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Rochester Institute of Technology
School of Computer Science and Technology

The Relationship Between Computer Interaction
and Individual User Characteristics

by

Kathleen Lambert

A thesis, submitted to
The Faculty of the School of Computer Science and Technology
in partial fulfillment of the requirements for the degree of
Master of Science in Computer Science.

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Abstract

Development of effective human computer interaction is being approached independently by two disciplines -- user interface design and computer aided instruction. The lack of communication between the two fields has left each separately pursuing different paths toward the same goals. This thesis attempts to bridge the gap between these two disciplines. An exploratory study was conducted to analyze whether user choices in a computer aided instruction environment and personality types as defined by the Myers-Briggs type indicator are related strongly enough to provide the basis for future user models. The results demonstrated that no single instructional strategy was preferred, implying the need for more than one user model. The amount of instruction chosen did not increase performance. These conclusions have impact on research efforts to understand how both user and system characteristics influence the use of computer technology. The current research efforts to incorporate artificial intelligence techniques by both user interface designers and computer aided instruction developers has heightened the need for knowledge-based systems incorporating interdisciplinary research efforts.

Key words: user interface (UI), human computer interaction (HCI), interactive systems, dialogue types, human factors, artificial intelligence (AI), computer aided instruction (CAI), intelligent computer aided instruction (ICAI), cognitive style

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1. Introduction

Interactive systems designed to provide information vary in the method of interaction expected from the user. The study of human factors attempts to develop rules and guidelines to provide optimum interaction. This assumes that a standard can be found that will satisfy everyone (Yoder, 1986).

An early goal of computer aided instruction (CAI) was the development of individualized instruction. Researchers in intelligent computer aided instruction (ICAI) have developed sophisticated user models, based on cognitive theories, to address this goal. Kearsley notes, however, that CAI is still addressing the same issues being investigated twenty years ago (Kearsley, et al., 1983).

User characteristics have been found to be a necessary component of information systems (Sage, 1981). Researchers in ICAI have concluded the need for a student model based on more than cognition (Kearsley, 1987). Researchers in CAI and user interface (UI) design acknowledge the need for more studies in human behavior. The implication is that by understanding human skills and capacity, more effective computer systems can be designed. Both areas have turned to the techniques of artificial intelligence to provide more effective systems for users.

The development of an effective user model is a common focus of research efforts in both CAI and UI. Since both fields have recognized the need to incorporate personality variables and cognitive styles within the user model, an effective model could be developed with application in both disciplines.

The emphasis on developing a model which is optimal for everyone ignores the differences found in people by both educators and psychologists. True individualization through the application of artificial intelligence (AI) techniques ignores the similarities found. Patterns of behavior have been observed with respect to individual differences (Lawrence, 1979; Myers & Myers, 1980; Rich, 1983). Observation of how computer usage fits these patterns could result in a set of user models designed to provide optimal interaction for a user, without a full understanding of cognitive processes, a long user history, or the developmental effort required in a dynamic system.

This thesis proposes that UI and CAI designers are searching for the same user model. Furthermore, it argues that a single, universal model cannot meet the divergent needs of individual users. To explore this theory, a study is presented to demonstrate that a single user model is inadequate. Subjects were given control of the order, quantity, and format of

instruction they received. It was expected that, given the choice, user preferences will be made according to established personality types.

Chapter 2 of the thesis discusses the attempts by researchers to design effective user interfaces. The limited understanding of human behavior remains an obstacle. Evidence is presented to support the argument that this obstacle prevents the development of effective user models in both designer-specified and system-inferred interfaces.

The efforts in computer aided instruction to provide individualized instruction are reviewed in Chapter 3. The challenge of how to teach prevents the development of true individualism. The limited student model used in intelligent computer aided instruction is presented and its drawbacks discussed. It is argued that a single user model is inadequate. A review of authoring systems and their limitations is presented.

Chapter 4 presents arguments in support of the thesis. The need for an effective user model in both UI and CAI is summarized. The theory that both fields are searching for the same model is presented along with supporting discussion. Evidence is presented to argue that the individualism of UI and CAI user models be made along similar personality dimensions.

Cognitive type theory is described in Chapter 5. The theories of Isabel Briggs-Myers are presented in some detail. Myers-Briggs personality typing will be used in the study to define user types. Keirsey's interpretation of Myers-Briggs' theories to describe temperaments is reviewed.

Chapter 6 describes the study designed to test the hypothesis that differing formats of the same information will be differentially useful to individuals according to Myers-Briggs personality types. This hypothesis argues against the development of a universal model. The study should also demonstrate that more than one personality variable is important for both UI and CAI user models. The results expected and a case study are presented. How these results relate to the theories presented are also discussed.

The results of the study are presented in Chapter 7. Both raw data and their statistical significance are given. Details of the study are also included. Drawbacks and limitations of the study are discussed.

Chapter 8 draws conclusions from these results and discusses their implications with regard to the hypotheses presented in the thesis. The conclusions drawn are compared to the research efforts of others. How the results correlate to the search for an effective user model in UI and CAI are presented and discussed. This chapter also explores the future of further work in this area. Recommendations for the direction and focus of this research are given, as well as a detailed research plan.

2. Human Factors Issues in User Interface Design

Approaches to UI Design

As computer usage has moved beyond computer scientists to the general public, the user interface increasingly has determined the success of the system (Gaines & Shaw, 1986a). The interface has become the major factor in product differentiation in the market (Woodmansee, 1984). Software has moved from being designed around the computer and forcing users to adapt, to designing for the convenience of the user.

The emphasis on human factors began as a result of poor user interfaces (Martin, 1973). User dissatisfaction was expressed by market forces:

"...users reported experiencing feelings of intense frustration and of being 'manipulated' by a seemingly unyielding, rigid, intolerant dialogue partner, and these users began disconnecting from time-sharing services at a rate which was very alarming to the industry." (Walther & O'Neil, 1974)

Designers design for themselves. The user model is implicit, and frequently the designer uses himself as a model (Eason, 1975; VanDerVeer, et al., 1985; Yoder, 1986). For example, the primary designers of video games are young men and so are their users (Schneiderman, 1987). Mason and Mitroff have found that not only do designers of information systems project their own psychological type onto the user, but have assumed only one psychological type, one class of problems, and one mode of presentation (Mason & Mitroff, 1973). Even when recognizing that others are different, there is a failure to understand 'them'. This is reflected in Wasserman's choice of title, "The design of 'idiot-proof' interactive systems" (Wasserman, 1973).

As the use of interactive systems grew, the need to provide designers with increased knowledge of their users became apparent. For example, Benbasat conducted a study to determine whether interface and user characteristics affect decisions and user behavior in an interactive problem-solving environment. Two user characteristics: experience and cognitive style, and three interface characteristics: dialogue, command, and default types were examined. The results indicated that both user and interface characteristics are important in using system options and information requests. The study also showed that some interface characteristics could cause dysfunctional user behavior (Benbasat, et al., 1981). These conclusions are well supported by Schneiderman's finding that suitable representations of

problems are critical, by VanDerVeer's studies demonstrating that cognitive styles and personality factors are important in problem-solving behavior, and by Mason and Mitroff's results showing that what is information to one user will not be helpful to another (Mason & Mitroff, 1973; VanDerVeer, et al., 1985; Schneiderman, 1987). The recommendation of Benbasat is that the designer should have more knowledge of the interface characteristics that are best for the user, environment, and task (Benbasat, et al., 1981).

To expect system designers to gain enough understanding of the diversity of human behavior is an unrealistic goal. Schneiderman recognizes both the need and the difficulty:

"The remarkable diversity of human abilities, backgrounds, motivations, personalities, and workstyles challenge interactive system designers. A right-handed male designer with computer training and a desire for rapid interaction using densely packed screens may have a hard time developing a successful workstation for left-handed women artists with a more leisurely and free-form work style. Understanding the physical, intellectual, and personality difference among users is vital." (Schneiderman, 1987).

Bolt offers the solution of providing a completely natural interaction between humans and computers. He proposes the management of information spatially, in a way that is natural and intuitive to the user (Bolt, 1984). While intuition may suffice in some situations, less obvious representations could be difficult to interpret. Acker warns that if assumptions about the user's cognitive processes are incorrect, users may become confused and fail to make the computer operate (Acker, 1985-86). Confusing software limits both the usefulness and adoption of any computer system. Furthermore, Schneiderman points out that users raised learning Japanese or Chinese cannot be expected to view a screen in the same manner that users raised learning English or French would. Cultures with more reflective styles have a different orientation than cultures with action-oriented styles (Schneiderman, 1987).

Another approach to the improvement of human computer interactions has been to develop rules and guidelines for designers. Schneiderman collected many of these rules together. He criticizes these lists for containing contradictory recommendations and qualitative goals which are difficult to define and measure (Schneiderman, 1980). For example, the most common rule defined is 'know the user'. Since these rules and guidelines were developed because UI designers did not understand users, it is difficult to implement such an imprecise rule. Benbasat also criticizes the development of rules because it is not known whether these varying design approaches will work for different user types, problem types, organizational environments, etc. (Benbasat, et al., 1981). The number of guidelines has grown over the years. When Gaines and Shaw saw their rules exceed 500, they proposed the time had come for a new approach (Gaines & Shaw, 1986b).

Other researchers have recognized the importance of taking into account some

characteristics of users. Schneiderman has gathered together the results of many studies which examine user preferences for both hardware and software (Schneiderman, 1987). These studies are done by collecting data on the average person's performance. Rich criticizes studies of this kind. Their weakness lies in the assumption that people constitute a homogeneous set. This assumption results in values that are concluded to characterize a 'typical person' (Rich, 1983). Using the 'typical person' scenario to design a computer system that can be used by everyone ignores the studies which demonstrate that individual users vary so much, that a single user model is insufficient (Mason & Mitroff, 1973; Bariff & Lusk, 1977; Benbasat, et al., 1981; Rich, 1983; VanDerVeer, et al., 1985). For example, a study of the performance at text editing by experienced users conducted by Card led to the recommendation that the number of keystrokes to form a command be minimized (Card, et al., 1980). Correspondingly, Ledgard reported results showing that people learning to use an editor prefer English-like full word commands (Ledgard, et al, 1980). Clearly, there are different classes of users here and attempts to force each group to operate as a 'typical person' would satisfy neither.

Attempts to improve human computer interaction led to the development of alternate styles of dialogue. Gaines and Shaw characterize the styles as follows:

- formal dialogue where computer activities are presented with a minimum amount of 'syntactic sugar';
- natural language dialogue in which communication is in the language of humans, masking computer activities;
- graphic dialogue where information is communicated by objects and simulation (Gaines & Shaw, 1986b).

Formal dialogue represents the prompt response dialogues of interactive systems. The user sees what is there. Formal dialogue requires the user learn how to use it. However, this projection of the actual system aids the user by helping to form a correct model of the system. The designer must develop some skill in the appropriate use of 'syntactic sugar'. Syntactic sugar has been described by Gaines and Shaw to represent the input and output structures which convey semantic content to the user (Gaines & Shaw, 1986b). The appropriate use and the nature of syntactic sugar is the purpose of this chapter.

To overcome the drawbacks of users having to learn to use a computer system, natural language dialogues have been developed. The idea is to give the computer a skill which users already have. By projecting the structure of a person, expectations can be raised in the user which the system cannot fulfil (Gaines & Shaw, 1986b). The need to develop protocols for human computer interaction becomes more acute since a loose and accepting system may accept input it cannot fully decode accurately, while a tight and rigid system may make it difficult for the user to determine what is acceptable (Gaines & Shaw, 1986b). Clearly, natural language

dialogue will not solve the complexities of user interface design without adding more problems of its own.

Graphic dialogue uses the graphic capabilities of a computer to create a world with which the user is already familiar. The problem is that graphic dialogue and simulation may have to deviate from the real world due to technical limitations. In addition, the problem of extending generic commands to a natural physical icon when the meaning is less than obvious only results in more protocols being established. For example, an icon of a book may be clear to most people, but what are a user's physical concept of commands such as edit file, delete line, etc.

Integration of all three styles within a single interface has been effective in minimizing some of the weaknesses (Gaines & Shaw, 1986b). The Apple Macintosh is an example of a system which combines graphic dialogue with menus of formal dialogue. The most effective ways to combine the different dialogue styles to enhance the user interface will have to be investigated. In addition, as advances in technology add speech recognition, multiple screens, gesture, and other channels for integrated communication, how and when to incorporate the increasingly rich computer resources to enhance computer use will have to be investigated.

Dimensions of the User Model

These studies demonstrate the need for the development of an effective user model. Rich describes user models along three dimensions:

- one model versus a collection of models;
- models specified by the designer versus models inferred by the system;
- models of long term user characteristics versus models of short term user characteristics (Rich, 1983).

One model versus a collection

A single user model implies that given enough understanding regarding human computer interaction, a model could be developed to appeal to everyone. This assumes users are a homogeneous group (Rich, 1983). A collection of models could range from a limited set, differentiated by specific personality variables, to an unlimited collection designed for each individual user. The variables upon which to differentiate the models would need to be addressed in any collection.

The limitations of developing a single user model have been well studied (Benbasat, et al., 1981; Rich, 1983; VanDerVeer, et al., 1985). Mason and Mitroff have argued that the job of the designer is not to get all types to conform to one, but to give each type the kind of information the user will use most effectively (Mason & Mitroff, 1973). Since designers have

been unable to change the user, a better approach is to adjust the system (VanDerVeer, et al., 1985). Rich agrees that very few systems will be used exclusively by people who are similar. As some system features will facilitate only some of the users, while making the task difficult for others, the interface cannot be based on a single model (Rich, 1983).

A collection of models requires the definition of variables which would differentiate one user from another. Bariff and Lusk have proposed that psychological tests be used to facilitate the output of information systems to be compatible with the user's information processing capabilities (Bariff & Lusk, 1973). Eason suggests that people who occupy similar jobs will have certain characteristics as computer users in common and these characteristics could be catered to (Eason, 1975). Rich agrees, suggesting that 'stereotypes' which allow certain user characteristics to be grouped would help the system to form an initial model and allow the user to begin (Rich, 1983). VanDerVeer proposes offering different users with a choice of help facilities from global to specific. Users could ask for examples, explanations, overviews, etc. Error messages could adapt to user level and expertise. He suggests the starting point in design be the variability expected among users, instead of a single typical model (VanDerVeer, et al., 1985).

The number of user models developed can vary from one 'typical user' to an unlimited number of individual models which would provide the user with an individualized interface. Allowing a user to modify the system to suit themselves leaves a lot of responsibility in the hands of the user, and is probably inappropriate (Rich, 1983). True individualization would require the application of artificial intelligence techniques. These dynamic systems require long user histories, powerful computers, and large developmental efforts.

Designer-specified versus system-inferred models

User models specified by the designer have resulted in extensive criticism. Designers will need to gain a far greater awareness of their users to alleviate the problems. A model inferred by the system must contain enough knowledge about human computer interaction to effectively model the user. A designer of such a system must therefore, be aware of individual user differences.

Models specified by system designers place the interface variables in control of the designer. The type of interface which results contains no knowledge of the individual user, environment, or task characteristics. Designer-specified models suffer from dependence on the designer's ability to guess who will use the system, how it will be used, and what the system's task will be. The needs of novice and casual users have been found to be quite different from the needs of experienced users (VanDerVeer, et al., 1985; Schneiderman, 1987). A user model designed for an inexperienced user will not meet the same user's needs as s/he becomes more proficient.

A system capable of inferring the user model should be able to present an interface tailored to each person's own characteristics. The burden of constructing the model is placed on the system, which must build it on the fly. Systems that extract the user model from the user's behavior must grapple seriously with conflicting information and the relative significance of each action. Having the system build its own model, based on user interaction, relies on decisions made from information which are only guesses (Rich, 1983). Failing to correctly translate user behavior to an appropriate user model could end up frustrating the user.

Long term versus short term characteristics

Models of long term user characteristics have the disadvantages of keeping large user histories and taking too long for a significant pattern to emerge. Short term user characteristics may not contain enough information to be useful. Both models must know what characteristics are important and how to interpret them.

Models of long term user characteristics would include such variables as experience, use of system options, preference for graphics, frequency of help requests, and level of problem-solving skills. Constant updating of these variables as the user gains experience and expertise could result in the evolution of an accurate user model. The large amount of user information which the system would need to maintain and the time to continually update the information could become a burden to the system. In addition, the length of time required to develop an accurate picture of the user, could hinder the user when first learning to use the system.

Short term user characteristics the system could maintain are variables such as the kind of command last used, whether the last help request resulted in successful completion of an interaction, and if the user prefers abbreviations to full length commands. The user history is relatively small and quickly updated. On the other hand, changes in the user's style have to be detected. Whether these changes represent a more complete understanding of the system or another user offering help would be difficult to interpret.

Rich suggests developing a user model based upon stereotypes, clusters of traits common to people in certain occupations. As a person interacts with the system, additional information about the user is provided to the system. The system can gradually update its model of the user until it becomes an individual model. The greatest effort will be expended on frequent users and less on casual users. An infrequent user would not get enough user satisfaction to justify extensive modeling (Rich, 1983).

UI Needs

It is fortunate that the computer has the capacity to increase personalization since it also

produces the need for it. Computers are now doing many jobs previously done by people. The people who performed these tasks were able to accommodate the diverse needs of the individuals with whom they dealt. Computers will have to be able to accommodate some individual needs to complete the same tasks satisfactorily (Rich, 1983). Advances in technology will increase the range of jobs the computer will perform. For people to profit from technology, their needs must be met. If users are unable to access the information they need, computers have made their job more difficult, not less.

Technological advances are influenced by society as much as technology impacts on people (Gaines & Shaw, 1986a). When society developed a need to process large amounts of information, computer technologies evolved to make the task easier. Now that computer use has moved from the hands of a few experts into the general population, the importance of the human computer interaction is influencing system designers. There is clearly a need for more extensive study of personality factors and cognitive style in human computer interactions. The limited understanding of human behavior results in poor interface design and user frustration. Since people and computers are very different systems, there are no universally obvious ways in which they should interact (Gaines & Shaw, 1986b).

Recognizing that the general public has become the other partner in human computer interactions, designers and researchers have improved that relationship. The advances made in computer technology offer the designer a wealth of tools with which to design an effective user interface. There is no clear way to assemble these tools without the development of a more sophisticated user model. What is needed is a better understanding of human computer interactions. Gaines and Shaw hypothesize that human computer interaction is pivoted between computing based on algorithms and computing based on knowledge, learning, and goals. They propose that greater understanding of human computer interaction will result in movement toward man-machine symbiosis (Gaines & Shaw, 1986a).

3. Individualization of Instruction in Computer Aided Instruction

Individualized Instruction

Computers offer education a solution to an old problem -- individualized instruction. Educators have long acknowledged that no instructional strategy would be best for all students. Some students are always left behind, their skills unrecognized by formal education. One of the earliest goals of CAI was to provide the kind of learning that appealed to each student's unique style (Sleeman & Brown, 1982). This goal is not only unattained at present, but computers have not had the expected impact in education that has been achieved in other areas of society (Kearsley, 1987).

The ability to adapt is the strength of CAI. Being able to offer instruction to students at different knowledge levels and learning styles greatly facilitates learning. Federico found that adapting instruction to individual differences in the student's cognitive attributes helps to maximize both learning and achievement. He concluded that individual differences are important enough to necessitate more than one method of instruction (Federico, 1982). Acker supports this conclusion and advocates both responsiveness to individual needs and active student involvement as desirable characteristics in the system. Programmed instruction that rigidly enforces a predetermined sequence of instruction hinders learning (Acker, 1985-86). Forcing users to sort through information to obtain what is needed causes frustration.

CAI has demonstrated the potential of individualized instruction. Kearsley reports both improvements in student achievement and favorable acceptance. He notes, however, that most of the individualization strategies employed in CAI courseware are crude. There has not been much achievement of sophisticated individualization (Kearsley, et al., 1983).

Issues such as user control have been well studied. Traditional CAI programs have been criticized as not allowing the student to circumvent the teaching strategy (Kearsley, et al., 1983). Romiszowski offers three positions:

- The prescriptive approach, which attempts to measure student's individual differences and match instructional strategies to them, according to a predetermined algorithm.
- The student-directed, open, or free-learning approach, which attempts to let the student have maximum control over the choice of learning strategies and media (even sometimes content and objectives).

- The cybernetic approach which attempts to set up an interactive system, adaptive to the student's needs in an on-line manner, based on what the system has learned concerning the student's needs, learning styles, difficulties, etc. (Romiszowski, 1986)

The prescriptive approach is best described as drill. The programs use predefined algorithms based on educational theories. Early CAI programs used Skinnerian behaviorism as their theoretical basis (Kearsley & Seidel, 1985). Judgements regarding student response range from binary (right or wrong), to quantitative, where mathematics and probability are used to analyze human behavior. Attempts to overcome predefined structures led to generative CAI. New problems could be created by combining elements in a database, but instruction was still limited to drill. (Kearsley, 1987)

Student-directed learning resulted from attempts to explore other educational theories. Papert, employing Piaget's theories, argues that computers should not program children. Rather, the development of LOGO is based on a model of children as gifted learners who should be allowed to build their own knowledge structures in their own way (Papert, 1980). The philosophy behind SOLO was belief in the natural genius of students, who were allowed to sequence modules to suit their own style (Sleeman & Brown, 1982).

Intelligent Computer Aided Instruction

ICAI emerged as computer scientists started examining other learning and problem-solving theories. ICAI is the application of artificial intelligence principles to the design of instructional systems. The idea of using artificial intelligence in CAI originated with Carbonell in his development of SCHOLAR, a geography tutor (Carbonell, 1970). The introduction of artificial intelligence to CAI has demonstrated the individualized interaction that computers can provide.

ICAI has produced programs of different function and structure than traditional CAI (Kearsley, et al., 1983). ICAI systems involve knowledge networks which generate student dialogues and problems directed by tutoring rules. The instructional strategy is typically determined by making inferences about the student's learning process and then offers advice or tutoring based on student response. Typically containing mixed intuitive dialogues, either the student or computer can take the initiative to ask a question or present an idea, these dialogues have given the user control while still offering direction. ICAI programs have sophisticated student models based on the cognitive process of human memory which allow them to understand what a student does and does not know. Understanding what is being taught and the student's misconceptions are what makes these programs intelligent (Kearsley, et al.,

1983).

ICAI programs operate by continuously comparing the student model with the knowledge network (what an expert would do) to determine what the state of the student is. Discrepancies are analyzed by the teaching/tutoring rules to identify what component of the knowledge network should be presented first. Error/diagnostic rules identify mistakes in the student's response, provide feedback, and update the student model. This process continues as long as there are discrepancies (Carbonell, 1970; Brown, et al., 1982; Anderson & Reiser, 1985; Kearsley, 1987).

All intelligent CAI systems have adopted an information processing view of cognition for their student model. The student model, therefore, is a causal model which attempts to maintain an awareness of the state of the student's knowledge. Student behavior is seen as a collection of rules based on what s/he knows (Sleeman & Brown, 1982). For example, the Basic Instructional Program (BIP) developed by Barr uses a network of skills to model the student. A student may be viewed as not having, maybe having, or definitely having the various skills of the network. The skills are interrelated by dependencies and level of difficulties. The next information to present is determined by the level of a student's acquisition of skills (Barr, et al., 1976).

These programs have shown that they are capable of providing the kind of instruction provided by a good teacher. Anderson and Reiser found that students with private human tutors needed 11.4 hours to complete a course in LISP. Students who used the LISP tutor required 15 hours with their computer tutor to complete the material. This success is significant when compared to the 26.5 hours needed by on-your-own students and 40 hours spent in a traditional classroom (Anderson & Reiser, 1985).

Burton and Brown also noted similar success with their computer based coaching system. When an experiment was conducted between a coached and uncoached version of their game, they found that not only did the coached students perform better, but stated they enjoyed it more (Burton & Brown, 1979).

While demonstrating adaptive instruction, ICAI programs still suffer from instructional shortcomings as summarized by Sleeman and Brown:

- instructional material is often at the wrong level of detail; as the system assumes too much or too little student knowledge;
- the system assumes conceptualization of the domain, coercing a student into its own conceptual framework. These systems cannot work within the student's conceptualization;
- tutoring and critiquing strategies used are excessively ad hoc relying on intuition about how to control their behavior;

- user interaction is too restrictive, limiting both the student and tutor's ability to diagnose misconceptions (Sleeman & Brown, 1982).

Kearsley concurs the need for a better research basis in learning. He states that the understanding of how people learn needed for intelligent tutors is mostly lacking. ICAI systems were developed primarily as research vehicles to demonstrate the application of artificial intelligence to CAI (Kearsley, 1987). Practical application of these systems will need a more effective student model.

There are several additional obstacles to the practical application of ICAI. The number of problems which can be solved is limited, restricting its usefulness. Though the state of the student is limited to awareness of how the user is solving the problem, user patterns take too long to develop. This restriction argues against a more global, long term student model with a history of previous performance and capabilities. In addition, ICAI programs are computationally very demanding. The number of scientists in the ICAI field is small, further limiting advances (Kearsley, 1987).

Authoring Systems

Another promising area of CAI research is the development of authoring systems. Authoring systems represent an area of computing where the concept of automatic programming has been attempted on a relatively large scale. An authoring system is a program with a high level interface intended to allow authors to create courseware without having to learn a programming language. The author specifies the content to be taught and sometimes the instructional logic or strategy to be used and the authoring system generates the code (Kearsley, 1982).

Authoring is the process of creating computer aided instruction. There are three levels of programming skills required. First, the author is also a programmer who creates a CAI program from a general purpose programming language. Second, are author languages, which provide programming features specifically designed for creating instructional programs. Though requiring some programming, some of the burden is assumed by the system. The third alternative is authoring systems, which require no programming skills and automates as much of the development process as possible

The purpose of author languages and authoring systems is to speed up courseware development and place that process in the hands of educators, not computer programmers. Three types of authoring systems have been developed: macro-based systems which provide the user with a set of high level commands, form-driven systems which require the author to complete on-line forms, and prompting systems which request the information needed. The

information obtained is then used to construct the program.

The problem with many authoring systems is that the instructional strategy and content are intermixed. Teaching rules are embedded in the instruction and cannot be explicitly designed. The student model is generally represented by counters and buffers. The structure that makes authoring systems easy to use also restricts the design of instruction. Kearsley summarizes further limitations as follows:

- present systems are suitable for development of text-based lessons and testing where presentation follows a predetermined pattern, restricting flexibility;
- though graphics are considered an enhancement to learning, facilities for creating and using graphics are limited or do not exist;
- most systems are built around tutorial type instructional strategies and do not allow the development of simulations;
- current systems are not capable of individualizing instruction or diagnosing student errors (Kearsley, 1982).

There is a need for an authoring system which allows the author to develop and incorporate both interactive sequences and multi-media components. A knowledge-based approach in which content and instructional strategies are structured as semantically-related concepts and inference rules would greatly enhance the resulting courseware (Kearsley, 1982).

Authoring systems represent a significant effort at automatic programming and provide the basis for future work in this domain. By providing users with the tools of educational technology, software can be developed quickly by educators who are novice computer users.

Characteristics of the Student Model

CAI, ICAI, and authoring systems attempt to provide computer based education that enhance learning. There is a growing acceptance that instructional theories must be incorporated to produce effective instructional delivery systems. Powerful systems cannot solve the problem of 'how to teach' (Kearsley, 1987). The view of the student as what s/he knows must be expanded to include the most effective instructional strategy for that student as well.

That people learn in different ways is well established (Hunter, et al., 1975; Mayer, 1976; Bork, 1981; Federico, 1982). It has been argued that any single style of teaching will invariably leave some students behind (Lawrence, 1979; Papert, 1980; Myers & Myers, 1980). Educators have established that new information is more easily acquired if the student has an experience or familiar model to relate it to (Mayer, 1976). Previous learning and knowledge is used during the acquisition process (Wang, 1983). Since individuals have different sets of

experience and levels of knowledge, no single instructional strategy suffices. CAI has the potential to address the issue or perpetuate it. Bork maintains that learning aids cannot be developed until there is a greater understanding of how students learn (Bork, 1981).

In addition to the lack of understanding of how people learn, not enough is known about the effects of the major instructional variables used in computer based education. For example, Kearsley states that though it is known that graphics is important in most applications, it is not known what contribution they make and hence, how to use them effectively. Most designers of CAI courseware rely on intuitive guidelines, which can reduce their effectiveness (Kearsley, et al., 1983). Similarly, other instructional features such as natural language, audio, and simulation provide tools to courseware developers, but not the knowledge to use them effectively. Caivarelli agrees that the implementation of instruction is hampered by the lack of understanding of the appropriateness and contribution of the many instructional features that the computer can provide (Caivarelli, 1986). The existing methodology for representing and analyzing instructional behavior were developed for textbook presentation and are not appropriate to interactive and multi-media instruction (Kearlsy, et al., 1983).

User control is another unresolved issue. Acker proposes that the best way to respond to the varying learning styles of users is to give the student control of the learning module (Acker, 1985-86). Hunter disagrees, stating that a student-centered approach can place too much responsibility on the user (Hunter, et al., 1975). Atkinson supports a compromise -- since the learner plays an important role, his judgement should be one of several items of information in making decisions. His studies argue against complete control, with data indicating that the learner is an ineffective decision maker (Atkinson, 1972). Rubincam and Olivier have evidence that personality traits influence learner decisions. They suggest that the incorporation of learner control options would be more effective if those aspects of personality that affect choices are better understood (Rubincam & Olivier, 1985).

Suitable representation of problems have been clearly shown to be critical to solution finding and learning (Schneiderman, 1987). In addition, Sage found that it is necessary to incorporate not only the problem characteristics, but also the problem solver characteristics into the design of information systems (Sage, 1981). The format in which information is presented must take into account that each style has various degrees of usefulness to an individual. Choosing a single method of instruction will force some users to learn in a way that is ineffective for them.

The need for a great deal more research is evident. Kearsley offers the following suggestions:

- a systematic methodology is needed for the process of involving users in the design and implementation of CAI systems;

- research is needed to identify the variables which affect learning activities and instructional strategies;
- a conceptual framework is needed to guide the design of student performance data collection techniques;
- research is needed to fully explore the various roles that can be played by computer control of multi-media devices;
- the development of instructional design principles tailored to CAI is needed;
- research is needed on how to develop higher level interfaces for both authors and students;
- the development of new test theory is needed which specifically addresses the considerations associated with interactive, on-line testing;
- research is needed which relates the various input, output, and processing features of hardware to specific training outcomes and effects (Kearsley, et al., 1982).

Early programs offered prose, progressed to graphics and simulations, and current research involves the application of artificial intelligence techniques. One of the major outcomes of these systems is the realization that computers cannot provide effective teaching without a greater understanding of individual learning. Technology can be a multiplier of ideas, but it does not in itself produce them. Kearsley states that the issues in instructional computing being discussed now were being discussed twenty years ago, and not only are most of the problems still with us, but many more have emerged (Kearsley, et al., 1983).

4. Correlation Between UI and CAI

UI/CAI Similarities

The goal of studies in CAI is to ultimately enhance learning; to make learning more natural, easier to understand, and to provide individualized instruction. The focus of human factors research in interface design is to provide a more intuitive interaction; emphasizing ease of use, and a personalized environment. Researchers in both fields have highlighted the need for a stronger theoretical foundation in human computer interaction.

System designers are accused of designing for their own personality and educators of teaching in their own best learning style (Mason & Mitroff, 1973; Lawrence, 1979). The conflicting theories regarding instructional strategy and the proliferation of rules and guidelines in interface design, all point to the need to develop an effective user model. Studies of personality factors which focus on a single variable are not able to account for cognitive decisions. Modeling the user solely on cognition has been shown to be too limiting (Kearsley, 1987).

Advancement in both fields is hindered by the reliance on intuition and heuristics in developing a user model (Gaines & Shaw, 1986b). That CAI and UI share common goals, criticism, and needs is not surprising. The separation of the two disciplines breaks down when viewed as the shared purpose of providing information.

The need for a greater understanding of human behavior in the development of user models is approached in UI as a collection of personality traits, and in ICAI as cognition. However, in his study to explore the relationship between personality and certain aspects of cognitive functioning, Diceman theorizes:

"...the existence of an association between a personality trait and a manner of processing information might simply indicate that the same psychological processes are being measured in different ways and are being given different labels." (Diceman, 1985)

Learning cannot be separated from personality. Rubincam and Olivier's study giving students' control of receiving either test or instruction first, found no correlation between test scores and option chosen. They did find that the students who were the most consistent in their choices, irregardless of the choice, performed better than inconsistent choosers. They suggest that personality influences learner-controlled decisions (Rubincam & Olivier, 1985).

This conclusion has been well substantiated by others (Sage, 1981; Federico, 1982; VanDerVeer, 1985; Acker, 1985-86).

CAI cannot be separated from the design of the user interface. The concern of CAI is the most effective way to present information and the focus of interface design is the presentation of information. Whether information is formatted in natural language, graphics, or simulation; or whether displayed as a function of user or computer control; the ease of communication with the computer determines how well students learn (Hamel, 1986). The cognitive process of the student and the information processing capabilities of the computer meet at the interface.

VanDerVeer proposes that the user interface must be designed to adapt to different user characteristics, and that cognitive styles and personality variables are important in problem-solving and the learning process of beginning and occasional users. Striking variation in novice behavior related to individual differences have been found (VanDerVeer, et al., 1985). This implies the development of a model for novice and casual users as a learner. Designers need to view a novice as someone who is learning how to obtain information from a computer.

If the user model in UI needs to be developed with the incorporation of cognition in addition to personality variables and the student model in CAI requires an emphasis on user characteristics beyond the cognitive processes, then both fields are trying to develop the same model. This is further demonstrated in Bolt's arguments for a natural interface rooted in what is already familiar (Bolt, 1984). The search for an intuitive interface appears to rely on the view of educators that all learning situations are transfer tasks which integrate new information with old (Mayer, 1976; Wang, 1983). The application of this idea to computer interaction is supported by Carlson's case study monitoring interactive problem-solving. He found that when changes were made in the system, users retreated to what was familiar (Carlson, et al., 1977).

The arguments of Mason and Mitroff that management information systems have assumed one psychological type, one class of problems, one or two methods of generating evidence, and one mode of presentation can be made for many CAI systems (Mason and Mitroff, 1973). Kearsley criticized existing authoring systems for assuming a single stereotype of an author, one type of instructional strategy, one level of experience, and one resulting format for the courseware. Current authoring systems do not address the needs of different types of authors (Kearsley, et al., 1982). The type of courseware developed and the teaching strategy desired by an elementary school teacher should be markedly different from the needs of a college professor.

Authoring systems in themselves further bring together the fields of UI and CAI. As computer usage moving from the hands of computer programmers into the general population

forced designers to examine the needs of their users, automated programming brings software development into more general use and with it new concerns. Authoring systems have to provide not only an effective interface to the author, but the resulting courseware must provide an effective interface to the student. If researchers in CAI and UI cannot decide the most effective uses of dialogue, graphics, and other system features needed to provide information effectively, how much of that responsibility should be given to the author?

UI/CAI Research Needs

Kearsley summarized the basic needs of CAI as follows: 'What functions should the machine do, what functions should the human perform, and exactly how should they work together in harmony' (Kearsley, et al., 1982). Gaines and Shaw answer this by discipline:

- the AI approach would be to put all the load on the computer and make it clever enough to deal with the casual user;
- the applied psychology approach would put all the load on the person and make him clever enough to cope with the computer;
- the human computer interaction approach would be to remove as much of the load as possible from both systems and share what is left (Gaines & Shaw, 1986b).

What all these approaches ignore, is that individual users will vary strongly in the level of interaction they want. For example, an engineer may prefer to learn as much about the system as possible, even spending time in training to gain more knowledge about the system. A physician, on the other hand, would probably not want to spend time learning how to operate the system, preferring only to obtain information quickly and easily.

While different fields approach the design of the user model in different ways, there exists common issues that all must address. The evolution of book-based technology resulted in the development of aids to its user. How to get information from a book is not intuitive; people learn how to use titles, tables of contents, chapter headings, page numbers, indexes, etc. Computer based technology must develop its own mechanisms to aid its users (Striebel, 1984). Tools provided are formal languages, natural languages, graphics, simulations, videodisks, and speech recognition. How these tools and others still being developed fit into the human computer interaction cannot be determined without a more effective user model.

Researchers in CAI and UI have turned to the techniques of artificial intelligence to further investigate effective interaction. AI represents a blending of ideas and efforts in computer science and psychology. By building computer models of cognitive processes, AI researchers have been forced to account for more aspects of intelligent behavior than was previously required (Bregar & Farley, 1980). The top-down approach of needs, goals,

constraints, and users must be described first. This requires the designer to deal with human computer interactions early in the design (Streibel, 1984).

Both UI and CAI have investigated user models inferred by the system. Users provide information about themselves in the way they use the system. How to interpret that information and what patterns are significant still needs to be determined.

Rich suggests several techniques that can be used for modeling: identification of the vocabulary and concepts employed by the user, gauging the response with which the user seems satisfied, and using stereotypes to generate many facts from a few. A user who begins work with a series of advanced commands is probably an expert, while someone whose attempts are rejected by the system probably needs help (Rich, 1983). This approach emphasizes that certain stereotypes (ie., experienced users versus novice users) interact with computers in different ways.

The approach taken by CAI investigators to model users is based on what the student does or does not know. Early CAI programs used binary judgements on the student response (correct or incorrect) to determine branching. Current ICAI student modeling assesses the state of the student from analysis of their responses.

Researchers in UI have investigated many separate personality variables and system features to understand users. Investigators in ICAI have been able to produce some effective intelligent teaching systems. Both fields are searching for a more complete user model. The next step should be to gain insight from the progress made by the other. For example, VanDerVeer's suggestion that designers should be able to offer users with a choice of help facilities such as examples, explanations, and overviews in a range from global to specific, could be used by ICAI to offer more individualized teaching strategies (VanDerVeer, et al., 1985). The successful use of mixed initiative dialogues in ICAI could assist system designers in understanding when and how the system should offer help.

The design and development of intelligent CAI programs lie at the intersection of computer science, cognitive psychology, and educational research (Kearsley, 1987). The success of the user interface depends on computer science, cognitive science, and human computer interaction researchers working together (Gaines & Shaw, 1986b). The needs presented are extremely complex and can be solved only through the coordinated efforts of many disciplines.

The continued parallel development of user model(s) by investigators in different fields neglects the advances made by the other. In addition, the theories of psychologists and educators need to establish their validity in human computer interactions. When interface design guidelines explicitly eliminate human-like responses and CAI programs developed by educators are unsuccessful, there can be no assumptions made to translate human-human

interaction, communication, and learning directly to the human computer interaction. White argues that computers need to be viewed as new tools for the mind. She claims that through the use of imagery, they change the way information is represented, affecting the way we view and analyze a problem. This in turn changes the decision-making process and ultimately the way we think (White, 1988).

The need for researchers in several different fields to work together is clearly established. Reliance on previous studies and heuristics may not suffice in the next computer generation (Gaines & Shaw, 1986b). Complex human-computer systems cannot wait for a complete understanding of human psychology or an exhaustive study of human factors. The development of an effective user model(s) which transcends a specific usage is needed to ensure its effectiveness in the next computer generation.

5. Cognitive Style

Cognitive Style

Cognitive style is defined as the method of information processing, an individual's preferred way of knowing. Although many conceptualizations and operationalizations of cognitive style exist, each measurement technique relates to one or both of the following activities: perception of data and formulation of cognition from the assimilated data (Bariff & Lusk, 1977). An individual's cognitive style is believed to influence selection among alternative courses of action (Mason & Mitroff, 1973). This is demonstrated by studies conducted by Schwabish and Colin who investigated the influence of cognitive style on visual inspection. They reported a connection between performance and reflective-impulsive cognitive style (Schwabish & Colin, 1984). These results are supported by other researchers, demonstrating that cognitive style can be used to predict performance (Mason & Mitroff, 1973; Bariff & Lusk, 1977; Henderson & Nutt, 1980; Schwabish & Colin, 1984).

Many studies have investigated personality variables with respect to computer usage along dimensions such as (VanDerVeer, et al., 1985; Schneiderman, 1987):

- risk taking/risk avoidance
- internal/external locus of control
- reflective/impulsive
- convergent/divergent
- high/low anxiety
- high/low tolerance for stress
- high/low tolerance for ambiguity
- field dependence/independence
- assertive/passive
- high/low motivation
- high/low compulsiveness
- left/right brain orientation
- extroversion/introversion
- operational learning/comprehension learning
- perception of competence
- factual knowledge
- experience
- fear of failure

Frequently, studies are done on a single dimension of personality, while acknowledging that other factors come into play in learning and information processing. An all-inclusive theory of learning is not required to develop optimum procedures (Atkinson, 1972). Rather, a

theory that addresses the entire personality warrants investigation. Bariff and Lusk propose psychological tests be used to facilitate output compatible with the user's processing capabilities (Bariff & Lusk, 1977). Personality characteristics and cognitive styles have been found to be stable (VanDerVeer, et al., 1985). A personality theory which includes both could form the basis of user model(s) for both UI and CAI.

Myers-Briggs Theories

Several frameworks consisting of multiple dimensions have been proposed to study decision-making. The theory of personality developed by Isabel Briggs-Myers is based on Carl G. Jung's work involving psychological types. Jung saw patterns in the way people prefer to perceive and make judgements (Myers & Myers, 1980). This theory is particularly attractive because it provides a basis for understanding both the similarities and differences among human behavior. The descriptions of type include many of the variables which have been investigated separately. Learning preferences are included within the personality types and explain why one student can find knowledge illuminating while it is boring to another (Lawrence, 1979). Performance in problem-solving situations has been shown to differentiate according to Myers-Briggs typing (Henderson & Nutt, 1980; Hunter & Levy, 1982). The typing also transcends cultures, demonstrated by its use at the Nippon Recruit Center in Tokyo (Myers & Myers, 1980). Most important, the theory's validity has been demonstrated by many studies in the last two decades (Mason & Mitroff, 1973; Lawrence, 1979; Henderson & Nutt, 1980; Myers & Myers, 1980; Hunter & Levy, 1982).

The theories of Isabel Briggs-Myers describe patterns in the way people prefer to perceive and judge. Everyone uses the four processes, but differ in the degree each is used. Conscious mental behavior is classified in four dimensions (Lawrence, 1979):

S/N	sensing/intuition, which describes learning preferences
J/P	judging/perceiving, which reveals work habits
E/I	extroversion/introversion, which is concerned with interests
T/F	thinking/feeling, which examines commitments and values

Each individual has a preference to exercise one of the two choices over the other in each dimension. This results in sixteen possible permutations within the Myers-Briggs classification. Brief descriptions of characteristics found within each classification follow (Myers & Myers, 1980):

Sensing A sensing learner prefers using the five senses to gain knowledge, particularly the eyes. Learning is best gained in a step-by-step orderly fashion

with practical results. Enjoys 'as is' instead of theories and wants standard ways to solve problems.

Intuitive - An intuitive learner prefers using the imagination to come up with new ways to solve problems. Learning is best obtained in leaps by understanding how facts come together. Enjoys theories, ideas, and using new skills.

Judging - A judging person likes to have a plan before starting and seeks closure. The desire to settle things may result in deciding things too quickly.

Perceiving A perceiving person wants to remain flexible and ready for the unexpected. The desire to miss nothing may result in never finishing.

Extroversion The extrovert's interests involve the outer world of people and things. Attention is outwardly directed, action oriented.

Introversion The introvert's interests are primarily in the inner world of concepts and ideas. Typically reflective, they want to understand life before living it.

Thinking A thinking individual reaches conclusions by a logical process. The goal is an impersonal finding.

Feeling A feeling individual's conclusions are based on appreciation. A decision is determined by bestowing a personal, subjective value to it.

The resulting types are not considered as absolute values, but as theoretical constructs only. The two types within a dimension are viewed as opposite poles. A classification results from being more inclined towards a behavior, so the degree of the preference can vary among individuals within the same type. It is the blending of these types that make up the actual personality.

Myers-Briggs typing makes for a natural difference in learning styles. Sensing types prefer using their senses for perception. If their knowledge comes from experience, it is more trustworthy. Intuitives like to learn by insight, craving inspiration. The effect of this preference is strongly demonstrated in education. The following table shows the correlation between type and learning (Hoffman & Betkowski, 1981):

<u>number</u>	<u>subjects</u>	<u>sensing</u>	<u>intuitives</u>
71	Rhodes scholars	7%	93%
671	National Merit Scholarship finalists	17%	83%
3676	Ivy league college freshman	41%	59%
3503	College prep 11th and 12th graders	58%	42%
1430	Non-college prep 11th and 12th graders	85%	15%
500	Adults not completing 8th grade	99.6%	.4%

The explanations given for these differences is based on the teaching and testing strategies employed in education. Lawrence maintains that in spite of having less than 10% introverted intuitive (IN) types in classrooms, the emphasis on learning through spoken and written symbols strongly favors an IN individual. In addition, the writers of textbooks, standardized tests, and intellectual tests are mostly INs so intellectual success is usually determined and measured by IN types (Lawrence, 1979). Sensing types were found to reread questions, emphasizing soundness of understanding, rather than quickness. Sensing students lose out on tests designed for speed. Myers and Myers report that a decrease in the demand for speed produces higher test results for sensing individuals (Myers & Myers, 1980).

The other dimension that has an effect on learning is judging and perceiving, which describes work habits. Learning something in which one has no interest or aptitude is more likely to be accomplished by judging types who complete their undertakings to seek closure.

Choice of occupation has been found to be influenced strongly by type. Myers and Myers report the sensing/intuitive dimension as most strongly affecting career choices. Intuitives, with their preference for possibilities and creativity prefer occupations such as research science or higher mathematics when combined with the thinking process, and counseling or health-related professions when coupled with feeling. Sensing types who prefer facts and realism, become accountants or bankers if they are also thinking types, and educators, nurses, or salespeople when associated with feeling. In addition, the extroversion/introversion dimension influences one's interests. For example, physicians who are introverts are more likely to choose specialties such as anesthesiology, pathology, or research which reflect their interest in the world of ideas, while extroverts are more likely to choose pediatrics or teaching which involve them in the world of people. The judging/perceiving dimension reflects preferences in work habits, with judging types preferring occupations where the work is planned and organized, and perceiving types desiring to work in response to the needs of the moment. (Myers & Myers, 1980)

Theory of Temperament

Keirsey further combined the preferences to develop a possible connection between temperament theory and type. One's temperament is determined by a consistency in one's actions. This grouping results in the following four temperaments (Keirsey, 1978):

SJ:	includes ESTJ, ISTJ, ESFJ, ISFJ
SP:	includes ESTP, ISTP, ESFP, ISFP
NT:	includes ENTJ, INTJ, ENTP, INTP
NF:	includes ENFJ, INFJ, ENFP, INFP

In the general population, SPs and SJs each constitute about 38% of the total, while NFs and NTs represent 12% each.

Characteristics of each temperament, as described by Keirsey follow:

INTUITIVE FEELER

- wants to grow
- meaning and significance
- guide others
- make a better world
- self-realization
- catalyst
- becoming is most important

SENSING JUDICIOUS

- wants a place
- membership
- responsibility
- accountability
- duty
- traditionalist
- serving is most important

INTUITIVE THINKER

- wants to know
- competence
- knowledge
- power over nature
- intelligence
- visionary
- knowing is most important

SENSING PERCEIVER

- wants spontaneity
- freedom to choose the next act
- impulses
- action
- grace
- negotiator
- doing is most important

The following gives brief descriptions of Keirsey's work as summarized by Brownsword (1987):

SJs are good with detail. They make plans and schedules, consistently follow through, and seek closure. They are dependable and dislike change, seeking stability. SJ students are not usually interested in abstract theories or long range thinking. They hand in homework on time and seek specific and concrete guidance from a teacher.

SPs excel in times of crisis. They see facts and realities, focusing on the concrete and practical. They live in the present and want to respond to the flow of things. SP students need to learn by doing, preferring action. They need to see the practical usefulness in what they study. They can be so focused on the concrete that they don't see patterns in problems and can't generalize from them.

NTs like to see possibilities. They look for meanings and relationships. They like to think about ideas, abstractions, concepts, and theories. They want to know why and want things to make logical sense. NT students are curious, independent, and challenging. Their quest for knowledge is never satisfied. They look to abstract principles to guide them in their decision-making.

NFs view the world in terms of possibilities, relationships, connections, and meaning. They make decisions based on values. They act on what matters to them. They are not good with detail. NF students have a wide range of interests. They are not good with routine but grasp abstractions and see interconnections quickly.

The descriptions of temperament are based on the uniformity of four of the sixteen Myers-Briggs personality types. They are considered sketches in contemporary form of observed patterns of behavior. An important aspect of temperaments is that they are considered patterns of behavior that are deep in each person's makeup that are not going to change (Keirsey, 1978).

6. Design of Study

Project Description

To test the hypothesis that differing formats of the same information would be preferred along established behavioral types, a CAI program was developed. One unit of instruction was provided solely by this program. This unit consists of instruction on three programming constructs. Each of the constructs offers six different instructional strategies from which the student could choose.

The hardware used was the Apple IIe. The language used to both implement the system and to teach to the students was Apple Pascal using turtlegraphics. Both the hardware and software were chosen because they are used in the Survey of Computer Science course at RIT, whose students were the subjects. Being an introductory level course, the students in this course represent a variety of majors, which provided a wide range of personality types, yet they have similar, limited experience with computer systems (experienced users are advised to take other courses).

The questionnaire chosen to determine Myers-Briggs personality type was the 32-question Personal Style Inventory developed by Hogan and Champagne (Appendix A). Though lacking the large amount of validity data found for the Myers-Briggs Personality Indicator, the Personal Style Inventory has sufficient correlation data to indicate reasonable accuracy in Myers-Briggs typing. In addition, the 32-question Personal Style Inventory takes approximately 10 minutes to administer, alleviating a drawback of the 166-question Myers-Briggs Personality Indicator, which can take up to an hour to complete.

The personality questionnaire was given on-line and the results stored in the student's file (see the first part of Appendix C for an example of how a question on personality type was presented to a student). Once completed, the actual instruction is offered. The CAI program teaches the *for*, *while* and *repeat* loops. The system is menu-based and allows the student control over both when and how to receive instruction. After choosing which new construct to learn, the student could choose the method of instruction to view. The total amount of instruction to receive is also user controlled; the student can view as few, or as many formats as s/he desires.

This study was placed in the course as an option the student could choose to take. To ensure a serious attempt to learn the material, a quiz for extra credit points was given after the

student received the instruction from the CAI program. There were two quizzes provided to the lab proctors to help ensure test integrity (Appendix B). The lab proctors chose a quiz and administered it. Additional information recorded on the quiz included the student's major field of study, gender, and year of study. This information, as well as the results of the quiz, was analyzed against the student's personality type and choice of instruction. The final grade received in the course was also obtained to verify that the quiz score obtained in the study was unrelated to overall mastery of course material. The student's social security number was also recorded on the quiz and used to match data received on the quiz to data obtained by the computer interaction.

User Perspective

When students requested the extra credit, the lab proctor gave them the disk containing the computer aided instruction and personality questionnaire, and an instruction sheet (Appendix C). The program starts by asking the student to input their social security number and to verify its correctness. If the student has no previous file, the personality questionnaire is displayed first. If there is a previous file, the program resumes from where the student left off.

For each question, the personality questionnaire displays directions at the top of the screen and presents two statements. The student is asked to give a personal value to each statement. The input is error-checked and the student is given the opportunity to change it. The student may choose to quit before completing the questionnaire, and the responses are saved.

After completing the personality questionnaire, the main menu is displayed. This menu offers the student choices between which of the three programming loops to learn next as follows:

- 1) repeat loop
- 2) while loop
- 3) for loop
- 4) quit

A selection of one of the three loop choices results in a second menu being displayed. The instruction menu describes the various styles of instruction available for each loop as follows:

- 1) Why loop is needed
- 2) What loop is used for
- 3) Graphic explanation
- 4) Text explanation
- 5) Graphic examples
- 6) Code examples
- 7) Quit and return to loop menu

The user choice of options 1 through 6 results in approximately one screen full of instruction being displayed. Upon completion of the instruction chosen, the instruction menu is displayed again until the user chooses to quit. After quitting the instruction menu, the main menu is again displayed. The student can then choose to study a different loop or quit the program.

The type of instruction offered for each of the six choices contains similar information content, but varies in their format and emphasis. The following is a summary describing the method of instruction presented for each choice (see Appendix D for the six types of instruction offered for the repeat loop):

- 1) A theory-oriented description of why the loop is needed and a syntax diagram are presented.
- 2) A practical description of specifically what the loop is used for and general form are displayed.
- 3) A graphic explanation of how the loop executes is given. Pascal code using the loop is displayed on the graphics screen. As the loop executes, inverse video is used to highlight the line of code being executed while the object is drawn. In addition, the boolean expression in the *repeat* and *while* loop, and the counting variable in the *for* loop are displayed and changed with each execution. The subject controls the loop iteration with the carriage return key.
- 4) A text explanation of how the loop works is displayed. This is similar to instruction found in a textbook.
- 5) Examples of loop usage are presented. A brief description of how the loop is used to draw an object is followed by the graphic results.
- 6) Examples of programming code which uses the loop are presented, along with a brief text description which describes what the code will draw.

The first two choices are concerned with why the loop is important to learn and the other four choices with how to use the construct. Formats 3 and 5 are primarily graphic in content while formats 4 and 6 consist solely of text. Formats 3 and 4 are concerned with explaining how the loop works while formats 5 and 6 present examples only. It was expected that each student would use a combination of the six choices in their attempt to learn each programming loop. Viewing all six formats is not necessary to learn any of the three constructs since the information provided is similar. The students are reminded of this with a message displayed at the top of the screen with the instruction menu.

System Specification

The CAI program developed in this study is menu-driven. The flow is determined by user input controlling a case statement. The data type used for all student input is the UCSD Pascal string. This was chosen to ensure that all incorrect student input is considered a string of characters and thus handled by error messages and does not cause a type clash. After error-checking, the input is concatenated to the end of the string which contains all the subject's choices.

All user input is stored as a string in a file created the first time the student uses the instructional program. The student's social security number becomes the name of the student's data file to ensure a unique file name and proper identification of results. The program first searches for the student's file and creates one if none exists. If a file is found, the previous data it contains is read into a string and all subsequent information added to it. When the student finishes using the program, the string containing the user input is written into the file and the file closed.

All instruction displayed as text and the statements comprising the personality questionnaire are stored in text files that are opened and written to the screen when called by the case statement. Graphic displays are coded as procedures within the program and are called by the case statement when the student selects them. All the files that make up the CAI program reside on one disk. A second disk was used to contain the students' data files. The second disk was required to provide adequate memory for an unknown quantity of users, each with varying amounts of data

Case Study

The following case history is presented to provide an example of a typical subject's interaction with the program. It is not an actual subject's session, but a composite based on

data results and casual observation of the subjects during the study.

Upon requesting the extra credit disks from the lab proctor, the student received two disks labeled by disk drive and an instruction sheet (see appendix C). Reading the instruction sheet, the student learns he will be completing an on-line personality questionnaire, use computer aided instruction to learn three programming loops, and when finished with the program, taking a quiz for extra credit.

When the student starts, the first interaction requests the student provide his social security number. All student input is error-checked and the student is asked to verify his responses as follows (computer generated output is in upper case, student input is lower case and outlined):

PLEASE ENTER YOUR SOCIAL SECURITY NUMBER WITHOUT SPACES
OR DASHES, FOLLOW WITH A CARRIAGE RETURN.

999-99-9999

THIS ISN'T CORRECT, ENTER 9 DIGITS ONLY

999999999

IS THIS CORRECT? ENTER 'Y' FOR YES, 'N' FOR NO, FOLLOW WITH
A CARRIAGE RETURN.

Y

The program uses the student's social security number to determine if the student has used the program previously. He hasn't so the on-line personality questionnaire begins with the first question as follows:

COMPARE THE TWO STATEMENTS AND ASSIGN A VALUE FOR EACH SO
THE TWO VALUES TOTAL 5.

0 1 2 3 4 5

FEEL VERY NEGATIVE

STRONGLY AGREE

1A. MAKING DECISIONS AFTER FINDING OUT WHAT OTHERS THINK

1B. MAKING DECISIONS WITHOUT CONSULTING OTHERS.

PREFERENCE FOR A): 1

YOUR ANSWER FOR B) IS: 4

ENTER 'Y' TO ACCEPT THIS RESPONSE

Y

The questionnaire continues until the student answers 32 questions (see Appendix A for complete questionnaire). The student is only requested to answer part A) and the program calculates and displays part B). He is asked to verify each choice made. The student is also allowed to quit at any time and the portion of the questionnaire completed up to that point will be saved. The main menu is displayed upon completion of the personality questionnaire as follows:

REPEAT..UNTIL	WHILE LOOP	FOR LOOP	QUIT
1	2	3	4

ENTER CHOICE 1 TO 4 FOLLOWED BY CARRIAGE RETURN.
␣

The student's selection of the repeat..until loop causes the choices of instruction for that loop to be displayed. A reminder that the student does not need to view all six formats is printed at the top of the screen. The student's view is as follows:

MOST OF THE INSTRUCTION IS DUPLICATED WITHIN THESE CHOICES. CHOOSE TO SEE ONLY THOSE YOU FIND USEFUL.
1) WHY LOOP IS NEEDED
2) WHAT LOOP IS USED FOR
3) GRAPHIC EXPLANATION
4) TEXT EXPLANATION
5) GRAPHIC EXAMPLES
6) CODE EXAMPLES
7) QUIT AND RETURN TO LOOP MENU
ENTER CHOICE 1,2,3,4,5,6, OR 7 FOLLOWED BY CARRIAGE RETURN. ␣

The student then sees a description of why the repeat loop is needed in a programming language and a syntax diagram (see Appendix D for actual instruction given). When the student finishes reading the information, a carriage return brings him back to the repeat loop menu displayed above. This time he choses to view the graphic explanation and sees the following:

REPEAT

MOVE(40);

TURN(90)

UNTIL TURTLEANG = 0;

>

ANGLE EQUALS 0

REPEAT

MOVE(40);

TURN(90)

UNTIL TURTLEANG = 0;

→

ANGLE EQUALS 0

REPEAT

MOVE(40);

TURN(90)

UNTIL TURTLEANG = 0;

→

ANGLE EQUALS 90

REPEAT

MOVE(40);

TURN(90)

UNTIL TURTLEANG = 0;

ANGLE EQUALS 90



This continues with each line of code being highlighted as it is executed and the graphic results of the code displayed. The current value of the angle is displayed and execution terminates when it equals zero. The student controls the iteration by using the carriage return to advance to the next line.

Upon returning to the repeat loop menu, the student then chooses the text explanation and reads a description of how the loop works, along with examples of Pascal code (see Appendix D for complete explanation). He finds the explanation similar to the instruction found in a textbook.

Next the student decides to see what information the code examples can provide him. He views examples of actual code, a description of the graphic results, and the strategy used to develop the code (Appendix D). Completing this, the student decides he knows enough about repeat loops and chooses to quit.

Finding himself back at the main menu, the student decides to explore the while loop. The while loop menu displays the same choices as the repeat loop menu. The student decides to view the graphic explanation and code examples only. He repeats this strategy to learn the for loop.

Having viewed a total of seven screens, the student selects the quit choice on the main menu. He returns the disks to the lab proctor and requests a quiz (see appendix B for quizzes given). Receiving quiz A, the student fills out the personal information requested and answers the ten quiz questions. Upon turning in his quiz, the lab proctor grades the quiz and informs the student that he will receive seven points of extra credit. The entire session took forty minutes.

This description is considered the average subjects' experience with the study. There were students who choose to receive no instruction and students who made over twenty selections. The time required to complete the study is based on observations by the lab proctors, with an average completion time of 30 to 60 minutes.

Analysis of Data

Objective data only was obtained. The following information was collected for each subject:

- personality type
- instructional choices made
- frequency of individual choices made
- total number of displays viewed
- major
- year of study
- sex
- quiz score
- grade

The data was analyzed with respect to the following hypotheses:

1. Different formats of the same information are preferred by different personality types.
2. The amount of information desired varies among individual users.
3. Type of instruction preferred does not correlate to student's major, year of study, sex, or quiz score.

Student preferences for the type of information preferred was based solely on the choices made and not on a subjective questionnaire. Though user experience was assumed to be similar, it was not determined or controlled.

It was expected that individual subjects would differ in the choices made, demonstrating that no one single method of instruction is right for everyone. The particular formats chosen were anticipated to correlate along personality dimensions, with certain personality types preferring certain formats.

The number of choices made was also expected to vary between individuals, with some subjects viewing only a few displays and others nearly all. It was not assumed that those who viewed more would score higher on the quiz. Instead, the amount of information chosen should relate only to the individual's personality type.

The student's major should not be evenly distributed among all Myers-Briggs personality types. Previous studies have demonstrated tendencies for certain types to prefer certain

occupations. Any subsequent relationship between field of study and choices made should be the result of personality typing.

The year of study and gender should not influence the type of instruction preferred, the amount of instruction received, or the quiz score. Both variables were expected to prove independent of all others.

The score on the quiz, though not expected to show a correlation with which displays were chosen or the total number of displays viewed, could possibly demonstrate strength in the course material by certain personality types. To determine this, the final course grade was obtained and compared to the score on the quiz. The instructional strategy offered in the course should only be effective for certain types, so the final grade should vary from the quiz score which measures the results of the CAI program and offers choices to other types.

The results of the analysis of data was expected to demonstrate the need for user models developed along multiple personality dimensions. By varying the format of instruction only, the importance of how information is received is demonstrated. This supports the theory that both UI and CAI are searching for the same user model. The development of individualized systems, adaptive along multiple personality dimensions could result in more effective systems designed to meet varying individual needs.

7. RESULTS

Description of Study

The study was completed as specified in Chapter 6. The instructional program was written in Pascal using turtlegraphics and implemented on the Apple IIe. The program is menu-driven and consists of text and graphics displayed on the screen in response to student choices. Six sets of disks, the student handouts, and quizzes, were made available to the students.

A total of 68 subjects completed the on-line personality questionnaire, received the instruction, and took the quiz. The study went smoothly. Students had no problems understanding the instructions or using the program. The choices made by students were recorded in files identified by the students' social security number. Upon completion of the study, the social security number was used to match data obtained by computer interaction to data recorded on the quiz.

The mean score on each of the two quizzes is as follows (see Appendix E for data):

	<u>count</u>	<u>mean</u>
quiz A	44	6.11
quiz B	34	6.35
total	78	6.21

The two quizzes were determined to be comparable in level of difficulty. The total number of quizzes taken was 78, indicating that ten students took the extra credit quiz without completing the personality questionnaire or viewing the program. Since there is no additional data on these ten subjects, they are not included in any further analysis.

The 32-question Personality Style Inventory is scored by comparing the number of points assigned to each aspect within a dimension. The total points possible in each dimension is 40, and a preference toward typing is indicated by one aspect being larger than the other. For example, if an individual scores 18 points as an introvert and 22 points as an extrovert, that person is considered an extrovert. The situation of a 20/20 or 21/19 split in scoring is categorized as balanced, with no clear preference towards one type or the other. As a result, each dimension can be classified as being one of three possible types, i.e., extrovert, balanced, or introvert.

Subjects who scored as balanced on any dimension, are not reported as being completely typed. The distribution of Myers-Briggs personality types that resulted is as follows (see Appendix F for complete data):

<u>type</u>	<u>count</u>
I-introvert	24
E-extrovert	30
N-intuitive	26
S-sensing	29
T-thinking	18
F-feeling	32
P-perceptive	15
J-judging	40

A total of 24 subjects were typed in all four dimensions. The remaining 44 subjects scored as being balanced in at least one dimension, and their data are limited to analysis by single dimension only. The subjects who were completely typed on all four dimensions are reported below:

<u>type</u>	<u>count</u>	<u>type</u>	<u>count</u>
INFJ	2	ENFJ	1
INFP	1	ENFP	3
INTJ	1	ENTJ	2
INTP	1	ENTP	0
ISFJ	3	ESFJ	5
ISFP	0	ESFP	0
ISTJ	2	ESTJ	3
ISTP	0	ESTP	0

The Myers-Briggs typings that resulted are within expectations based on the Rochester Institute of Technology's (RIT) student population. This population consists of the following top eight types, listed in order of frequency (personal communication with Paul Kazmierski):

1. INTP
2. INTJ
3. ISTJ

4. ESTJ
5. ENTJ
6. ESFJ
7. ENFJ
8. ENFP

75% of the study's resulting types were within RIT's top eight types. The typing performed on the RIT student population is the result of the 166-question Myers-Briggs Type Indicator. The results reported here, using the 32-question Personal Style Inventory, appear to correlate with the longer questionnaire.

The frequency of viewing each of the formats offered was fairly consistent. The total number of times each of the formats was viewed, for all 68 subjects, regardless of type is as follows:

	<u>theory</u>	<u>practical</u>	<u>graphic explanation</u>	<u>text explanation</u>	<u>graphic examples</u>	<u>code examples</u>
total	143	137	164	136	140	138
mean	2.10	2.01	2.41	2.0	2.06	2.03
range	7.0	5.0	7.0	6.0	6.0	8.0
S.D.	1.51	1.37	1.57	1.48	1.42	1.70

No single format was viewed significantly more than the others. This is interpreted as meaning that all six formats were somewhat useful to someone and that no one format was clearly better than the rest. The graphic explanation was viewed with the highest frequency and the text explanation, the lowest. This is interesting because the text explanation is simply an on-line version of material found in traditional textbooks, while the graphic explanation consists of viewing the graphic results of code executed one line at a time; something difficult to implement by traditional learning methods. No conclusions can be drawn on this observation, however, because it could simply be due to the novelty of the instruction.

The measurement of student preference for a format was interpreted to be reflected in the number of times a student viewed it. It was concluded that if the format was useful in learning one new construct, the student would view it for the next. If a format was viewed at least three times (once for every loop), this format was considered to be useful to the student. The following table shows the percentage of students within each dimension who preferred each format (see Appendix G for complete data):

<u>type</u>	<u>theory</u>	<u>practical</u>	<u>graphic explanation</u>	<u>text explanation</u>	<u>graphic examples</u>	<u>code examples</u>	<u>count</u>
E	60%	50%	60%	57%	53%	40%	30
I	50%	54%	63%	50%	46%	50%	24
S	55%	45%	66%	52%	48%	59%	29
N	50%	50%	42%	42%	38%	35%	26
T	44%	50%	56%	44%	39%	39%	18
F	53%	53%	66%	50%	44%	44%	32
P	47%	33%	33%	27%	7%	40%	15
J	48%	45%	60%	45%	48%	53%	40

Subjects who viewed 18 or more formats total (viewed at least every format once), were defined as needing large amounts of information. The following table shows the distribution, by dimension of the total who viewed over 18 formats, together with the mean quiz scores for all subjects within that dimension:

<u>dimension</u>	<u>count viewing >18</u>	<u>% of dimension</u>	<u>mean quiz score</u>
E	11	36.67%	6.10
I	5	20.83%	6.33
N	5	19.23%	6.31
S	11	37.93%	6.28
T	4	22.22%	6.28
F	10	31.25%	6.34
P	2	13.33%	6.93
J	10	25.00%	6.03

In spite of sensing types having the largest percentage of subjects who viewed 18 or more formats, quiz scores were close to those of intuitives. This is as expected, as sensing individuals tend to look at a lot of data. The intuitives did not outperform sensing individuals on the quiz, losing their speed advantage.

The percentage of perceiving types who viewed a lot of formats was the lowest of all dimensions at 13.33%. Yet perceiving individuals performed better on the quiz, demonstrating that the quantity of information received had no impact on the amount learned.

The following table shows the distribution of the 24 subjects who were typed on all four dimensions, giving the mean frequencies for each format, total number viewed, and quiz score:

<u>type</u>	<u>count</u>	<u>theory</u>	<u>practical</u>	<u>graphic explanation</u>	<u>text explanation</u>	<u>graphic examples</u>	<u>code examples</u>	<u>total</u>	<u>quiz score</u>
INFJ	2	2.0	3.5	2.0	3.0	1.0	0.5	12.0	6.0
INFP	1	3.0	3.0	3.0	3.0	2.0	3.0	17.0	6.0
INTJ	1	0.0	1.0	0.0	0.0	1.0	0.0	2.0	6.0
INTP	1	1.0	0.0	2.0	0.0	2.0	2.0	7.0	10.0
ISFJ	3	2.3	2.3	3.0	2.0	3.3	2.7	15.7	6.0
ISTJ	2	1.5	2.5	2.5	1.5	2.0	2.5	12.5	7.0
ENFJ	1	3.0	1.0	1.0	0.0	3.0	1.0	9.0	3.0
ENFP	3	4.0	2.7	2.3	3.0	2.0	2.7	16.7	7.0
ENTJ	2	1.0	1.5	2.0	2.0	2.0	2.0	10.5	5.0
ESFJ	5	2.6	2.6	4.4	3.0	3.4	2.8	18.8	6.2
ESTJ	3	2.0	1.7	1.0	1.3	2.0	2.3	10.3	7.3

To determine if a student's temperament revealed a preference for the method of instruction, data were grouped according to temperament. The percentage, within each temperament, who preferred each format is as follows (see Appendix H for temperament typing data):

<u>temperament</u>	<u>theory</u>	<u>practical</u>	<u>graphic explanation</u>	<u>text explanation</u>	<u>graphic examples</u>	<u>code examples</u>	<u>count</u>
NF	60%	60%	40%	50%	30%	30%	11
NT	50%	63%	63%	38%	50%	25%	8
SJ	57%	43%	65%	48%	48%	61%	23
SP	50%	0%	0%	0%	0%	0%	2

The distribution, by temperament, of subjects viewing over 18 formats and the mean quiz score for all subjects in that temperament, did not demonstrate any significant differences. The results are shown below (see Appendix H for temperament typing data):

<u>temperament</u>	<u>count viewing >18</u>	<u>% of dimension</u>	<u>mean quiz score</u>
NF	3	27.27	6.55
NT	2	25.00	6.25
SJ	8	34.78	6.39
SP	0	00.00	6.50

The tendency of sensing judging types here to view more than the other temperaments, while not doing any better on the quiz, is consistent with the SJ preference for a lot of data. The SP temperament consisted of only two subjects, and conclusions cannot be drawn as to their preferences.

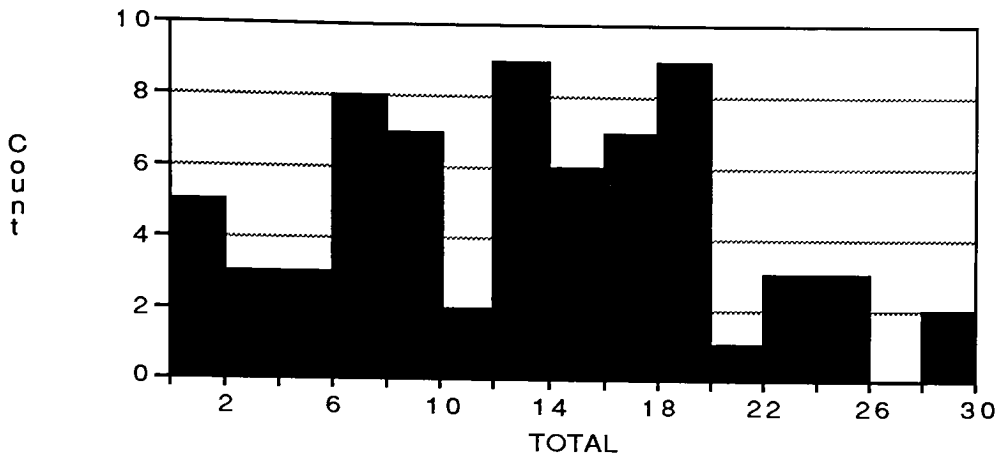
The population studied consisted of 35 freshman, 13 sophmores, 13 juniors, and 7 seniors. Males dominated the group at 62%, which is compatible with RITs male/female ratio. The students' field of study was classified as either a technical major such as engineering, mathematics, or computer engineering; or a nontechnical major such as printing, hotel management, or business. This resulted in 50 nontechnical and 18 technical subjects. The final grade obtained in the course was also collected. See Appendix I for data listed by individual.

Statistical Analysis

As the collected data are observed frequencies, the statistical analysis was performed using chi-square distributions. To ensure good approximation, each expected frequency should be at least five. Some of the data were grouped into broader categories to meet this requirement and will be noted.

The first hypothesis tested was: different formats of the same information are preferred by different personality types. The frequency of viewing a particular format was grouped into two categories: zero to two times was interpreted as not liking the format while greater than or equal to three was indicitive of preference. This was based on a mean of 2.10 choices per format. For each format, a chi-square test was run for each dimension of the Myers-Briggs typing to see if the responses of different types were nonrandomly distributed. The extrovert/introvert, intuitive/sensing, and thinking/feeling dimensions were not statistically significant. In the perceiving/judging dimension, the graphic explanation was preferred by judging types over perceiving types at a significance of 0.02. People who use perception also do not like text explanations or graphic examples, both with a significance of 0.01. None of the temperament typings showed significant results for format preferences.

The second hypothesis tested was: the amount of information desired varies among individual users. The mean of the total number of formats chosen was 12.6 with a range from 0 to 28 and a standard deviation of 6.98. This demonstrates the markedly different amounts of information desired by different individuals. The following table shows the wide distribution that resulted:



The total number of formats viewed and the score obtained on the quiz were grouped for the chi-square distribution based on their mean as follows:

total viewed

0 - 8 low

9 - 17 medium

>= 18 high

scores

1 - 4 poor

5 - 7 average

8 - 10 good

There was no significance relating the amount viewed to the quiz score obtained, indicating that the amount of instruction received had no relationship to how much was learned.

The third hypothesis tested was: type of instruction preferred does not correlate to the student's major, year of study, sex, or quiz score. The chi-square test for the student's year of study and the score received on the quiz were not significant. The distribution of the student's major showed significance at the 0.005 level for nontechnical majors preferring the graphic explanation format and the technical majors not choosing it. Technical majors dislike of graphic examples was also significant at 0.005. The chi-square distribution for type of instruction preferred by gender, showed a significance level of 0.03 for males preferring the theory-oriented format over females. At a significance of 0.005, males also had a higher interest in the text explanation while females preferred code examples.

When the final grade received by the student in the course was compared to the quiz score to determine if the score was based on better performance in general; no significance was found. There was also no relationship found between the quiz scores and Myers-Briggs types or temperaments. This appears to signify that the instruction was not better for just one type.

Limitations

This study was considered exploratory in its purpose, since there is a lack of adequate research that would predict the behavior of most of the variables examined. There are also many other variables involved that were neither examined nor controlled which could strongly influence the behaviors that resulted.

User experience was neither determined nor controlled. The importance of the distinction between novice and experienced users has been well established (VanDerVeer, et al., 1985; Schneiderman, 1987). A user with previous programming experience would primarily be interested in the syntax of Pascal loops, rather than the knowledge of why loops are needed or how they are used. A determination of previous user experience certainly would have been a variable worth exploring. In addition, subjects who attended lecture could have a stronger theoretical basis with which to understand a new construct than those who routinely skipped class. This is important with the subjects of this study, as more than two thirds of the class have stopped attending by the middle of the course. The level of previous knowledge and experience are very important variables not examined in the study.

The amount of help provided to the students in forms other than the CAI program was not controlled. Subjects could receive input from the lab proctors, lectures, and course textbooks, in addition to the program. This input could strongly influence both how much instruction they choose to receive from the program and the resulting quiz score. An attempt to control these variables could have significantly altered the results.

The simple nature of the interface limited the information the student could provide about himself. For example, user control is an important issue in CAI programs and UI design, but it was not examined (Atkinson, 1972; Hunter, et al., 1975; Rubincam & Olivier, 1985; Acker, 1985-86). The user was given complete control of the quantity of instruction, the formats to view, and the order to view them in. Being able to examine the student's ability to use the new information would have greatly enhanced knowledge about the user. Seeing how the user solved problems which required the use of programming loops could be accomplished by having the student write a program which required their use. Examination of the resulting computer interaction and program could provide a greater understanding of how effective the instructional choices were.

The limitations of both the hardware and software restricted the resulting program to text and simple graphics. A more powerful system would have allowed for a more sophisticated program which offered choices in simulation, computer versus user control, graphic versus natural language dialogues, and other features now available to designers.

The number of subjects was too small a sample to provide adequate numbers for each

Myers-Briggs type. Requiring the entire class to complete the questionnaire could have provided information about those who choose not to complete the extra credit. Making this unit mandatory for the entire class could also have provided a larger sample.

The personality questionnaire used to determine Myers-Briggs typing further limited complete typing of the 68 subjects. Only 24 subjects resulted in typing on all four personality dimensions. The Myers-Briggs Type Indicator, though longer, would have resulted in full use of all 68 subjects who participated in the study.

The short term nature of this study also severely restricted its usefulness. Subjects can easily spend one unit of course material simply exploring the different styles of instruction offered. Expanding the study to several units or even the entire course would give the students time to decide their preferences for instruction and ultimately chose only those they find useful.

Subjective observation of the subjects could enhance the knowledge of how the students used the program. For example, a choice is recorded whether the subject glanced at the screen or was very interested and spent several minutes studying it. The behavior exhibited while using the program could provide important clues in human computer interaction.

An important limitation is that all the formats were designed and written by one person. The strong evidence previously discussed regarding the designer's tendency to design for their own type must be considered here (Mason & Mitroff, 1973; Eason, 1975; VanDerVeer, et al., 1985; Yoder, 1986; Schneiderman, 1987). Format choices developed by other psychological types could have resulted in stronger preferences among the subjects.

Any results reported in this study have to be viewed as providing direction for future exploration. The limitations restricting this study should serve as guidelines with which to design the next exploratory study. It is only after patterns of behavior are developed that more strictly controlled experiments can be conducted to determine the feasibility of developing user models based on Myers-Briggs personality typing.

8. CONCLUSIONS

Interpretation of Results

The research effort presented here contained many variables which were neither controlled nor examined. The number of subjects involved was small. Little data of statistical significance resulted, but certain trends can be observed.

Yoder reported a stronger preference for graphics by extroverts and feeling individuals, while introverts, judging, and thinking individuals preferred prose. She also found extroverts favoring examples, while introverts and feeling types chose explanations (Yoder, 1986). The results presented here do not corroborate with these conclusions, but both studies suffered from small numbers of subjects.

The results of Yoder's research indicated that no one type of help facility could satisfy everyone (Yoder, 1986). This conclusion is substantiated by the results presented here. The mean number of times each format was viewed by an individual ranged from 2.0 to 2.41. This indicates that presenting just one type of information would not have been useful to everyone. Each personality type has a different concept of useful information (Mason & Mitroff, 1973). The importance of how information is presented is demonstrated, as well as the need for multiple user models.

Sensing individuals may be too data bound and can collect data forever. Intuitives, on the other hand, may be too data free, coming to conclusions too soon. The percentage of sensing types who viewed over 18 formats (all of them) was 38% while only 19% of intuitive individuals did. The total number of choices made by all subjects varied from 0 to 28 with a standard deviation of 6.978, indicating that similar amounts of information will not satisfy everyone.

The perceiving/judging dimension demonstrated the only results of statistical significance with regard to Myers-Briggs typing. Judging individuals preferred graphic explanations, text explanations, and graphic examples over their perceiving counterparts. This must be interpreted with the knowledge that only 13% of perceiving types looked at over 18 formats, while 25% of people who prefer judging viewed over 18. Instead of concluding that judging individuals like graphics and explanations, there is a stronger indication that perceiving types looked at less. People who prefer judging are more likely than perceivers to follow through to completion.

The results of temperament typing did not produce any significant results. Having only

two SP subjects is limiting. The one format where preference was noticeably different was in the percentage who viewed code examples at least three times. Here SJs received 61% compared to 30% for NFs, 25% for NTs, and 0% for SPs. This could be the result of SJs being good with detail and wanting practical knowledge. A format which displays the actual Pascal code to use provides both.

The score received on the quiz did not demonstrate dependency on any other variables. Those individuals who viewed a lot of formats did not perform better on the quiz than those who viewed only a few. Students who scored well on the quiz did not show a preference for any single type of instruction. This indicates that no one format provided better teaching than the other formats, which supports the argument for multiple styles of instruction. The lack of correlation between the quiz scores and final course grade is interpreted as demonstrating that, at least for some students, this CAI unit was more meaningful than traditional classroom instruction.

Individuals who were in nontechnical majors showed preference for graphic explanation and graphic examples, while people with technical majors disliked both graphic formats. The preference for graphics appears to have a love/hate relationship when applied to computer interaction. Its usefulness is clearly demonstrated, but only by some individuals. The results by Yoder strongly corroborate its effectiveness only with certain types of personality (Yoder, 1986). The conclusion drawn here advocates its use, but only in addition to other teaching options.

The gender distinctions showing male preference for theory-oriented instruction and text explanation versus female preference for code examples contradicts previous research demonstrating problem-solving behavior as not being influenced by gender (Hunter, et al., 1982). The limitations previously discussed in Chapter 7 could strongly influence the results obtained.

The results received here were not as clear as could be expected from previous research. Sensing types were expected to desire practical knowledge as provided by formats describing how to use the loop, graphic explanations, text explanations, and code examples. Intuitive types should have preferred theory-oriented instruction and graphic examples which demonstrate possibilities. Intuitive types should lose their speed advantage over sensing types on self-paced instruction, and no significant difference was found in their quiz scores.

Though lacking clear results, certain observations can be noted. The conclusions which can be drawn from the study are summarized as:

- Varying formats of the same information are differentially useful to different individuals, demonstrating the need for multiple user models.
- The amount of information desired will vary among individual users, which

argues against fixed instructional strategies.

- Increasing the amount of information to a user does not necessarily result in better performance.
- Removing speed restrictions allows sensing individuals to perform at the level of their intuitive counterparts.

Discussion

The distinction between which part of the program used in this study is the user interface and which part provides the instruction cannot be easily determined. Both the function and the presentation are concerned with providing information to users. The teaching strategy used was teacher-centered, using students as passive partners. The information content did not vary, only the method of presentation.

The theory explored was based on the belief that the user is a learner and decision-maker, and that personality influences learner-controlled decisions. Decision style is an important determinant of behavior and appears to be the result of a user's cognitive style which differs for different psychological types. Distinct styles react differently to the same information, which results in differing decision-making behavior (Mason & Mitroff, 1973; Henderson & Nutt, 1980).

Bolt's argument for a natural interaction that is intuitive to the user, cannot be supported by the findings in this thesis (Bolt, 1984). The subjects in this study responded in varying ways to the information provided. There is no evidence to support an interface or teaching style that is best for everyone.

The validity of Myers-Briggs typing is too well demonstrated to discontinue further investigation. Rich's recommendation of designing interfaces based on stereotypes is particularly well suited to Myers-Briggs typing. She suggests that instead of waiting for a significant user history to emerge, designers should take advantage of the observation that human traits frequently occur in clusters. The presence of a few traits could be a trigger which activates the suggestion that the user possesses other traits within the stereotype (Rich, 1983). Using the Myers-Briggs types could provide a well investigated stereotyping method. For example, a user who demonstrates a preference for facts and is good with detail could be inferred to be a sensing type; other qualities such as preference for learning step-by-step by doing and the desire for practical results would become traits also associated with the user. Further investigation of human computer interaction within the different dimensions of the types warrants further investigation.

Adaptive teaching strategies could also be based on the theories of Isabel Briggs-Myers.

The need for individualized teaching is based on the failure of traditional teaching to meet the needs of all students. Lawrence maintains that current methods favor introverted intuitives. The application of typing to education has been well investigated (Lawrence, 1979). This research forms a natural starting place for appropriate teaching strategies in ICAI. A study conducted by Hunter and Levy demonstrated that problem-solving performance patterns did differentiate by typological grouping (Hunter & Levy, 1982). An early goal of CAI was to provide learning that was appropriate to each student's style. Researchers in typing have differentiated learning styles. Investigation of the appropriateness of these instructional strategies in CAI needs to be determined.

The appropriate use of tools available to designers has been the focus of research in both UI and CAI. How and when to use graphics, simulation, natural language, and other features to enhance the interaction has been largely unanswered. A natural direction to pursue is that different types prefer different dialogue styles and system options. Yoder's work showing extroverts preferring graphics and introverts preferring text can be interpreted as resulting from the extrovert's preferences towards the outer, physical world and introverts favoring the world of ideas (Yoder, 1986). Since sensing individuals prefer a hands-on, learning by doing style, simulations which display the consequences of their decisions could greatly enhance understanding. People who prefer intuition may desire formal dialogue for the understanding of what the system is doing beyond the interface. Trying to incorporate computer tools in one way to appeal to everyone neglects the past two decades of research demonstrating the ineffectiveness of one strategy.

One of the most well studied issues in CAI is that of learner control (Kearsley, et al., 1983; Rubincam & Olivier, 1985). The issue is how much and what kind of control the user should have. Opinions range from not allowing the student to circumvent the teaching strategy to giving the student complete control of the computer and their learning activities. Fry found that the student's ability to use learner control effectively appeared to be a function of personality traits. He found subjects with a preference for the ambiguous and unexpected, coupled with high aptitude, more suited for learner-controlled environments (Fry, 1972). This finding is suggestive that individuals who use intuition and perception should be given control over their learning. Sensing and judging types with their preference for guidance and situations planned in advance would probably do better with system control. Sensing individuals use extrinsic motivation -- response and reinforcement, such as provided in traditional CAI programs. Intuitives are motivated intrinsically, preferring exploration such as found in the LOGO environment. The issue is not how much control to give every user but what level of control different personality types prefer.

The conclusion that there is no typical person gives rise to the need for guidance in

suitable representation of problems, method of individualized instructional strategy, appropriate use of 'syntactic sugar', level of user control, and suitable use of system features. The desire to move away from designing computer systems meant for one psychological type and the need to select personality characteristics upon which to differentiate users and interpret user interaction, should not be undertaken as a unique experience related only to human computer interaction. Researchers should use the previous work done by investigators in other fields to guide them. Incorporating established theories with the unique features offered by computers could result in more rapid acceptance and widespread usage of computer systems by the general population.

Proposal

Gaines and Shaw have stated that computer technology cannot wait for researchers to develop a complete understanding of human behavior (Gaines & Shaw, 1986b). This thesis argues that computer scientists can develop a useful and effective user model without a full study of human behavior. Long term studies can be done, which start with the theories of human behavior and learning as already investigated by psychologists and educators. Observations of how people react to the interface and system features can provide evidence of human computer interaction. Adjustments and improvements to the system should result from these observations. The ultimate goal is a collection of user models, based on both cognition and personality characteristics, which transcends a particular application or system.

The next step in the development of effective user models is a further investigation of the appropriateness of Myers-Briggs typing theories. An exploratory study is again warranted to further develop trends worthy of more specific, controlled experimentation. The study should be based upon the efforts presented here, with many of the drawbacks and limitations removed or reduced.

The next investigation should be placed in the same type of introductory level course used in the study presented here. The large pool of subjects with varying interests and backgrounds should provide adequate numbers in each Myers-Briggs type if all students in the course are used.

To explore the differences in behavior between novice and experienced computer users, the subjects will first answer a questionnaire designed to determine user experience. Previous courses taken in computer programming and computer usage can be determined. The subjects will also be given the 166-question Myers-Briggs type indicator to ensure accurate and complete typing.

Input to the user from sources other than the CAI program can be monitored by taking

attendance in class and restricting the kind of help and instruction lab proctors provide. This variable can not be controlled well. Help from friends or textbooks could impact significantly on the results.

The short term nature of the study reported here can be alleviated by developing the program to cover the entire course. The user patterns that develop should be more pronounced than those from short term studies. Subjects will eventually learn to do only what benefits them. Short term studies suffer from being completed before the user develops a pattern of behavior.

Personal observation of subjects is not warranted in an exploratory study, but will be more appropriate in controlled experimentation. Instead, monitoring the time each format is on the screen could demonstrate the depth of a student's interest in it. The time spent viewing a format can be used to give significance to the choice made, with a few second of viewing carrying little weight and several minutes being assigned a larger weight.

The biggest drawback of the study presented here was clearly the simple nature of the interface and instruction necessitated by the hardware. A more powerful system which can provide more sophisticated graphics, multiple windows, natural language, and simulations in addition to text would provide far more information as to their usefulness to different personality types.

The plan for the development of the formats needs to be more sophisticated than the one used in the study presented here. One designer will influence the resulting formats to the point that their differences are no longer able to be distinguished by type. There is too much evidence supporting the belief that designers design for themselves (VanDerVeer, et al., 1985; Schneiderman, 1987). The appropriate next step is to find four CAI designers, one sensing/judging (SJ), one sensing/perceiving (SP), one intuitive/thinking (NT), and one intuitive/feeling (NF). To provide for all sixteen Myers-Briggs types would be too demanding at this stage. The four types chosen are based on Keirsey's theory of temperament and provide a good starting point. The four designers found (college faculty and graduate students should provide appropriate designers) will be given a description of the course material to be covered in each unit and told to use the facilities available on the computer system to develop a CAI program. This approach to design offers several advantages. The removal of the resulting program being influenced by one psychological type will enhance the differences in approach. Also, since educators have been found to teach primarily to their own type, the variation in the resulting courseware can be examined for use of system features along the dimensions of type (Lawrence, 1979). The result will be four choices of instruction in every unit. The choices will again contain the same content, but each will be a complete instruction on the unit without needing to view several choices to gain a complete picture. The instruction chosen by the

subjects will provide clear distinctions.

Upon completion of each unit, the student will be offered choices of problems to program. Programming problems will also be developed by the designers. The type of problem selected and the method chosen to solve that problem, will provide additional data on each subject.

The information collected for each subject should give a clear picture of how each completed the course. Patterns of behavior should be more pronounced. The variables which will be obtained are summarized as follows:

- user experience
- user's Myers-Briggs type
- preference for instruction (weighed by time spent, classified by designers' temperament)
- preference for problem type (classified by designers' temperament)
- method of problem-solving used

The information collected from the users will be analyzed with respect to the following hypotheses:

- Previous experience does affect the type of instruction desired.
- Type of instruction preferred will correlate with Myers-Briggs and temperament typing.
- The designers will make different choices in their use of dialogue styles and system features.
- The subject's preference for instruction and problem-solving strategy will be the result of the subject and designer's psychological types matching.

In addition, the particular usage of system features by each designer can be observed, noting how and when the designer incorporated each feature. Differences found can be used as the basis of further experimentation.

Trends observed in this study can be used to isolate variables which differentiate Myers-Briggs personality types. The variables obtained can be tested with respect to their application in disciplines other than computer aided instruction. A system such as that developed by O'Shea would serve as an excellent research vehicle. O'Shea's self-improving quadratic tutor contains an adaptive teaching program that is expressed in production rules and a self-improving unit that makes changes in the production rules (O'Shea, 1979). The

effectiveness of these changes are measured statistically and if student performance improves, measured by such variables as completion time, lower error rate, and increased test score, the modification is incorporated into the production rules. In a similar manner, the variables obtained as the result of the exploratory study which are deemed important to different personality types can be further refined. A self-improving system can be developed and goals such as speed or lower rate of errors established. Subjects will be personality tested, allowed to use the self-improving system, and the final state which the system has adapted itself to, determined. Examination and comparison of the final state reached for each type in a non-CAI system could provide useful information towards the development of an application-independent and discipline-free set of user models.

Future Research

The need for user models transcending application becomes increasingly apparent with each technological advancement. The development of additional modalities for parallel, integrated communication emphasizes the lack of knowledge about the best way to incorporate them in an overall system. The user model cannot be redesigned with each technological breakthrough. As each computer generation began, a new systems technology came into existence. The technology depended on the simultaneous advancement of interrelated subsystems technology (Gaines & Shaw, 1986a). The current emphasis on knowledge-based systems, moving away from predefined algorithms, is based on encoding knowledge, learning, and goals. This top-down approach from user needs requires interdisciplinary research.

The separation of the user model from both the application and system is required to provide the different levels of interaction needed by people in various roles using multiple computer subsystems. To achieve this goal, theories are needed which will enable the design of systems locally optimized for individuals and globally optimized for overall performance. These theories must contain increased knowledge of people, computers, and their interaction (Gaines & Shaw, 1986b).

The development of effective user models is hindered by the fragmentation of disciplines separately pursuing the same goal. The current trends of knowledge-based systems and automatic programming are forcing designers to view programming, learning, and interaction as inseparable user activities.

Kearsley states that intelligent computer aided instruction researchers are few, due to the difficulty in becoming knowledgeable in two or three different fields simultaneously (Kearsley, 1987). The removal of the need for designers to develop user models is necessary to maximize

developmental efforts.

This thesis, therefore proposes the continued investigation of the application of personality theories, such as Myers-Briggs, directed towards the goal of application- and system-independent user models. A collection of models, differentiated along established personality theories, is required to provide novice and casual users with an effective interaction without waiting for a pattern to emerge. Once the important aspects of personality which impact on computer interaction are investigated, the starting point for a user model can be based on the type of user expected. A dynamic model inferred by the system will provide an individualized interaction, based on actual user history. Long term user characteristics can be maintained without having to store and maintain large histories if user actions can be classified by different personality types. For example, an interaction can be inferred to represent an intuitive trait at a specified weight and added to previous totals maintained for each personality dimension. The type of interaction offered can be based on the current personality typing. This will allow for a flexible design which can provide an effective interaction with both short and long user histories.

The focus of the research efforts to investigate and isolate relevant variables must begin with continued exploratory studies. As patterns and trends develop, further controlled experimentation is required to verify the observations. Mason and Mitroff propose a program of research to identify psychological type, class of problem, method of evidence, organizational context, and mode of presentation. Since each variable can assume several different states, they propose further research to test the interaction of all possible combinations (Mason & Mitroff, 1973).

The development of user models does not require complete understanding of human behavior. A model that captures the essential features of that part of personality which comes into play in human computer relationships can provide an effective interaction. The emulation of human intelligence by artificial intelligence has demonstrated the application of this approach. Heuristics developed by knowledge engineers can be used to develop production rules which account for human behavior. ICAI student models which represent the student's knowledge state based on comparisons between the student's performance and that of an expert, can apply pattern recognition to the student's history to understand why a response was made.

The ultimate goal of computing technology must be to place the tools in the hands of the general population. The appropriate ways to use the technology must first be addressed by computer scientists. CAI programs developed by educators were unsuccessful because teachers are trained to deliver content to groups of students. The kind of thinking required to develop problem-solving skills using the computer are being advanced by intelligent computer

aided instruction researchers, not educators. Computer scientists must understand the needs of its users before it can expect other disciplines to view the technology as beneficial to them.

The objectives for the sixth-generation computer era require the interdisciplinary collaboration of physiologists, psychologists, linguists, logicians, and computer scientists to develop foundations for knowledge science and technology (Gaines & Shaw, 1986b). Artificial intelligence research is concentrated on the combination of people and computers in joint problem-solving. The total knowledge system must see the processes of the person mirrored in the computer (artificial intelligence) and the processes of the computer mirrored in the person (cognitive science) (Gaines & Shaw, 1986a). The demands of the fifth-generation computer era with its emphasis on complex knowledge-based systems involving close human computer interaction, has put demands on human factor specialists that stretch beyond their current limits. Future computer systems will increasingly be built top-down from user needs rather than bottom-up from technology availability. Knowledge-based systems that require the development of complete user models, also hold the promise of providing the basis for their development.

Appendices

PERSONAL STYLE INVENTORY

R. Craig Hogan and David W. Champagne

The following items are arranged in pairs (a and b), and each member of the pair represents a preference you may or may not hold. Rate your preference for each item by giving it a score of 0 to 5 (0 meaning you really feel negative about it or strongly about the other member of the pair, 5 meaning you strongly prefer it or do not prefer the other member of the pair). The scores for a and b MUST ADD UP TO 5 (0 and 5, 1 and 4, etc.). Do not use fractions.

- 1a. making decisions after finding out what others think.
- 1b. making decisions without consulting others.

- 2a. being called imaginative or intuitive.
- 2b. being called factual and accurate.

- 3a. making decisions about people in organizations based on available data and systematic analysis of situations.
- 3b. making decisions about people in organizations based on empathy, feelings, and understanding of their needs and values.

- 4a. allowing commitments to occur if others want to make them.
- 4b. pushing for definite commitments to ensure that they are made.

- 5a. quiet, thoughtful time alone.
- 5b. active, energetic time with people.

- 6a. using methods I know well that are effective to get the job done.
- 6b. trying to think of new methods of doing tasks when confronted with them.

- 7a. drawing conclusions based on unemotional logic and careful step-by-step analysis.

Appendix A

- 7b. drawing conclusions based on what I feel and believe about life and people from past experiences.
- 8a. avoiding making deadlines.
- 8b. setting a schedule and sticking to it.
- 9a. talking awhile and then thinking to myself at a later time.
- 9b. talking freely for an extended period and thinking to myself at a later time.
- 10a. thinking about possibilities.
- 10b. dealing with actualities.
- 11a. being thought of as a thinking person.
- 11b. being thought of as a feeling person.
- 12a. considering every possible angle for a long time before and after making a decision.
- 12b. getting the information I need, considering it for a while, and then making a fairly quick, firm decision.
- 13a. inner thoughts and feelings others cannot see.
- 13b. activities and occurrences in which others join.
- 14a. the abstract or theoretical.
- 14b. the concrete or real.
- 15a. helping others explore their feelings.
- 15b. helping others make logical decisions.
- 16a. change and keeping options open.
- 16b. predictability and knowing in advance.
- 17a. communicating little of my inner thinking and feelings.
- 17b. communicating freely my inner thinking and feelings.

Appendix A

- 18a. possible view of the whole.
- 18b. the factual details available.

- 19a. using common sense and conviction to make decisions.
- 19b. using data, analysis, and reason to make decisions.

- 20a. planning ahead based on projections.
- 20b. planning as necessities arise, just before carrying out the plans.

- 21a. meeting new people.
- 21b. being alone or with one person I know well.

- 22a. ideas.
- 22b. facts.

- 23a. convictions.
- 23b. verifiable conclusions.

- 24a. keeping appointments and notes about commitments in notebooks or in appointment books as much as possible.
- 24b. using appointment books and notebooks as minimally as possible (although I may use them).

- 25a. discussing a new, unconsidered issue at length in a group.
- 25b. puzzling out issues in my mind, then sharing the results with another person.

- 26a. carrying out carefully laid, detailed plans with precision.
- 26b. designing plans and structures without necessarily carrying them out.

- 27a. logical people.
- 27b. feeling people.

- 28a. being free to do things on the spur of the moment.
- 28b. knowing well in advance what I am expected to do.

Appendix A

29a. being the center of attention.

29b. being reserved.

30a. imagining the nonexistent.

30b. examining details of the actual.

31a. experiencing emotional situations, discussions, movies.

31b. using my ability to analyze situations.

32a. starting meetings at a prearranged time.

32b. starting meetings when all are comfortable or ready.

QUIZ A

NAME _____
 SS# _____
 MAJOR _____
 SEX (M OR F) _____
 YEAR(FRESHMAN, ETC.) _____

You may assume that any code fragments are part of a correct program with appropriate variable declarations, begin..end, etc.

_____1. Which of the following will draw a square and stop:

- | | |
|---|---|
| a) <code>turnto(30)</code>
<code>repeat</code>
<code>move(10);</code>
<code>turn(90)</code>
<code>until turtleang = 0;</code> | b) <code>turnto(30);</code>
<code>repeat</code>
<code>move(30);</code>
<code>turn(90)</code>
<code>until turtleang = 30;</code> |
| c) <code>turnto(0);</code>
<code>repeat</code>
<code>move(10);</code>
<code>turnto(90)</code>
<code>until turtleang = 0;</code> | d) <code>turnto(0);</code>
<code>repeat</code>
<code>move(10);</code>
<code>turn(10)</code>
<code>until turtleang = 0;</code> |

- _____2.
- | | |
|--|---|
| a) <code>for count:=1 to 4 do</code>
<code>turnto(0);</code>
<code>move(30);</code>
<code>turn(90);</code> | b) <code>count:=0;</code>
<code>while count < 4 do</code>
<code>move(30);</code>
<code>turn(90);</code>
<code>count:=count+1;</code> |
| c) <code>turnto(0);</code>
<code>repeat</code>
<code>move(30);</code>
<code>turn(90);</code>
<code>until turtleang=0;</code> | |

Which of the above draw the same object:

- a) all three
- b) the first two
- c) the last two
- d) they all draw different things

____3. In a repeat loop, the boolean expression or condition:

- a) represents the exit condition - when to stop
- b) represents the condition upon which to continue
- c) gets incremented automatically
- d) none of the above

____4. In a while loop, the boolean expression or condition:

- a) is always true at least once
- b) represents the condition upon which to stop if true
- c) represents the condition upon which to execute if true
- d) none of the above

____5. for count:=2 to 6 do

```
begin
    move(30);
    turn(30)
end;
```

How many times will this loop execute:

- a) none
- b) 2
- c) 4
- d) 6

Appendix B

_____6. count:=0;
 while count < 4 do
 move(30);
 turn(90);
 count:=count + 1;

What will the above code draw:

- a) a square
- b) a line of length 120
- c) a line of length 30
- d) none of the above

_____7. for count:=5 to 2 do
 begin
 move(30);
 turn(90)
 end;

How many times will this execute:

- a) none
- b) 3
- c) 5
- d) forever

- _____8. turnto(0);
 repeat
 move(10);
 turn(90);
 until turtleang > 0;

How many times will this loop execute:

- a) never
- b) 3
- c) 1
- d) 4

Appendix B

____9. moveto(139,95);
 repeat
 move(30);
 moveto(139,95);
 turn(10)
 until turtleang = 0;

What will this draw:

- a) a circle
- b) a polygon
- c) a 3-dimensional object
- d) none of the above

____10. turnto(0);
 while turtleang > 0 do
 begin
 move(10);
 turn(90)
 end;

How many times will this loop execute:

- a) 4
- b) none
- c) forever
- d) none of the above

QUIZ B

NAME _____
SS# _____
MAJOR _____
SEX (M OR F) _____
YEAR(FRESHMAN, ETC.) _____

You may assume that any code fragments are part of a correct program with appropriate variable declarations, begin..end, etc.

- _____1. If some instructions will be executed only if turtleang is greater than zero, use:
- a) the for loop
 - b) the while loop
 - c) the repeat loop
 - d) any of the above
- _____2. count:=0;
 repeat
 move(10);
 turn(90)
 until count = 4;
- How many times will this loop execute:
- a) none
 - b) 4
 - c) 1
 - d) forever
- _____3. The repeat loop does not need a begin and end to enclose more than one statement because:
- a) the repeat...until encloses the statements within the loop
 - b) only one statement can be enclosed in the repeat loop
 - c) there needs to be some way to distinguish between loops
 - d) none of the above

Appendix B

_____4. count:=0;
 while count < 5 do
 begin
 move(10);
 turn(90);
 end;

How many times is this loop executed:

- a) none
- b) 5
- c) forever
- d) none of the above

_____5. for count:=1 to 4 do
 move(10);

What will happen when this code is executed:

- a) will draw a square
- b) will draw a line of length 10
- c) will draw a line of length 40
- d) nothing, variable count was not initialize

_____6. The while loop is used to:
a) execute code repeatedly without having to list it many times
b) change the order of execution from sequential
c) execute code only if a certain condition is true
d) all of the above

_____7. for counter:=1 to 4 do
 begin
 move(10);
 counter:=1
 end;

What will happen when this code is executed:

- a) will execute forever
- b) will draw a line of length 40
- c) will draw a line of length 10
- d) will never execute

_____8. count:=0;
 while count < sides do
 begin
 move(10);
 turn(360 div sides);
 count:=count + 1
 end;

What will this draw:

- a) a hexagon
- b) a triangle
- c) any polygon, depending on the value of variable sides
- d) none of the above

_____9. Which of the following will draw a square and stop:

- | | |
|--|---|
| a) turnto(0);
while turtleang > 0 do
begin
move(10);
turn(90)
end; | b) count:=0;
while count < 4 do
begin
move(10);
turn(90)
end; |
| c) turnto(30);
while turtleang > 0 do
begin
move(10);
turn(90)
end; | d) count:=0;
while count < 4 do
begin
move(10);
turn(90);
count:=count + 1
end; |

Appendix B

- ____10. A for loop is best when:
- a) the instructions may never be executed
 - b) the number of loop executions is known beforehand
 - c) a condition may vary
 - d) there are only a few instructions

EXTRA CREDIT INSTRUCTIONS - STUDENT

This extra credit is part of a study to examine how learning styles are reflected in "on-line" instruction. You will be asked to enter your social security number and all other input will be recorded automatically.

PERSONALITY QUESTIONNAIRE:

To determine personality preferences 32 questions will be presented. Each question will consist of 2 statements. Rate your preference for each statement by giving it a score of 0 to 5.

0 1 2 3 4 5
feel very negative<----->strongly prefer

Enter 0, 1, 2, 3, 4, or 5 for the first item only. The second item will be calculated so the two together total 5. For example:

I prefer: a) making decisions after finding out what others think
 b) making decisions without consulting others

preference for a) _____

If you enter 4 for choice a), then choice b) will automatically be given the value 1. If you enter 2 for choice a), then choice b) will automatically be given value 3. Only whole numbers between 0 and 5 are acceptable.

INSTRUCTION:

After completing the questionnaire, the instruction is offered. At the top of the screen, you will see the 3 programming loops you will be learning. You can choose them in any order, but must go through all 3. After making your choice, there are 6 types of instruction offered for each loop:

1. a description of why the loop is needed;

Appendix C

2. a description of what the loop is used for;
3. a graphic explanation of how the loop works;
4. a written explanation of how the loop works;
5. graphic examples showing objects that can be drawn;
6. examples of code which use the loop.

Much of the information is duplicated within the six choices. It is expected that you will need to view more than one instruction listed above for each loop to understand the concepts, but seeing all 6 should be unnecessary.

If you quit the instruction before finishing, note the disk number. Ask the proctor for that disk when you come back and you will not be asked to redo the personality questionnaire. The quiz covers all 3 loops. The quiz can only be taken once and there is no practice.

EXAMPLES OF PROGRAM DISPLAYS

Why Loop is Needed:

There is often a need to execute a series of instructions several times in a row, without having to list them repeatedly. The repeat loop:

```
---->REPEAT---->statement---->UNTIL---->boolean expression
          |               |
          +-----+
          compound statement
```

will execute the statement(s) listed until some condition, called a boolean expression is true. The statement(s) can be executed a fixed number of times or controlled based on data values.

What Loop is Used For:

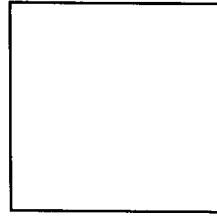
```
REPEAT
  <statement>;
  .
  .
  <statement>
UNTIL <boolean expression>
```

The repeat loop tells the computer to repeat certain instructions until a certain condition, called a boolean expression is met. This can be used to draw polygons without listing 'move' and 'turn' several times in a row, or to draw the same object several times.

Graphic Explanation:

```
REPEAT
  move(40);
  turn(90)
UNTIL turtleang = 0;

angle equals ____
```



Text Explanation:

The repeat loop starts by executing the instructions contained between the repeat and until part of the loop. Then the exit condition is checked. If this condition is true, the loop terminates. If the condition is false, execution 'jumps' back to the first statement of the repeat loop and all the statements in the loop are done again. The exit condition is evaluated again, and if false, the instructions within the loop are executed again. This continues until the exit condition is true and execution continues with the statement following the repeat loop. You must guarantee that the loop will eventually terminate. For example:

```
counter:=0;
REPEAT
  writeln(counter)
UNTIL counter = 100;
```

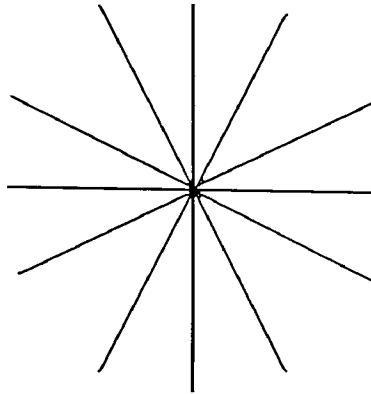
This will execute forever because counter is set to zero and never changes so the exit condition of counter equaling 100 never becomes true. The following code is correct:

```
counter:=0;
REPEAT
  writeln(counter);
  counter:=counter + 1
UNTIL counter = 100;
```

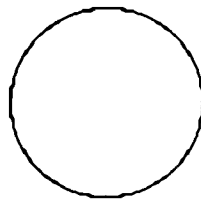
This will write numbers from 0 to 100 and then terminate.

Graphic Examples:

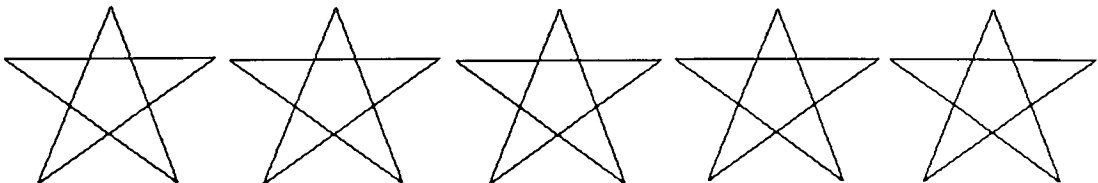
Use the repeat to draw a flower by drawing a line, returning to center, turn a little. Continue until turtleang = 0.



Use repeat to draw a circle as a 20-sided polygon.



By setting a counter to zero and defining a procedure to draw a star, use repeat to draw a star, move, increment counter until counter equals five.



Appendix D

Code Examples:

```
turnto(0);  
REPEAT  
  move(20);  
  moveto(139,95);  
  turn(10)  
UNTIL turtleang = 0;
```

This code will result in drawing a flower. The strategy here is to draw a line, come back to the center and turn a little. The repeat loop causes the 3 statements to be executed until back to where you started.

```
turnto(0);  
REPEAT  
  move(10);  
  turn(18)  
UNTIL turtleang = 0;
```

These instructions draw a circle. The idea is to envision a circle as a many sided polygon. Care must be taken to ensure that turtleang will eventually reach zero.

```
counter:=0;  
REPEAT  
  star;  
  moveto(turtlex + 20, turtley + 15);  
  counter:=counter + 1  
UNTIL counter = 5;
```

This will draw 5 stars. By initializing a counter to 0 and incrementing it, the repeat loop will continue to draw stars until 5 have been completed.

Subject Scores

<u>subject number</u>	<u>quiz A or B</u>	<u>score</u>
1	A	6
2	B	6
3	B	7
4	B	4
5	A	8
6	A	5
7	B	5
8	A	6
9	B	6
10	B	5
11	A	6
12	B	3
13	B	7
14	A	6
15	B	9
16	A	6
17	B	3
18	A	5
19	B	10
20	A	5
21	A	5
22	A	4
23	B	5
24	B	3
25	B	6
26	B	8
27	B	10
28	A	8
29	A	8
30	B	4
31	A	8

<u>subject number</u>	<u>quiz A or B</u>	<u>score</u>
32	A	10
33	A	8
34	A	8
35	A	4
36	A	5
37	A	7
38	A	5
39	A	4
40	A	4
41	B	7
42	B	6
43	A	6
44	A	6
45	B	3
46	A	7
47	B	8
48	B	8
49	A	7
50	B	8
51	A	5
52	A	8
53	B	8
54	A	7
55	B	1
56	B	10
57	A	5
58	B	6
59	A	3
60	A	10
61	A	6
62	B	7
63	A	7
64	A	7

Appendix E

<u>subject number</u>	<u>quiz A or B</u>	<u>score</u>
65	A	6
66	A	7
67	A	3
68	B	10
69	B	9
70	B	7
71	B	5
72	A	4
73	B	7
74	B	5
75	A	8
76	A	4
77	A	7
78	A	3

Myers-Briggs Types

<u>subject number</u>	<u>introvert/extrovert</u>	<u>intuitive/sensing</u>	<u>thinking/feeling</u>	<u>perceiving/judging</u>
1		N	F	P
2	I	N	T	J
3	E	S	T	J
4	E	S	F	J
5		S	F	P
6			F	
7				P
8			F	J
9	I	S	F	J
10		S	F	J
11	I	N	T	
12	E	N	F	J
13	I	N	F	
14	I		F	J
15	I		F	P
16	E	N		P
17	E		F	P
18	I	S	F	J
19	E	N	F	
20	E		F	P
21	E		F	J
22		N	T	J
23	I	S		J
24	I	N		
25	E	S	F	J
26	I		F	J
27	E	N	F	P
28	I	S		J
29	E	N	F	P
30	E			J
31		S		J

Appendix F

<u>subject number</u>	<u>introvert/extrovert</u>	<u>intuitive/sensing</u>	<u>thinking/feeling</u>	<u>perceiving/judging</u>
32	E	N		P
33	E	S	F	J
34	I	S	T	J
35	E	S	F	
36		S	T	J
37	I	N	F	J
38	E	S	F	J
39	E	N		J
40	I	S	T	
41	E			J
42	I	S		J
43		S		J
44	E	S		
45	I	S	T	
46	E	N	T	J
47	E	S	F	J
48		N		J
49	E	N	T	
50		S	T	J
51	E	S		P
52	E		F	J
53	E	S	T	J
54	I		T	J
55		N		J
56	I	N	T	P
57	I	N	F	J
58	I	N	F	P
59	E	N	T	J
60		N		P
61	I	S	T	J
62	E	N	F	
63	E	S	T	J
64	I	N	T	

Appendix F

<u>subject number</u>	<u>introvert/extrovert</u>	<u>intuitive/sensing</u>	<u>thinking/feeling</u>	<u>perceiving/judging</u>
65	E	S		J
66	I	S	F	J
67	E	N	F	P
68		S	F	

Subject Choices

<u>subject</u>	<u>format 1</u>	<u>format 2</u>	<u>format 3</u>	<u>format 4</u>	<u>format 5</u>	<u>format 6</u>	<u>total</u>
1	1	0	0	0	0	0	1
2	0	1	0	0	1	0	2
3	3	3	3	3	4	3	19
4	3	2	2	2	3	1	13
5	2	2	2	2	2	2	12
6	1	1	3	3	3	1	12
7	0	1	5	1	0	0	7
8	0	0	0	0	0	0	0
9	1	3	3	0	3	3	13
10	1	1	3	1	2	4	12
11	4	3	4	3	6	4	24
12	3	1	1	0	3	1	9
13	1	0	0	0	3	2	6
14	0	2	4	0	1	2	9
15	3	3	0	0	0	0	6
16	0	2	2	0	1	3	8
17	0	0	3	3	1	0	7
18	3	3	3	4	5	4	22
19	5	4	4	3	2	2	20
20	3	3	3	2	1	4	16
21	4	4	4	4	4	4	24
22	3	3	3	1	3	1	14
23	3	2	3	3	2	3	16
24	1	0	1	3	2	1	8
25	2	2	5	3	4	3	19
26	3	3	3	3	3	3	18
27	2	1	2	0	1	0	6
28	4	4	3	5	4	8	28
29	3	3	3	3	3	4	19
30	2	2	3	3	2	0	12
31	3	0	0	0	0	0	3

Appendix G

<u>subject</u>	<u>format 1</u>	<u>format 2</u>	<u>format 3</u>	<u>format 4</u>	<u>format 5</u>	<u>format 6</u>	<u>total</u>
32	3	1	2	1	1	3	11
33	1	1	5	2	3	3	15
34	1	3	2	3	1	0	10
35	0	3	3	3	0	0	9
36	1	0	2	2	0	0	5
37	1	4	0	2	2	0	9
38	4	5	7	4	4	4	28
39	4	2	2	1	3	0	12
40	4	4	5	3	3	4	23
41	0	3	3	3	2	3	14
42	0	0	1	0	0	0	1
43	3	3	3	3	2	4	18
44	3	3	5	3	4	4	22
45	0	0	3	3	0	0	6
46	1	3	3	3	3	3	16
47	3	3	3	4	3	3	19
48	2	3	3	3	3	3	17
49	4	3	3	3	3	2	18
50	0	1	0	1	0	1	3
51	3	1	0	2	2	1	9
52	0	0	0	1	1	0	2
53	0	0	0	0	2	3	5
54	3	3	3	3	2	3	17
55	2	2	1	1	4	4	14
56	1	0	2	0	2	2	7
57	3	3	4	4	0	1	15
58	3	3	3	3	2	3	17
59	1	0	1	1	1	1	5
60	1	0	0	0	0	0	1
61	2	2	3	0	3	5	15
62	3	3	3	3	2	2	16
63	3	2	0	1	0	1	7

Appendix G

<u>subject</u>	<u>format 1</u>	<u>format 2</u>	<u>format 3</u>	<u>format 4</u>	<u>format 5</u>	<u>format 6</u>	<u>total</u>
64	3	3	3	1	2	1	13
65	3	3	3	3	4	3	19
66	3	1	3	2	2	1	12
67	7	4	2	6	2	4	25
68	3	3	3	3	3	3	18

Temperament Types

temperament subject format 1 format 2 format 3 format 4 format 5 format 6 total quiz score

NF	1	1	0	0	0	0	0	1	6
	12	3	1	1	0	3	1	9	3
	13	1	0	0	0	3	2	6	7
	19	5	4	4	3	2	2	20	10
	27	2	1	2	0	1	0	6	10
	29	3	3	3	3	3	4	19	8
	37	1	4	0	2	2	0	9	7
	57	3	3	4	4	0	1	15	5
	58	3	3	3	3	2	3	17	6
	62	3	3	3	3	2	2	16	7
	67	7	4	2	6	2	4	25	3
NT	2	0	1	0	0	1	0	2	6
	11	4	3	4	3	6	4	24	6
	22	3	3	3	1	3	1	14	4
	46	1	3	3	3	3	3	16	7
	49	4	3	3	3	3	2	18	7
	56	1	0	2	0	2	2	7	10
	59	1	0	1	1	1	1	5	3
	64	3	3	3	1	2	1	13	7
SJ	3	3	3	3	3	4	3	19	7
	4	3	2	2	2	3	1	13	4
	9	1	3	3	0	3	3	13	6
	10	1	1	3	1	2	4	12	5
	18	3	3	3	4	5	4	22	5
	23	3	2	3	3	2	3	16	5
	25	2	2	5	3	4	3	19	6
	28	4	4	3	5	4	8	28	8
	31	3	0	0	0	0	0	3	8

Appendix H

<u>temperament</u>	<u>subject</u>	<u>format 1</u>	<u>format 2</u>	<u>format 3</u>	<u>format 4</u>	<u>format 5</u>	<u>format 6</u>	<u>total</u>	<u>quiz score</u>
SJ	33	1	1	5	2	3	3	15	8
	34	1	3	2	3	1	0	10	8
	36	1	0	2	2	0	0	5	5
	38	4	5	7	4	4	4	28	5
	42	0	0	1	0	0	0	1	6
	43	3	3	3	3	2	4	18	6
	47	3	3	3	4	3	3	19	8
	50	0	1	0	1	0	1	3	8
	53	0	0	0	0	2	3	5	8
	57	3	3	4	4	0	1	15	5
	61	2	2	3	0	3	5	15	6
	63	3	2	0	1	0	1	17	7
	65	3	3	3	3	4	3	19	6
	66	3	1	3	2	2	1	12	7
SP	5	2	2	2	2	2	2	12	8
	51	3	1	0	2	2	1	9	5

Subject Information

<u>subject</u>	<u>year of study</u>	<u>sex</u>	<u>major*</u>	<u>final grade</u>
1	2	M	N	A
2	4	F	T	F
3	3	M	N	D
4	1	M	N	D
5	1	F	N	C
6	1	M	N	B
7	3	M	N	C
8	4	F	N	C
9	1	F	N	D
10	3	F	N	B
11	4	M	N	F
12	1	F	N	B
13	2	M	T	C
14	1	M	N	A
15	1	M	N	A
16	2	M	N	B
17	3	M	N	A
18	1	F	N	B
19	1	M	T	C
20	1	F	T	B
21	1	M	T	C
22	3	M	N	D
23	1	M	N	B
24	1	M	N	D
25	1	F	N	C
26	2	M	N	C
27	1	M	T	B
28	1	M	N	B
29	3	M	N	A
30	1	M	N	A
31	4	F	T	B

*N = nontechnical
T = technical

Appendix I

<u>subject</u>	<u>year of study</u>	<u>sex</u>	<u>major*</u>	<u>final grade</u>
32	4	M	T	C
33	1	F	N	B
34	1	M	N	A
35	1	F	N	B
36	1	M	T	A
37	1	M	N	C
38	3	F	N	D
39	3	M	N	C
40	1	M	N	B
41	2	M	N	D
42	3	F	N	C
43	2	F	N	A
44	2	M	T	B
45	4	M	N	B
46	1	F	N	C
47	1	F	N	A
48	2	M	T	C
49	1	M	N	C
50	3	M	T	B
51	2	M	N	B
52	1	F	T	D
53	1	F	N	B
54	3	F	N	A
55	2	F	T	D
56	2	M	N	C
57	1	M	N	B
58	2	M	T	A
59	2	F	N	B
60	1	M	T	
61	1	M	N	A
62	1	F	N	B
63	1	M	T	F
64	3	M	N	B

*N = nontechnical
T = technical

Appendix I

<u>subject</u>	<u>year of study</u>	<u>sex</u>	<u>major*</u>	<u>final grade</u>
65	1	M	T	D
66	3	F	N	C
67	4	F	N	D
68	1	F	N	C

*N = nontechnical
T = technical

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