Summer 1991

A Robust Approach to Human-Computer Interface Design Using the Taguchi Method

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A Dissertation Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

ENGINEERING MANAGEMENT

OLD DOMINION UNIVERSITY
August 1991

Approved by:

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ABSTRACT

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Old Dominion University, 1991
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The application of Dr. Genichi Taguchi's approach for design optimization, called Robust Design, to the design of human-computer interface software is investigated. The Taguchi Method is used to select a near optimum set of interface design alternatives to improve user acceptance of the resulting interface software product with minimum sensitivity to uncontrollable noise caused by human behavioral characteristics.

Design alternatives for interaction with personal micro-computers are identified. Several important and representative alternatives are chosen as design parameters for the Taguchi matrix experiment. A noise field with three human behavioral characteristics as noise factors were chosen as a representative noise array. Task accomplishment scenarios were developed for demonstration of the design parameters on an interactive human-computer interface. Experimentation was conducted using selected human subjects to study the effect of the various settings of the design

parameters on user acceptance of the interface. Using the results of the matrix experiment, a near optimum set of design parameter values was selected.

A verification experiment was developed and performed using the predicted near optimum design parameter values. Analysis of the follow-up experiment indicated improved levels of user acceptance with the near optimum values.

This study suggests that the Taguchi Method of design optimization is applicable to human-machine engineering in general, and to the design of human-computer interface software in particular, as a means of selecting a near optimum set of design alternatives. This methodology is useful in reducing the number of total experiments required for optimization where several design alternatives exist in a richly interdependent context.

DEDICATION

To Gwen, Dennis, Michael and Daniel

ACKNOWLEDGEMENTS

As I complete the highest level of education, I am genuinely aware of the support and patience given during the period of my studies. Dr. Laurence D. Richards has been the most understanding and persevering mentor that any student could ever hope to have. For his confidence in me, his continuing guidance and timely suggestions I truly express my deepest thanks.

Special thanks are due to Dr. Resit Unal whose patience and direction were crucial in attempting to follow and apply Dr. Taguchi's methods in system design. I express special gratitude to Dr. Barry A. Clemson and Dr. Frederick Steier for their urging, interest and support throughout my program of study.

I am very grateful to my other committee member, Dr. Stephen A. Zahorian, for his helpful suggestions and support.

In addition, I wish to thank the College of Engineering and Technology and the Department of Engineering Management who granted me assistantship and the opportunity to gain experience through teaching. I owe a great deal to Dean Cross for his confidence and continuing support during my studies.

I reserve special appreciation and loving thanks for my wife Gwen Reed for her undying spirit, her love and understanding during this long academic journey past.

Most of all, I want to thank my Lord for being with me always and carrying me when I would stumble and fall.

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CHAPTER 1

INTRODUCTION

The recognition that consideration of the user as a necessary element in the successful design of human-computer interfaces is not a new revelation. The degree to which users accept an interface design plays a significant role in the utility that the computer tool can provide to society. Experience with the introduction of personal, micro and mini-computer technology into the work place has yielded collections of unused software resulting from rejection by the intended users. In many cases this has been a costly and frustrating experience for the individual or organization introducing the software technology.

The seemingly high user rejection level of application software for the micro-computer makes it desirable to include qualitative and quantitative measures of user acceptance as input during the early stages of human-computer interface software development. This process would provide the potential to reduce waste in the initial design process while increasing the potential for improved user acceptance of the production software. Attempts to include user input into the early stages of design have traditionally been limited primarily to the experience of the designers and in some cases the inclusion of generalized feedback from the user population from published sources and recognized software interface design experts. In many instances user feedback has not been available for specific designs until well into the development of the interface software when prototypes are available for evaluation by potential users. Inclusion of user feedback at this point in the development often requires the costly rewriting of software programs and can result in inefficient software processing routines if the changes are not carefully engineered. Where designers attempt to include user acceptance measures into the design, they often face the problem of trying to optimize the design through the selection of correct levels of implementation of many variables. The design solution is traditionally approached through a lengthy and costly iterative process involving numerous evaluations and changes to prototypes in an attempt to provide a functional and efficient design. Unfortunately, studying these variables one at a time or by trial and error is a common approach in design optimization (Phadke 1989). The task of design in this context often fails to produce a product that is acceptable to the users because the iterative process cannot be adequately pursued due to cost and time constraints. The goal of this research is to present a methodology by which the designer can select the best values for this complex set of design variables in the expected environment or context of use in order to maximize the extent of user acceptance in a manner which reduces the number of traditional experiments required to optimize the large array of variables. Taguchi's robust design methodology was chosen for investigation. Application of the Taguchi Method to human-computer interface design would introduce human behavioral questions into the traditional process and product oriented robust design methodology as a new and beneficial thrust in the design of human-computer systems.

The concept of including end user input in the design process should provide a more robust final product with respect to acceptance by the user. Development of an approach to this robust design concept using the Taguchi Method as the methodology for optimization of software design parameter values considering user acceptance as uncontrollable noise will be the contribution of this research to the field of designing human-computer interfaces.

Related Research

Humans and machines are only two components in the much more global system in which they interact. They interact in some context of social, organizational and physical environments. In the case of computers, failure of the machines to achieve acceptance by the broad spectrum of users is multidimensional. Richardson and Otway (1985) suggest seven dimensions for evaluating user acceptance. They are:

(1) the technical design process;

(2) the organizational and social environment;

(3) the hardware, software and physical environment;

(4) the job design;

(5) the user support and training;

(6) the implementation process;

(7) and the human and organizational impacts."

The focus of the research in this study is upon the dimensions of "the hardware, software and physical environment" with specific interest in human-computer interface software and "the technical design process." Software provides a vehicle for user-computer communications and as such employs a philosophy of human control of the software program. Short of a universally acceptable natural language interface, the currently practical alternatives range from specific programming languages with precise syntax and vocabularies at one extreme to elaborate hierarchical menus on the other (Savage and Habinek 1984). All alternatives have advantages and disadvantages, primarily as a function of the user and his context. The user's perception of the functionality and his ultimate acceptance of the interface depends upon this philosophy of human control as implemented in his system. Evaluation of user acceptance of human-computer interface software and its human control philosophy should then be regarded as a necessary part of interface design, complementary to traditional system analysis, in order to provide robustness in the satisfaction of a broad spectrum of users.

<u>Scope and Limitations of Related Research</u>

The adaptation of system software control structures in various ways to the user has become known as "software psychology and software ergonomics" (Shneiderman 1980). The central concern of research in software ergonomics has been on enhancing efficiency, ease of use in computer systems and establishing the requirement that machines must be adapted to humans (Paetau and Pieper 1985). The adaptation of control structures in general programming languages, special purpose languages and other systems aspects have produced several viable query languages for use in human-computer dialogue. Much has been done on the characteristics of video display screens and keyboards, the layout and shaping of displayed information, input devices and interaction formats such as menus, lists and control function selection devices. In particular, query language is the primary area of investigation in the literature (White, Rijnsdorp, and Reuhman 1985; Welty and Stemple 1981; Small and Welton 1983; Boyle, Bury, and Evey 1983).

While the literature offers several alternative approaches to human-computer dialogue and many forms of hardware and software implementation, little has been proposed with regard to selecting the optimum set of these alternatives such that user satisfaction and acceptance will be improved. Some researchers even feel that the pursuit of some optimum design for human-computer interfaces is not warranted. Ackermann (1985) states, "In view of different personality traits affecting different ways of task accomplishment and the extremely important fact that, despite these differences, the efficiency of different approaches tends to be similar, there is no reason to search for pseudo-objective optimal dialogue design." According to Ulich (1981), searching for the one best way in the design of working-activities is at least a doubtful procedure.

Purpose of the Study

The subject of this investigation is a methodology for the identification and selection of various previously developed human-computer interfacing schemes and philosophies during system design to enhance acceptance by the end users of the interface. The design process must facilitate the application and arrangement of the computer processing, query and interface languages in some structure with which the user interacts to control the computer. It is this idea of task accomplishment structure within the interface, and its selection, that is of primary concern and is a major contributor to user acceptance. Although there may be no single optimum design for the broad user population as suggested by some, it is plausible that some near optimum or certainly better arrangement of computer interface alternatives exists that will enhance user acceptance. What has been lacking is an efficient methodology for optimization of the many possible arrangements of computer communication and control technologies in the realm of human preferences.

Research Objectives

There are many possible task accomplishment schemes that the interface designer may contrive for the control of and communication with computers. The variety and flexibility available to the designer may serve to make the selection tasks more difficult. When user population characteristics and preferences vary as they most often do, user needs, desires and wants add greater complexity to the task. As part of this study, these same considerations were addressed in investigating a methodology for optimization of design alternatives.

Specific research objectives are as follows:

(1) Determine if there exist recognized and accepted human-computer interface communication and control alternatives for task accomplishment that are known to influence user acceptance of the interface.

(2) Identify human characteristics and preferences that are known to be important human factors in user acceptance of human-computer interfaces.

(3) Develop an optimum human-computer interface design for a selected user population using Taguchi's system of experimental design. As part of the Taguchi methodology, develop a human-computer interface using selected interface design alternatives and a task accomplishment scenario for use in user evaluation and data collection.

(4) Demonstrate and evaluate the optimum human-computer interface design selected using the Taguchi Method to evaluate differences in user acceptance.

CHAPTER 2

REVIEW OF LITERATURE

Use of the Taguchi Method for optimizing a process design requires finding near optimum settings of the design parameters or control factors to make the process or product insensitive to sources of variation. These methods of design are also referred to as Robust Design (Phadke 1989). There are three distinct stages in Robust Design: system design; parameter design; and tolerance design (Bendell 1988; Phadke 1989).

System Design

System design is the process of applying scientific and engineering knowledge to produce a basic functional prototype design (Kackar 1986). The prototype model defines the configuration and attributes of the process or product undergoing analysis or development. An understanding of the needs of the user of the product or process is required for conceptualization in system design. For this study, the system was defined as: a human being; a micro-computer with a high resolution color video display unit of standard office quality; a standard QWERTY type keyboard entry device; and application software to provide an interaction medium for selected task accomplishment. Additional discussion of the specific system characteristics is provided in chapter three.

Parameter Design

Parameter design is an investigation conducted to identify settings of product design characteristics that reduce the sensitivity of engineering designs to the sources of variation (Kackar 1986). Parameter design is based on classifying the variables that affect a product's performance into two categories: design parameters and sources of noise (Kackar 1985). Design parameters are the product or process design characteristics whose specific nominal values or settings may be specified by the design engineer. Sources of noise are all those variables that cause variation in performance of the product. Parameter design requires some form of experimentation for the evaluation of the effect of noise factors on the performance characteristic of the product defined by a given set of values for the design parameters. This experimentation aims to select near optimum levels for the designer controlled design parameters such that the product exhibits a high level of performance over a wide range of conditions and is relatively insensitive to sources of variation or noise. The Taguchi Method of robust design provides the designer a systematic and efficient approach for conducting experimentation to determine near optimum settings of design parameters for robustness (Bendell 1988; Kackar 1985; Phadke 1989).

For this study, it was necessary to identify a reasonable set of software and system control alternatives for task accomplishment to be used as controllable design parameters in the Robust Design experiments. Several currently achievable levels of implementation philosophy for interfacing with computers within the constraints suggested by Savage and Habinek (1984) were identified. These various levels are suggested in order to satisfy the characteristics presented by the broad spectrum of the user population. The investigation to identify attributes, types and methods of implementation of software control philosophies for use as design parameters produced the following:

(1) Grouping of information on the video display (Sanders and McCormick 1987; Bailey 1982).

(2) Visual clarity as a function of information highlighting, enumeration of important information and direction of contrast for presented information (Ravden and Johnson 1989; Sanders and McCormick 1987; Bailey 1982).

(3) Flexibility in structure and control of the interface, in terms of what the user can do, to suit the needs of users such that the user feels in control (Ravden and Johnson 1989; Bailey 1982).

(4) User guidance and support that is relevant and convenient to help the user understand and use the system (Ravden and Johnson 1989; Rushinek and Rushinek 1986).

(5) Information feedback on progress in the system, actions taken, successfulness of actions and what actions should be taken next (Ravden and Johnson 1989; Bailey 1982).

(6) Explicitness as to the way the system works and is structured (Ravden and Johnson 1989).

(7) Format of information presented with regard to the overall organization of the material presented on the video display (Sanders and McCormick 1987; Bailey 1982).

(8) Appropriate functionality in meeting the needs and requirements of the users when carrying out tasks (Ravden and Johnson 1989).

(9) Compatibility of information presentation and operation of the system with user conventions and expectations (Ravden and Johnson 1989; Sanders and McCormick 1987; Bailey 1982).

(10) Consistency of presentation of information and operation (Ravden and Johnson 1989; Sanders and McCormick 1987; Bailey 1982).

(11) Error prevention and correction facilities incorporated to minimize the possibility of user error (Ravden and Johnson 1989; Bailey 1982).

(12) Computer response time in responding to control and input actions by the user (Bailey 1982).

It is not the intent of this research to imply that the set of software philosophies identified above is the complete set or an optimum set, but a set that was useful in investigating Taguchi's robust design methodology in the context of human-computer interface design.

To complete the process of parameter design as described by Kackar (1985), it was necessary to identify sources of noise as well. Physical limitations, lack of knowledge and the inability to recognize some sources of variation limit the completeness of the set of noise parameters. It is important, however, to include those sources of noise that are likely to affect the performance of the product in its use environment. In this study, user acceptance of the human-computer interface is the performance characteristic to be optimized. Noise in the context of user acceptance is related to human characteristics, computer interface operational characteristics and physical environment. For research purposes, this study focused on the human characteristics component as the source of noise.

Although it is recognized by many that user acceptance measures should be regarded as an integral part of human-computer interface design (Richardson and Otway 1986; Savage and Habinek 1984), there is a noted lack of definition of these measures in the literature. The technical support variables of education, documentation and troubleshooting, along with user expectation, system popularity measures and system type are considered as measures of user satisfaction and acceptance (Rushinek and Rushinek 1986). Other researchers offer additional measures, some similar and others very different. Through literature review, several widely recognized and accepted user characteristics were identified that can be regarded as being representative components of the factors that influence user acceptance. These characteristics are difficult to control in a broad user population, qualifying them as noise parameters. The following user characteristics were identified as candidate sources of noise for inclusion in the Taguchi Method of design optimization:

(1) User search and perception capability (Sanders and McCormick 1987).

(2) User's attitude toward computer technology (Bailey 1982).

(3) Visual acuity of user (Sanders and McCormick 1987).

(4) Frequency of use of the computer interface software for particular task assignment (Bailey 1982).

(5) Level of computer related training and education (Rushinek and Rushinek 1986; Bailey 1982).

(6) User's expertise in computer-related specialties (Bailey 1982).

(7) User expectations about how the interface software should work in meeting the user's needs (Rushinek and Rushinek 1986).

(8) User's level of experience with particular tasking using similar interface software applications (Bailey 1982).

Tolerance Design

Tolerance design is the process of determining tolerances around the nominal settings identified in the parameter design process (Kackar 1986). Tolerance design is to be used if parameter design cannot produce a good enough product (Bendell 1988). In the industrial design arena, tolerances are usually assigned by convention rather than by scientific method. Tolerance design was not investigated as part of this research.

Summary of Review of Literature

The number of choices available for implementation of human-computer interfaces, and the abundant sources of variation in the factors that affect user acceptance, form an impossible optimization task for the designer using traditional iterative experimentation approaches. The dilemma that the designer faces when trying to select the optimum interface control methodology makes human-computer interface design a worthy candidate for the investigation of new design optimization techniques.

The Taguchi Method has been used effectively to improve the performance characteristics of many production and manufacturing processes and products. None of the previous studies have reported the application of Robust Design methods to the design of systems where human behavioral characteristics are important considerations in the interactions that take place between humans and machines like human-computer interfaces. The potential for improvement of user acceptance of interface software applications using the Taguchi Method as a systematic and efficient approach for design optimization is the major reason for this study. This study extended the results of previous studies by applying the Taguchi Method to the design of interactive systems where human behavior is important.

CHAPTER 3

THEORY AND DESCRIPTION OF THE TAGUCHI METHOD

The Taguchi Method for optimizing a process or product was developed during the 1950's in Japan by Genechi Taguchi (Taguchi 1987). The Taguchi Method is founded in the design of experiments methodology developed by Sir R.A. Fisher of Great Britain in the 1940's for agricultural research (Bendell 1988). Up to that time scientific experimentation had been conducted on a 'one at a time' basis, an approach still in use today by many design engineers. The need for greater food production caused by the Second World War required 'all at once' or systematic agricultural experimental methods be developed to reduce the delay associated with the annual agricultural cycle. Following the war, the methods were adapted to industrial applications but have only lately become popular as design and optimization methods for broad use.

The primary thrust of the Taguchi Method lies in the realm of parameter design (Dentskevich and Appleton 1988). Parameter design is an investigation conducted to identify settings or values of product design characteristics that minimize loss of performance of the product due to any noise to which the product may be subjected (Kackar 1985). The product design characteristics are those parameters whose nominal settings can be specified and controlled by the product designer. Noise is interpreted as all those variables that cause performance variation in the product during its life span and across different units of the product.

The performance of a product is characterized by a response referred to as a performance statistic. The performance statistic estimates the effect of noise on the performance characteristics of the product. The response is assumed to be governed by two types of factors: control factors or design parameters and noise factors. The design parameters are set during manufacture or design of the product and are not altered thereafter. The noise factors are subject to inherently uncontrollable, and for the most part, random variations even though they are often bounded in magnitude. Common examples of noise factors are: variations in environmental variables such as temperature, humidity, dust, and vibration; human variations in operating or using the product; manufacturing imperfections; and product deterioration (Kackar 1985).

Optimization of the performance characteristic involves estimating the relationship between the response and the design parameters. Several traditional approaches exist for optimization of such systems. A long established technique, the 'one at a time' technique, involves changing the value of each design parameter in turn while holding all others fixed in an attempt to determine the effect of each on the response. This approach may be adequate for products where there are small numbers of design parameters but for products with multiple design parameters subjected to noise fields with several identifiable factors, the experimental process becomes extremely time consuming, costly and increasingly difficult to analyze. For example, if engineers were studying nine design parameters at three discrete values each in a single valued noise field, varying them one factor at a time would require 19,683 trials to optimize the design (3^9).

A major part of what has become accepted as the Taguchi Method is the use of his tabulated sets of orthogonal arrays as a basis of experimental design to optimize a process or design with fewer trials than the full factorial approach (Bendell 1988). Orthogonal arrays are generalized Latin Squares that make up all common fractional factorial designs for experiments (Kackar 1985).

Orthogonal Arrays

As indicated earlier, an exhaustive investigation of the complete design parameter space by full factorial methods is often not cost or time effective. Statistical design of experiment methods can be used to select an intelligent subset of the design parameter space called the design matrix (Kackar 1985). Taguchi (1987) recommends the use of orthogonal arrays of strength two for constructing these design matrices. The columns of the design matrix represent the design parameters and the rows represent the different settings of the individual parameters. Orthogonal arrays allow the design parameters to have different numbers of test settings. At least two settings that are wide apart are chosen for each parameter such that the design matrix covers a wide region of the parameter space. If possible, Taguchi recommends that three or more settings be chosen where one setting would represent the nominal value. Three or more test settings can reveal nonlinearities in the main effects of the design parameters (Kackar 1985).

Orthogonal array experiments have the pairwise balancing property that every test setting of a design parameter occurs with every test setting of all other design parameters the same number of times. Because of this property, any two columns of an orthogonal array form a two factor complete factorial design. This makes a comparison of different test settings of a design parameter valid over the ranges implied by the test settings of other test parameters (Kackar 1985). This comparison is valid only when there are no interactions among design parameters.

A performance statistic is evaluated for every design parameter in the design matrix during the conduct of the matrix experiment. Orthogonal array experiments minimize the number of tests while keeping the pairwise balancing property. However, these fractional factorial designs fundamentally sacrifice information about interactions between design parameters to reduce testing, although a limited number of interactions can be included (Bendell 1988). Taguchi (1987) provides linear graphs as an aid in incorporating design parameter interaction analysis into the design matrix.

A typical orthogonal array tabulation is shown in Figure 1. Here there are four parameters A, B, C and D shown as columns. Each of the four parameters exist at three levels each represented by the numerals in each column. For example, A and B may be process temperature and pressure, in each case with 1 = low, 2 = medium and 3 = high. In contrast, C and D may be material choices

	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Figure 1. L_9 (3^4) Orthogonal Array.

with levels 1, 2 and 3 representing a different but independent variant of each material. The particular level specified for each parameter in each row of the matrix defines the orthogonal nature of the array. This is an L_9 design, the 9 indicating the nine rows, trials or prototypes to be tested with the test characteristics or parameter levels in each case defined by the rows of the table. The L denotes the Latin Square-like design. Note that this design reduces $3^4 = 81$ trials to nine.

Taguchi (1987) also recommends the use of orthogonal arrays for constructing the noise matrix. The noise matrix is a selective rather than a random subset of the noise space, providing appropriate coverage of the noise space (Kackar 1985).

In engineering and industrial design, factors that disturb production or product performance, or are not economically feasible to control in bulk processes, should be manipulated as part of the optimization experiment. The desire is to identify a design or a production line calibration which can best compensate for the transient effects in the manufacturing process or in the use of the product caused by these normally uncontrollable noise factors. Forcing diversity of the noise conditions is accomplished in the matrix experiment by crossing the design orthogonal array with the noise factor orthogonal array. In this way, each trial of the design matrix is evaluated against the background of each combination of the noise conditions. To perform this evaluation, Taguchi introduces the signal-to-noise ratio or S/N ratio.

Signal-To-Noise Ratio

Taguchi's concept of signal-to-noise ratio is a major source of confusion and criticism of the Taguchi Method (Bendell 1988). His S/N ratio is a performance measure used to choose design parameter settings that are least sensitive to disturbances or noise. The S/N is constructed so that the maximum value of the S/N is optimum since it is usually desirable to maximize signal relative to the noise.

When the performance characteristic is a continuous, non-negative variable with a fixed target, the S/N ratio takes on one of three forms depending upon whether larger is better, smaller is better or a specific target value is best. Suppose $y_1, y_2, \ldots, y_n$ represent multiple values of the performance characteristic Y. The Taguchi S/N ratios can then be written as follows (Phadke 1989; Bendell 1988; Taguchi 1987; Kackar 1985):

The larger the better:

(3.1) $$S/N = -10 \log [1/n \, \Sigma \, (1/y_i^2)]$$

The smaller the better:

(3.2) $$S/N = -10 \log (1/n \, \Sigma \, y_i^2)$$

A specific target value is best:

(3.3) $$S/N = 10 \log (\bar{y}^2/s^2)$$

where $\bar{y} = 1/n \, \Sigma \, y_i$

and $s^2 = [1/(n-1)] \, \Sigma \, (y_i - \bar{y})^2$

On the basis of these three usual cases, several forms of S/N ratios can be constructed to suit specific applications.

Analysis of Variance

Conventional statisticians criticize Taguchi for the apparent simplicity of much of his statistical analysis, and his own view of Analysis of Variance methods appears to vary in his writings (Bendell 1988; Gray and Harris 1988). The most routine analysis for the Taguchi Method is graphical. Mean response and S/N ratio are typically plotted versus the settings for each of the design parameters. The settings that produce the greatest S/N ratio and the most favorable mean response are determined graphically. The graphical scales are generally chosen to be identical so that comparisons can be made of the importance of each factor in selecting the optimum. Phadke (1989) and Bendell (1988) suggest that traditional Analysis of Variance methods be used to verify that the effects of factors are statistically significant and not just due to small sample sizes.

The simplified graphical analysis is predicated on an additive model that uses orthogonal arrays to construct the design matrix. This model can be written as (Kackar 1985):

$$(3.4)\quad |Z(\theta)|_{i=1\ldots n,\ j=1\ldots k} = \mu_o + |\theta_1|_1 + |\theta_2|_1 + \ldots |\theta_n|_1 + |\theta_1|_2 + |\theta_2|_2 + \ldots |\theta_n|_2 + \ldots |\theta_n|_k + r$$

where μ_o represents the initial value; $|\theta_i|_j$ represents the effect of the j^{th} test setting of the design parameter θ, on the performance statistic $Z(\theta)$ for $i = 1, 2, \ldots n$ and $j = 1, 2, 3, \ldots k$; and r represents the residual. For the Taguchi Method, the performance statistic $Z(\theta)$ is the S/N ratio. The residuals r for different values of the design parameter θ are assumed to have independent and identical distributions with zero mean and constant variance. The computed values of $Z(\theta)$ are used to estimate the effects of $|\theta_i|_j$. The estimated values of $|\theta_i|_j$ are in turn used to identify the test settings of each design parameter that produce a larger value of $Z(\theta)$ or S/N. These test settings define new settings of the design parameters. If the additive model in Equation 3.4 is a reasonable approximation of the true situation, the new settings will then be better than the original settings.

In order to confirm the validity of the statistical model underlying the design and analysis of an orthogonal array experiment, it is necessary to conduct follow-up experiments with the new settings for the design parameters. If the underlying assumptions are true, the follow-up experiments should show that the S/N ratio improves for the new values of the design parameter settings.

Applicability of the Taguchi Method

Taguchi Methods are powerful and efficient tools for use in the search of design parameter values at which a product or a process is stable in the presence of outside disturbances (Taguchi, Elsayed and Hsiang 1989). The Taguchi Method reduces the number of experiments to be conducted to resolve optimization problems when compared to the full factorial method. The Taguchi Method of experimental design has been used effectively in the improvement of products and processes and in the design of new products in the automobile, aircraft, chemical products and consumer electronics industries (Wille 1990; Phadke 1989; Logothetis and Salmon 1988).

The Taguchi Method can be applied to any process where the values of the design parameters can be controlled (Wille 1990; Taguchi 1987). This appears to be the key constraint in the application of the methods; although other factors, such as independence of design parameters, as discussed earlier, are important to the additive model concept. The extension of the methodology to the design of human-computer interface software with human behavioral characteristics treated as noise, appears to be appropriate. This extension is plausible because the values of design alternatives have been the subject of traditional interface design and assigned discrete values in many applications. The fact that functional interface designs currently exist is sufficient evidence that the design parameters are controllable. The need for a methodology to provide credibility to design choices in the realm of human-computer interface design, where technology has provided much flexibility, is an important issue deserving of further research.

CHAPTER 4

METHOD

Theoretical Framework

The theoretical framework for the conduct of this study is the Design of Experiments method developed by R.A. Fisher in the 1940's and 1950's and expanded upon by Genichi Taguchi since. Design of Experiments can be defined as the whole of a universal technique for the heightening of the efficiency of acquisition of information by experiments (Taguchi 1987). The experiments are mathematical experiments using orthogonal array analysis of assigned values representing multilevel design and noise variables or parameters for the purpose of selecting the optimum combination of the values to maximize the output of the process, in this case the user acceptance of human-computer interfaces.

Process of Application of the Taguchi Method

Phadke (1989) lists eight steps for the conduct of Robust Design using the Taguchi Method:

(1) Identify the main function;

(2) Identify the noise factors and testing conditions;

(3) Identify the quality characteristics to be observed and the objective function to be optimized;

(4) Identify the control factors (design parameters) and their alternative levels;

(5) Design the matrix experiment and define the data collection and analysis procedure;

(6) Conduct the matrix experiment;

(7) Analyze the data and determine near optimum levels for the control factors (design parameters);

(8) Predict the performance at the near optimum levels.

In addition to the above steps, it is desirable to conduct a validation experiment at the near optimum levels to assess the improvement in the system. This validation experiment was included in this study along with Phadke's eight steps as a model for the application of the Taguchi Method.

Identify the Main Function

Identifying the main function is the same process as System Design as described by Bendell (1988) and Kackar (1986). For this study the system was an <u>IBM™ Personal System/2 Model 50</u> micro-computer, <u>IBM™ Personal System/2 Color Display</u>, <u>IBM™ Model M Enhanced Keyboard</u>, IBM™ Disk Operating System Version 3.30©, WordPerfect™ Version 5.1, task accomplishment scenarios using the various values of the design parameters for performance on the computer interface, human subjects to perform the tasks and data gathering instruments.

The video display color palette used for the task accomplishment experiments was selected from the WordPerfect™ Version 5.1 setup function. The specific settings used are given in Appendix A.

The task accomplishment scenarios used in the conduct of the matrix experiment for evaluation of the various settings of the design parameters are given in Appendix B. The task chosen for accomplishment by the subjects was an on screen editing task to be performed on text presenting a tutorial procedure. Identification of the design parameters and their settings are described later.

The components of the human-computer interface system specified above were chosen as part of this investigation for several reasons. The chosen micro-computer hardware is representative of the devices that are found in many offices, businesses, educational institutions, homes and other locations where computers are used. The chosen application interface software, WordPerfect™ Version 5.1, provided the flexibility, versatility and fidelity to demonstrate the selected design parameters at the various settings for the matrix experiments. It provided a convenient programming environment not requiring special programming skills for this researcher to develop task accomplishment scenarios useful for evaluation by users. WordPerfect™ Version 5.1 is somewhat similar to previous versions (4.2 and 5.0) providing an interface software environment for which subjects with adequate experience were easily identifiable yet yielding a sufficient portion of the computer user population that was unfamiliar with the software for experimentation purposes.

Identify the Noise Factors

As discussed previously, noise factors are those effects that cause variability in the process or product that can not be controlled or are too difficult or costly to control (Phadke 1989). Of the eight candidate noise factors identified in Chapter 2, three were chosen for inclusion in this study. They are:

(1) User's expertise in computer-related specialties and, in particular, their experience with microcomputers and control devices.

(2) User expectations about how the interface software should work in meeting the user's needs.

(3) User's level of experience with particular tasking using similar interface software applications.

These three noise factors were chosen because they were assessed to be important in the system under investigation. In addition, they represent user characteristics that can be assigned quantitative values representing the relative extent to which the users possess the chosen attribute. Subjects that possess these characteristics at readily identifiable levels are representative of the human-computer interface user population and are available as subjects for experimental evaluation.

The settings of the noise factors were chosen at two values representing relative extremes for the factors. For the micro-computer experience factor (number (1)), the two levels were very experienced representing considerable familiarity and expertise in using micro-computers and limited experience representing only casual familiarity and infrequent use as stated by the user. For the user expectation factor (number (2)), the levels were openness to various methods of software control implementation and highly predisposed with regard to the way in which the software interface should function. Openness refers to the potential willingness of the user to use software implementation schemes that were new or different from their normal experience. Predisposed represents inflexibility in using software that did not meet their expectations about how the software should function. The experience level with the tasking using similar software was assigned settings at very experienced level representing considerable familiarity with the tasking and the application software and the unfamiliar level representing little experience with the tasking and the software.

Prospective subjects were screened using a questionnaire in which they were asked to provide a self assessment on their experience and feelings on questions relating to the chosen noise factors. The questionnaire used in this screening process is given in Appendix C. Using the results from the survey, subjects were chosen and categorized with respect to level or setting value for each noise factor.

Identify the Quality Characteristics to be Observed and the Objective Function to be Optimized

In this study, designing a human-computer interface for user acceptance is the objective. User acceptance is then the quality or performance characteristic to be observed. The objective function to be optimized is the overall user acceptance of the system under study:

> Maximize user acceptance as a measure expressed in scalar terms by the participants in the task accomplishment experiments.

Identify the Design Parameters and Their Alternative Levels

The literature review of Chapter 2 produced several viable design parameters. This is representative of the dilemma that the designer faces when trying to select the optimum interface control philosophy and methods in satisfaction of a large and diverse set of apparent requirements to be considered in design. A primary objective of this study is to develop an optimum human-computer interface design for a selected user population using the Taguchi Method. A very important part of that process is the development of the parameter and noise space for use in the design of the matrix experiment. For the purposes of this investigation into the application of the Taguchi Method to human-computer interface design, four of the previously identified candidate design parameters were chosen as the parameter design space. They are representative of the variety that the designer faces in doing design and satisfy the difficulty of choice by traditional approach desired to demonstrate the utility of the Taguchi Method for such applications. The design parameters chosen for inclusion in this study are:

(1) Visual clarity as a function of information highlighting, enumeration of important information and direction of contrast for presented information.

(2) Flexibility in structure and control of the interface, in terms of what the user can do, to suit the needs of users such that the user feels in control.

(3) User guidance and support that is relevant and convenient to help the user understand and use the system.

(4) Information feedback on progress in the system program, actions taken, successfulness of actions and what actions should be taken next.

For the purposes of the matrix experiments, these design parameters will be controlled at two levels. Typically these levels will represent high and low degrees of implementation of each design parameter. These extremes were chosen in order to increase the chance of capturing any nonlinearity in the relationships between the design parameters and the noise factors (Phadke 1989). These design parameter levels define the experimental space to be studied.

The first design parameter described above will be termed "Highlighting" for discussion. For the low level setting of Highlighting, no character intensity enhancement, use of color contrast in video foreground or background presentation or underlining was used to draw attention to task related text or screen prompts. At the high level setting, combinations of screen character presentation intensity, color contrast and underlining were used to enumerate selected task related display items. The different levels of Highlighting and the specific implementation are illustrated in Appendix B.

Design parameter (2) above will be termed "Control Flexibility." The levels presented for evaluation were achieved by providing different options to the subjects for controlling the computer software in accomplishment of the assigned tasking. The high level of implementation was accomplished by providing the user freedom of choice to use a menu driven control format, a regime of fixed-function key strokes or free-form manual manipulation of their design in order to accomplish the assigned tasking. The low level of Control Flexibility was demonstrated by restricting the available software control options to either the menu driven control format or a specified regime of fixed-function keystrokes for a given matrix experiment. The menu available for controlling the software is shown in Appendix B, matrix experiments three through six.

The design parameter related to user guidance and support will be termed "Help." For the high level setting of Help, assistance in performing the assigned tasks was provided in the form of a keyboard template offering abbreviated instructions and other shorthand forms of guidance and an on-line help function resident in WordPerfect™ Version 5.1. At the low level setting, only the keyboard template was available to the user.

The design parameter related to information feedback provided by the computer to the user will be termed "Feedback." For the high level of implementation, prompts for the next action to be taken by the user and explanation of the meaning of coded prompts provided by WordPerfect™ Version 5.1 were displayed prominently for the user at the point in the task sequence where follow-on actions were required. At the low level setting, these prompts and explanations were not provided. The different levels of Feedback and the specific implementation are illustrated in Appendix B.

Design the Matrix Experiment and Define the Data Collection and Analysis Procedure

The object of the matrix experiment is to identify the settings of the design parameters at which the effect of the noise parameters on the performance characteristic, user acceptance, is minimum. These optimum settings are predicted in the Taguchi Method by systematically varying the settings of the design parameters in the experiment and comparing the effect of the noise factors for each test run. The Taguchi methodology uses orthogonal arrays to study the parameter space, usually containing a large number of decision variables, with a small number of experiments. Based on design of experiments theory, Taguchi's orthogonal arrays provide a method for selecting an intelligent subset of the parameter space called the design matrix. The columns of the design matrix represent the design parameters and the rows represent different settings of the parameter space. A performance statistic is calculated for every setting in the parameter space. Likewise, orthogonal arrays are used for constructing the noise matrix.

In order to select the appropriate orthogonal array to satisfy this investigation, it is necessary to determine the total number of the degrees of freedom to find the minimum number of experiments that must be performed to identify a near optimum parameter set (Phadke 1989). One degree of freedom is assigned to the overall mean regardless of the number of design parameters. Each design parameter has a degree of freedom equal to one less than the number of setting levels. For this study:

Design Parameter		Degrees of Freedom
Overall Mean		1
Highlighting	2 - 1 =	1
Control Flexibility	2 - 1 =	1
Help	2 - 1 =	1
Feedback	2 - 1 =	1
Total		5

For this study, the five degrees of freedom require that at least five experiments be conducted to reach near optimum settings for the design parameters. Taguchi's standard L_8 array will accommodate up to seven design parameters at two levels requiring that eight experiments be conducted. This array fits the requirements of this study and was chosen as the model for the design parameter experiments. The L_8 array is shown in Figure 2.

This study investigates only four design parameters so three columns of the array will be empty. Orthogonality is not compromised by having one or more columns of an array empty (Phadke 1989).

	A	B	C	D	E	F	G
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

Figure 2. L_8 (2^7) Orthogonal Array.

Using the same approach, the degrees of freedom of the three noise factors was determined to be four. Taguchi's standard L_4 array will accommodate up to three noise factors at two levels requiring that four experiments be conducted. This array fits the requirements of this study and was chosen as the model for the noise factor experiments. The L_4 array is shown in Figure 3.

	A	B	C
1	1	1	1
2	1	2	2
3	2	1	2
4	2	2	1

Figure 3. L_4 (2^3) Orthogonal Array.

Once the appropriate orthogonal arrays were selected, it was necessary to develop a procedure to investigate the variation in the quality characteristic, user acceptance, caused by the noise factors. Taguchi proposes an orthogonal array based simulation to evaluate the mean and the variance of a product or process response resulting from variations in the noise factors (Taguchi 1987). To accomplish this, the orthogonal array of the controllable design parameters is crossed by the orthogonal array of noise factors in a full factorial manner (Bendell 1988). Thus the diversity of the noise conditions are forced on the design parameters. The results of each experiment run for each combination of design parameter and noise factor experiment are denoted by $Y_{i,j}$. Using this approach, the design parameter and noise factor spaces were studied by conducting 32 discrete experiments. The orthogonal array based simulation derived by crossing the design parameter and noise factor arrays is shown in Figure 4.

Task accomplishment scenarios were developed using the setting for the design parameters specified for each experiment run in the design parameter orthogonal array shown in Figure 2. These scenarios are given in Appendix B.

Each subject that was categorized as fitting a specified noise factor orthogonal array column performed each of the eight design parameter experiment runs in the same environmental setting on the computer interface

Noise Factor Array

	1	2	3	4
N1	1	1	2	2
N2	1	2	1	2
N3	1	2	2	1

Design Parameter Array

	A	B	C	D	E	F	G	$Y_{i,j}$				MEAN	STD
1	1	1	1	1	1	1	1						
2	1	1	1	2	2	2	2						
3	1	2	2	1	1	2	2						
4	1	2	2	2	2	1	1						
5	2	1	2	1	2	1	2						
6	2	1	2	2	1	2	1						
7	2	2	1	1	2	2	1						
8	2	2	1	2	1	1	2						

Figure 4. Orthogonal Array Based Simulation Algorithm.

described earlier. Data was collected from each subject on the stated subjective assessment of their level of acceptance of the interface based on the interaction while accomplishing the assigned tasking. The data gathering instrument was a questionnaire and is given in Appendix D. The questions were taken primarily from human-computer interface evaluation checklists developed by Ravden and Johnson (1989).

The experiment evaluation questionnaire was divided into four sections. Each section represented a design parameter chosen for the matrix experiment. Each section contained several questions concerning the users understanding of what was being evaluated, factors that may be important to the user regarding the evaluation topic and the meaning of the attributes of the subject design parameter. The purpose of these questions was to focus the subject upon the particular design parameter under consideration. The participants were encouraged, through instruction and questionnaire design, to evaluate their acceptance of the demonstrated level of implementation of the given design parameter independent of other design parameters in the task accomplishment scenario. This was done in an effort to reduce interaction between design parameters during the experiment. The final question in each section asked the participants to rate the interface in terms of the design parameter of interest. The scaler response on this last question in each section was used in computing the response, overall user acceptance Y_i, for the interface design given in each experiment trial. The participant's recorded responses for each of the four questionnaire sections were averaged to find Y_i. The data from the five subjects in each noise category were then averaged to obtain the $Y_{i,j}$ values for the matrix experiment of Figure 4.

In an effort to reduce the variability in the results caused by participant assessment variations and bias and by noise factor array column categorization errors, five participants for each noise category performed the eight experiment scenarios. In all, 20 subjects participated in the matrix experiment. Each subject possessing the characteristics defined by the noise factor array performed each of the design parameter array experiment trials. The order of conduct of the experiment trials was varied among participants to counter effects of variations in assessed level of experience of participants in each noise factor array column.

The human-computer system definition, task accomplishment scenarios, data collection instruments, prospective subject screening questionnaires and procedures regarding the use of human subjects in the conduct of this research were reviewed and approved by the Old Dominion University Human Subjects Review Board.

Conduct the Matrix Experiment

The matrix experiment shown Figure 4 was conducted using the system, methods and procedures described above. The response ($Y_{i,j}$) was determined for each combination of design parameter and noise factor experiments.

Columns B, D and F of Figure 4 were left empty since only four design parameters were selected for investigation. For the design parameter array, the following describes the assignment to each column:

Column	Design Parameter
A	Highlighting
C	Control Flexibility
E	Help
G	Feedback

1 - Denotes Low Level of Implementation
2 - Denotes High Level of Implementation

For the noise factor array, the following describes the assignment to each row:

Row	Noise Factor
N1	User's Computer Expertise 1 - Denotes Limited Expertise 2 - Denotes Very Experienced
N2	User's S/W Familiarity 1 - Denotes Unfamiliar 2 - Denotes Very Familiar
N3	User's Expectations 1 - Denotes Predisposed 2 - Denotes Openness

For each combination of the design parameter settings, the mean level of user acceptance and the standard deviation were computed. These were used to assess the variability in user acceptance caused by the noise factors.

Analyze the Data and Determine Near Optimum Levels for the Design Parameters

The object of the analysis of the data from the matrix experiment is to choose the near optimum values for the design parameters such that the process or product is relatively insensitive to noise. The Taguchi Method uses a signal-to-noise ratio or S/N ratio as a performance statistic that takes both the mean and the variability into account (Phadke 1989; Kackar 1985). The S/N is a performance measure for choosing design parameter levels that best cope with noise and is constructed such that a maximum S/N is optimum (Bendell 1988). Taguchi offers several forms of S/N equations depending on the criterion for response or quality characteristic to be optimized. The smaller-is-better form of the S/N ratio was used to analyze the results of the matrix experiment since the objective was to maximize user acceptance of the human-computer interface where maximum was indicated by the smallest numbers on the data gathering instruments. The smaller-is-better S/N ratio is defined as (Phadke 1989; Bendell 1988; Taguchi 1987; Kackar 1985):

$$S/N = -10 \log (1/n \, \Sigma \, Y_i^2) \quad (4.1)$$

The S/N ratios for the data of the matrix experiment were computed for use in determining near optimum design parameter settings.

Since the experimental design is orthogonal in nature, it is possible to separate out the effect of each factor (Bendell 1988). This was accomplished by creating a response table in which the average S/N ratio is computed for a design parameter (A, C, E and G) for each time it appeared at a given level (Level 1 or 2). The average S/N ratios for each level of the four design parameters are then tabulated in the response table format shown in Table 1.

Average S/N Ratio

	A	C	E	G
1	S/N	S/N	S/N	S/N
2	S/N	S/N	S/N	S/N

Table 1. Response Table Format.

The most routine and basic analysis for Taguchi methodology is graphical (Bendell 1988). The graphical analysis is performed by plotting the average S/N ratios from the response table and examining the resulting plots. Setting levels are chosen for each design parameter corresponding to the greatest signal-to-noise ratio value.

Predict the Performance at the Near Optimum Levels

When mathematical expressions can be written for the quality characteristic and the objective to be optimized, numerical simulations can be performed to predict the performance of the product or process at the new design parameter settings. Statistical comparisons can be made to determine if improvements exist in the variation in the performance and in the signal-to-noise ratio. Since no mathematical expression was proposed in this study for the quality characteristic to be observed, user acceptance of the human-computer interface, or the objective function to be optimized, overall user acceptance of the interface, it is not possible to predict performance at the new levels. If the Taguchi Method is appropriate for this design application, the near optimum settings will hopefully provide greater levels of user acceptance than any of the alternatives examined in the matrix experiment.

It is not possible to know if a statistical model underlying the design and analysis of an experiment is valid (Kackar 1985). Therefore, it is necessary to confirm by follow-up experiments that the new settings for the design parameters improve the quality or performance characteristic for the system.

Conduct the Validation Experiment

The validation experiment was designed using the procedures described above for the matrix experiment. The system for the conduct of the validation experiment was the same as used for the matrix experiment. The same noise factors and settings were used. Settings for the design parameters were those chosen from the results of the graphical analysis of the matrix experiment. The task accomplishment scenario developed to demonstrate the design parameter settings for evaluation is presented in Appendix E. This scenario is of the same format used in the matrix experiment. The resulting design for the conduct of the validation experiment is shown in Figure 5.

Two subjects representing each noise category of the noise factor array performed the validation experiment task accomplishment scenario for the purpose of evaluation. Participants for the validation experiment were selected from those who participated in the matrix experiment. Data was collected from each subject using the instrument given in Appendix D. The data from the two subjects in each noise category were averaged to obtain the $Y_{i,j}$ values. The mean level of user acceptance, standard deviation and signal-to-noise ratio was computed.

Noise Factor Array

	1	2	3	4
N1	1	1	2	2
N2	1	2	1	2
N3	1	2	2	1

Design Parameter Array

	A	C	E	G	$Y_{i,j}$				MEAN	STD	S/N
1	2	2	2	1							

Figure 5. Validation Experiment Design.

CHAPTER 5

RESULTS AND DISCUSSION OF FINDINGS

This chapter discusses the findings of the research. Some of the findings, inherent to the application of the Taguchi methodology, were discussed in Chapters Two and Four and will not be duplicated here. Discussion of the results of the investigation conducted to identify recognized and accepted human-computer interface communication and control alternatives for task accomplishment that are known to influence user acceptance of the interface was presented in Chapter Two. The results of the process to determine which of these design alternatives would be included in this study are included in Chapter Four, Identify the Design Parameters and Their Alternative Levels. Results of the investigation to identify human characteristics and preferences that are known to be important human factors in user acceptance of human-computer interfaces were discussed in Chapter Two. The results of the process to determine which of these human factors would be included in this study as noise factors are included in Chapter Four, Identify the Noise Factors.

The following additional issues are addressed:

1. Design of the matrix experiment and development of the human-computer interface and task accomplishment scenarios for use in user evaluation and data collection;

2. Analysis of the results of the matrix experiment and selection of the near optimum design parameters;

3. Analysis of the results of the validation experiment.

How these findings relate to the research objectives set out in Chapter One is summarized in Chapter Six.

Design of the Matrix Experiment

The design of the Taguchi matrix experiment for optimizing the selection of settings of controllable design parameters for robustness to noise depends largely upon the ability of the designer to identify appropriate design parameters and noise factors. Appropriate design parameters are those that affect the objective function for the system in some definable, measurable and controllable manner. For manufacturing, chemical and production process systems these are often those well defined, measurable parameters and variables such as temperature, pressure, flow rate, composition of ingredients, weight, tensile strength, defects per unit area or volume and so forth. In the design of human-computer interfaces and the design of other interactive systems where human behavior is important, the appropriate design parameters are not always easily identifiable. It is one thing to say that user acceptance of an interface depends upon the grouping of information on the video display screen and quite another to develop a meaningful and valid quantization scenario to measure and study the interdependence. This difficulty of construct formulation and measure limit the selection of design parameters to those that the designer is clever enough to capture and demonstrate in the intended context of use and in a measurable sense. Such was the case in this study. Of the twelve candidate design parameters identified in Chapter Two, only four were used in the design of the matrix experiment. The four were chosen primarily because they could be demonstrated at their various settings within the capabilities of the system defined for study as fabricated by this researcher. Although the Taguchi methodology could support the investigation of all twelve candidate design parameters, limitations imposed by the ability of the designer to fabricate demonstration task accomplishment scenarios for evaluation in the defined system precluded investigation of all twelve. The designer must decide which candidate design parameters can be adequately demonstrated and whether or not they are important factors affecting the objective function for the system. The decision in this study was that the four chosen design parameters provided sufficient fidelity to warrant additional investigation using the Taguchi Method.

Similar considerations arose with selection of noise factors. If the designer's goal is to design a system or product that is robust to certain types of noise, it is important that the noise be well defined and that the noise field be represented by the selected noise factors and their range of settings. In designing human-computer interfaces, user characteristics of interest must be definable and easily assessed in recognized terms. This did not prove to be difficult in this study because user characteristics were more clearly documented in the literature and the users themselves provided the context. If designing for a broader spectrum of the population, identification of specific characteristics need not be done if adequate subjects representative of the population are used in the conduct of the matrix experiment and the variation in the users themselves is taken as the sum of all user noise. For the design of human-computer interfaces using the Taguchi Method, the selection and specification of noise is not as difficult as the selection of design parameters.

Studying the four design parameters at two levels by varying one factor at a time would require that 16 experiments be conducted at each level of noise. With the three noise factors at two levels as selected in this study, 128 experiments would have to be conducted using the one at a time approach. Using the Taguchi methodology, the matrix experiment design described in Chapter Four required that only 32 experiments be conducted. In this study, each of the eight experiments of the design parameter matrix were performed with five different subjects from each column of the noise matrix resulting in the conduct of 160 total trials. These additional runs were conducted in an attempt to reduce the variability in the evaluation scores due to individual bias by the subjects in each noise column. The effect of any variability that may have been introduced by not averaging the results of redundant runs was not assessed.

Results of the Matrix Experiment

The response ($Y_{i,j}$), representing overall user acceptance for this study, was determined for each combination of design parameter and noise factor experiments. For each combination of the design parameter settings, the mean level of user acceptance and the standard deviation was computed. The results of the matrix experiment are tabulated in Figure 6.

In computing the response Y_i for each participant, it was noted that the strength of the stated level of acceptance increased for the design parameters they considered as most important as they performed increasing numbers of experiment trials. This was indicated by the rating response approaching the extremes of the scale as experiment trials were performed. The participants apparently became more familiar with the scenario tasking and developed stronger ideas with regard to their preferences as they gained experience. The effect on discrete experiments among participants was mitigated by varying the order in which participants performed the experiment trials.

The signal-to-noise ratios for the data of the matrix experiment were computed using Equation 3.1. The results are shown in Figure 7. The design parameter settings for experiment number six yielded the greatest value of S/N for the matrix experiment at -6.84. These settings do not necessarily represent the near optimum values for the matrix experiment.

In order to determine the near optimum values of the design parameters, additional analysis must be performed. The effect of each factor in the orthogonal array is separated out by creating a response table. The response table presents the average S/N ratio for each design parameter at each setting value used. The response table for the matrix experiment is shown in Table 2.

Graphical analysis based on the Taguchi Method was used to analyze the S/N ratios given in Table 2. The average S/N ratios were plotted versus the setting values for each design parameter. These graphs are shown in Figure 8. The graphs reveal that design parameter A (Highlighting) is more significant than any other having the greatest effect on user acceptance. Level two appears to be the best choice

Noise Matrix

	1	2	3	4
N1	1	1	2	2
N2	1	2	1	2
N3	1	2	2	1

Design Parameter Matrix

	A	B	C	D	E	F	G	$Y_{i,j}$				MEAN	STD
1	1		1		1		1	2.83	3.0	3.15	3.13	3.03	.148
2	1		1		2		2	2.83	2.42	2.93	2.90	2.77	.237
3	1		2		1		2	3.08	2.46	3.40	3.40	3.09	.443
4	1		2		2		1	2.54	1.96	2.78	2.40	2.42	.344
5	2		2		2		2	2.33	1.58	2.68	2.15	2.19	.459
6	2		2		1		1	2.50	1.83	2.40	2.0	2.18	.319
7	2		1		2		1	2.67	2.21	2.65	2.30	2.46	.237
8	2		1		1		2	2.33	2.04	2.35	2.38	2.28	.158

Figure 6. Results of the Matrix Experiment.

Design Parameter Matrix

	A	B	C	D	E	F	G	S/N
1	1		1		1		1	-9.63
2	1		1		2		2	-8.87
3	1		2		1		2	-9.85
4	1		2		2		1	-7.74
5	2		2		2		2	-6.93
6	2		2		1		1	-6.84
7	2		1		2		1	-7.84
8	2		1		1		2	-7.16

Figure 7. Signal-to-Noise Ratio for Y_i.

Average S/N Ratio

	A	C	E	G
1	-9.02	-8.37	-8.37	-8.01
2	-7.19	-7.84	-7.85	-8.20

Table 2. Response Table for Design Parameters.

for design parameters A, C (Control Flexibility) and E (Help) since it exhibits the greatest average S/N ratio while level one appears to be the best choice for design parameter G (Feedback).

As a result of the graphical analysis, the near optimum levels for the four design parameters were chosen as follows:

Design Parameter	Level	Setting
Highlighting	2	High
Control Flexibility	2	High
Help	2	High
Feedback	1	Low

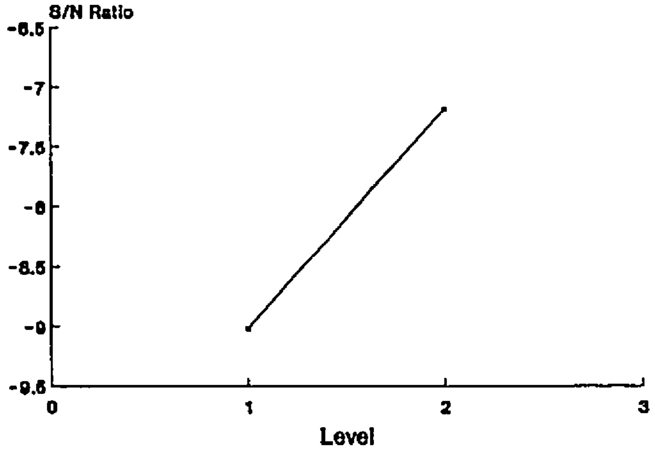
Examination of the above combination of predicted near optimum levels for the design parameters reveals that this combination was not considered in the original matrix experiment design shown in Figure 3. In applying the Taguchi Method, the predicted near optimum settings for the design parameters need not correspond to one of the rows of the matrix experiment (Taguchi 1987). This occurs because of the orthogonal nature of the experimental design. It is this property of orthogonal array experiments that facilitates a thorough search of the design parameter space with a minimum of experiment trials.

Results of the Validation Experiment

The validation experiment was developed using the same system, methods and procedures used in the design and conduct of the matrix experiment. The validation experiment was conducted using the near optimum settings for the design parameters derived from the analysis of the results of the matrix experiment. The results of the validation experiment are shown in Figure 9.

Comparison of the results of the validation experiment to the findings of the matrix experiment yielded several indications of improvement in user acceptance of the

Parameter A



Parameter C

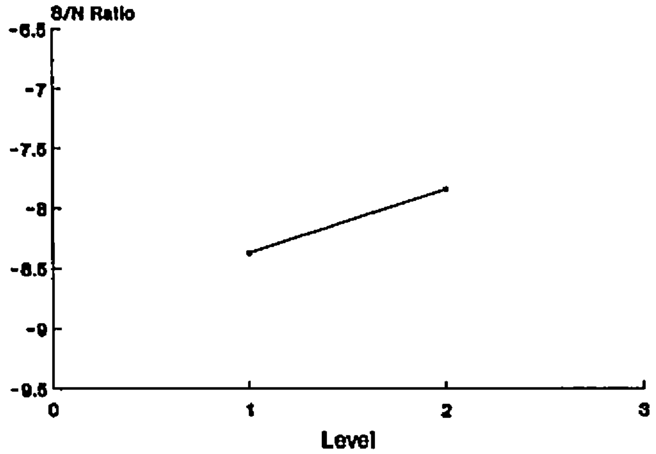


Figure 8. Signal-to-Noise Ratio Graphs. (a) Parameters A and C.

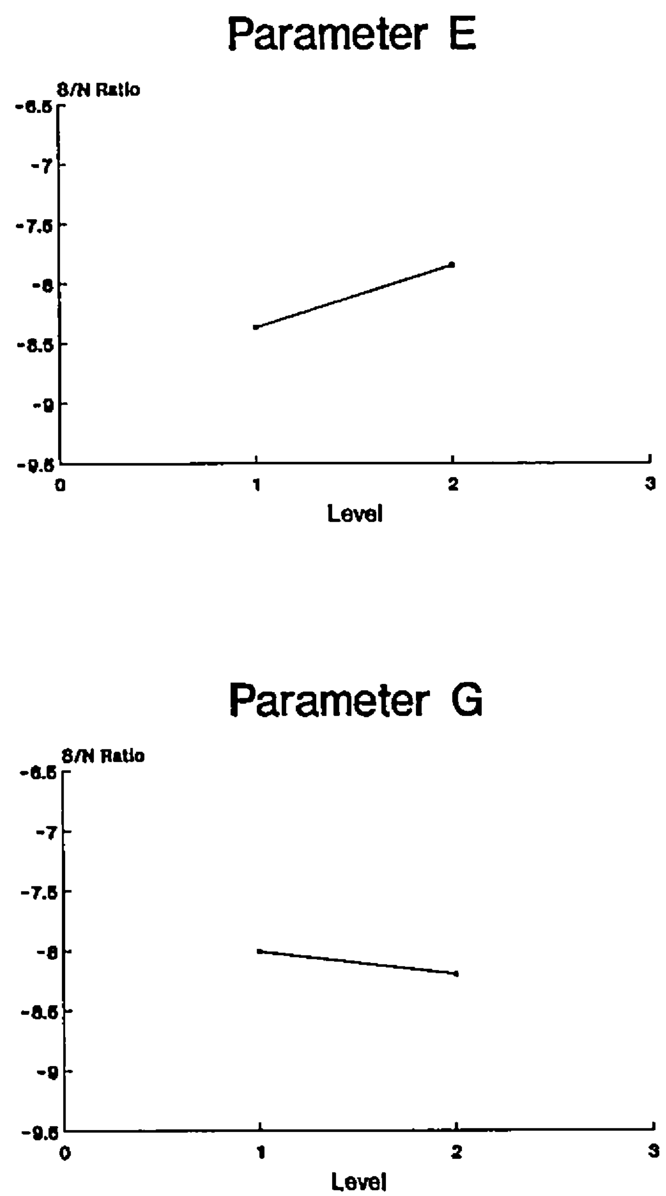


Figure 8. Signal-to-Noise Ratio Graphs. (b) Parameters E and G.

interface. The mean value of $Y_{i,j}$ for the validation experiment was improved by a factor of 1.2 over the best value in the matrix experiment (2.18 in Figure 6). S/N improved from -6.84, the best value for any combination ofsettings for design parameters in the matrix experiment (Figure 7), to -5.07 in the validation experiment. These results indicate improvement in user acceptance of the interface using the settings for the design parameters predicted in the matrix experiment.

Noise Factor Array

	1	2	3	4
N1	1	1	2	2
N2	1	2	1	2
N3	1	2	2	1

Design Parameter Array

	A	C	E	G	$Y_{i,j}$				MEAN	STD	S/N
1	2	2	2	1	1.88	1.75	1.50	2.0	1.78	.214	-5.07

Figure 9. Validation Experiment Results.

CHAPTER 6

CONCLUSIONS

In this chapter, the major findings of the research are summarized. Then, the applications and limitations are discussed. In closing, directions for future research are suggested.

Major Findings

The following relate the findings of this study to its research objectives.

1. Human-Computer Interface Communication and Control Alternatives for Task Accomplishment Exist That Influence User Acceptance of the Interface. Research Objective One was to determine if recognized and accepted alternatives existed for human-computer interface interaction software implementation that affect user acceptance of the interface software. The existence of these alternatives was investigated by conducting an extensive literature review. This review produced twelve alternative implementation schemes that affect user satisfaction and acceptance of the associated interface. In all cases, the software implementation variable was studied as a single variable within the human-computer system under investigation. Each

source study suggested which means or level of implementation of the alternative under study produced increased levels of acceptance. The literature was lacking in studies where the effect of more than one software implementation alternative was investigated at a time. Therefore, there is a lack of information on the effect of combinations of various alternatives and the interactions between them.

There were adequate single variable software implementation studies to provide alternative design parameters for use in this study.

2. Human Characteristics and Preferences That Are Important Human Factors in User Acceptance of Human-Computer Interfaces Were Identified. Research Objective Two was to identify human behavioral factors that affect user acceptance of interface software. These factors were identified in an extensive literature review. This review produced eight human behavioral factors that affect user satisfaction and acceptance of interface software. Each source study suggested the effect of a human characteristic or preference on the level of user acceptance of the interface software. The literature was again lacking in studies where the effect of more than one human behavioral characteristic was investigated. Therefore, there is a lack of information on the effect of combinations of various human behavioral factors and the interactions between them.

There were adequate human behavioral factors to define the noise space and alternative noise factors for this study.

3. A Near Optimum Human-Computer Interface Was Developed for a Selected User Population Using the Taguchi Method. Research Objective Three was to design a near optimum human-computer interface for a selected user population using the Taguchi Method. The computer selected for the investigation was chosen because of its popularity and versatility of use. The personal micro-computer represents a tool with which many users potentially interact in a wide variety of applications. Designing an interface software for use on this type of computer posed a very challenging development activity as a basis of evaluating the applicability of the Taguchi Method to this type of process.

Programming language was not of interest in this investigation. Of primary concern was the interaction medium provided by the video display screen content and the keyboard control interface. The design parameters chosen represented several of the interaction alternatives available to an interface software designer participating in the development of application software. These alternatives were molded into the framework of an orthogonal array for use in the Taguchi Method.

The definition of the noise factors for use in this study did not appear to be as critical a task as choosing the design parameters for study. Variations in human behavior include what appears to be sufficient definition of the noise space to provide adequate uncontrollable impact on the overall acceptance of the interface to ensure robustness to noise. Designing for segments of the user population that possess known perceptions, preferences and traits introduce boundaries on the total human behavioral noise space making the design less robust but perhaps more achievable in technology, implementation and cost. Human characteristics appear to fit very well within the framework of the Taguchi Method as noise for use in design of human-computer interfaces.

In order to conduct the experimental evaluation, it was necessary to construct a means to evaluate the setting values of the design parameters. The fidelity and clarity with which the distinct values of the settings are depicted for evaluation by the users is critical to the design process. The designer must include in the evaluation measures to assess the degree to which the intended meanings of the displayed design parameter values were properly interpreted by the evaluator. The design of the presentation and task accomplishment scenarios for use in experimental evaluation become a learning experience for the designer and may be an important contributor to the quality of the design itself. The design of the task accomplishment scenarios and computer demonstration for data gathering and analysis were the most arduous tasks in the entire study. The scenarios used in this study were evaluated as successful in providing adequate demonstration of the design parameters in a controllable process to meet the requirements of the Taguchi Method.

Analysis of the results of the matrix experiment produced a near optimum set of values for the design parameters. Graphical analysis of the resulting signal-to-noise ratios provided unambiguous optimum values for the chosen parameters. This result supports the postulated applicability of the Taguchi Method to the human-computer interface design process of this study.

4. A Validation Experiment Confirmed That the Near Optimum Settings Chosen for the Interface Improved User Acceptance. Research Objective Four was to demonstrate and evaluate the optimum human-computer interface design selected using the Taguchi Method to evaluate differences in user acceptance. The follow-up experiment using the near optimum settings chosen in the matrix experiment showed that the new settings improved the objective function, user acceptance, alleviating concerns about improper assumptions underlying the model. This result appears to support the use of the Taguchi Method in the design of human-computer

interfaces for the selection of near optimum values of the settings of the design parameters.

Limitations of the Research

The limitations of this research appear to be as follows.

1. This research investigated the design of human-computer interface software for an interaction medium provided by the video display screen content and the keyboard control interface of a specific micro-computer. The design parameters chosen for investigation were those currently adopted for use in various software programs. No attempts were made to evaluate new interaction techniques or program languages for interaction.

2. The participants in the evaluation experiments were familiar with personal micro-computers and their standard interaction devices and had used them previously, to some degree, in the performance of tasks similar to those performed in the matrix experiment. The results of this study therefore do not necessarily predict the level of acceptance of the interface used for study by other users. This issue does not negate the major finding of this study as demonstrated previously with regard to the application of the Taguchi Method.

3. Interactions between design parameters during the conduct of the matrix experiment were assumed not to have occurred. Attempts to minimize interaction were made.

These included design parameter selection, value assignment of implementation levels for the design parameters, instruction of the participants and design of the data gathering instruments. Effectiveness of these efforts were not directly assessed in the research. Improvement in the performance characteristic for the validation experiment over the results of the matrix experiment indicated that any interaction between design parameters was negligible.

4. In applying the Taguchi Method to design processes where the most important sources of noise are human behavioral characteristics introduced special considerations. The experience level of the participants increased during the conduct of the matrix experiment trials. This can effect the expressed response of the participants over the course of the experiment, especially where the response is based upon subjective assessment. In this research, an attempt was made to mitigate the effect of this factor by varying the order of conduct of the experiment trials among participants. The effectiveness of this effort was not assessed in this research. The results of the validation experiment indicate that this effect did not negate the major findings of this research.

5. No attempts were made to evaluate the use of computer interaction control devices other than the keyboard described previously.

Directions for Future Research

During the study it became apparent that there were other opportunities for investigation that may result in additional findings and useful information.

Areas for future research include the following.

1. This research can be expanded to investigate the application of the Taguchi Method to the design of other human interactive systems where the utility of the system is dependent upon human behavioral characteristics and responses.

2. This research can be applied to investigate other quality and performance characteristics, such as life-cycle costs, as considerations in the design of human interactive systems.

3. This study should be extended to investigate the effects of wider ranges of human familiarity and experience with computer interfaces on the potential acceptance of alternative interface designs. Investigations that consider the whole of human behavioral response as the noise field, without further discrimination or categorization, using broader sample populations could be used to study the effects sample size, level of experience with system under study and the change in experience that occurs during experiment trials.

4. Additional investigation is needed into the effect of interaction between design parameters in human-computer

interface design using the Taguchi Method. Although, in this research, application of the method was shown to be appropriate to a specific set of design parameters and noise factors, use of the method where greater numbers of design parameters are under study require consideration of parameter interaction. Taguchi's linear graph techniques should be investigated as a methodology for studying interactions in the context of interface design.

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APPENDIX A

COLOR PALETTE SELECTIONS FOR EXPERIMENTATION

The following are the foreground and background colors selected for the video display screen using the WordPerfect™ Version 5.1 setup function. The colors available were those provided in the Normal Font Only, 16 Foreground Color mode with a 640 by 480 pixil VGA display card in the IBM™ Personal System/2 Model 50 and Color Display.

Attribute	Foreground	Background
Normal	H	B
Blocked	H	E
Underline	A	D
Strikeout	A	D
Bold	O	B
Double Underline	B	D
Redline	E	H
Shadow	J	H
Italics	O	B
Small Caps	E	D
Outline	F	D
Subscript	E	H
Superscript	F	H
Fine Print	A	F
Small Print	H	F
Large Print	E	A
Very Large Print	D	A
Extra Large Print	H	A
Bold and Underline	A	C
Other Combinations	A	G

The colors associated with the alphabetic codes are:

A - Black
B - Blue
C - Green
D - Cyan
E - Red
F - Pink
G - Orange
H - White
I - Gray
J - Magenta
K - Bright Green
L - Bright Cyan
M - Bright Orange
N - Bright Pink
O - Bright Yellow
P - Bright White

APPENDIX B

MATRIX EXPERIMENT VIDEO DISPLAY PRESENTATIONS

The following represent the video displays presented to the subjects for evaluation in each matrix experiment. Each page represents the content of the video display screen at initialization.

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER ONE

Settings:

Highlighting	Low
Control Flexibility	Low
Guidance and Support	Low
Feedback/Explicitness	Low

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER ONE (CONTINUED)

The purpose of this exercise is to present information and provide control options via this computer interface to allow you the user to experience the interface medium and then to provide feedback about various aspects of your interaction with the computer and its interface.

You will be asked to perform tasks with which you may possess varying levels of familiarity. You should attempt to perform the tasks to the best of your ability within the directions provided to you and the computer tools available.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER ONE (CONTINUED)

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

[HRt]
[TAB]The useful size of the screen is somewhat[SRt]
restricted in the current mode of operation. Please[SRt]
restore the screen to its maximum useful size by[SRt]
following the prompt on the last line presented on this[SRT]
screen.[HRt]

Press **Reveal Codes** to restore screen

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER ONE (CONTINUED)

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER ONE (CONTINUED)

The following procedure is being prepared as a hand-out for driver education students at the high school level concerning the operation of a motor vehicle.

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER ONE (CONTINUED)

Upon review of the above procedure you discover several errors in the sequence of operations provided to the student. One of these is the location of the guidance to "Fasten your seat belt". You decide that this step belongs in Step 2, "Getting behind the wheel". Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. Use only the keyboard template provided to obtain help in performing this task.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

3. In this exercise, you must use the Function Key Control Options to complete the tasks.

4. The only means available to you for accomplishing this task is through the use of the MOVE function within the Function Key Control Options.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER ONE (CONTINUED)

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

You have successfully completed the first portion of the exercise. Depending upon the level of familiarity you have with the particular software in use, the task may have been somewhat of a learning experience as you discovered how to use this particular editing tool. To allow you to have a broader base of experience to use in your evaluation, you will be asked to perform a similiar task again.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER ONE (CONTINUED)

Upon further review of the above procedure you discover another error in the sequence of operations provided to the student. This error is the location of the guidance to "Is there sufficient fuel in the tank?". You decide that this step belongs in Step 3, "Starting the engine.". Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. Use only the keyboard template provided to obtain help in performing this task.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

3. In this exercise, you must use the Function Key Control Options to complete the tasks.

4. The only means available to you for accomplishing this task is through the use of the MOVE function within the Function Key Control Options.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER ONE (CONTINUED)

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.
   - Fasten your seat belt.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.

YOU HAVE COMPLETED THE EXERCISE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER TWO

Settings:

Highlighting	Low
Control Flexibility	Low
Guidance and Support	High
Feedback/Explicitness	High

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER TWO (CONTINUED)

The purpose of this exercise is to present information and provide control options via this computer interface to allow you to experience the interface medium and then to provide feedback about various aspects of your interaction with the computer and its interface.

You will be asked to perform tasks with which you may possess varying levels of familiarity. You should attempt to perform the tasks to the best of your ability within the directions provided to you and the computer tools available.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER TWO (CONTINUED)

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

[HRt]
[TAB]The useful size of the screen is somewhat[SRt]
restricted in the current mode of operation. Please[SRt]
restore the screen to its maximum useful size by[SRt]
following the prompt on the last line presented on this[SRT]
screen.[HRt]

Press **Reveal Codes** to restore screen

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER TWO (CONTINUED)

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

Press Reveal Codes means: DEPRESS F11.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER TWO (CONTINUED)

The following procedure is being prepared as a hand-out for driver education students at the high school level concerning the operation of a motor vehicle.

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER TWO (CONTINUED)

Upon review of the above procedure you discover several errors in the sequence of operations provided to the student. One of these is the location of the guidance to "Fasten your seat belt". You decide that this step belongs in Step 2, "Getting behind the wheel". Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use the Keyboard Template, the on-line HELP F3 function or the MENU at the top of the screen to obtain help in performing this task. The MENU at the top the screen is accessed by depressing the Alt key.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. In this exercise, you must use the MENU Control Options to complete the tasks.

4. The only means available to you for accomplishing this task is through the use of the MOVE function within the MENU Control Options.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER TWO (CONTINUED)

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER TWO (CONTINUED)

You have successfully completed the first portion of the exercise. Depending upon the level of familiarity you have with the particular software in use, the task may have been somewhat of a learning experience as you discovered how to use this particular editing tool. To allow you to have a broader base of experience to use in your evaluation, you will be asked to perform a similiar task again.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER TWO (CONTINUED)

Upon further review of the above procedure you discover another error in the sequence of operations provided to the student. This error is the location of the guidance to "Is there sufficient fuel in the tank?". You decide that this step belongs in Step 3, "Starting the engine.". Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use the Keyboard Template, the on-line HELP F3 function or the MENU at the top of the screen to obtain help in performing this task. The MENU at the top the screen is accessed by depressing the Alt key.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. In this exercise, you must use the MENU Control Options to complete the tasks.

4. The only means available to you for accomplishing this task is through the use of the MOVE function within the MENU Control Options.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER TWO (CONTINUED)

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.
   - Fasten your seat belt.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.

<u>**YOU HAVE COMPLETED THE EXERCISE**</u>

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER THREE

Settings:

Highlighting	Low
Control Flexibility	High
Guidance and Support	Low
Feedback/Explicitness	High

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER THREE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The purpose of this exercise is to present information and provide control options via this computer interface to allow you to experience the interface medium and then to provide feedback about various aspects of your interaction with the computer and its interface.

You will be asked to perform tasks with which you may possess varying levels of familiarity. You should attempt to perform the tasks to the best of your ability within the directions provided to you and the computer tools available. You will be advised when you should begin considering this exercise for the purpose of evaluation.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER THREE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

Press Reveal Codes means: DEPRESS F11.

[HRt]
[TAB]The useful size of the screen is somewhat[SRt]
restricted in the current mode of operation. Please[SRt]
restore the screen to its maximum useful size by[SRt]
following the prompt on the last line presented on this[SRT]
screen.[HRt]

Press **Reveal Codes** to restore screen

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER THREE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

Press Reveal Codes means: DEPRESS F11.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER THREE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The following procedure is being prepared as a hand-out for driver education students at the high school level concerning the operation of a motor vehicle.

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER THREE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Upon review of the above procedure you discover several errors in the sequence of operations provided to the student. One of these is the location of the guidance to "Fasten your seat belt". You decide that this step belongs in Step 2, "Getting behind the wheel". Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. Use only the keyboard template provided to obtain help in performing this task.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. You may use any means available to you to accomplish this task including the MOVE function, DELETE function, INSERT/TYPEOVER function or others that you may identify.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER THREE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER THREE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

You have successfully completed the first portion of the exercise. Depending upon the level of familiarity you have with the particular software in use, the task may have been somewhat of a learning experience as you discovered how to use this particular editing tool. To allow you to have a broader base of experience to use in your evaluation, you will be asked to perform a similiar task again.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER THREE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Upon further review of the above procedure you discover another error in the sequence of operations provided to the student. This error is the location of the guidance to "Is there sufficient fuel in the tank?". You decide that this step belongs in Step 3, "Starting the engine.". Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. Use only the keyboard template provided to obtain help in performing this task.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. You may use any means available to you to accomplish this task including the MOVE function, DELETE function, INSERT/TYPEOVER function or others that you may identify.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER THREE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

YOU HAVE COMPLETED THE EXERCISE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FOUR

Settings:

Highlighting	Low
Control Flexibility	High
Guidance and Support	High
Feedback/Explicitness	Low

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FOUR (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The purpose of this exercise is to present information and provide control options via this computer interface to allow you to experience the interface medium and then to provide feedback about various aspects of your interaction with the computer and its interface.

You will be asked to perform tasks with which you may possess varying levels of familiarity. You should attempt to perform the tasks to the best of your ability within the directions provided to you and the computer tools available. You will be advised when you should begin considering this exercise for the purpose of evaluation.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FOUR (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

[HRt]
[TAB]The useful size of the screen is somewhat[SRt]
restricted in the current mode of operation. Please[SRt]
restore the screen to its maximum useful size by[SRt]
following the prompt on the last line presented on this[SRT]
screen.[HRt]

Press **Reveal Codes** to restore screen

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FOUR (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FOUR (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The following procedure is being prepared as a hand-out for driver education students at the high school level concerning the operation of a motor vehicle.

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FOUR (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Upon review of the above procedure you discover several errors in the sequence of operations provided to the student. One of these is the location of the guidance to "Fasten your seat belt". You decide that this step belongs in Step 2, "Getting behind the wheel". Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use the Keyboard Template, the on-line HELP F3 function or the MENU at the top of the screen to obtain help in performing this task. The MENU at the top the screen is accessed by depressing the Alt key.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

3. You may use any means available to you to accomplish this task including the MOVE function, DELETE function, INSERT/TYPEOVER function or others that you may identify.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FOUR (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FOUR (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

You have successfully completed the first portion of the exercise. Depending upon the level of familiarity you have with the particular software in use, the task may have been somewhat of a learning experience as you discovered how to use this particular editing tool. To allow you to have a broader base of experience to use in your evaluation, you will be asked to perform a similiar task again.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FOUR (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Upon further review of the above procedure you discover another error in the sequence of operations provided to the student. This error is the location of the guidance to "Is there sufficient fuel in the tank?". You decide that this step belongs in Step 3, "Starting the engine.". Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use the Keyboard Template, the on-line HELP F3 function or the MENU at the top of the screen to obtain help in performing this task. The MENU at the top the screen is accessed by depressing the Alt key.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

3. You may use any means available to you to accomplish this task including the MOVE function, DELETE function, INSERT/TYPEOVER function or others that you may identify.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FOUR (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

YOU HAVE COMPLETED THE EXERCISE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FIVE

Settings:

Highlighting	High
Control Flexibility	High
Guidance and Support	High
Feedback/Explicitness	High

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FIVE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The purpose of this exercise is to present information and provide control options via this computer interface to allow you to experience the interface medium and then to provide feedback about various aspects of your interaction with the computer and its interface.

You will be asked to perform tasks with which you may possess varying levels of familiarity. You should attempt to perform the tasks to the best of your ability within the directions provided to you and the computer tools available. You will be advised when you should begin considering this exercise for the purpose of evaluation.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FIVE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

Press **Reveal Codes** means: **DEPRESS F11.**

[HRt]
[TAB]The useful size of the screen is somewhat[SRt]
restricted in the current mode of operation. Please[SRt]
restore the screen to its maximum useful size by[SRt]
following the prompt on the last line presented on this[SRT]
screen.[HRt]

Press **Reveal Codes** to restore screen

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FIVE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

Press **Reveal Codes** means: **DEPRESS F11.**

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FIVE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The following procedure is being prepared as a hand-out for driver education students at the high school level concerning the operation of a motor vehicle.

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FIVE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Upon review of the above procedure you discover several errors in the sequence of operations provided to the student. One of these is the location of the guidance to **"Fasten your seat belt"**. You decide that this step belongs in **Step 2, "Getting behind the wheel"**. Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use the **Keyboard Template**, the on-line **HELP F3** function or the **MENU** at the top of the screen to obtain help in performing this task. The **MENU** at the top the screen is accessed by depressing the **Alt** key.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. You may use any means available to you to accomplish this task including the **MOVE** function, **DELETE** function, **INSERT/TYPEOVER** function or others that you may identify.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FIVE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - **Fasten your seat belt.**

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FIVE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

You have successfully completed the first portion of the exercise. Depending upon the level of familiarity you have with the particular software in use, the task may have been somewhat of a learning experience as you discovered how to use this particular editing tool. To allow you to have a broader base of experience to use in your evaluation, you will be asked to perform a similiar task again.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FIVE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Upon further review of the above procedure you discover another error in the sequence of operations provided to the student. This error is the location of the guidance to "**Is there sufficient fuel in the tank?**". You decide that this step belongs in **Step 3, "Starting the engine."**. Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use the **Keyboard Template**, the on-line **HELP F3** function or the **MENU** at the top of the screen to obtain help in performing this task. The **MENU** at the top the screen is accessed by depressing the **Alt** key.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. You may use any means available to you to accomplish this task including the **MOVE** function, **DELETE** function, **INSERT/TYPEOVER** function or others you may identify.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER FIVE (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - **Is there sufficient fuel in the tank?**
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

YOU HAVE COMPLETED THE EXERCISE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SIX

Settings:

Highlighting	High
Control Flexibility	High
Guidance and Support	Low
Feedback/Explicitness	Low

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SIX (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The purpose of this exercise is to present information and provide control options via this computer interface to allow you to experience the interface medium and then to provide feedback about various aspects of your interaction with the computer and its interface.

You will be asked to perform tasks with which you may possess varying levels of familiarity. You should attempt to perform the tasks to the best of your ability within the directions provided to you and the computer tools available.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SIX (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

[HRt]
[TAB]The useful size of the screen is somewhat[SRt]
restricted in the current mode of operation. Please[SRt]
restore the screen to its maximum useful size by[SRt]
following the prompt on the last line presented on this[SRT]
screen.[HRt]

Press **Reveal Codes** to restore screen

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SIX (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SIX (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

The following procedure is being prepared as a hand-out for driver education students at the high school level concerning the operation of a motor vehicle.

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SIX (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Upon review of the above procedure you discover several errors in the sequence of operations provided to the student. One of these is the location of the guidance to **"Fasten your seat belt"**. You decide that this step belongs in **Step 2, "Getting behind the wheel"**. Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use only the **keyboard template** provided to obtain help in performing this task.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

3. You may use any means available to you to accomplish this task including the **MOVE** function, **DELETE** function, **INSERT/TYPEOVER** function or others that you may identify.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SIX (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - **Fasten your seat belt.**

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SIX (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

You have successfully completed the first portion of the exercise. Depending upon the level of familiarity you have with the particular software in use, the task may have been somewhat of a learning experience as you discovered how to use this particular editing tool. To allow you to have a broader base of experience to use in your evaluation, you will be asked to perform a similiar task again.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SIX (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Upon further review of the above procedure you discover another error in the sequence of operations provided to the student. This error is the location of the guidance to "**Is there sufficient fuel in the tank?**". You decide that this step belongs in **Step 3**, "**Starting the engine.**". Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use only the **keyboard template** provided to obtain help in performing this task.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

3. You may use any means available to you to accomplish this task including the **MOVE** function, **DELETE** function, **INSERT/TYPEOVER** function or others you may identify.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SIX (CONTINUED)

File Edit Search Layout Mark Tools Font Graphics Help

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - **Is there sufficient fuel in the tank?**
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

YOU HAVE COMPLETED THE EXERCISE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SEVEN

Settings:

Highlighting	High
Control Flexibility	Low
Guidance and Support	High
Feedback/Explicitness	Low

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SEVEN (CONTINUED)

The purpose of this exercise is to present information and provide control options via this computer interface to allow you to experience the interface medium and then to provide feedback about various aspects of your interaction with the computer and its interface.

You will be asked to perform tasks with which you may possess varying levels of familiarity. You should attempt to perform the tasks to the best of your ability within the directions provided to you and the computer tools available. You will be advised when you should begin considering this exercise for the purpose of evaluation.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SEVEN (CONTINUED)

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

[HRt]
[TAB]The useful size of the screen is somewhat[SRt]
restricted in the current mode of operation. Please[SRt]
restore the screen to its maximum useful size by[SRt]
following the prompt on the last line presented on this[SRT]
screen.[HRt]

Press **Reveal Codes** to restore screen

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SEVEN (CONTINUED)

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SEVEN (CONTINUED)

The following procedure is being prepared as a hand-out for driver education students at the high school level concerning the operation of a motor vehicle.

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SEVEN (CONTINUED)

Upon review of the above procedure you discover several errors in the sequence of operations provided to the student. One of these is the location of the guidance to **"Fasten your seat belt"**. You decide that this step belongs in **Step 2, "Getting behind the wheel"**. Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use the **Keyboard Template**, the on-line **HELP F3** function or the **MENU** at the top of the screen to obtain help in performing this task. The **MENU** at the top the screen is accessed by depressing the **Alt** key.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

3. In this exercise, you must use the **MENU Control Options** to complete the tasks.

4. The only means available to you for accomplishing this task is through the use of the **MOVE** function within the **MENU KEY Control Options**.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SEVEN (CONTINUED)

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - **Fasten your seat belt.**

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SEVEN (CONTINUED)

You have successfully completed the first portion of the exercise. Depending upon the level of familiarity you have with the particular software in use, the task may have been somewhat of a learning experience as you discovered how to use this particular editing tool. To allow you to have a broader base of experience to use in your evaluation, you will be asked to perform a similiar task again.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SEVEN (CONTINUED)

Upon further review of the above procedure you discover another error in the sequence of operations provided to the student. This error is the location of the guidance to **"Is there sufficient fuel in the tank?"**. You decide that this step belongs in **Step 3, "Starting the engine."**. Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use the **Keyboard Template,** the on-line **HELP F3** function or the **MENU** at the top of the screen to obtain help in performing this task.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

3. In this exercise, you must use the **MENU Control Options** to complete the tasks.

4. The only means available to you for accomplishing this task is through the use of the **MOVE** function within the **MENU Control Options.**

<u>DEPRESS THE "PAGE DOWN" KEY TO CONTINUE</u>

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER SEVEN (CONTINUED)

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - **Is there sufficient fuel in the tank?**
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

YOU HAVE COMPLETED THE EXERCISE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER EIGHT

Settings:

Highlighting	High
Control Flexibility	Low
Guidance and Support	Low
Feedback/Explicitness	High

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER EIGHT (CONTINUED)

The purpose of this exercise is to present information and provide control options via this computer interface to allow you to experience the interface medium and then to provide feedback about various aspects of your interaction with the computer and its interface.

You will be asked to perform tasks with which you may possess varying levels of familiarity. You should attempt to perform the tasks to the best of your ability within the directions provided to you and the computer tools available. You will be advised when you should begin considering this exercise for the purpose of evaluation.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER EIGHT (CONTINUED)

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

Press **Reveal Codes** means: **DEPRESS F11.**

[HRt]
[TAB]The useful size of the screen is somewhat[SRt]
restricted in the current mode of operation. Please[SRt]
restore the screen to its maximum useful size by[SRt]
following the prompt on the last line presented on this[SRT]
screen.[HRt]

Press **Reveal Codes** to restore screen

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER EIGHT (CONTINUED)

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

Press **Reveal Codes** means: **DEPRESS F11.**

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER EIGHT (CONTINUED)

The following procedure is being prepared as a hand-out for driver education students at the high school level concerning the operation of a motor vehicle.

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

<u>**USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE**</u>

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

<u>**DEPRESS THE "PAGE DOWN" KEY TO CONTINUE**</u>

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER EIGHT (CONTINUED)

Upon review of the above procedure you discover several errors in the sequence of operations provided to the student. One of these is the location of the guidance to **"Fasten your seat belt"**. You decide that this step belongs in **Step 2, "Getting behind the wheel"**. Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. Use only the **keyboard template** provided to obtain help in performing this task.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

3. In this exercise, you must use the **FUNCTION KEY Control Options** to complete the tasks.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

4. The only means available to you for accomplishing this task is through the use of the **MOVE** function within the **FUNCTION KEY Control Options.**

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER EIGHT (CONTINUED)

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - **Fasten your seat belt.**

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER EIGHT (CONTINUED)

You have successfully completed the first portion of the exercise. Depending upon the level of familiarity you have with the particular software in use, the task may have been somewhat of a learning experience as you discovered how to use this particular editing tool. To allow you to have a broader base of experience to use in your evaluation, you will be asked to perform a similiar task again.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER EIGHT (CONTINUED)

Upon further review of the above procedure you discover another error in the sequence of operations provided to the student. This error is the location of the guidance to **"Is there sufficient fuel in the tank?"**. You decide that this step belongs in **Step 3, "Starting the engine."**. Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. Use only the **keyboard template** provided to obtain help in performing this task.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

3. In this exercise, you must use the **FUNCTION KEY Control Options** to complete the tasks.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

4. The only means available to you for accomplishing this task is through the use of the **MOVE** function within the **FUNCTION KEY Control Options**.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX B (CONTINUED)

MATRIX EXPERIMENT NUMBER EIGHT (CONTINUED)

Preparing for Your Road Test

1. Survey the external appearance of the car.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - **Is there sufficient fuel in the tank?**
   - Is the windshield clean and clear?
   - Are headlights/tailights/signals intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

USE THE "ARROW DOWN" KEY TO MOVE DOWN THE PAGE

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

YOU HAVE COMPLETED THE EXERCISE

APPENDIX C

PARTICIPANT SCREENING QUESTIONNAIRE

Name:________________________

The following questions are posed in an effort to identify prospective candidates to participate in an Human Factors Evaluation of a Human-Computer Interface for the purpose of collecting data for Human Factors design research. Please circle the appropriate responses commensurate with your experience.

1. Indicate your level of experience using IBM compatible or Apple type Personal Computers. If you have experience using both, indicate your experience with each.

IBM	APPLE	BOTH			
Extensive	Extensive	Extensive	IBM	Apple	Both
Limited	Limited	Limited	IBM	Apple	Both
Cursory	Cursory	Cursory	IBM	Apple	Both

2. Indicate your experience with application software control methods by marking the control options shown below that you have used and are familiar with:

KEYBOARD	MENU BAR	DIGITIZED TABLET
Fixed Function Keys	Keyboard Control	
Programmable Fcn Keys	Keyboard Cursor	
	Mouse or Joy Stick	

3. Indicate your experience with the following:
E = EXTENSIVE L = LIMITED C = CURSORY

MultiMate E L C	**WordPerfect 4.2** E L C	**MACWrite** E L C	**Word** E L C
WordStar E L C	**WordPerfect 5.0** E L C	**LOTUS** E L C	**DBase** E L C
VolksWriter E L C	**WordPerfect 5.1** E L C	**MACPaint** E L C	

4. Do you consider yourself:

(A) to have developed strong beliefs concerning how word pro-cessing(WP) should work? (typing, editing, pagination)

(B) too inexperienced with any WP software to have any predisposition about how it should work?

(C) open minded about how WP software should work since you work frequently with several types?

(D) to have a slight preference for the way a certain WP program works even though you frequently use several?

APPENDIX D

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

Experiment Evaluation Questionnaire

Experiment Number:______________

Date:___________

Subject's Name:__________________________

Subject Data:

Noise Array Column Number: 1 2 3 4

Answer Summary:

Section 1:	Weight:________%	Rating:________
Section 2:	Weight:________%	Rating:________
Section 3:	Weight:________%	Rating:________
Section 4:	Weight:________%	Rating:________

Computed Overall Rating:________________

Evaluation Overall Rating:______________

APPENDIX D (CONTINUED)

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

Section 1: Highlighting/Enumeration

1. Is important information highlighted on the screen? (e.g. cursor position, menu, instructions, errors)

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

2. Are bright or light colors displayed on a dark background, and vice versa?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

3. Does the use of color help to make the displays more clear?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

4. Is it easy to find the required information on the screen?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

5. Is highlighting alone adequate to draw your attention to important information?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

APPENDIX D (CONTINUED)

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

---

6. Were you able to perform the assigned tasks to your satisfaction with the degree of highlighting used on the displays?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

7. Is the level of implementation of highlighting/ enumeration in the interface a factor in your overall acceptance of the interface?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

8. On a scale of 1 to 10, where would you place the importance of 'highlighting' in your "acceptance equation" for using a computer software application?

____

9. Overall, how would you rate the interface in terms of highlighting/enumeration?

Very Satisfactory	Moderately Satisfactory	Neutral	Moderately Unsatisfactory	Very Unsatisfactory

1--------------2------------3-----------4--------------5

APPENDIX D (CONTINUED)

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

Section 2: Flexibility and Control

This section asks questions regarding the structure of the interface: the way information is presented and in terms of what the user can do, to suit the needs and requirements of the individual user, and to allow them to feel in control.

1. Is there an easy way for the user to 'undo' an action, and step back to a previous stage or screen? (e.g. if the user makes a wrong choice or does something unintended)

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

2. Are shortcuts available when desired? (e.g. to bypass a sequence of activities or screens)

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

3. Did you feel you had control over the order in which information could be requested or in carrying out a series of activities?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

4. Can the user look through a sequence of screens in either direction?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

APPENDIX D (CONTINUED)

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

---

5. Can the user access a particular screen in sequence of screens directly?

Always	Most of the time	Some of the time	Never
1	2	3	4

6. When using menus, was it easy to return to the main menu from any part of the system?

Always	Most of the time	Some of the time	Never
1	2	3	4

7. Did the system allow you the flexibility to choose the way you preferred when accomplishing a task?

Always	Most of the time	Some of the time	Never
1	2	3	4

8. Did you feel you were in control when you wanted to be in control?

Always	Most of the time	Some of the time	Never
1	2	3	4

9. Were you able to perform the assigned tasks to your satisfaction with the degree of flexibility allowed you?

Always	Most of the time	Some of the time	Never
1	2	3	4

APPENDIX D (CONTINUED)

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

10. Is the level of implementation of 'control flexibility' in the interface a factor in your overall acceptance of the interface?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

11. On a scale of 1 to 10, where would you place the importance of 'control flexibility' in your "acceptance equation" for using a computer software application?

____

12. Overall, how would you rate the interface in terms of 'control flexibility'?

Very Satisfactory	Moderately Satisfactory	Neutral	Moderately Unsatisfactory	Very Unsatisfactory

1--------------2------------3-----------4--------------5

APPENDIX D (CONTINUED)

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

Section 3: User Guidance and Support

This section asks questions regarding the availability of informative, easy-to-use, and relevant guidance and support to help the user understand and use the system.

1. If there was some form of on-line help facility to help the user when using the system, then:

a. Could you request this easily from any point?

Always	Most of the time	Some of the time	Never
1	2	3	4

b. Is it clear how to get in and out of the help facility?

Always	Most of the time	Some of the time	Never
1	2	3	4

c. Is the help information presented clearly, without interfering with the user's current activity?

Always	Most of the time	Some of the time	Never
1	2	3	4

d. When the user requests help, does the system clearly explain what the user needs to do in order to take a particular action?

Always	Most of the time	Some of the time	Never
1	2	3	4

APPENDIX D (CONTINUED)

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

---

e. When using the help facility, can the user find relevant information directly, without having to look through unnecessary information?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

f. Does the help facility allow the user to browse through information about other parts of the system?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

2. If there was no on-line help facility available, could you perform the assign tasks to your satisfaction using only the template for help?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

3. Was it clear from the template what the user needs to do in order to take a particular action?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

4. Were you able to perform the assigned tasks to your satisfaction with the degree of help available you?

Always	Most of the time	Some of the time	Never

1--------------2------------3-----------4

APPENDIX D (CONTINUED)

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

5. Is the level of implementation of 'help facility' in the interface a factor in your overall acceptance of the interface?

Always	Most of the time	Some of the time	Never

1--------------2-------------3-----------4

6. On a scale of 1 to 10, where would you place the importance of 'help facility' in your "acceptance equation" for using a computer software application?

____

7. Overall, how would you rate the interface in terms of providing the required level of help?

Very Satisfactory	Moderately Satisfactory	Neutral	Moderately Unsatisfactory	Very Unsatisfactory

1--------------2-------------3-----------4--------------5

APPENDIX D (CONTINUED)

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

Section 4: Information Feedback/Explicitness

This section asks questions regarding knowing what the system is doing, what actions have been taken, and what actions should be taken next.

1. Are instructions and messages displayed by the system concise and positive?

Always	Most of the time	Some of the time	Never
1	2	3	4

2. Do instructions and prompts clearly indicate what to do?

Always	Most of the time	Some of the time	Never
1	2	3	4

3. Is it clear what actions the user can take at any point?

Always	Most of the time	Some of the time	Never
1	2	3	4

4. Where there are several modes of operation, does the system clearly indicate which mode the user is currently in? (e.g.Caps Lock, Numbers Lock, Underline)

Always	Most of the time	Some of the time	Never
1	2	3	4

APPENDIX D (CONTINUED)

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

5. Where the user is presented with a list of options (e.g. in a menu), is it clear what each option means?

Always	Most of the time	Some of the time	Never
1	2	3	4

6. In general, is it clear what the system is doing?

Always	Most of the time	Some of the time	Never
1	2	3	4

7. Were you able to perform the assigned tasks to your satisfaction with the degree of feedback presented you?

Always	Most of the time	Some of the time	Never
1	2	3	4

8. Is the level of implementation of 'feedback' in the interface a factor in your overall acceptance of the interface?

Always	Most of the time	Some of the time	Never
1	2	3	4

9. On a scale of 1 to 10, where would you place the importance of 'feedback' in your "acceptance equation" for using a computer software application?

______

10. Overall, how would you rate the interface in terms of 'feedback'?

Very Satisfactory	Moderately Satisfactory	Neutral	Moderately Unsatisfactory	Very Unsatisfactory
1	2	3	4	5

APPENDIX D (CONTINUED)

DATA GATHERING INSTRUMENT FOR MATRIX EXPERIMENTS

Looking back on the interface and the questionnaire presented above and with specific regard to your acceptance of this interface as a user, how would you rate the overall implementation of the interface as presented within the context of the areas examined above?

Areas: (1) Highlighting/Enumeration
(2) Control Flexibility
(3) Guidance/Support/Help
(4) Feedback

Very Satisfactory	Moderately Satisfactory	Neutral	Moderately Unsatisfactory	Very Unsatisfactory
1	2	3	4	5

What specific factors, if any, influenced your assigned rating? Please comment below.

APPENDIX E

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

The following represent the video displays presented to the subjects for evaluation in validation experiment. Each page represents the content of the video display screen at initialization.

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

The purpose of this exercise is to present information and provide control options via this computer interface to allow you to experience the interface medium and then to provide feedback about various aspects of your interaction with the computer and its interface.

You will be asked to perform tasks with which you may possess varying levels of familiarity. You should attempt to perform the tasks to the best of your ability within the directions provided to you and the computer tools available. You will be advised when you should begin considering this exercise for the purpose of evaluation.

<u>DEPRESS THE "PAGE DOWN" KEY TO CONTINUE</u>

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

[HRt]
[TAB]The useful size of the screen is somewhat[SRt] restricted in the current mode of operation. Please[SRt] restore the screen to its maximum useful size by[SRt] following the prompt on the last line presented on this[SRT] screen.[HRt]

Press **Reveal Codes** to restore screen

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

The useful size of the screen is somewhat restricted in the current mode of operation. Please restore the screen to its maximum useful size by following the prompt on the last line presented on this screen.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

The following procedure is being prepared as a hand-out for driver education students at the high school level concerning the operation of a motor vehicle.

Preparing for Your Road Test

1. Survey the external appearance of the vehicle.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Do all lights and indicators appear intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - Fasten your seat belt.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

Upon review of the above procedure you discover several errors in the sequence of operations provided to the student. One of these is the location of the guidance to **"Fasten your seat belt".** You decide that this step belongs in **Step 2, "Getting behind the wheel".** Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use the **Keyboard Template,** the on-line **HELP F3** function or the **MENU** at the top of the screen to obtain help in performing this task. The **MENU** at the top the screen is accessed by depressing the **Alt** key.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

3. You may use any means available to you to accomplish this task including the **MOVE** function, **DELETE** function, **INSERT/TYPEOVER** function or others that you may identify.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

Preparing for Your Road Test

1. Survey the external appearance of the vehicle.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - Is there sufficient fuel in the tank?
   - Is the windshield clean and clear?
   - Do all lights and indicators appear intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.
   - **Fasten your seat belt.**

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

You have successfully completed the first portion of the exercise. Depending upon the level of familiarity you have with the particular software in use, the task may have been somewhat of a learning experience as you discovered how to use this particular editing tool. To allow you to have a broader base of experience to use in your evaluation, you will be asked to perform a similiar task again.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

Upon further review of the above procedure you discover another error in the sequence of operations provided to the student. This error is the location of the guidance to **"Is there sufficient fuel in the tank?"**. You decide that this step belongs in **Step 3, "Starting the engine."**. Your task is to correct the procedure. In performing this task, please follow the specific instructions provided below.

Specific Instructions:

1. You may use the **Keyboard Template**, the on-line **HELP F3** function or the **MENU** at the top of the screen to obtain help in performing this task.

2. Perform all of your manipulations on the copy of the procedure following these instructions.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

3. You may use any means available to you to accomplish this task including the **MOVE** function, **DELETE** function, **INSERT/TYPEOVER** function or others you may identify.

DEPRESS THE "PAGE DOWN" KEY TO CONTINUE

APPENDIX E (CONTINUED)

VALIDATION EXPERIMENT VIDEO DISPLAY PRESENTATIONS

File Edit Search Layout Mark Tools Font Graphics Help

Preparing for Your Road Test

1. Survey the external appearance of the vehicle.
   - Is the license plate attached and current?
   - Is the inspection sticker visible and current?
   - Are all tires inflated?
   - **Is there sufficient fuel in the tank?**
   - Is the windshield clean and clear?
   - Do all lights and indicators appear intact?

2. Getting behind the wheel.
   - Adjust the position of the seat to your driving position.
   - Adjust the rear and side view mirrors.
   - Insert the key into the ignition switch.
   - Check the gear shift in PARK.
   - Fasten your seat belt.

3. Starting the engine.
   - Depress the brake.
   - Depress the accelerator pedal to the floor and release.
   - Turn the key to Start until the engine starts.
   - Check the instrument panel for normal engine operating conditions.

4. Leaving the parking lot.
   - Check the path clear.
   - Depress the brake.
   - Place the gear shift in DRIVE.
   - Release the brake.
   - Depress the accelerator and steer the vehicle safely out of the parking lot.

<u>YOU HAVE COMPLETED THE EXERCISE</u>

AUTOBIOGRAPHICAL STATEMENT

Billie M. Reed was born on August 9, 1944 in Mobile, Alabama. He received his secondary education at Fairhope High School in Fairhope, Alabama. After high school graduation and five years of U.S. Naval service, he attended Auburn University in Auburn, Alabama where in 1971 he earned a Bachelor Degree in Mechanical Engineering. He graduated as Outstanding Engineering Graduate and was elected to the Honor Society of Phi Kappa Phi in recognition of his academic achievement. After completing undergraduate studies, he was commissioned as an officer in the U.S. Navy where he served in the nuclear submarine force until his retirement in 1982.

Following his retirement from military service, he began his second career as a systems engineer and human-machine interface designer for highly complex and interactive computer based systems for use by the Department of Defense. His work included aircraft, space and ship systems for control, communications, navigation, threat sensing and weapons delivery. These efforts resulted in the publication of many technical specifications, documents and drawings.

He enrolled as a part time student in the Engineering Management program at Old Dominion University in January 1984 and received his Master of Engineering Management degree in May 1987. He was again elected to the Honor Society of Phi Kappa Phi for academic achievement in graduate studies. In January 1988, he continued his education in the Doctoral Program in the Engineering Management Department as a full time student. While pursuing his doctoral studies, he worked as a Graduate Teaching Assistant and full-time instructor in the Engineering Management Department. He taught 'Engineering Economics', 'Human Factors Engineering' and 'Project Management'.