained by noting that the scale measures how an individual perceives events in life, and the extent to which s/he is able to exert influence and control over such phenomena. In all likelihood, the scale is too general and is presumably incapable of predicting how one might use control options in an instructional sequence, which, unlike the scale, is highly specific. The design, therefore, was examined without the use of covariates.

Inter-rater reliability for the posttest, was established at r = .98 for recall of basic facts, and r = .87 for recall of procedure. Final scores for both components of the test were derived by averaging the raters' tabulations. Cell means and standard deviations for recall of basic facts and procedural steps, and time on task measures, are presented in Tables 1, 2, and 3 respectively.

TABLE 1
Cell Means and Standard Deviations for Recall of Basic Facts

Prior Achievement		Instructional Group LINEAR	DESIGNER	LEARNER	Total
LOW	M	18.81	14.25	14.39	15.89
	SD	3.48	3.45	4.83	4.45
	n	8	6	9	23
HIGH	M	20.71	20.67	13.29	18.44
	SD	4.01	2.22	4.32	4.83
	n	7	9	7	23
Total	M	19.70	18.10	13.91	17.16
	SD	3.73	4.20	4.50	4.77
	n	15	15	16	46

TABLE 2
Cell Means and Standard Deviations for Recall of Procedure

Prior Achievement		Instructional Group LINEAR	DESIGNER	LEARNER	Total
LOW	M	23.06	21.67	22.89	22.63
	SD	3.60	3.82	2.60	3.20
	n	8	6	9	23
HIGH	M	24.00	23.33	20.93	22.80
	SD	3.43	2.32	4.55	3.54
	n	7	9	7	23
Total	M	23.50	22.67	22.03	22.72
	SD	3.43	3.00	3.59	3.33
	n	15	15	16	46

TABLE 3
Cell Means and Standard Deviations for Time on Task[1].

Prior Achievement		LINEAR	DESIGNER	LEARNER	Total
		Instructional Group			
LOW	M	104.63	98.83	86.78	96.13
	SD	16.99	11.75	8.76	14.67
	n	8	6	9	23
HIGH	M	89.14	77.33	75.14	80.26
	SD	13.18	10.40	15.21	13.67
	n	7	9	7	23
Total	M	97.40	85.93	81.69	88.20
	SD	16.81	15.17	13.01	16.15
	n	15	15	16	46

'Time in minutes

A multivariate analysis of variance yielded significant main effects for instructional control, $F_{Hote/(}$ (6,74) = 4.25, p < .01, and for academic ability, F_{HoftU} (3,38) = 8.01, p < .01. However, no significant aptitude-by-treatment interaction was observed. The univariate effects on the three dependent measures are summarized in Table 4.

In an attempt to isolate differences between levels of instructional control, a discriminant function analysis was conducted. A significant difference was noted between linear and learner control. The discriminant function accounted for 43% of the variance, $R*$ = .655, *Wilks'* A = .57, p < .01. Group centroids were .87 and -.81 for linear and learner control respectively. The difference in group centroids provide a significant discriminating set of predictors for the two groups. Most of the predictive ability to discriminate between groups, however, is derived from the recall of basic facts and time on task measures. Subjects in the linear condition significantly outperformed their learner control counterparts on factual recall, but they also spent a significantly longer time on task while doing so. No significant discriminant functions were observed for designer and linear, or designer and learner treatments.

Discussion

The results of this study do not support the predicted aptitude-by-treatment interaction. It was found that regardless of ability, subjects in the linear-controlled condition outperformed subjects in the other two conditions. While this is not entirely consistent with previous aptitude-by-treatment interaction research (Cronbach& Snow, 1977;Jonassen, 1985;Snow, 1980),thereareanumber of plausible explanations. Among these, the absence of prior knowledge must be considered as a prominent mitigating factor. Clark (1982), in a review of relevant literature, concluded that learners often select methods of instruction from which they learn the least. Given full control over instruction without the commensurate prior knowledge, learners may choose inappropriate or illogical paths, either as a function of preference or simply because they do not know better. The absence of interaction effects might also be explained by interpreting the characteristics of the high ability learners. Clark noted that high ability students expect a high level of support when given choices, such as additional practice and examples, but learn less when left on their own.

TABLE 4
Univarlate Effects on All Measures.

Source	SS	DF	MS		
			Recall of basic facts		
Control	264.34	2	132.17	9.14	.001
Ability	59.32	1	59.32	4.10	.050
CxA	71.48	2	35.74	2.44	.100
Error	578.59	40	14.47		
			Recall of procedure		
Control	16.69	2	8.35	.73	.487
Ability	.28	1	.28	.03	.876
CxA	28.13	2	14.07	1.24	.301
Error	455.16	40	11.38		
			Time on task		
Control	2036.18	2	1018.09	6.15	.005
Ability	2907.11	1	2907.11	17.56	.000
CxA	184.88	2	92.44	.56	.577
Error	6621.98	40	165.55		

Still another rationalization may be explored in the context of advisement and coaching. It can be assumed that learners who had control over instruction, but did not possess prior knowledge, were ill-prepared to make appropriate choices, or did not make choices that they should have. Hannafin (1984) proposes that learner-controlled instruction should include advisement to aid in decision making. Milheim and Azbell (1988) have further suggested that to include guidance provides the student with a foundation on which s/he is able to make decisions as tocontent and sequence, while at the same time the program can offer suggestions based on a given choice. And Tennyson (1980) has reported consistently lower posttest performance in learner control conditions, because subjects often terminate instruction too early, or do not select important content. Given some sort of guidance, a student would be better prepared to make appropriate and meaningful selection decisions.

An analysis of the paths that learner-controlled subjects chose in the present study is indicative of their poor performance. In most'cases, the students did not follow the sequence that had been prescribed for linear-controlled subjects, but it should not be inferred that the order in which they made selections was inappropriate. Rather, the error of their ways is a function of early termination of many sequences, and/or chosing not to initiate sequences that contained important information. In several instances, subjects began the instruction with the practice section but soon realized that they did not possess sufficient knowledge to continue.

The present study also found that learner-controlled subjects took significantly less time to complete the instruction, a finding at odds with much of previous research (Balson et al., 1984-85; Beland et al., 1985; Goetzfried & Hannafin, 1985;Ross&Rakow, 1981;Schaffer &Hannafin, 1986) which suggests that students in internally-imposed conditions take significantly more time to complete instruction. In this study, there can be little doubt that it is a consequence of poor sequence selection. In fact, since the difference in group centroids, which is a composite compilation of the predictive ability of the three measures, was so divergent, it is fair to conclude that learner-controlled performance was not only vastly inferior, but also very different vis-a-vis time on task.

As previously mentioned, the internality/externality as measured by Rotter's scale did not influence performance, despite the fact that some previous research (Holloway, 1978) has found it to be a contributing factor with respect to instructional control. Additional research is needed using both Rotter's and other standardized instruments before any conclusions may be drawn with regard to whether internal/external ratings can affect performance within different levels of program control. And the hypothesis that high prior knowledge subjects would perform better under self-imposed control conditions was left untested in this study. In the absence of such data one is left with the conclusion of past research which has tended to support the prediction.

To summarize, the results of this study suggest that in the absence of prior knowledge, regardless of ability, and regardless of internality loading on locus of control, superior performance is achieved through, but more time is spent on, externally-controlled mechanisms. This research further supports, in general, the notion that program-controlled instruction is more suitable for procedural learning and the acquiring of basic facts (Hannafin, 1984; McNeil& Nelson, 1991; Ross & Morrison, 1989).

Additional research is needed to examine the effects of learner control for higher order learning, a lacuna which has been recognized but appears to have been largely overlooked. Future research should also investigate the effects of including adaptive control strategies to advise students of alternative learning pathways, if it appears that their course is likely to have debilitating or dilatory effects. There is substantial evidence to suggest that adaptive learner control strategies can yield positive results and put learners into a better position to make informed decisions, if they are advised appropriately (Clark, 1984; Cohen, 1984; Hannafin, 1984, 1985; Merrill, 1980; Milheim & Azbell, 1988). Thus, building upon this background, an important and sustainable area for investigation would be methods or types of advisement formats which best conform to learner characteristics. In short, matching learner variables with production techniques for varied instructional tasks should increasingly represent the cutting edge of research into interactive video design strategies, as this dynamic technology becomes more commonly accesssible.

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