Learner Control and Learner Characteristics in an Interactive Video Environment

Aaron-Henry Brauer

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ABSTRACT

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This study examined the extent to which different levels of instructional control and varying degrees of 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 condition (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 ability, according to their scores on the vocabulary section of the Nelson Denny Reading Test. A prior knowledge test and Rotter's Internal-External Locus of Control Scale were administered to determine if these measures could predict performance. A multivariate analysis of variance established significant main effects for instructional control and prior ability. The results indicated that linear control outperformed learner control, and that the former took significantly more time to complete the instruction than the latter. No other significant differences were observed.

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CHAPTER 1

Introduction

One of the most exciting technologies of the late twentieth century is interactive video. It is especially promising for today's educational technologist, because it permits the convenient union of the modern microcomputer with its interactive capabilities and the visual expository features of video (Palmer & Tovar, 1987), while at the same time provides the opportunity to exploit a vast array of instructional designs and strategies. Since the goal of any instruction must be to foster learning, it is appropriate to pursue the use of this new medium to determine how its effectiveness and efficiency can be exploited and optimized in order to facilitate learning.

Particularly germane to educational technology is the study of learner control, and how instructional strategies can best be applied that are fully cognizant of the individuality of the learner and the particulars of the material to be taught. Comparative examinations of different instructional innovations continues to mount, yet the results of many studies are either mixed or inconclusive. In fact Reeves (1986), is quite critical of the standard experimental design that pits a *new* technology against a so-called traditional method. This is becoming increasingly evident as computer-aided instruction and interactive video are subjected to typical experimental comparison. Despite the fact that literally hundreds of comparative studies have been conducted, with virtually every instructional technology known, few have produced useful outcomes (Clark, 1983; Hoban, 1958).

The underlying theme of this criticism suggests that research needs to be conducted within an instructional innovation, and not between. Already though, interactive video is falling victim to the standard experimental model (Dalton, 1986; Holmgren, Dyer, Hilligoss, & Hillel, 1979-1980; Henderson & Landesman, 1988-89; Ketner, 1982; Schroeder, 1982). These studies all compared interactive video with other methods of instruction, but failed to observe significant differences in instructional effectiveness. If interactive video is to have a successful future, it will be necessary to explore those features of the medium that maximize the effectiveness of the instructional strategy, including the extent to which an individual can control his own learning, so that educational objectives can be realized.

To a degree, studies have investigated the effects of learner control. Steinberg (1977), in a review of the literature noted that those studies examining learner control either found no differences or found learner-controlled subjects to be the poorest performers. In those studies where no differences were observed, learner-controlled subjects as a rule, took longer to complete instruction. Learner control also fared poorly, vis-à-vis the amount of prior knowledge that the students possessed. "The poorest decision makers were the students who knew little about the subject or who were performing poorly in it" (Steinberg, 1977, p. 88).

The lessons learned from early research with learner control provide some valuable insight into how this effect can be properly managed in an interactive video environment. Central to this theme, are the characteristics of the learner and the type of instruction to which learner control is amenable. The purpose of this study was to examine the effects of learner/program control, using interactive video in the teaching of biochemistry laboratory procedures, in order to determine the conditions under which learner control is suitable, with respect to the type of instruction and the type of learner.

CHAPTER 2

Review of the Literature

There have been a number of recent studies that have investigated the use of interactive video in science education in general (Burrows, Eiserman, & Williams, 1986; Glover, Graham, & Macdonald, 1989; Hall, Thorogood, Hutchins, & Carr, 1989; Henderson & Landesman, 1988-1989; McInerney, 1989; Mercer, Pringel, Rae, Harkin, & Lauder, 1989; Sorge, 1988) and in chemistry education in particular (Brooks, Lyons, & Tipton, 1985; Russell, Staskun, & Mitchell, 1985; Smith & Jones, 1986, 1989; Worthy, 1987). It is clear from many of these studies that interactive video is not only an appropriate medium in which to teach the subject, but in many cases it is the only way that certain instructional sequences can be presented. Glover et al. note that interactive video is particularly appropriate in science education, because it allows complex, dangerous, and difficult experiments to be simulated. Similarly, Mercer et al. in developing an interactive video lesson in pathology, noted that "learning is an active process and may involve making mistakes and CAL can provide the opportunity for clinical mistakes to be made safely" (p. 245).

The issue of safety is equally applicable in chemistry education. Laboratory exercises are an integral part of most chemistry curriculum, where students are given the opportunity to see, touch, and smell chemicals, and to observe chemical reactions (Smith & Jones, 1989). "Unfortunately, instructional laboratories face increasing obstacles from questions about the potential hazards of exposure to chemicals and from the difficulty of doing meaningful experiments at an acceptable cost in the allotted time" (Smith & Jones, 1989, p. 8). The visual reality of video combined with the interactive capabilities of the computer, provide the student with an opportunity to learn about chemical reactions and consequences in a safe environment.

Unfortunately, few of the above studies explored the instructional effectiveness of the medium itself, and the way in which students could internally manage their own learning. There were however, some observations that would indicate the need for further research. Burrows et al. (1986) found that learners actually wanted to have control over the hardware and software. Mercer et al. (1989) are developing an upgrade to their pathology lesson that incorporates learner control features, and Smith and Jones (1989) suggest that additional work needs to address the limits of the technology, how best to use it, and its effectiveness as an instructional aid.

Kearsley, Hunter, and Seidel (1983) and Milheim and Azbell (1988) both agree that learner control is essentially concerned with the extent of control that a student can and should have over his learning process. The literature is replete with endorsements calling for the need to include mechanisms for learner control within instruction and to consider the characteristics of the learner. Ross and Morrison (1989) insist that research is needed that identifies those learner control variables that are relevant and appropriate for different learners and tasks. Cohen (1984) suggests that if a student is made to become actively involved with the learning situation, it becomes increasingly likely that the student will learn. She advocates that the learner should be able to follow instruction in a non-linear path because it "promotes higher learning by allowing the content to be organized in the student's mind according to individual needs and his or her own internal logic-order of the subject matter" (p. 17). However, Hannafin (1984) and Steinberg (1977) suggest that this is only appropriate if the learner has prior knowledge or is a high ability student.

There appears to be two general schools of thought, vis-à-vis the characteristics of the learner. One is concerned with the ability of students and the interaction of aptitude-by-treatment (Carrier, 1984; Clark, 1984; Corno & Snow, 1986; Hannafin, 1987). The other is a function of the motivation that students invest in computer-based instruction (Clark, 1984; Copeland, 1988; Hannafin, 1984, 1985; Merrill, 1980). The latter suggests that the degree to which an individual perceives events to be under his control, will have an effect on performance with respect to program or learner control. Rotter (1966) explored the notion of reinforcement and attributed to subjects who did not seek reinforcement, an external locus of control rating. External learners 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).

The general consensus seems to endorse learner control, but researchers have cautioned that its use must be deployed judiciously (Brody, 1984; Laurillard, 1984). Hannafin (1984) suggests that learner control is likely to favour program control under the following conditions:

- learners are older, more mature
- they are more capable
- higher order skills rather than factual information is being taught
- content is familiar
- advisement is provided to aid in decision making
- control is used consistently within a lesson
- provision is included for switching unsuccessful learners to program control strategies
- formative evaluation is used and instruction is revised based on paths chosen by effective learners.

Research on learner control and learner characteristics using interactive video has not been abundant, and for the most part, results have been either inconclusive or mixed. Some of these studies, as well as relevant research that used computer-aided devices, are discussed below.

In an early study of control mechanisms in computer-aided learning, Fry (1972) examined differential effects of learner characteristics (college aptitude, inquisitiveness) and learner control among college students in a computer learning environment. It was hypothesized that high aptitude - high inquiry subjects would perform best under conditions of learner control and high aptitude - low inquiry subjects would perform best under conditions of program control. Standardized tests to measure inquisitiveness and aptitude were administered and subjects were randomly assigned to treatments so as to maximize the match between instructional locus of control and learner characteristics. The instructional materials were designed in such a way as to allow a learner to begin at any point and proceed along any path without detrimental consequences. The results confirmed the hypotheses and support the notion that learning styles and characteristics are related to instructional locus of control. In fact, the high aptitude - low inquiry subjects under program control demonstrated superior achievement compared to the other experimental conditions. As has been found in a number of other studies, subjects under program control learned significantly more than those subjects under learner control, although Fry suggests that the superior performance of the high aptitude - low inquiry group in this study, may be more a function of the familiar instructional strategy presented to them. It was also noted that learner control subjects did not take full advantage of self-directed learning opportunities, sustaining the idea that not all learners are necessarily good judges of how best to proceed.

Fisher, Blackwell, Garcia, and Greene (1975) conducted research to look at differences in choice that fourth and fifth graders might make in an arithmetic CAI program. The study attempted to determine the relationships between student choice, problem difficulty levels, locus of control attributions, and engagement. Subjects were assigned to either a choice or a yoked control treatment. It was found that choice subjects demonstrated more task engagement, but worked on significantly fewer problems. Significant differences on three dimensions of locus of control were also observed. In concluding, the researchers noted that while choice may be a motivating factor, it can lead to poor academic performance for some children.

Ross and Rakow (1981) studied learner control versus program control in the context of learning mathematics rules without using computer-assisted instructional materials. The experimenters hypothesized an aptitude-by-treatment interaction, expecting subjects with high levels of prior achievement to require less instructional support and conversely, higher instructional support as a necessity for low achievers. Undergraduatc educational psychology students were assigned to one of four levels of instructional locus of control, including program control where examples were adapted to subjects' pretest scores, and learner control in which examples were selected by subjects. Results demonstrated superiority of program control over other strategies. Not only were learner control subjects the poorest performers, but they showed a marked decline from the immediate to the delayed posttest. Additionally, low prior ability students performed well under program control, but poorly under learner control. These findings are consistent with previous aptitude-by-treatment interaction research (Mabee, Neimann, & Lipton, 1979) and support the issue of matching instructional locus of control with learner characteristics.

In a similar study using computer-assisted instruction, Goetzfried and Hannafin (1985) examined the effects of locus of instructional control on the learning of mathematics rules. Seventh grade students who were enrolled in a remedial mathematics class participated in the study. Subjects were assigned to one of three treatments, adaptive control which consisted of externally controlled CAI with branching by the computer when warranted, learner control with advisement which consisted of internally controlled CAI, and linear controlled CAI which presented instruction in a predetermined sequence and provided control over pacing only. Students were grouped into two levels of prior achievement (low and below average). The study reported a significant aptitude-by-treatment interaction, where below average students scored higher on the dependent measure, as well as a significant main effect for prior achievement. It was also noted that the linear-controlled group averaged less time to complete the instruction than either of the other two groups with no loss in achievement. In concluding, the researchers attribute the findings to the possibility that younger and less able students, lacking sufficient background knowledge in the content area, are less effective in making decisions about their progress and their need for remediation and/or additional instruction.

Judd (1972) conducted experiments designed to compare student performance given the absence or presence of control mechanisms with respect to the sequence and selection of instruction in a CAI program. The program was designed to provide remedial mathematics instruction for college level students lacking prerequisite skills to further their studies in calculus. The investigator had hypothesized lower posttest scores from subjects under the learner control of how much practice to be received condition. In two of the three content areas (exponents and logarithms) unexpected findings were reported, when learner-controlled students obtained higher posttest scores than their program-controlled counterparts. It was suggested that these results were a factor of the former exercising good judgement in determining when to terminate practice segments. On the other hand, subjects who had control over the sequence and selection of instruction did not perform as well as the program control group in the content area of logarithms. Logarithms were reported to be the most difficult area of study compared to the other topics, and it was suggested that subjects who had control over the selection of material, exercised the available options and deliberately avoided studying the more difficult material.

Belland, Taylor, Canelos, Dwyer, and Baker (1985) investigated differences in instructional control, and hypothesized that moderate levels of external control would result in more effective learning. It was further hypothesized that a) moderate levels of external control would show an improvement in the time efficiency needed to learn the instruction and b) that lower achievers may not choose options for additional instructions and may have to be externally controlled upon demonstration of errors. The authors used a CAI program that was designed to teach subjects about the parts and operation of the human heart. Subjects were assigned to one of four experimental conditions, self-paced, externally paced with cognitive processing time, externally paced without cognitive processing time, and control. Significant differences were found between treatments (subjects in the externally paced with cognitive processing time outperformed those subjects in the externally paced without cognitive processing time condition, but there was no significant difference between the self-paced and externally paced with cognitive processing time condition). Belland et al. concluded that self-paced CAI instructional methods may not be the most appropriate way to address individual learning differences and that moderate levels of external control can improve overall learning.

Klein and Keller (1990) explored the effects of student ability, instructional control, and students' locus of control, on performance and the motivational outcome of confidence among seventh grade students. Subjects completed an ability and a locus of control measure and were assigned to one of two instructional treatments (internally or externally controlled) that were designed to teach four defined concepts in advertising, delivered by computer-based instruction. The purpose of the research was to examine to what extent do types of control over instructional strategy, student ability, and locus of control, have on performance. The authors reported interesting, but expected results; high ability students performed better on the posttest than average ability students, who performed better than low ability students. In addition, students with an internal locus of control score outperformed students with an external locus of control score. Subjects did not differ on the posttest, vis-à-vis instructional control and no significant interactions were present. While numerous studies have reported positive effects from having learner control, they are almost always invariably a function of student ability and type of instruction. In this case, the researchers found that the informed, motivated student performed better, regardless of the condition of instructional control. On the other hand, in defence of learner control, it was noted that "the amount of control given to students in the learner control group may not have been adequate to give them the perception that they had control" (Klein & Keller, 1990, p. 145).

In studies supportive of learner control in computer-based environments, Campanizzi (1978) investigated the effects of instructional locus of control and provisions for overview using computer-assisted instruction among college students. The study examined differences in achievement gain and response latency across two levels of control (learner, program) and two levels of overview (absence, presence). It was found that learner control appeared to influence achievement gain. Differences associated with response latency were not present. While no differences were observed with respect to the number of times review segments could have been presented, learner control subjects chose to review significantly fewer sequences than was presented to the program control group. The author concluded by suggesting that given control of instruction that includes advising the learner when to select review sequences, that advice may not necessarily be followed; however the learner will choose a path that inevitably leads to achievement.

Kinzie, Sullivan, Beyard, Berdel, and Haas (1987) investigated the effectiveness of learner and program control on student learning in science education using CAI as a medium of delivery. Reading ability and gender were additional variables that were examined in the study. Significant main effects were reported for the experimental treatment, gender and, reading ability. The boys outscored the girls, higher verbal ability students did better than those of lower ability, and those students who had control over the program obtained higher scores than those who did not. Interestingly, high ability females did better under learner control than under program control, whereas no differences were reported between learner and program control for high ability males. The authors concluded that students under limited learner control adjust their study behaviours to achieve greater learning in the same amount of time.

Studies with interactive video have had similar, mixed reviews. Atkins and Blissett (1989) conducted a small scale exploratory study of interactive video among a group of 9 to 13 year old students. The instructional content required subjects to undertake three tasks, all of which were related to the concept of probability. Videotaped observations of the student - interactive video interaction were recorded and the investigators identified six types of learning activities from a preliminary analysis. This analysis showed that a large percentage of learning activity was devoted to reading, watching, and listening, whereas activities such as discussion, decision entry, technical, and dead time were observed much less frequently. Subsequent analyses measured the extent to which variations in learning activity were accounted for by the group. While the authors did not attempt to generalize their findings, it was noted that there was a high level of 'on-task' behaviour, supporting the large percentage of time spent on reading, watching, and listening that was observed.

Balson, Manning, Ebner, and Brooks (1984-85) investigated the use of instructional control with interactive video programs for training military paramedics. Soldier subjects were assigned to one of three instructional conditions, instructor, or student controlled, and a third group received instruction that was delivered via traditional teaching conventions. The purpose of the instruction was to teach the student how to prepare and administer an intramuscular injection. The results yielded no significant differences across the three groups on both an immediate and a delayed posttest. Furthermore, the objective of reducing instructional time on task without loss of achievement was also observed. In fact, the instructor-controlled group saved the equivalent of one class period in completing the instruction.

Milheim (1990) attempted to determine the effects of learner versus program control of pacing and sequence in an interactive video lesson on photography. Undergraduate students enrolled in a media course were assigned to one of two conditions of pacing and one of two conditions of sequence. Learner control of pacing allowed students to proceed by pressing a computer key. Conversely, program control of pacing presented text screens for a predetermined period of time based on the amount of information on a given screen. In the learner control of sequence condition, students chose the order of the lessons to be presented, whereas in the program control of sequence condition, the material was presented in a pre-established order. Although significant differences were found for pacing on both an immediate and delayed posttest, no differences were observed for sequence or its interaction with pacing. Subjects who had control over pacing performed better on both tests than their program-controlled counterparts. This is not entirely consistent with previous research, where positive achievement effects have been observed for both learner and program control of pacing. With respect to sequence control and the lack of associated positive achievement effects, the author concluded by implying, that the perception of control may not have been readily evident, and therefore students may not have had a feeling of significant control over their learning.

Schaffer and Hannafin (1986) explored the idea that progressive interactivity would increase learning. High school students were assigned to one of four treatments, video only, video plus embedded questions, video plus embedded questions plus feedback, and fully interactive video, and were blocked as either high or low in prior academic achievement. The authors hypothesized that incremental amounts of interactivity would enhance learning. An aptitude-by-treatment interaction was observed, indicating superior performance from the high achievers in all treatments except video plus questions, where the low achievers outperformed the high achievers. Additionally, incremental interactivity resulted in increased learning time. In concluding, the authors offer evidence supporting the notion that computer-based interactive video enhances certain types of learning.

Gay (1986) explored the effects of prior knowledge and learner control on performance using computer-assisted video instruction on college students studying introductory biology. It was hypothesized that subjects possessing prior knowledge would learn best under conditions of learner control and that subjects without such prior knowledge would learn best under conditions of a more structured program control. The study found that low prior knowledge subjects in the learner-controlled treatment did not perform as well as their counterparts in the program-controlled treatment, nor did they perform as well as the high prior knowledge subjects in either experimental condition. Furthermore, high prior knowledge subjects in the learner-controlled condition were more efficient than all other groups in their use of time. The findings support other research that has shown learner control to be an appropriate instructional strategy in cases where students have demonstrated prior knowledge (Carrier, 1984; Hannafin, 1984, 1987; Milheim & Azbell, 1988).

Hannafin and Colamaio (1987) studied the effects of variation in lesson control and practice using interactive video to teach cardiopulmonary resuscitation to undergraduate students. Subjects were assigned to one of three experimental conditions. In the first condition (linear control) students followed a predetermined linear path, were not provided with options for controlling the sequence of the lesson, and the lesson contained no provisions for imposed remediation or question repetition. The second condition (designer control) had students follow a path that was deemed most advisable by expert lesson designers. These subjects had the option of continuing on to the next segment if their response to an embedded question was correct, or to branch to a review segment if it was incorrect. Students in the final condition (learner control) controlled the sequence of the lesson at points where designer imposed decisions had been enforced in the other treatments. The ability to choose the order in which to view the video segments was also provided. The authors hypothesized that both learner and designer controlled groups would outperform the linear-controlled group. If was further predicted that an interaction between type of learning and practice would also occur. The results confirmed the hypotheses; designer and learner controlled groups performed better than the linear-controlled group, but no differences were found between designer and learner control. The study provides support of learner over linear controlled designs. In concluding remarks, the researchers noted that "the more interactive the instruction, the greater the learning of factual information" (p. 210). Additionally, they demonstrated that the use of practice was an important element, vis-à-vis the learning of facts and problem solving skills, but of little consequence with respect to the learning of procedures.

Dalton and Hannafin (1987) studied the effects of knowledge versus context-based design strategies on learning from interactive video. Subjects were selected from a ninth grade introductory economics class and were assigned to one of three treatment conditions. In the first condition (knowledge-based strategy) learners were presented with video segments depicting specific factual information. Each segment was followed by a recall question. In the second condition (context strategy) learners were shown video scenes that portrayed the utility of lesson concepts and not the specific concept definitions. Questions following each scene paralleled the topic in the knowledge-based strategy but required the application of lesson knowledge and not simply the demonstration of knowledge. A third condition (control) presented the entire video segment in a linear fashion with neither embedded questions, nor computer-based interaction. Subjects were blocked as either high or low in prior achievement. No aptitude-by-treatment interaction was observed. However, significant main effects for treatment and prior achievement were reported, but these effects were characterized by different patterns for factual versus application learning. Knowledge and context-based groups demonstrated similar performance on a recall test, but the context-based group scored significantly better on an application test. In all cases, the control group performed the poorest. The authors concluded by suggesting that context-based design strategies are effective ploys with respect to the teaching of basic and application-type skills, and that well designed interactive video instruction can be appropriate for teaching such skills.

Soled, Schare, Clark, Dunn, and Gilman (1989) compared interactive video and traditional lecture methods among undergraduate nursing students. The authors hypothesized that there would be no difference in cognitive achievement across the two groups, but that differences would be observed among attitudes toward learning. The first hypothesis is supported by earlier research, which has shown cognitive gains with interactive video equalling or exceeding gains with traditional methods. Subjects were assigned to either the traditional method where they met for 90 minutes to receive lectures, or to the experimental group where students learned from, and responded to questions in the interactive video lesson. The topic of instruction was health assessment of patients with diabetes. No significant differences were found between groups on the cognitive score, supporting research that has suggested interactive video instruction to be as effective as traditional lecture methods. The second research hypothesis was also confirmed, but here the authors concluded that the more positive attitudes noted are attributable to factors relating to control. "It appears that the format for learning with videodisc allows students to learn at their own pace, to go back over material they are unsure about, and to learn through several senses" (Soled et al., 1989, p. 5).

Lawrence and Price (1987) used interactive video to teach the Language Experience Approach (LEA) to reading instruction. The investigators were interested in examining the effectiveness of interactive video to this approach to reading. Half the sample size received instruction via traditional methods and the other half used an interactive video lesson. It was hypothesized that there would be no difference between groups in knowledge gain from the LEA approach to the teaching of reading. The results yielded no significant differences on posttest scores across the two groups. Furthermore, both groups gained significantly from the pre to post-test, and it was concluded that both methods were equally effective. Although attitude data were not collected, the interactive video group generally expressed favourable attitudes with the medium "and enjoyed the feeling of control which they felt" (Lawrence & Price, 1987, p. 7). Additionally, the ability to review material at will was among positive comments received. Soled et al. (1989) reported similar findings, vis-à-vis attitude measures, further supporting at least from the student perspective, the use of control variables within an instructional sequence.

In an exploratory study, Gay, Trumbell and Smith (1988) studied the activities of undergraduate students who worked at an interactive video lesson. The purpose of the instruction was to help students learn to identify different kinds of waterfowl as they appear in their natural habitats. The researchers were particularly interested in examining students' perceptions of four areas of learner control, namely navigating within the lesson, examining things more carefully, exploring the speed and direction of the moving images, and using help and glossaries. Analyses of questionnaires completed by the subjects revealed that over half (59%) expected to have control of the program. It is interesting to note that students who had expected control of the program made more effective use of control options and were more positive about the task. This may be due though, to a high reported correlation between use of control options and previous experience with computers, that is, it would be expected that such previous experience would give the perception that control options within a computer program generally exist. In support of research that endorses matching learning characteristics to instructional locus of control, it is worthwhile to note that in this study, students who did not perceive that they would have control of the program, did not select activities that would have improved their performance and that overall, students did not make much use of the available control options.

It appears from the literature, that no general prescription exists with respect to when and how learner control should be deployed. Some studies have found that performance is improved with learner control, others have observed opposite effects, or no difference across treatments. It is however clear, that the characteristics of the learner are a meaningful, if not critical factor and need to be addressed in the design of instruction. The present study, therefore examined the influence of learner control in an interactive video environment, in order to answer the following questions and discuss the ensuing hypotheses.

Research questions and hypotheses

1. Is there a difference on posttest performance between groups that are provided with different levels of instructional control (program control, limited learner control, full learner control)?

2. Is there a difference on time spent with 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?

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.

CHAPTER 3

Method

Subjects

Students enrolled in a large urban university (n = 46) participated in the study. Forty three of them (42 undergraduate, 1 graduate) were following degree programs leading to a major in a science discipline (chemistry, biochemistry, biology, or exercise science). The remaining three were pursuing independent 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 experimental conditions were designed in conjunction with the author and a research team that was formed for the express purpose of assisting in the development of the instructional materials, and the administration of the treatments. The materials were created using a videodisc that had been produced, and was evaluated by a target audience of undergraduate biochemistry students (Doiron, 1990). The instruction teaches the materials that are required, and the steps needed to conduct a 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 (Doiron, 1990;

Palmer, 1988; Palmer & Tovar, 1987) as they are likely to come in contact with radioactive substances, and must be aware of the potential hazards.

Three interactive video programs were produced that provided identical instruction on how to perform a Swipe Check, but differed to the extent to which control options were present, absent or, quasi-present. These three conditions were labelled linear control (absent), designer control (quasi-present), and learner control (present).

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.

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. Figure 2 presents the introduction menu structure.

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 3. Two of the components presented instruction, vis-à-vis the tools and materials that were required. In the first

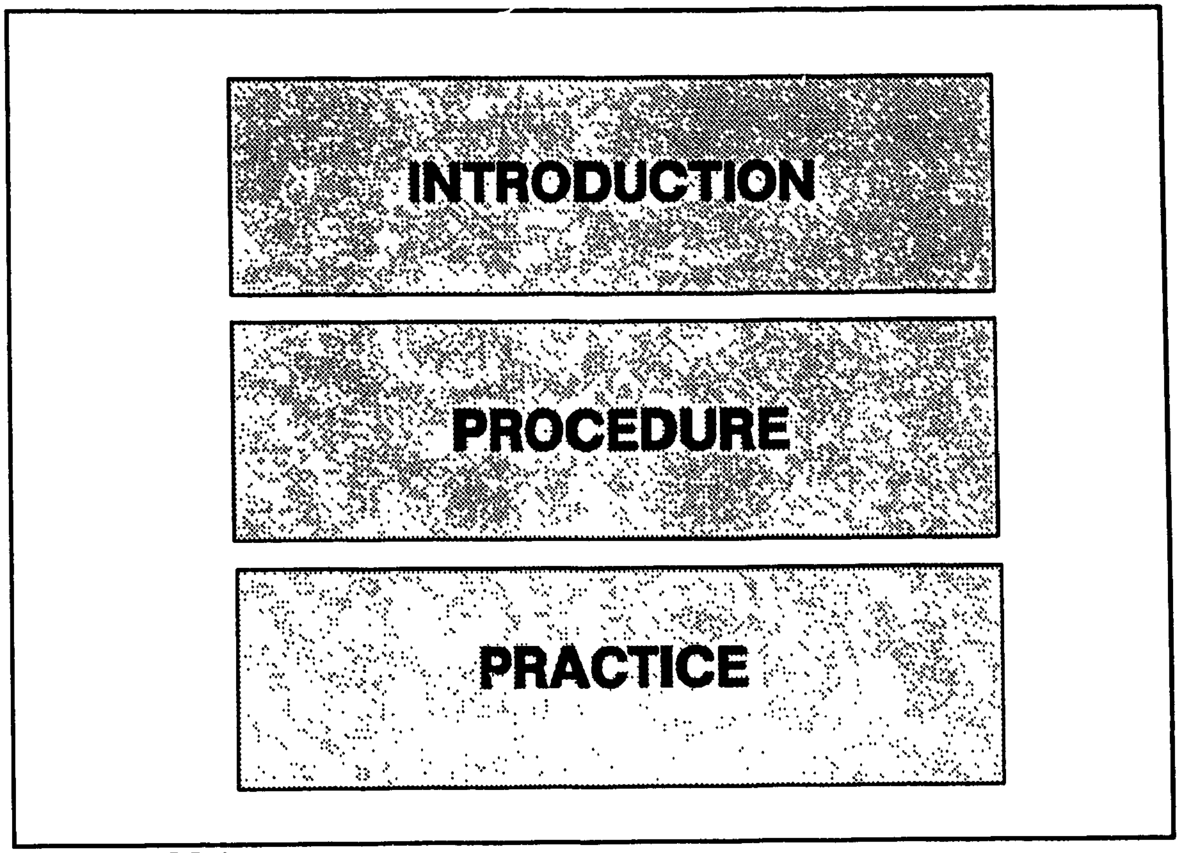

Figure 1. Main menu structure

tools and materials subsection, a still frame video image of each tool was presented in a predetermined order and had a textual description superimposed on it. The chart of tools subsection presented a text screen that listed all of the tools in a random order (they did not appear in the same order in which they were presented in the first tools and materials subsection) as shown in Figure 4.

The other components provided four ways to learn about the fourteen steps that comprise the actual procedure. One presented a video segment which showed a lab technician carrying out the Swipe Check, while a narrator described each step as he went along. In another component, each

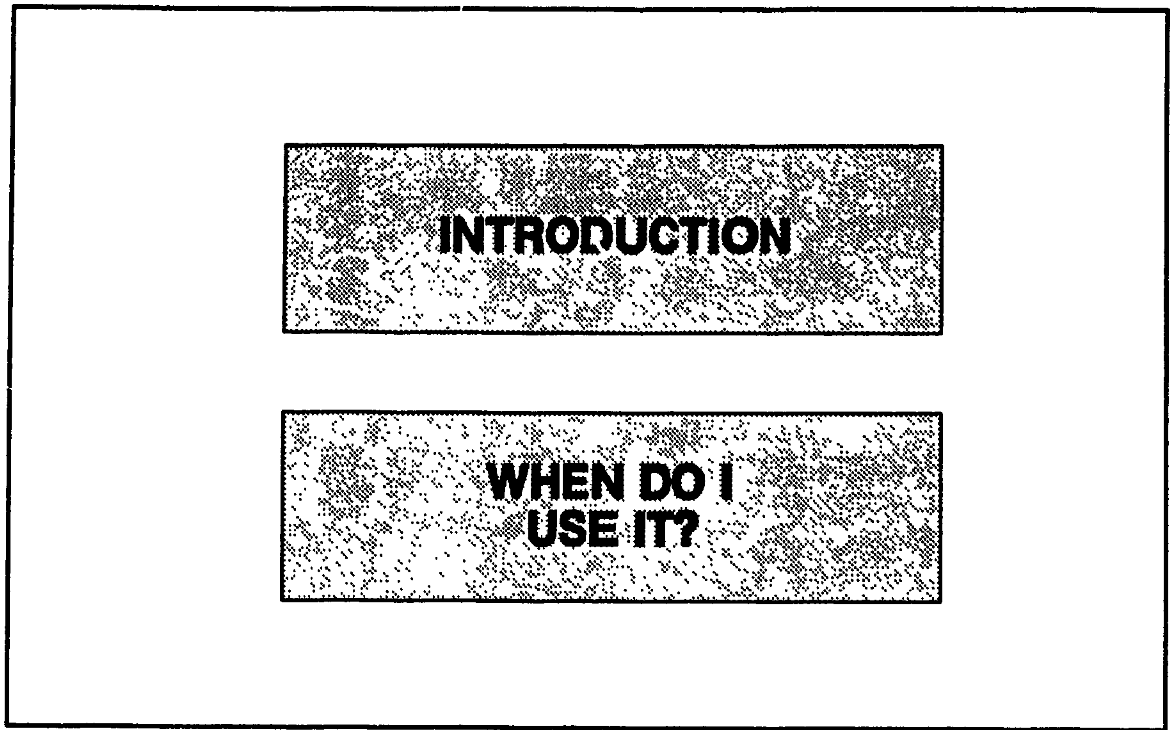

Figure 2. Introduction menu structure

step was broken down into individual segments which included a textual description of the step superimposed on the video, and was presented in the order in which the step must be carried out. The learner's response caused the video segment to be played as the textual information disappeared from the screen. A textual list of the fourteen steps was a third means of instruction, 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 would respond by indicating that the step was correct, or

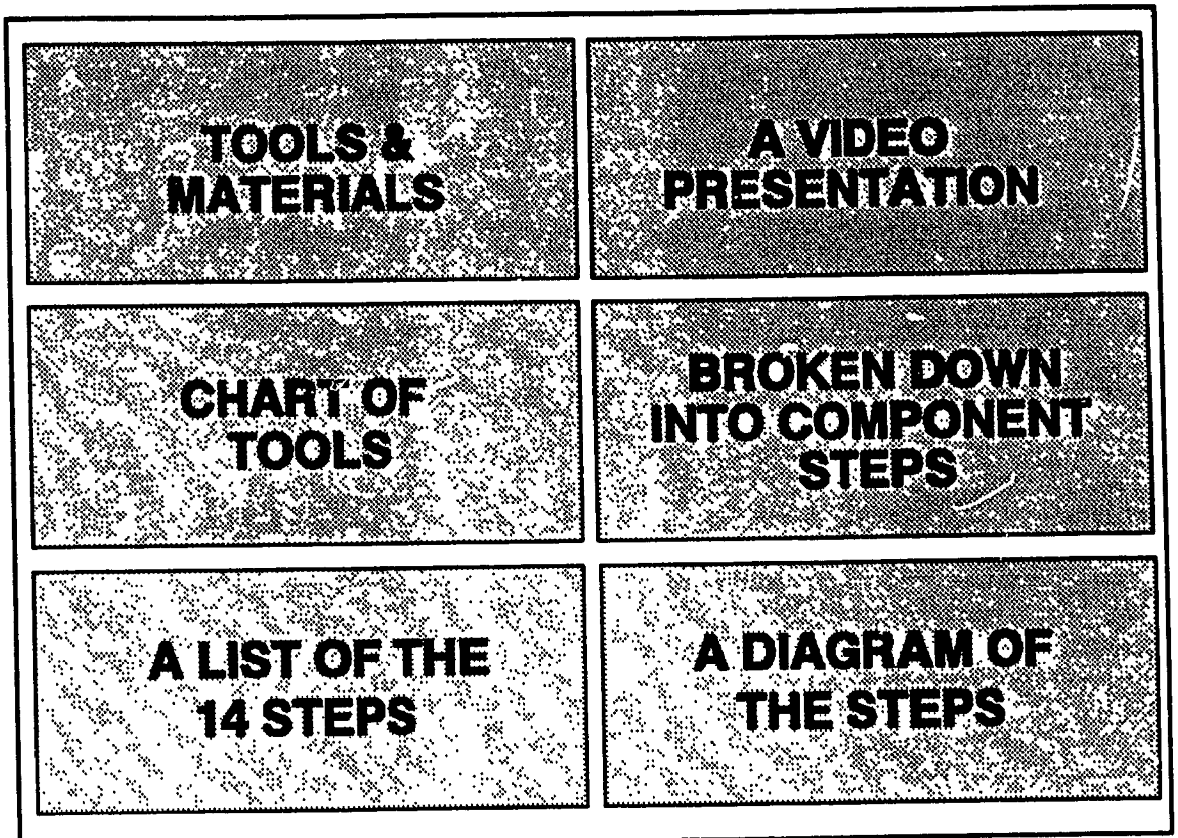

Figure 3. Procedure menu structure

in the alternative, was required to supply the step by typing it at the keyboard. If the 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 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, those steps that were answered incorrectly, and in the case of learner control, to be discussed, those steps that were not attempted) was displayed upon completion of the exercise.

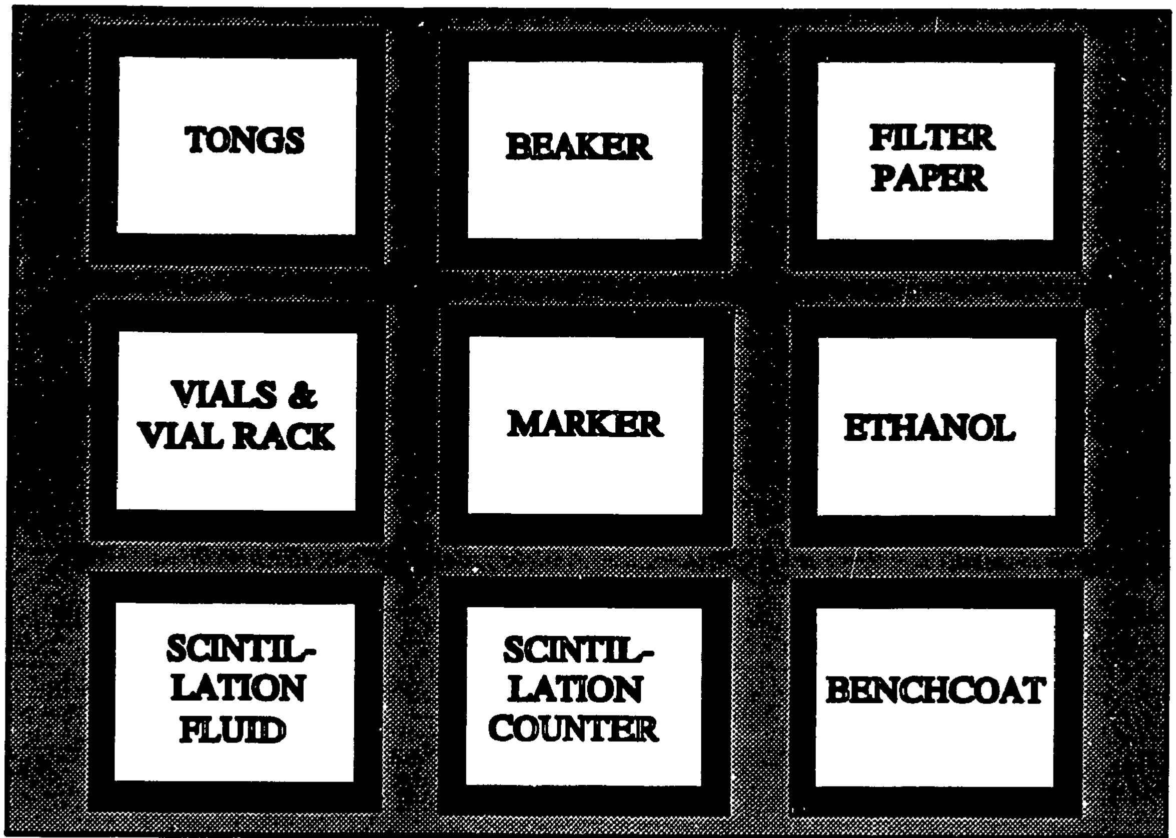

Figure 4. Chart of tools

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 would touch that part of the screen that corresponded to his desired action. Allen 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 enabled in the event of an incorrect step to allow the learner to supply the answer. The particulars 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 was 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 which was preceded with the menu structure that appears in Figure 2. The first component was once again initiated by touching the screen, causing the colour of the introduction box to change before the video began playing. Upon completion of the first video segment, the menu structure in Figure 2 re-appeared, and the second component began which utilized the same initiation protocol as the first.

At the conclusion of the introduction, the main menu structure was re-displayed and the procedure section began according to the touch any part of the screen - box changing colour protocol. The procedure was preceded with the menu structure appearing in Figure 3 and the lesson resumed with the presentation of all six components in the order left to right, starting from the top. The menu structure in Figure 3 re-appeared before each component began and was initiated with the same touch - colour protocol. In those components that contained more than one still frame video image and/or more than one computer/text display, the learner had control over pacing by touching an appropriately labelled box on the screen. Within a component, he could neither go back, nor exit. Similarly, once a section had been completed, it could not be re-initiated.

The practice section began with the appearance of the main menu structure and complied with the touch - colour protocol. The learner was then presented with two screens of instructions and completed all fourteen practice exercises. To respond to a question, he would touch a box labelled *continue*, if the step was correct. If it was incorrect, he would touch a box labelled *make the correction* and would then, in his own words, type the correct step at the 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 he had answered incorrectly.

Designer control. In addition to providing control over pacing, this condition offered a limited degree of instructional control. The program began in the same fashion as did the linear control version, and used the same touch - colour protocol. 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 choice. However, once introduction or procedure had been selected, individual choices, vis-à-vis any of the components that comprised the section, could not be made. If introduction or procedure was selected, 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 touching an 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 at each question. The status grid was displayed when the learner had either, completed the practice, or in the event that the exit option was exercised. In the case of the latter, and in place of correct/incorrect, the words *not done* appeared next to the corresponding step(s). Two control options were then available. The learner could either re-select a question he had attempted by touching the appropriate part of the grid, or he could exit the practice and return to the main menu. Questions that were not tried could not be re-viewed.

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. Within sections (specifically *introduction* and *procedure*) the subsections could also be repeatedly selected by touching the appropriate box, and themselves contained control options not present in the other two conditions.

The two introduction subsections could be selected in any order, and their video segments 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 repeatedly selected in any order. 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 4). Finally, in *a diagram of the steps*, any step could be played by touching that part of the diagram that corresponded to the step (see Figure 5). The other two subsections contained the same control options that were present in designer control.

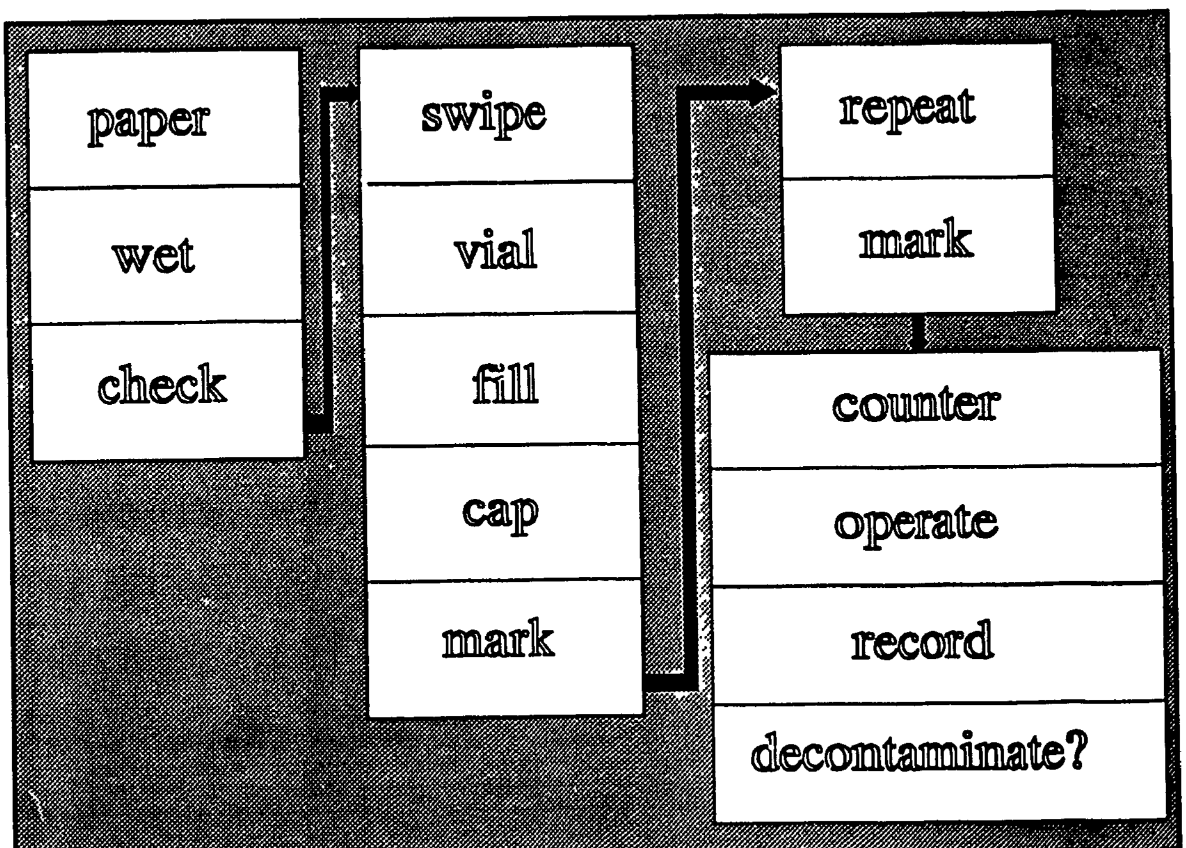

Figure 5. A diagram of the steps

With the exception of the status grid, the practice section was identical to the designer control treatment. In addition to providing the ability to re-view attempted questions or exit, the facility to re-view questions not 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 prior achievement, (median point split) as determined by the vocabulary section of the Nelson Denny Reading Test. This test has shown potential for estimating students' academic ability (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 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 way in which subjects in the learner control condition navigated through the instruction was recorded by the computer program, and was examined descriptively. All effects were analyzed using MANOVA procedures and multivariate *post hoc* comparisons.

Procedure

Four instruments were used in the study, a pretest (Appendix I), the Nelson-Denny Reading Test (Form E), Rotter's Internal-External Locus of Control Scale, and a posttest (Appendix II). The posttest consisted of two parts, 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 a testing session that had been previously scheduled. 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 completion of the pretest, 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 tester initiated a computer program that was designed to acquaint the learner with the touch screen interface. This program included examples that demonstrated, for example, the action that might occur when a part of the screen was touched. It was explained to each subject, that while there was some keyboard interaction, the lesson made extensive use of the touch screen, and this was deemed appropriate and necessary practice. The assigned program was then started and the subject was told that he could take as much time as he wished, and to simply tell the tester when he had finished. The tester 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 was administered as an interpolated task, designed to eliminate 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 posttest, and after finishing was thanked for his involvement and was asked not to reveal any details of the session so as not to create an inherent bias to future participants.

CHAPTER 4

Results

A preliminary scan of the pretest data revealed that the sample did not possess 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 it was 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 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.

Interrater reliability for the posttest was established at $r = .98$ for recall of basic facts, and $r = .87$ for recall of procedure. Scores for both components of the test were derived by averaging the raters' tabulations.

Cell means and standard deviations for the recall, procedure, and time on task measures are presented in Tables 1, 2, and 3 respectively.

A multivariate analysis of variance yielded significant main effects for instructional control, $F_{Hotelling}(6,74) = 4.25, p < .01$, and for prior achievement, $F_{Hotelling}(3,38) = 8.01, p < .01$. The canonical correlations show that the predictive power of the dependent measures was highly loaded on one function. Table 4 presents the eigenvalues and the canonical correlations for these functions. No significant aptitude-by-treatment interaction was observed. The univariate effects on the three dependent measures are summarized in Table 5.

In an attempt to isolate differences between levels of instructional control, a discriminant function analysis was conducted. As a *post hoc* initiative, discriminant function analysis is the multivariate equivalent of univariate *post hoc* pair-wise comparisons (i.e. *Tukey*), which provides protection against inflating α. A similar level of protection in the multivariate case is afforded by the fewer number of *post hoc* comparisons. Specifically, a multivariate analysis of variance with three dependent measures requires a total of 3 comparisons, whereas separate univariate analyses of variance with the same three measures, requires a total of 9.

A significant difference was noted between linear and learner control. The discriminant function accounted for 43% of the variance, $R_c^2 = .655$, *Wilks'* $\lambda = .57, p < .01$. Groups 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 and time on task measures. No significant discriminant functions were observed for designer and linear, or designer and learner.

Table 1. Cell means and standard deviations for recall of basic facts

		Instructional Group			
Prior Achievement		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		Instructional Group LINEAR	DESIGNER	LEARNER	Total
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

[1]Time in minutes

Table 4. Canonical correlations of the discriminant functions

Function	Eigenvalue	Percent	Canonical correlation
1	.67867	98.52	.63584
2	.01018	1.48	.10041

Table 5. Univariate effects on all measures

Source	SS	DF	MS	F	P
			Recall of basic facts		
Control	264.34	2	132.17	9.14	.001
Ability	59.32	1	59.32	4.10	.050
C x A	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
C x A	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
C x A	184.88	2	92.44	.56	.577
Error	6621.98	40	165.55		

CHAPTER 5

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), there are a number of plausible explanations.

The absence of prior knowledge as one perspective, must be considered as a 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.

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 made. This theme is supported by the literature, and while not conclusive, by observing the way that learners navigated through the instruction. Hannafin (1984) proposes that learner-controlled instruction should include advisement to aid in decision making. Milheim and Azbell (1988) have suggested that to include guidance, provides the student with a foundation on which he is able to make a decision as to content and sequence, while at the same time, the program can offer suggestions based on a given choice. 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 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 also because they chose not to initiate sequences that contained important information. In more than a few instances, subjects began the instruction with the practice, but soon realized that they did not possess sufficient knowledge to continue.

It was also found that learner-controlled subjects took significantly less time to complete the instruction, although this is not consistent with previous research (Balson et al., 1984-85; Beland et al., 1985; Goetzfried & Hannafin, 1985; Schaffer & Hannafin, 1986) where students in externally-imposed conditions took significantly less time to complete instruction. In this study, there can be little doubt that it is a consequence of inadequate sequence selection. In fact 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-à-vis time on task.

As previously mentioned, the internality/externality as measured by Rotter's scale did not influence performance, despite the fact that previous research (Holloway, 1978) has found it to be a contributing factor with respect to instructional control. Perhaps a more robust test is needed to determine if an internal/external rating can affect performance, given different levels of program control.

The prediction that high prior knowledge subjects would perform better under self-imposed control conditions is also inconclusive. However, in the absence of such knowledge, and drawing from past research, it can be tentatively assumed that program control is more appropriate.

To summarize, the results of this study suggest that in the absence of prior knowledge, regardless of ability, and regardless of the subject's internality/externality, superior performance is achieved through, and more time is spent on, externally-controlled mechanisms. The study further supports the notion that program-controlled instruction is more suitable for procedural learning and the learning of basic facts (Hannafin, 1984, 1987; Ross & Morrison, 1989).

Additional research is needed to examine the effects of learner control for higher order learning, a need that has been recognized, but appears to have been largely overlooked. Future research should also investigate the effects of including adaptive control strategies to steer students onto the correct path, if it appears that their course is likely to have debilitating or dilatory effects. There is evidence to suggest (Clark, 1984; Cohen, 1984; Hannafin, 1984, 1985; Merrill, 1980; Milheim & Azbell, 1988) that adaptive learner control strategies can yield positive results, putting learners in a better position to make informed decisions, if they are advised accordingly. Still yet another area that may require exploration, is the interface between the student and a computer-mediated device. Effective learner control strategies, in addition to what has been previously cited, may also be a function of the way in which an individual interacts with a computer-based system. It is certainly plausible that *unnatural* mechanisms such as keyboards and touch screens are actually inhibiting some learners from making appropriate choices, that may well be remedied by using a more natural language interface. The inclusion of such an interface and its effects on the learner can and should not be ignored.

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APPENDIX I PRE TEST

Name____________________________

Do you know the steps involved in carrying out the Swipe Check for radio monitoring in a biochemistry lab?

No____

Yes____ Please list as many steps, in correct chronological order, as you can below. Number each step in consecutive order.

Step #

APPENDIX I PRE TEST

General Information

1. Sex___________

2. Age___________

3. First or maternal language______________________

4. On the list below, please indicate the range that best corresponds to your current grade point average, either from your high school or CEGEP before entering Concordia University, or from your previous semester at Concordia.

   ____ 1.0 - 1.5 (D- to D; 50 to 54%)

   ____ 1.5 - 1.99 (D to D+; 55 to 59%)

   ____ 2.00 - 2.25 (C-; 60 to 62%)

   ____ 2.25 - 2.50 (C- to C; 63 to 65%)

   ____ 2.50 - 2.75 (C; 66 to 67%)

   ____ 2.75 - 2.99 (C+; 68 to 69%)

   ____ 3.00 - 3.25 (B-; 70 to 72%)

   ____ 3.25 - 3.50 (B- to B; 73 to 75%)

   ____ 3.50 - 3.75 (B; 76 to 77%)

   ____ 3.75 - 3.99 (B+; 78 to 79%)

   ____ 4.00 (A; 80 to 100%)

5. What type of student are you? ____ Full Time

   ____ Part Time

   ____ Independent

6. Are you or do you plan to be a Science major?_______________

7. What year of your program are you in at Concordia University?________

APPENDIX II POST TEST

Name________________________________

Post-test (Swipe Check for Radiation Monitoring)

The following questions are designed to provide us with information about the program that you have just seen. We would like to find out how much you can recall from the presentation in order to assess whether the material was clear and comprehensible.

I. What are the **two** most important reasons for performing a swipe check in a bio-chemistry lab?

1)____

2)____

II. Name **three** specific times or situations when a swipe check should be carried out.

1)____

2)____

3)____

III. **Seven** specific areas for radiation monitoring in a biochemistry lab were mentioned in the program. Try to identify as many as you can.

1)____

2)____

3)____

4)____

5)____

6)____

7)____

IV. a. On what level of isotopes would you normally perform a swipe test?

____

b. Name two specific examples of this level of isotope mentioned in the program.

1)____

2)____

c. What other type of radiation level monitoring was mentioned?

____

V. In the program, there were **nine** tools/materials required to perform the swipe check. List as many of these as you can below.

1)____

2)____

3)____

4)____

5)____

6)____

7)____

8)____

9)____

APPENDIX II POST TEST

VI. The program that you have just seen contained 14 specific steps or procedures in describing how to carry out the Swipe Check. Please list as many of these steps, in chronological order - or from start to finish - as you can. **Be as precise as possible when describing the steps.**

Step #

1)____

2)____

3)____

4)____

5)____

6)____

7)____

8)____

9)____

10)_______________________________________

11)_______________________________________

12)_______________________________________

13)_______________________________________

14)_______________________________________