INTERACTIVE VIDEO:
THE EFFECTS OF ADAPTIVITY AND MODALITY

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ABSTRACT

The effectiveness of interactive video instruction in improving learner performance was compared with computer assisted instruction, video instruction and textual instruction in a 2 x 2 factorial design. Two levels of adaptivity (low and high) were crossed with two levels of modality (unimodality and multimodality). Four instructional technologies were operationalized as follows: text: low adaptivity/unimodality; video: low adaptivity/multimodality; computer assisted instruction: high adaptivity/unimodality; interactive video: high adaptivity/multimodality. Fifty-two, ninth-through-twelfth graders were randomly assigned to the four instructional treatment groups and were presented with parallel forms of the same computer hardware lesson, differing only in presentation media (text, video, computer assisted instruction, interactive video). The lesson was immediately followed by a recall test and a retention test was given two weeks later. Two interactive video subjects were interviewed about their experiences. Analysis of variance was performed on three dependent variables: instructional time, post test scores and retention test scores. Results indicate that

interactive video is not necessarily a more effective instructional technology than the other three tested. The nature of the adaptivity built into the controlling computer program was found to be critical to the effectiveness of interactive video.

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INTRODUCTION

Educators have long been fascinated by the image of a robot "teacher". An omnipotent, omniscient machine immune to the failings of its human brethren. The teaching robot may never materialize, but self-paced, teacherless instruction techniques do exist and continue to develop. The behaviouralist inspired teaching machine of the 1920's is probably the first recognizable educational technology in the twentieth century. Modern computer and communications technologies have given impetus to the field. These teaching technologies have been alternately praised as a panacea for everything wrong with education, and damned as one more example of the dehumanizing influence of machines. Interactive video (IV) is one such technology.

IV is a marriage of computer and video techniques. IV hardware consists of some form of video player (tape or disc) connected to a microcomputer. The video player functions (play, rewind, and fastforward) are under the control of the microcomputer, thus allowing random access to any part of the video tape or videodisc. Various degrees of computer control are possible, varying from none (sometimes referred to as "level 1") up to complete computer control ("level 3").

IV allows for a new type of instructional delivery which is, depending on how you look at it, video based instruction that need not proceed in the usual linear fashion; or computer assisted instruction (CAI) that has the "supergraphics" capability of moving pictures and sound. CAI containing video images provides an auditory and visual realism not yet available with computer generated sound and graphics alone. Video instruction under computer control allows for adaptivity to the needs of the user not possible with conventional linear video material.

STATEMENT OF THE PROBLEM

The field of CAI has undergone considerable research in recent years, first, to test the effectiveness of the instructional technique; and second, to develop principles and guidelines for the design and implementation of CAI. Very little of this type of research has been done with IV. As Hannafin, Phillips and Tripp (1986) point out:

> Future research with interactive video should help to determine the relative uniqueness of, and the similarity among, interactive video and other instructional systems across affective, cognitive, and pragmatic concerns. p.138.

Research to date has focused on the similarities among instructional techniques. While it may be true that the general principles of learning must apply to all instructional technologies, a more profitable line of research may be to examine what is unique to each. An understanding of the uniqueness of IV could lead to more effective design and application of IV technology.

What is it about IV that makes it unique? Surely the fact that it is a hybrid of two other instructional technologies: computer assisted instruction and video.

> Research related to the two component technologies, computer assisted instruction (CAI) and video-based instruction, may provide insights into the instructional effectiveness of interactive video. (Schaffer & Hannafin, 1986, p.89.)

Adaptivity is the characteristic of IV that it shares with its parent technique, CAI. Adaptivity is, in fact, the raison d'etre for CAI. If CAI courseware could not adapt instruction to the responses of the user, it would be no different from a lecture or a text book.

Video instruction takes place via two sensory modalities: visual and auditory. The visual modality has two channels of relevance: text and pictures. The auditory channel also has two relevant channels: verbal and sound. IV shares this characteristic of multimodality with its other parent: video instruction.

This study was designed to answer the following questions:

* Is IV an effective method of instruction when compared to other forms of "teacherless" instruction?

* And if so, does it owe this effectiveness to:
  a. its adaptive nature,
  b. its multimodal nature,
  c. a combination or interaction of these two factors?

OVERVIEW OF METHOD

To investigate the problems outlined above, an experiment was designed to compare the effectiveness of four instructional technologies: text, video, CAI and IV in such a way as to measure the relative contributions of adaptivity and modality. As Figure 1 illustrates, these four instructional technologies represent the four possible combinations of high/low adaptivity and uni/multi modality. If the same lesson was taught using each of these four instructional technologies then effectiveness of the technology could be measured as the amount of learning produced. IV should be most effective because it has the best of both parent techniques: high adaptivity and multimodality. Text should be the least effective because it has the worst characteristics of the parent techniques: low adaptivity and unimodality. The other two techniques should be of intermediate effectiveness. As a general case the high adaptivity technologies should produce better results than the low adaptivity technologies; and multimodal technologies should produce better results than the unimodal technologies.

STATEMENT OF HYPOTHESIS

Given the same lesson presented in four different media (text, video, CAI, IV), to four different treatment groups:

1. Effect of instructional technology: There will be a significant difference (alpha = .Ø5) between the four instructional techniques (text, video, CAI, IV) for the following dependent variables:
   a. immediate recall - score on a test given immediately after treatment.
   b. retention - score on a parallel version of the same test given two weeks later.
2. Effect of adaptivity: There will be a significant difference (alpha = .Ø5) between low adaptivity instructional techniques (text, video) and high adaptivity instructional techniques (CAI, IV) for the following dependent variables:
   a. immediate recall - score on a test given immediately after treatment.
   b. retention - score on a parallel version of the same test given two weeks later.
3. Effect of modality: There will be a significant difference (alpha = .Ø5) between

uni-modality instructional techniques (text, CAI) and multimodality groups (IV, video) for the following dependent variables:

a. immediate recall - score on a test given immediately after treatment.

b. retention - score on a parallel version of the same test given two weeks later.

4. Interaction effects between adaptivity and modality: There will be no significant interaction effect (alpha = .05) between modality and adaptivity for the following dependent variables:

a. immediate recall - score on a test given immediately after treatment.

b. retention - score on a parallel version of the same test given two weeks later.

5. Effect of instruction time: There will be no significant difference (alpha = .05) between the four instructional techniques (text, video, CAI, IV) for the dependent variable instructional time - number of minutes spent on the learning task.

REVIEW OF THE LITERATURE

Interactive video (IV) can be viewed as a hybrid of CAI and instructional video. The following review will focus first on research related to CAI, then on the small number of IV studies to date, and finally on research related to two attributes of IV: adaptivity and modality.

RESEARCH IN CAI

A major focus of CAI research has been the development of guidelines for the production of pedagogically sound instruction. These guidelines have evolved from many sources: the users and developers of CAI, empirical investigations and comparative studies.

User Evaluation of CAI

One major source of CAI development guidelines is the user evaluation of existing software. This process has been carried out locally by the Provincial Educational Media Centre (PEMC) of the B.C. Ministry of Education and on an international scale by Educational Products Information Exchange (EPIE) at Columbia University (Bialo & Erickson, 1985). The main purpose of this type of evaluation is to provide the potential teacher-user with product information regarding content, grade level, and pedagogical value of the software (Reeves & Lent, 1984), (Walker & Hess, 1984). From these evaluations, however, hundreds of specific guidelines for CAI development can be extracted. They are reminders of the pinnacles and pitfalls of CAI but provide little in the way of a systematic approach to CAI development.

Experiential Guidelines

Another approach to guideline development is to focus on the CAI developer and not the user. From this approach can be developed guidelines to aid the programmer/instructional designer in his job. It should be noted that these guidelines are largely experiential and not experimentally substantiated.

Many authors have developed such guidelines for specific types of CAI: science (Bork, 1981), intelligent tutoring systems (Sleeman & Brown, 1982), simulations (Rowe, 1984), or one-computer/many-students applications (Hativa, 1984). Other authors have taken a more general approach and have produced "how to books" collecting many years experience into one volume (Burke, 1982), (Godfrey & Sterling, 1982). Checklists for the design of CAI, both general (Balman, 1984), (Jensen, 1985), (Hartley & Lovell, 1984) and specific (Friend & Milojkovic, 1984), (Gaines, 1984), (Gold, 1984) have been developed. Some authors bring a different perspective to the development of CAI guidelines. They have approached the question from fields related to CAI: instructional design (Gagne, Wager & Rojas, 1984), (Malone, 1981) and computer programming (Simpson, 1982).

Guidelines from Comparative Studies

A third approach to developing CAI guidelines has been to conduct research studies comparing CAI to standard instructional delivery techniques. This approach has been useful in that it specifically identifies those aspects of instruction where CAI has proven effective, thus providing guidelines for future focus in CAI development. These comparative studies have been the subject of a series of metaanalyses (Bangert-Downs et al, 1985), (Kulik et al, 1983). Some of the major findings are that CAI is most effective:

- at lower grades.
- as supplementary rather than replacement instruction.
- when structured rather than unstructured.
- as an enrichment activity.
- teaching math and science rather than English.
- with physically and mentally disabled students.
- in tutorial rather than drill mode.

Empirically Developed Guidelines

Perhaps the most promising source of CAI guidelines is research of the type typified by that of Tennyson and his associates (Tennyson et al, 1984). Here the focus is on "finetuning" CAI by manipulating instructional variables and measuring the learning that takes place. The Minnesota Adaptive Instructional System developed by Tennyson and associates can use a variety of strategies to adapt CAI to student needs. Important dimensions of adaptation have included: amount and sequence of instruction, instructional display time, feedback or advisement, and amount of student control over the learning process.

Summary of CAI Guidelines

There seems to be no lack of detailed guidelines when it comes to developing CAI instructional materials. General principles, however, are lacking. The following is a partial list of prescriptions compiled from the literature (much of it mentioned above) by Kearsley (1985). They constitute a general set of guidelines for developing CAI and by extension, IV.

1. Make it interactive - Ask questions and pose problems; encourage learners to make choices.
2. Make it motivating - Use graphics, color, sound effects, fantasy, etc. to make it interesting.
3. Provide learner control - Allow the student to control sequencing via menus, control commands, function keys, etc.
4. Make screen displays readable and visually stimulating.
5. Modularize as much as possible in order to provide the right level of difficulty.
6. Ensure that programs have instructions and adequate helps.

RESEARCH ON IV

General Information Articles

One quickly notes a developmental trend in the literature during the short history of IV research. Earlier articles (Molnar (1979-80), Copeland (1982), DeBloois (1982), Howe (1983), Glenn (1983), Brodeur (1985), Kearsley & Frost, 1985)) were very general as is appropriate when introducing a topic foreign to most readers. These articles focused on the technical aspects of IV systems; advocated the use of IV as an instructional delivery medium; and provided very elementary "cookbook" instructions for producing IV courseware. These articles were pioneer efforts but except for identifying research issues are of little value in the empirical and theoretical analysis of IV instruction. Some articles of this type continue to be written (Smith, 1987; Hosie, 1987), perhaps because IV is still a foreign topic to many, in spite of the fact that it is no longer new.

Case Studies

Many authors have developed IV instructional materials and field tested them in varying situations. Their concern has been to take advantage of the unique attributes of IV for a specific application, rather than to systematically research the medium itself. The following examples are cited to illustrate the breadth of application IV can have. They are basically case studies in the use of IV and not critical analyses of the technique.

IV has been used effectively to teach a number of skills to mentally handicapped, secondary school students. Kelly et al (1986) found IV to be a superior method of teaching fractions to special education students, but attributed the difference to instructional design features and not the instructional medium per se. IV was used to teach on-the-job social skills to mildly handicapped adolescents, (Malouf, 1986) and life skills to mildly retarded high school students (Browning et al, 1986). Results indicate that IV produced higher post test results than workbook methods.

Hasselbring et al (1987/88) also compared the effectiveness of teaching elementary fractions using a videodisc versus traditional teacher centred methods. They tested normal elementary students and found videodisc to produce significant gains in fraction skills and computation. However, they caution against comparative studies like this because of uncontrolled factors like teacher quality.

Not surprisingly the visual aspect of IV has found instructional application in the visual arts. Acker & Klein, (1986) performed a comparison of the effects of computer and video graphics on performance of visualizing spatial tasks. The main focus of the study was students' perception of media. Computers were seen as more demanding, while video was seen as friendlier and more entertaining. The suggestion was made that perhaps educational video protocols are needed to signal the watcher that "this is educational so pay attention." Abrams & Streit (1986) compared the effectiveness of IV and linear video to teach basic photography to college level students. Higher final exam results were attributed to increased control over instruction and increased attention induced by the novelty effect of IV. They noted the need for more systematic further study.

IV has been tested and has found a niche in medical instruction. Harless (1986) created an IV drama in which a group of medical students, along with an instructor, interact verbally with a computer to diagnose and prescribe treatment for a "video patient" in a hospital emergency ward. Branch et al (1987) implemented an IV method of teaching auscultation of the heart (i.e. diagnosing heart defects based on the sound of the heart beat) They found IV to be a cost effective alternative to the traditional method of using experimental animals.

Smith et al (1986) found that first-year college chemistry students performed better on lab write-ups and lab tests when IV lessons were used for prelaboratory instruction or as a replacement for traditional laboratory experiments.

In an interesting group application of IV, Milheim & Evans (1987) found many advantages over normal instructional video including: the stimulation of group discussion, the possibility of program interruption for group discussion, the capacity for program branching to multiple scenario endings and the capacity for computerized data gathering.

While the studies quoted above illustrate the breadth and innovation of current IV applications there are several commonalties that indicate attributes of appropriate IV applications. These include situations that require: social simulations, highly visual material, dangerous and/or expensive procedures. In addition, the benefits normally attributed to CAI are still enjoyed: increased student involvement and interaction, adaptation of content to the needs of the student.

Theoretical/Empirical Research

IV has suffered from a lack of serious theoretical and empirical research up to this point.

> The absence of empirical research in computer-based interactive video (CBIV) has provided little theoretical structure from which to develop effective software. (Ho, Savenye & Hass, 1986, p.126)

> The published literature ... has contributed little to the creation of a sound foundation for the design and application of interactive video. (Hannafin, 1986, p.101)

Without a theoretical basis for IV development and implementation, all that exists is a random collection of observations that eventually grow so large as to be useless. Recently a few studies have appeared in the literature which have begun to focus on the problem of developing a theoretical and empirical base for future IV development.

Dalton (1986) investigated the effectiveness of IV compared to CAI, and text presentations. Findings indicate that the interactive nature of IV could account for the effectiveness of these two techniques when compared to text. Attitudes toward learning were also better with the interactive learning technologies.

Ho, Savenye & Hass (1986) found that IV lessons containing review sections, whether user or computer controlled, produced better learning than those without.

Hannafin et al (1986) examined the combined effects of orienting, processing, and practicing activities on learning from IV. They found that the opportunity for practice which IV (and CAI) provides accounted for most of the differences between treatment groups.

Shaffer and Hannafin (1986) tested the effects of four levels of interactivity on subsequent learning. Results indicate that fully interactivated video is a more effective means of instruction than lesser activated versions. However, non-interactive, linear video is a more efficient system when time is considered.

Gay (1986) investigated the relationship between the subjects' prior level of subject understanding, degree of user control over the program and the subsequent effect on learning via IV. The results were consistent with similar studies of CAI: subjects who had some prior concept understanding of the material learned equally well whether the lesson was controlled by the computer or by themselves. On the other hand, subjects with lower prior conceptual understanding did not learn as well with learner control as with program control.

Summary of IV Research

Ebner et al (1984) and Hannafin (1985) emphasized the amount of IV research that needs to be done. The articles cited above have appeared since 1986 and are beginning to meet this need. The articles have obviously evolved from CAI roots. They focused on three variables that have traditionally occupied CAI researchers: locus of control (user or computer), advisement (degree and type), and degree of interactivity. As yet little has been done to investigate the visual and auditory attributes of IV.

RESEARCH ON ADAPTIVITY

Interactivity

Kearsley's number one CAI development guideline listed above says: "Make it interactive."

Bork agrees:

> ...the most valuable aspect of the computer in education is that it allows us to make learning interactive, with students constantly cast as participants in the process rather than as spectators. (Bork, 1981, p.275)

It is important to distinguish the term interactivity from the term adaptivity. The term interactivity, as it used above, refers not to adaptivity per se but simply refers to the dialog between the computer and student. This dialog may or may not be adapted to the needs of the student by the computer.

Adaptivity has meant different things to researchers in and out of the field of CAI. Glaser (1982) relates adaptivity to learning styles. Hartley and Lovell (1984) argue that adaptivity has to do with psychological characteristics of the learner.

Jonassen (1985) has also noted the difference between adaptivity and interactivity. He expands the concept of adaptivity to include external and internal adaptation. External adaptation adapts the delivery system to the learner. Internal adaptation adapts the content to the learner.

Adaptivity occurs in and out of the classroom. A medical doctor adapts treatment to the illness of his patient. A mechanic adapts his repairs to the nature of the car's defect. As described above, Tennyson and his fellow researchers on the Minnesota Adaptive Instructional System (MAIS) have focused on adapting four aspects of instruction to the learner: amount of instruction, sequence of instruction, display time, and advisement information. (Tennyson et al, 1984). Adaptivity of instruction could be defined as the diagnosis of misconceptions and prescription of remedial action.

ICAI Research

It is in the field of "intelligent computer assisted instruction" (ICAI) that this concept of adaptivity has been most highly developed. Programs that use artificial intelligence techniques to aid the learning process have been labeled as ICAI.

> (See Figure 3) In general the tutorial module uses the student module to learn what the student knows and in consultation with the expert module, decides what to teach next, at what level to present the material and with what teaching strategy. The tutorial module then presents the student with a task and uses the student's response to update the student module, and the cycle repeats. (Rambally, 1986, p.39)

A small number of ICAI programs have been developed. Most have been experimental rather commercial ventures. Well known examples include: "Debuggy", an arithmetic tutor (Burton, 1982); and "Lisp Tutor", a Lisp programming tutor, (Anderson et al., 1985)

The aspect of instruction of most concern when diagnosing and prescribing remediation is the size of the information "chunk".

> ...instructional materials produced by the system for student's query or mistakes are often at the wrong level of detail. The size of information chunk that a learner can handle in processing the knowledge varies as he/she progresses in learning: as he/she progresses in learning, he/she can handle a bigger chunks of knowledge units. Therefore, instructional materials should be organized at the appropriate level of chunking based on the

> learner's stages of progress. (Kim, 1986, p.15)

> Some of the criticisms leveled against CAI and early ICAI systems are that the material is discussed at the wrong level of detail, too much or too little knowledge is assumed on behalf of the student, and a particular conceptualization of the subject matter is assumed with no attempt made by the system to discover the conceptualization which the student has. (Rambally, 1986, p.40.)

When designing for adaptivity in CAI it is useful to imagine how a live teacher would handle a typical situation. Most instruction goes through continuous cycles of teaching, evaluation and reteaching. Evaluation can be thought of as any type of diagnostic activity. This diagnostic activity may be a test, the detection of a glazed look in a student's eyes, or simply a teacher's feeling about student comprehension. Diagnosis may be triggered by a student's request to "go over that again." In any case, evaluation often leads to remediation of the material just taught and the teacher may take several approaches when planning a strategy for this remediation. One of the common approaches may be to teach the material again but this time to break it down into smaller chunks. This facility to teach the same lesson or indeed the same concept with varying degrees of fineness, and to adjust this degree of fineness to the student's rate of comprehension would be desirable in any CAI. In this regard, the computer may be potentially superior to the live teacher. While a live teacher can only periodically diagnose and remediate, the computer can continuously assess and adjust the coarseness of instructional chunk. Of course the computer cannot diagnose more ambiguous forms of feedback like the "glazed look" in a student's eyes.

Figure 4 represents the cognitive structure of an imaginary cognitive domain. Looking at it from top down it could said that concept 1.Ø can be analyzed into two sub-concepts: concept 1.1 and concept 1.2. These concepts can be further analyzed into their component concepts, and so-on. Two things happen when moving from higher to lower concepts: the concepts become less general - more specific, and the concepts become less abstract - more concrete . At the lowest level of the conceptual hierarchy would be found the concrete examplars upon which all higher levels are based.

In the instructional setting, whether teacher or computer based, naive learners must receive instruction at the lowest level in the hierarchy.

Others with some background may be able to deal with abstraction and generality of an intermediate level. The most advanced students may only need a review at the very top level of the conceptual hierarchy.

Often, however, a student has gaps in his knowledge or understanding. He may have complete knowledge of one branch of the knowledge structure but no knowledge of another. In this case high level reviews would be required in some areas and low level, fine grained instruction in others.

Designing for Adaptivity

How could an adaptive system of teaching, diagnosis and remediation be incorporated into CAI? Knezek (1988) describes one such intelligent tutoring system (ITS):

> One can conceive of a traditional tutorial presented in Socratic form, such that the question is asked first and the presentation follows, rather than vice-versa as is the usual case in traditional CAI. With such a tutorial the presentation, response, and feedback might be identical in the traditional tutorial and the ITS, provided every question were answered correctly. The difference would arise when the learner entered a wrong answer.
>
> Remediation in a traditional tutorial usually involves repeating the set of screens covering the content not mastered. This is somewhat

> like a classroom teacher repeating a statement when a student fails to understand. The great hope for an ITS is to have the program comprehend the nature of the student's misconception and select appropriate remediation, just as is currently done by a good human teacher. (Knezek, 1988, p12)

Summary of Adaptivity

In designing the computer program that drives the IV lesson it is important to make it capable of adapting the lesson to the needs of the learner. This does not mean that the learner should have no control over the lesson. Ideally the learner should be involved and aware enough to direct his own learning. However, when the subject area is so foreign that the learner is unable to direct the learning, then the computer should take over that function.

While adaptivity is most important, simple interactivity has its place. Interactivity keeps the learner from becoming passive and gives him a chance to practice what he knows.

RESEARCH ON MODALITY

Adaptivity is the major feature that IV shares with CAI. The main distinguishing feature of these two is that while CAI presents instruction through written text and graphics, IV can utilize both of these modalities as well as sound and high quality still and moving pictures. This is a feature that IV shares with its other parent technology...video instruction.

When dealing with the question of modality and its effect on instruction through media it is important to first establish what the various sensory modalities are. In an exhaustive literature review on the subject, Hartman (1961) points out that media channels correspond to the human sensory modalities: hearing and vision. The visual channel can be subdivided into a pictorial channel and a print channel (visual verbal), while the auditory channel can be divided into two channels: auditory verbal (spoken words) and auditory non-verbal (sound effects and music). For the purposes of this study, video instruction can utilize three modalities: pictorial, visual verbal, and auditory verbal.

Comparing Modalities

What is known about the strengths and weaknesses of the pictorial, visual verbal and auditory verbal modalities when viewed in isolation from each other?

Hartman's review indicates that auditory verbal presentation is more effective than visual verbal presentation when the information is easily understood. The reverse was found to be true when the information is complex. Likewise, it is easier to associate information with a picture than it is to associate it with a word.

Hsia's (1968) review of single modality superiority concludes that:

> ....there are many factors influencing the relative effectiveness of A (audio perception) and V (visual perception), and that neither is inherently superior to the other. p.249.

The general conclusion about single modality superiority seems to be that there is no universally superior sensory modality. The effectiveness of instruction depends on the optimization of the match between the characteristics of the modality and the material being taught.

Combining Modalities

Much of the research has conceded that multimodal instruction can be superior to single channel instruction.

> ..tangible evidence suggests the possibility that when the amount of information to be processed is optimal, the AV channel may be a more effective means of communication than either single channel. (Hsia, 1968, p245)

> If the same information is stored both verbally and pictorially, it is more likely to be retrieved. (Kozma, 1986, p13)

> Comparisons of pictorial-verbal presentations strongly indicate advantage for the combination of channels. (Hartman, 1961, p245)

In spite of the concession that multimodal instruction must be superior to single modal instruction, the literature is far from unanimous (Severin, 1966). Much of this contradiction exists because of the lack of control exerted over the interaction between the two modalities.

Research suggests that the relationship between the information in the two channels can vary along a continuum from redundant, to related, to unrelated, to contradictory. As common sense would dictate, findings suggest that learning is maximized by redundant information in two modalities and minimized by contradictory information in two modalities (Hartman, 1961, Severin, 1966). The effect of related information is not a simple one however because of the difficulty of defining what related means.

Theoretical Explanations

A number of psychological theories have been proposed to explain the effects of instructional modality on learning.

1. Learning Theories

Cue Summation Theory: Cue summation theory predicts that the amount of learning is directly proportional to the number of stimulii or cues available. If this holds then multimodal instruction should be superior to single modal instruction (Severin, 1966).

Stimulus Generalization Theory: Stimulus generalization theory predicts that the amount to learning decreases as the recall situation becomes less similar to the learning situation. In other words, measurable learning decreases as the requirement to generalize increases. If this is true then multimodal instruction should be superior because the recall situation has two chances to match the learning situation instead of just one (Severin, 1966).

2. Information Processing Theories

One principle of information processing theories is that the central nervous system has a physiologically limited input capacity. If this is correct then care must be taken not to overload the central nervous system with too much information as might be the case with multimodal instruction (Hsia, 1968).

Dual Coding Theory

> Dual coding theory is based on the assumption that memory and cognition are served by two separate symbolic systems, one specialized for dealing with verbal information and the other with non-verbal information.... Interconnectedness means that representations in one system can activate those in the other... (Pavio, 1981)

If this theory is correct then multimodal instruction would be superior to single channel instruction because information gaps in one system might be filled by information stored in the other.

Single Channel Theory: This theory postulates that information is processed from only one channel at a time. During multimodal instruction the central nervous system switches between the visual and auditory modalities. If this is true, then multimodal instruction that is not completely redundant in both modalities will cause problems. Important information may be missed because the central nervous system is attending to the wrong modality. In addition, there is the possibility that the system may "jam" because it cannot simultaneously processes two sources of information (Broadbent, 1957).

Video Production Checklists

Another approach to instructional video production guidelines has been to take a much more empirical approach. In other words, find out what works and not worry so much about why it works.

One of the most prolific researchers in the area of visual learning is Francis Dwyer (1978). His findings have consistently supported the contention that the use of visuals specifically designed to complement oral and printed instruction improves student achievement. He has also found that this is not a simple, automatic relationship and that many variables affect it. These variables include:

- medium of instruction
- nature of informational content
- time spent viewing
- grade level of student
- use of color
- asthetics of visuals
- realism of visuals
- size of visual
- focusing questions

Braden (1986) offers a 2 page check list condensed from what he claims to be "tons" of materials that suggest good practice in visual design.

Modality Summary

In designing the video component of IV it is important to keep in mind the points reviewed above. One would be working from the theoretical assumption that the audio and visual modalities do have an complementary effect. And that this additive effect is not automatic but is achieved when the material presented in each modality closely complements each other. One advantage of IV over normal instructional video is the possibility of repeating segments of video on demand. This makes the problem of information overload, and single channel processing less serious. The learner can simply repeat a video segment until he understands the information.

SUMMARY

IV is a combination of two instructional technologies: CAI and instructional video. As such it possesses similar strengths and weaknesses. The design of IV courseware must take into consideration the principles of instructional design particular to each of its parent technologies. The key features of CAI and video are adaptivity and multimodality respectively. Design features dictated by these attributes must also be considered. In addition, IV is a unique medium and design principles are beginning to evolve that are unique to it alone.

METHOD

Subjects

Subjects were 52 ninth-through-twelfth graders selected from five computer studies courses offered in a small secondary school. All subjects were familiar with computer operation and were familiar with the background material to the actual lesson presented.

Procedure

During the month prior to the experiment, all subjects received instruction in the following topics:

1. General organization of a microcomputer,
2. Input devices,
3. Output devices,
4. Data storage devices: primary and secondary.

These lessons were taught in a regular classroom, using a lecture format, supplemented with appropriate visuals and display items. Each lecture was followed the next day with a short quiz to monitor the short term retention of the material. The purpose of this preliminary instruction was to provide a context for the eventual experimental lesson, and to familiarize the subjects with testing procedures.

Once these preliminary lessons were completed the actual experimental lesson was taught during regular classroom hours over a five day, Monday-through-Friday period. The experimental lesson dealt with the structure and function of one part of a microcomputer: the central processing unit. The 52 subjects were randomly assigned to one of four treatment groups and were taught the same material using one of four "teacherless" methodologies: text, video, CAI or IV. Small groups of text subjects silently studied paper copies of the lesson material. Small groups of video subjects watched a video presentation of the lesson material. CAI subjects completed their lessons individually on an Apple II computer running a tutorial-type CAI program. IV subjects carried out their lessons individually, using an Apple II computer interfaced with a Panasonic AG 6200 video cassette recorder by a Whitney Interactive Video interface. All subjects were informed that they could take as much time as they wanted with the lesson but in reality only the text subjects could control the amount of time spent.

Each subject was given a recall test immediately after completion of the lesson and a retention test two weeks after the original lesson. The time required to complete the lesson was also recorded. Two of the IV treatment subjects were interviewed after the experiment about their experience.

Instructional Treatments

The structure and function of the central processing unit, formed the content of the four experimental lessons. See Figure 5 for the cognitive structure of the concepts in the central processing unit lesson. The lessons differed only in instructional media: text, video, CAI or IV.

Text lesson: A two page written explanation of the structure and function of the central processing unit was developed. The readability level of the text lesson was Grade 10 according to the Flaich-Kincaid Readability Scale and thus appropriate for the subjects. See The appendix for a copy of the text lesson.

Video lesson: The text lesson provided the script for the auditory portion of the video lesson. The video portion of the lesson consisted of a number of moving, graphical images which illustrated the auditory material.

CAI lesson: The CAI lesson was essentially a tutorial "page-turner". The textual content of the CAI lesson was taken directly from the text lesson. Passages of text were presented on the computer screen for the subject to read. These passages were interspersed with multiple choice questions designed to assess the subjects understanding of the textual passages. The computer program adapted the order of text presentation based on the accuracy of subject responses to the questions. An explanation of the computer program and the logic behind its adaptive nature will follow the description of the IV lesson.

IV lesson: The IV lesson combined the adaptive computer program designed for the CAI lesson with the video tape developed for the video lesson. From the subjects' perspective, the only difference between the CAI and IV lesson was in the lesson material: on-screen text in the CAI lesson; video and voice in the IV lesson.

Adaptivity Algorithm: The following is a description of the adaptivity algorithm incorporated into the computer program that controlled both the CAI lesson and the IV lesson. Its development follows from material presented in the Literature Review under Research On Adaptivity.

Assuming the instructional materials (text, graphics, audio, video) have been prepared and are available in computer accessible form for each objective identified by the instructional design (see Figure 5); and assuming that criterion referenced questions have been prepared for each objective; then the CAI/IV program can be coded according to the following algorithm:

```
initialize instructional objective to 1.Ø
repeat
  display criterion question for objective
  if answer is correct then
    provide positive feedback
    if instructional objective is 1.Ø then
      set instructional objective to "done"
    else
      select higher instructional objective
  else
    if objective material already displayed then
      select lower instructional objective
    else
      display material for objective
until instructional objective is "done"
```

Note the following:

1. Criterion referenced questions are presented and answers are assessed prior to presenting instructional material. In this way unnecessary instruction can be avoided. This also avoids another approach to prescriptive tutoring - the lengthy pretest to predetermine objectives needing instruction.

2. The final, most global objective (1.0) is tested first. This is based on the assumption that if this objective is satisfied then all others at lower levels must have been mastered. When this objective has been learned, the instructional objective is set to "done" and the lesson terminates whether this is on the first iteration of the loop or the one thousandth.

3. Selection of the new instructional objective after an incorrect response is done by working down the instructional hierarchy (i.e.: select lower instructional objective). For example (refer to Figure 5) an incorrect response to the criterion test for objective 1.0 results in the selection of objective 1.1 as the new instructional objective.

An incorrect response on this objective results in the selection of objective 1.11.

4. Selection of a new instructional objective after a correct response is done by working up the instructional hierarchy (i.e.: select a higher instructional objective). For example, a correct response to the criterion question for objective 1.21 would result in the new instructional objective being set to 1.2.

5. Selection of a new instructional objective after a correct response is complicated by the fact that any objective may have coordinate objectives (i.e.: other objectives that are subordinate to the same superordinate objective) For example 1.11 and 1.12 are both subordinate to 1.1. As described in point 4 above, an incorrect responses to criterion question 1.11 sets the objective to 1.111. A correct response here sets the objective to 1.11. However a correct response here does not automatically set the objective to 1.1. There may by an additional misunderstanding in objective 1.21. This must be dealt with before testing objective 1.1. Thus the new objective is set to 1.12 and an incorrect response will result in 1.121

being the new objective and a correct response here will result in 1.1 being the new objective because now all of the objectives at the 1.1x level have been met.

The algorithm outlined above ensures that the CAI program will adapt to the learner and teach him at a level based upon his current level of understanding. It will not bore him by reteaching what he already knows; it will not confuse him by teaching concepts for which he does not have the prerequisite knowledge. The program will provide detailed instruction in those areas where the student's knowledge is weak or non-existent and quickly review those concepts which he already knows.

The adaptive programs that guided both the CAI and IV lessons in this study conformed to the above algorithm and were created using InSight 2000, a courseware authoring system created by Whitney Enterprises to complement their interactive video interface. Both programs were created using the authoring system which then translated them into BASIC code. The only difference between the CAI and IV versions of the program is that the CAI version displays chunks of text, and the IV version displays corresponding segments of video tape. All program logic is identical.

Criterion Measures

Recall Test: The principal dependent measure was a 16 question fill-in-the-blank test used to measure recall of lesson material. This type of test was used to avoid literal replication of the multiple choice questions used in the IV and CAI lessons. Subjects wrote the test immediately following completion of the lesson.

Retention Test: The second dependent measure was a 16 question fill-in-the-blank test. It was identical to the recall test except that the order of questions had been changed. The retention test was written by the subject in the second week following completion of the lesson.

Time: A third dependent measure was the time needed to complete the lesson. This was measured from the point at which the subject began work on the lesson, up to but not including the recall test. Instructional time measures could be used later either to confirm that there was no difference between the amount of instructional time received by each group; or provide the data to calculate a "rate of learning" score for each subject if instructional time did vary.

Interview: Two of the IV subjects were interviewed immediately following treatment. The purpose of the interviews was to investigate aspects of IV which would not be made evident by the narrow focus of this experiment. These two subjects were picked because they were observed to be intelligent and articulate students. This choice of students undoubtedly biased the results and the results were interpreted in this light. Individual differences in student response to IV would be a useful area of further research. The interviews lasted approximately 20 minutes. The questions asked focused on four main topics:

1. Questions about IV equipment and how it works.
2. Questions focusing on the actual lesson learned using the IV system, trying to assess depth of understanding and sources of possible confusion.
3. Questions comparing IV to the other methods. This required subjects to speculate about

other methodologies and to state preferences and reasons for these preferences.

4. Speculative questions about the effectiveness, desirability of an IV in the classroom.

Method of Analysis

A 2 x 2 factorial design was used. Two levels of adaptivity (Low and High) were crossed with two levels of modality (Unimodality and Multimodality). (See Figure 1) The four treatments were operationalized as follows:

- low adaptivity/unimodality: text
- low adaptivity/multimodality: video
- high adaptivity/unimodality: CAI
- high adaptivity/multimodality: IV

Seventeen subjects were assigned to each of the four treatment groups. The subsequent unequal numbers in each group were the result of attrition due to factors such as school absence or technical problems. Analysis of variance was performed on subject grade level to rule out grade-related differences. ($F(1,48) = .29$, $p > .05$)

Three dependent measures were made for each of the four groups: instructional time, recall test and retention test. Analysis of variance was performed on each dependent measure.

RESULTS

EFFECT OF INSTRUCTIONAL TIME

Before the data could be analyzed it had to be determined if the four instructional treatments had taken a similar or significantly different amount of time to complete. If there was a significant difference in completion time then it could be argued that the differences in the other dependent measures reflect the difference in time spent learning and not the effects of the instructional technique. Care had been taken in the design stage to make the learning tasks as similar as possible in all respects except media, but this needed empirical confirmation. The results in Table 1 can be interpreted to mean that there was no significant difference in instructional time between the four instructional techniques. ($F(3,48)=1.161$, $p > .05$) The original null hypothesis can be accepted. Instructional time can be ruled out as a contributor to the variance in the other dependent variables: recall score and retention score. Recall and retention scores can be used as is, without converting them to rate of learning scores.

EFFECT OF INSTRUCTIONAL TECHNIQUE

Instructional technique did have a significant effect on instructional effectiveness as measured by recall scores. (See Table 2, $F(3,48)=3.832$, $p < .05$) However the effect was in the exact opposite direction predicted. The rank order of instructional technique based on recall scores was: video, text, CAI, IV. Several possible explanations for this reversal of expectations will be offered later.

Retention test scores did not show any significant difference for the effect of instructional technique. (See Table 3, $F(3,48)=1.998$, $p > .05$) In an effort to explain this fact, loss scores were calculated. The calculation of loss scores was not part of the original plan but is good way of dramatizing the general trend. The loss score represents the amount of material forgotten in the time period between the recall test and the retention test. The results of these calculations are summarized in Table 4. Instructional technique did not have a significant effect on the amount of material forgotten by the subject but a trend could be observed. ($F(3,48)=1.896$, $p > .05$) The rank ordering of instructional techniques by loss scores, parallels those originally predicted (IV, CAI, video, text). Two explanations of these results are possible. IV and CAI produce more complete processing of information and thus less retention loss. Or perhaps the IV and CAI subjects simply had less to forget. That is, the retention scores may represent a kind of retentive baseline.

EFFECT OF MODALITY AND ADAPTIVITY

It was originally predicted that adaptivity and modality would account for the variability in effectiveness between different instructional techniques. In light of the fact that the predicted variability was not found, it is more appropriate to see if an explanation of these results can be found in the effects of modality and adaptivity.

According to the scores summarized in Tables 2, 3 and 4, modality did not have a significant effect on recall, retention or loss scores.

The same does not hold true for the effect of adaptivity. Adaptivity did have an effect on recall scores (See Table 2, $F(1,48)=7.919$, $p < .01$), and loss scores (See Table 3, $F(1,48)=4.861$, $p < .05$). This can be interpreted to mean that adaptivity as defined for this experiment had a negative effect on learning rather than a positive one. A modification of the adaptivity algorithm in the light of this fact is found in the Discussion section.

INTERACTION BETWEEN MODALITY AND ADAPTIVITY

It was originally predicted that there would be no interaction between modality and adaptivity. This hypothesis is rejected in the case of retention scores (See Table 3, F(1,48=5.38, $p < .05$). Figure 2 illustrates this interaction. The interaction effect is primarily due to the fact that IV was so much less effective than CAI. A possible explanation of these results follows in the Discussion Section.

INTERVIEW RESULTS

1. Questions about IV equipment and how it works.

Subjects were not very aware of the how the IV equipment worked even though that had been explained to them at the time of the experiment and they had used the equipment in the experiment.

2. Questions focused on the actual lesson learned using the IV system, trying to assess depth of understanding and sources of possible confusion.

Interviewed subjects had high scores on the recall test but differing opinions regarding the clarity of instruction. One subject made the point that he often didn't know if his performance was good or not. When asked to clarify the point, he referred to the fact that when he got a criterion question wrong he was never quite certain why. His problem stems from the nature of the adaptivity algorithm and will be discussed in the next section. Another subject, while feeling confident that the IV system was easy and straight forward to use had a gap in her knowledge that could have originated as a confusion while using the program. It is possible that she correctly guessed the answer to a question and thus was never exposed to that material. As a result she was not aware that she had missed anything.

3. Questions compared IV to the other instructional methods. This required subjects to speculate about other methodologies, their preferences and the reasons for these preferences.

Subjects were unanimous here. Both said they would have felt most comfortable with the text presentation. They commented that with text it was possible to refer back if necessary. It should be noted that these were good students and therefore very good readers. This preference may not have held for poor readers.

Subjects were unanimously opposed to the video presentation because it doesn't require any involvement. They commented that they may have become bored and not paid attention had they seen the video presentation

The subjects were ambivalent to CAI. They have probably had very little contact with that type of instruction. One interesting comment was that CAI would be good because unlike video you would have to do something.

4. Questions here required the subject to speculate about the effectiveness and desirability of IV in the classroom.

There was not much enthusiasm for an IV classroom. Comments centred around the desire for interaction with teachers and other students. Some comments suggested that students liked to be entertained. Other comments pointed out what would be lost in an IV classroom: an accessible reference person, sharing of opinions through group discussions, group problem solving and the learning and feedback that it provides.

There was no unanimity about suitable IV courses. The subjects did however point out aspects of courses that would be appropriately taught through IV. Two general categories emerged: visually oriented subjects like Western Civilization, History, Biology, drama in Literature courses; and "difficult" courses. That is, courses in which explanations, and examples may need repetition. Math and physics problem solutions as well as art and architecture study in Western Civilization 12 were mentioned in this category.

DISCUSSION

IV DESIGN ISSUES ARISING FROM STATISTICAL RESULTS

The primary hypothesis that IV is a more effective method of teacherless instruction than text, video or CAI due to its adaptive, multimodal nature was not supported by the evidence from this study. While this does not necessarily disprove the hypothesis, it does indicate a number of factors that influence the effectiveness of IV.

Familiarity of Instructional Media

Students are very familiar with reading text and watching video taped material. Outside of the school setting, high school students are probably more familiar with video than with any other information technology, including text. This may account for the fact that recall scores were higher for the low adaptivity groups (video and text) than for the high adaptivity groups (CAI and IV). It would seem that the rank ordering of the effectiveness of the four different treatments: video, text, CAI, IV, parallels the subject's normal familiarity with the media.

Casual observation of subjects during the experiment support the contention that familiarity with an instructional medium make it more effective. It was obvious that the "techies", the computer "whiz kids", were more relaxed with, more interested in, and less intimidated by the IV equipment than their less-experienced classmates.

The research on modality emphasizes the fact that the central nervous system has a limited processing capacity (Hsia, 1968). The student using a highly adaptive (i.e.: interactive) medium like CAI or IV for the first time is faced with two learning problems: learning the content material and learning to use the equipment. Use of interactive technology requires knowledge of keyboard use, menus and standard screen layout. It is probable that the first time user finds this overwhelming and this interferes with content learning.

The differing degrees of familiarity of the four instructional technologies has implications for IV design and implementation. From the developmental point of view, the user interface should be kept as simple as possible and in time, some standardized interface should be developed. From the point of view of classroom use, IV should only be used when a significant amount of teaching will take place via IV. The ratio of content learning to system learning must be kept high for any instructional technology to be effective. IV should not be introduced for its novelty or motivational side effects.

Further research would detail the relationship between familiarity of instructional medium and its effects on learning from the medium.

Adaptivity Reconsidered

Another possible explanation for the poor recall scores of the high adaptivity groups could lie with the adaptivity algorithm which controlled the order of material presentation.

The adaptivity algorithm used in this experiment may be more appropriate to the teaching of procedural than declarative concepts. One could assume, for example, that a student who can solve quadratic equations (higher level procedural concept) must already understand the multiplication tables (lower level procedural concept). It cannot be assumed that a student who knows the capital of

Canada is Ottawa (higher level declarative concept) knows that the capital of B.C. is Victoria (lower level declarative concept). The connections between declarative concepts are largely based on personal experience so that no inference about "higher" vs "lower" can legitimately be made.

It is not hard to imagine a subject in this experiment who makes an intelligent guess on the very first (highest order) criterion question in the lesson and has the program terminate, leaving him unaware of information at lower levels of the conceptual hierarchy.

Two aspects of the adaptivity algorithm require modification to make it more suitable: locus of control and advisement capacity.

Locus of control

One of the most thoroughly researched aspects of CAI and IV is locus of control (Tennyson, 1984; Gay, 1986). Should instruction be controlled by the computer or by the user? It is the commonly held belief that user control is preferable but not always possible when the user is not familiar with the content material. This desirability of user control was emphasized in the subject interviews. The comment was made that some mechanism should have been included that would allow the user to review a segment of the video tape on demand. This capability was not included in the IV and CAI programs. Inclusion was not possible if the adaptivity algorithm outlined earlier was to be strictly adhered to. An improved adaptivity algorithm would include such an option.

Advisement

Another aspect of CAI design on which there seems to be agreement is the fact that the student should be kept advised of his progress throughout the lesson (Tennyson, 1984). The IV and CAI programs used in this experiment did not do a good job of advising the subject of his progress. Interviews with IV subjects uncovered the fact that subjects were often confused by the order of information presentation. They did not always know where they were and where they were going. Students normally expect that an incorrectly answered question will be followed by an explanation of the correct answer. That is not necessarily what happens with the adaptivity algorithm used here. What subjects often encountered was another question designed to probe deeper into their misunderstanding. These questions could be nested up to 4 levels deep. When the correcting information was encountered, the question to which it was related may have been forgotten. The adaptivity algorithm is not necessarily wrong, it is simply not as sophisticated as the teacher it was designed to mimic. A teacher, sensing a deeper misunderstanding, would provide the student with orienting information. The teacher would inform the student that his problem was deeper than a simple misunderstanding and that the student should set aside his original problem until he learns some background material. This detailed advisement allows the student to actively manage his own learning. It provides the student with a "mental coat hook" on which to hang the immediate problem until such time as the underlying problem is dealt with. Then, having dealt with the underlying problem, the teacher would lead the student back to his original problem, reorient him, and provide remedial help. Some equivalent mechanism must be built into the adaptivity algorithm of this IV lesson.

A revised adaptivity algorithm would include improved user control and an improved advisement system to keep students oriented within the program. The question becomes: What is the best way to do this? One approach would be to develop a much more sophisticated program that would give the student more control over the learning situation but have the capacity to intervene with clear, concise advice when the student needed it. Such a program would fall in the realm of ICAI programming and would be more appropriately programmed in a language like Prolog or Lisp, rather than BASIC.

However, a completely different approach to adaptivity might be more appropriate and this is discussed later.

Textual Referability

One of the most difficult results to explain is the apparent interaction effect between modality and adaptivity. (See Figure 2). Adaptive technologies may have characteristics which, when uncontrolled, inhibit learning rather than facilitate it. But why would IV be so much less effective than CAI? One possible explanation may lie in the differing degrees of referability between text and audio input. As Hsia (1968, p.247) illustrates, text is highly referable, audio is not. A student can reread a passage of text if he does not understand it on first reading. He can also skim back through a passage of text to review the pertinent points. Audio input lacks this attribute. Once the passage has been heard, it usually cannot be recalled for review.

Because of a desire to incorporate classroom realism into the text and video treatments of this experiment, subjects were allowed to make notes while reading text or watching the video tape. CAI subjects could not make notes but they had visual text on the screen to read and re-read as often as needed. The only group that lacked referable text was the IV group. This design error may account for the fact that the IV group had the poorest performance of the four treatment groups.

In this experiment CAI was categorized as being unimodal, i.e.: visual only. IV was categorized as being multimodal, i.e.: visual and auditory. Research has shown that one of the most effective multimodal techniques is to combine verbal and visual text. Allow the student to read and hear the text being read at the same time (Hartman, 1961). This may be a good technique to incorporate into IV design. Multimodality would be expanded to include three modalities: visual pictures, visual text, and auditory text. Further research could identify effective ways of combining these three aspects of modality.

Another way of incorporating referable text into IV design would be to allow the student to make notes with the computer, within the program. These notes could be linked to particular video clips and be accessible for review purposes. This idea is discussed later in detail.

IV DESIGN ISSUES ARISING FROM INTERVIEWS

IV design issues raised in subject interviews tended to be of a more global nature than those raised by the statistical analysis of performance data.

Content

> Interactive video is not appropriate for the full range of learners, content to be learned, and types of learning tasks. ...At the present time, the scope of appropriate, desirable, or necessary applications of IV is simply unknown. Hannafin, 1985, p.244

To help clarify this content issue, Interviewed subjects were asked to speculate about areas for appropriate application of IV. Subjects identified several curricular areas. These ares can be grouped in two general categories: visually oriented disciplines and disciplines where explanations and examples may need repetition.

Math and physics were mentioned as fitting both categories. The material can be visually represented, often in the form of observation of demonstrations or graphs. Repetition was seen as desirable but often lacking in the classroom because of teacher frustration with repeated demonstrations and explanations.

School subjects mentioned as fitting only the highly visual category were: aspects of history, literature (especially drama), art and architecture as found in the Western Civilization 12 course.

The aspects of IV that make it appropriate for visual and repetitive teaching tasks are multimodality and adaptivity respectively. Perhaps these two factors could be used as guidelines when determining appropriate content for IV. This whole area of appropriate content needs further research.

Social Isolation

Interviewed subjects were not enthusiastic about the vision of an IV classroom because it would put them in isolation from other students and teachers. This may simply be another example of teenage "groupishness" but it probably is not. Tom Snyder, the keynote speaker at the 1988 fall conference of the Computer Using Educators of B.C., made this point when explaining the philosophy that guides his CAI development efforts. He quoted a Rand Corporation report that was commissioned by the US Department of Health Education and Welfare to identify the reasons that so many educational technologies have failed. The reason, they discovered, was relatively simple: Most educational technologies do not take into account the social context in which education takes place. The implication for IV design and use is obvious. If IV is utilized, as most CAI has been, in such a way as to socially isolate the learner then its field of application will be limited.

HYPERTEXT MODEL FOR IV DESIGN

It has often been suggested that the hidden agenda behind the development of computerized educational technologies is the elimination the teacher. This is often seen as desirable because of the teacher variability in skill, experience, training, motivation and general competence. But the real hidden agenda behind computerized educational technology is the elimination of the student. Thousands of hours are spent to develop sophisticated computer techniques that try to guarantee that a student will learn in spite of himself. No matter what roadblocks the student may erect: ignorance, stupidity, cultural deprivation, emotional illness, or plain old laziness the computer will circumvent them all. However, it is doubtful that this approach will ever be successful. It is doubtful that learning can take place without the cooperation and involvement of the student. A much better approach would be to enlist the student in his own learning rather than trying to eliminate him from the learning equation.

Hannafin (1985) argues in favor of a less restrictive approach to IV design when he states that:

> The manner in which information is integrated by learners is highly individualized, and based upon both individual learning experiences in general and notions of the topic under consideration in particular. p.245
>
> Designer-imposed interactivity does not capitalize on the unique mental processing capabilities of individual learners. p.244.

The original design for this experiment evolved from a mechanistic view of teaching. Inherent in this view are the twin assumptions that IF concepts are atomized to a level appropriate for the learner, and IF these concepts are presented in the correct order THEN learning will progress as inexorably as the wheels of any factory. This is a view held by many teachers, and for obvious reasons, held by many advocates of instructional technology.

Perhaps what IV needs is a different view of instruction. One that puts more emphasis on the student. One that puts more emphasis on using the most powerful processor currently available: the human brain and less emphasis on shifting this processing to a computer. One that uses the computer as an "empowering tool" (Brown, 1985) rather than manipulative instrument.

One of the most promising developments that could aid this type of IV design is the current resurrection of an old idea - hypertext

> Hypertext at its most basic level, is a DBMS [data base management system] that lets you connect screens of information using associative links. ...Hypertext products mimic the brain's ability to store and retrieve information by referential links for quick and intuitive access. (Fiderio, 1988, p.236)

Using a commercial implementation of hypertext like Apple's "Hypercard", IV design can take on a new, less mechanistic quality. Visual material becomes a visual data base, randomly accessible by the student. Graphic maps showing the logical or traditional linkages between the concepts represented in the visual data base become the advisement or guidance system for the student. Notes can be written and attached to pictures and text passages for further reference. And the adaptive mechanism of the system is the mind of the student as he struggles to organize, classify and comprehend this new body of material.

CONCLUSIONS

In her analysis of IV investigations in Canada Tobin (1984) warns:

> The use of visuals does not guarantee the students' attention - much less their continued commitment once the initial impact fades. Tedious, badly designed, unsuitable, or confusing computer-assisted instruction is no more palpable when accompanying a videodisc than it is by itself. ... Videodiscs, which combine television and CAI, can be the victim of the weaknesses of both these media - or they can combine their promising strengths. p.17

The relationship between modality and adaptivity, and its ultimate impact on the effectiveness of instructional technologies is not as simple as first hypothesized. While it may be true that highly adaptive, multimodal technologies like IV <u>should</u> be more effective than others like text, video, and CAI, more research is needed to investigate the many factors that can have a negative impact on this effectiveness including: the student's familiarity with the technology, the availability of textual references, and the conceptualization and implementation of an algorithm for adaptivity.

In addition to the empirical interrelationship between modality and adaptivity, other design concerns like instructional content, and context will have an impact on the effectiveness of IV. More research is needed to determine the effects of content and social isolation on IV effectiveness.

And finally, it may be profitable to rethink the mechanistic model of instruction that drives so many instructional technologies including IV. IV should be viewed as a effective tool to HELP a student understand rather than FORCE him to remember.

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APPENDIX
Sample Text Lesson

CENTRAL PROCESSING UNIT

At this point you should know the following:

* any computer is composed of four parts:
  1. input devices
  2. output devices
  3. storage (or memory) which consists of two types
     - primary storage
     - secondary storage
  4. the CPU or central processing unit

* you should also be familiar with various types of input, output, and storage devices.

The heart of every computer is its central processing unit or CPU. Perhaps we should have said "The brain of every computer is its CPU." It is here that the actual processing of data takes place.

The CPU can be studied in two ways:

1. structurally: in other words, "What parts make up the CPU."
2. functionally: in other words, "How does a CPU work."

Structurally the CPU is composed of two parts: the control unit and the arithmetic/logic unit.

The control unit in the "boss" of the computer. It controls the operation of all parts of the computer, and directs the flow of data processing.

The arithmetic/logic unit or A/L unit performs two operations: arithmetic and logic.

The arithmetic/logic unit performs the standard arithmetic operations: adding, subtracting, multiplying, and dividing.

The arithmetic/logic unit applies the Law of Trichotomy to determine the truth of relational equations. This law states that given two values a and **b**, one of 3 relationships must exist between the two values: either **a=b** or **a>b** or **a<b.**

Functionally, the CPU performs its operations in repetitive cycles known as machine cycles. These cycles may take place several million times per second in a large computer. A machine cycle consists of two parts: Instruction time (I-time) and Execution time (E-time).

To understand how the CPU functions, we must closely examine what happens in primary storage and in both parts of the CPU: the control unit and the arithmetic/logic unit. Primary storage is not part of the CPU but works closely with it. It is in primary storage that the program instructions and data are stored. During I-time the computer does the following: the computer gets an instruction from primary storage, interprets the instruction, gets the required data to carry out the instruction. The instruction and data are then passed to the A/L unit.

During the execution-time part of the machine cycle the computer does the following: upon receiving the instruction and data from the control unit, the arithmetic/logic unit executes the instruction and stores the result back in primary storage.

To summarize: the CPU performs its job in cycles:

- get an instruction from primary storage
- execute the instruction
- store the result

- get an instruction from primary storage
- execute the instruction
- store the result

- get an instruction from primary storage
- execute the instruction
- store the result

-
-
- and so on millions of times per second

Occasionally the instructions to the CPU are a little different.

- data may be required from an input device
- data or instructions may be required from secondary storage
- information in primary storage may need to be stored permanently in secondary storage
- or information may be passed to the user through an output device.

In any case the CPU processes information in cycles and controls the flow of that information within the various parts of the computer.

Table 1

INSTRUCTIONAL TIME IN MINUTES

ADAPTIVITY	MODALITY: UNI-	MODALITY: MULTI-	
LOW	TEXT N = 16 M = 12.56 S = 3.89	VIDEO N = 13 M = 14.54 S = 3.97	N = 29 M = 13.55 S = 4.05
HIGH	CAI N = 11 M = 11.45 S = 4.56	IV N = 12 M = 12.25 S = 4.09	N = 23 M = 11.85 S = 4.34
	N = 27 M = 12.01 S = 4.21	N = 25 M = 13.39 S = 4.19	N = 52 M = 12.75 S = 4.25

MAIN EFFECT OF TREATMENT
F = 1.161
DF = 3,48
P = .334
EFFECT OF ADAPTIVITY
F = 2.014
DF = 1,48
P = .1587
EFFECT OF MODALITY
F = 1.341
DF = 1,48
P = .2511
INTERACTION EFFECT
F = .2434
DF = 1,48
P = .6294

Table 2

RECALL TEST SCORES

ADAPTIVITY	MODALITY: UNI-	MULTI-	
	TEXT	VIDEO	
LOW	N = 16 M = 1Ø.5 S = 3.97	N = 13 M = 11.77 S = 3.14	N = 29 M = 11.13 S = 3.68
	CAI	IV	
HIGH	N = 11 M = 9.64 S = 2.19	N = 12 M = 7.42 S = 2.78	N = 23 M = 8.53 S = 2.75
	N = 27 M = 1Ø.Ø7 S = 3.39	N = 25 M = 9.59 S = 3.68	N = 52 M = 9.92 S = 3.52

MAIN EFFECT OF TREATMENT
F = 3.832
DF = 3,48
P = .Ø15
EFFECT OF ADAPTIVITY
F = 7.919
DF = 1,48
P = .ØØ8
EFFECT OF MODALITY
F = .2629
DF = 1,48
P = .616
INTERACTION EFFECT
F = 3.542
DF = 1,48
P = .Ø62

Table 3

RETENTION TEST SCORES

MODALITY

ADAPTIVITY		UNI-	MULTI-	
		TEXT	VIDEO	
	LOW	N = 16 M = 6.88 S = 2.20	N = 13 M = 8.98 S = 3.38	N = 29 M = 7.90 S = 2.98
		CAI	IV	
	HIGH	N = 11 M = 8.18 S = 2.72	N = 12 M = 6.5 S = 2.69	N = 23 M = 7.34 S = 2.98
		N = 27 M = 7.53 S = 2.51	N = 25 M = 7.71 S = 3.30	N = 52 M = 7.58 S = 2.92

MAIN EFFECT OF TREATMENT
F = 1.998
DF = 3,48
P = .125

EFFECT OF ADAPTIVITY
F = .4823
DF = 1,48
P = .4976

EFFECT OF MODALITY
F = .0519
DF = 1,48
P = .8052

INTERACTION EFFECT
F = 5.3800
DF = 1,48
P = .0231

Table 4

LOSS SCORES

		MODALITY		
		UNI-	MULTI-	
ADAPTIVITY	LOW	TEXT N = 16 M = 3.63 S = 3.76	VIDEO N = 13 M = 2.85 S = 3.76	N = 29 M = 3.24 S = 3.76
	HIGH	CAI N = 11 M = 1.45 S = 1.88	IV N = 12 M = Ø.92 S = 2.6Ø	N = 23 M = 1.19 S = 2.3Ø
		N = 27 M = 2.54 S = 3.31	N = 25 M = 1.88 S = 3.39	N = 52 M = 2.55 S = 3.37

MAIN EFFECT OF TREATMENT
F = 1.896
DF = 3,48
P = .142
EFFECT OF ADAPTIVITY
F = 4.861
DF = 1,48
P = .Ø3Ø3
EFFECT OF MODALITY
F = .5Ø14
DF = 1,48
P = .4891
INTERACTION EFFECT
F = .Ø167
DF = 1,48
P = .865

MODALITY

		UNI-	MULTI-
ADAPTIVITY	LOW	TEXT	VIDEO
	HIGH	CAI	IV

Figure 1

RESEARCH DESIGN

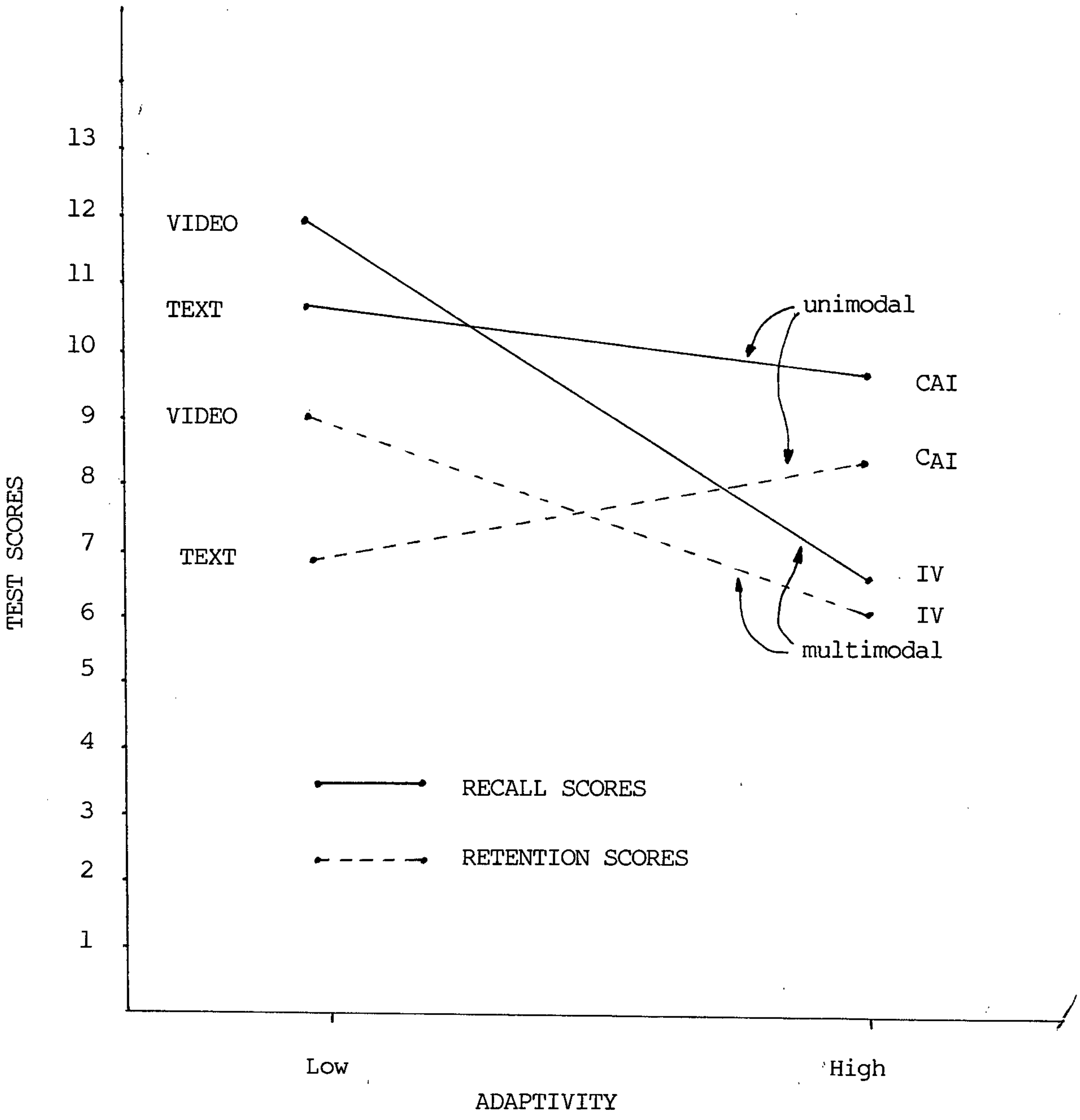

Figure 2
Interaction between Modality and Adaptivity

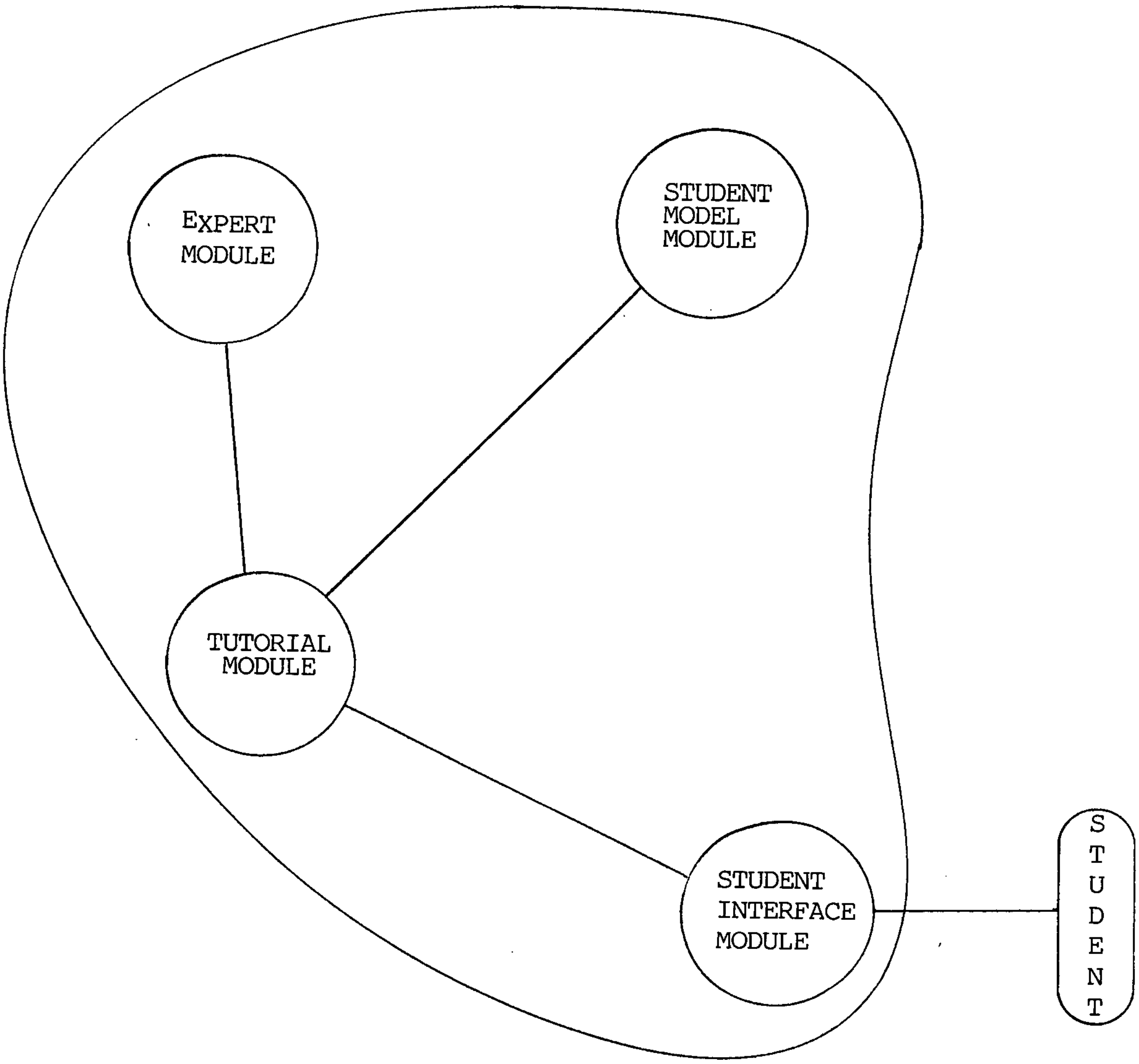

Figure 3

Overview of an ICAI System
(after Rambally, 1986)

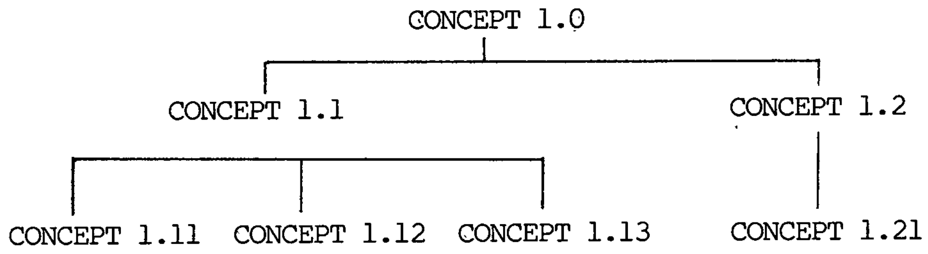

Figure 4

A Cognitive Structure for an Imaginary Cognitive Domain

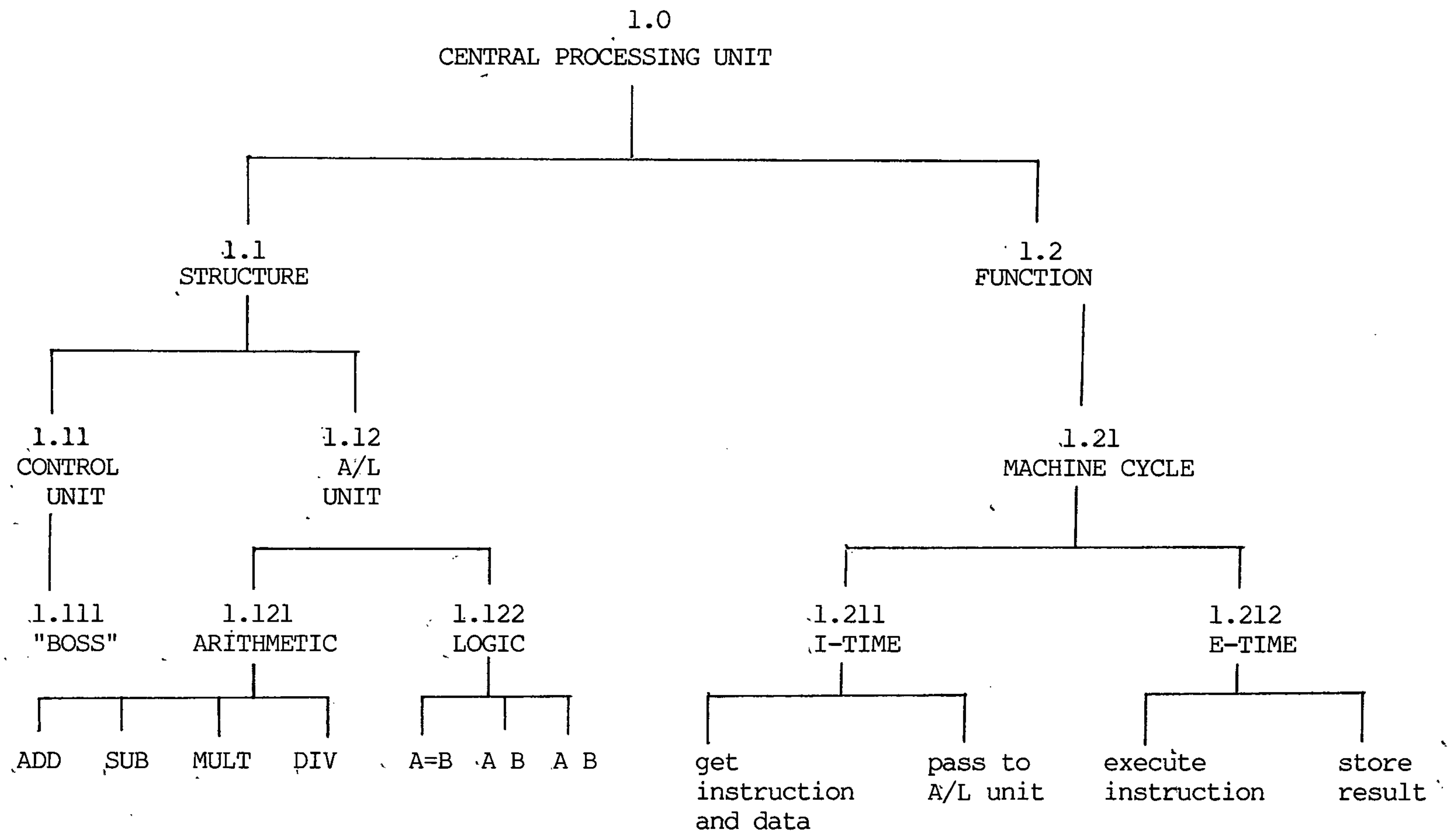

Figure 5

A Cognitive Structure for the Central Processing Unit Lesson