STATE ANXIETY RESPONSES AS A FUNCTION OF SPECIFIC COMPUTER INTERACTION EVENTS

by

JOHN VAVRIK

B.SC. , University of British Columbia, 1979

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS
in the Department
of
Math and Science Education
Faculty of Education

We accept this thesis as conforming to the required standard.

THE UNIVERSITY OF BRITISH COLUMBIA

September, 1987

Department of Math & Science Education

The University of British Columbia
1956 Main Mall
Vancouver, Canada
V6T 1Y3

Date 6/10/87

Abstract

The purpose of this study was to develop a model of investigating anxiety in human-computer interactions. The model was constructed from three components. Firstly, precursor conditions of anxiety were identified by assimilating several of the accepted theoretical viewpoints of the anxiety concept. Secondly, the computer-human interaction process was examined and typical events in this process were identified. Finally, a connection between the computer-human interaction process and anxiety was proposed by identifying a subset of specific interaction events that were representative of the anxiety inducing conditions. These were termed Computer-Interaction Anxiety (CIA) events. To test the validity of the model an experiment was carried out in which state anxiety data was collected while 31 subjects were engaged in an interactive computer programming session. There was a significant increase in the subjects' state-anxiety level immediately after experiencing typical CIA events.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

I. INTRODUCTION

Statement of the Problem

Advances in computer based information processing, like other technological developments, have a variety of secondary impacts in the social, economic and psychological domains. A larger number of computers and a broader scope of their application means that a larger and a more diversified spectrum of people are interacting with these machines. As the technology matures and more feedback from the users becomes available, more attention is being focused on the social and economic consequences of computerization. Some of the major issues include information privacy, loss of jobs due to automation, and general computer literacy. Very little work however has been done in researching the psychological effects of direct human-computer interaction (Ivancevich, Napier & Wertherbe, 1985). The goal of this study is to investigate one specific psychological impact of computers: The anxiety experienced as a result of direct interaction with computers.

Anxiety was selected for investigation for several reasons. Anxiety was previously found to be a major factor contributing to negative attitudes toward using computer equipment in both students and teachers (Cambre & Cook, 1985). It is also well documented that anxiety hinders performance on problem solving and reasoning tasks (Saranson, 1972). If it could be shown that working with a computer causes elevated anxiety responses in students, there would be direct implications for the vast body of research dealing with task performance in the context of the many types of computer aided instruction and computer based learning. By identifying and trying to eliminate the primary anxiety-producing factors, performance on CAI programs may be increased.

Anxiety may also hinder the learning of computer programming since in programming the interaction process is intense. Programming constitutes a major portion of most computer science curricula, from high school to the post secondary level, and the aquisition of programming skills has been shown to be a very demanding task (Dalby & Linn, 1985). It would be reasonable to assume that keeping the students' anxiety levels to a minimum would result in a more efficient and enjoyable learning of these important skills.

Finally, anxiety symptoms such as tension and nervousness have been linked to decreased work satisfaction, productivity and to increased health risks. Low productivity and high turnover rates in computer programmers is already a major concern in industry (Warrick, Gardner, Couger & Zawacki, 1985).

While the existence of computer related anxiety has been accepted, the exact nature and the sources of the anxiety have not been clearly established. The review of literature shows that two distinct approaches to the problem of computer related anxiety exist at the present time.

The first one, which is the predominant view, deals with the fear and apprehension exhibited by some novice computer users toward learning to use computer equipment (Blank & White,1985; Cambre & Cook, 1985). The fear of computers is attributed to a lack of previous exposure to the new technology and to a strong resistance to change.

The second approach is concerned with employee stress in occupations which involve extensive use of computer equipment, such as in data processing, programming, on-line communications and a host of other work sites utilizing computer automation (Brod,1985; Ivancevich, Napier & Wertherbe, 1985). Here the focus is on identifying conditions in the work place that are responsible for symptoms of chronic anxiety such as lack of energy, tension, irritability and frequent sick-leaves.

Interestingly enough, neither approach provides an explanation of computer anxiety with a direct reference to computers themselves. From the fear of computers perspective, anxiety is a function of personality traits and the amount of prior computer exposure, while the other view attributes anxiety to the structure of the work environment, for example tight schedules, lack of communication between levels of management, and poor planning for integrating new computer equipment (Brod, 1985). Yet Brod also reports that stress and anxiety symptoms were more prevalent in employees who were interacting more frequently, and more directly (coding compared to reading electronic mail for example) with computers. This would suggest that a possible source of computer anxiety may be found in the interaction process itself. Looking for causes at the level of work structure and job design may not be enough; a finer level of detail is necessary.

The level of analysis in the present study is the actual human-computer interaction process; in other words, the focus is on activities of the computer operator at the terminal and keyboard: planning and entering instructions and interpreting and evaluating computer output to carry out whatever goal the operator may have. It is in these activities themselves, that the causes of computer anxiety may have to be sought. Therefore, providing a plausible connection between the interaction process on the one hand, and the anxiety response on the other, constituted the research problem addressed by this study.

Statement of Purpose

To establish the existence of an anxiety response which results from events occuring during an interactive computer session it is necessary to have a framework for studying computer interaction anxiety. No such framework exists at the present time. The purpose of this study is to develop and validate the computer interaction anxiety model, and in doing so to provide some preliminary quantitative evidence for the existence of anxiety arising from a direct interaction with a computer system.

II. Review of Literature

Anxiety in the Psychological Literature

Anxiety is regarded as a fundamental human emotion which currently serves an important explanatory role in a variety of psychological theories of personality and psychopathology. In fact about 3500 anxiety related articles were published between 1950 and 1966 with the trend continuing at the present time (Spielberger 1976). But while anxiety research is abundant it is also characterized by a lack of theoretical and empirical agreement on the definition and causes of anxiety.

Like most psychological constructs, anxiety is viewed first and foremost as an affective response to the demands of an individual's social, cognitive or physical environment. More specifically, when the demands of the environment exceed, or are perceived to exceed an individual's ability to cope with it, the individual exhibits an anxiety response (Lazarus, 1966). It is generally considered to be a maladaptive response in the sense that the individual's ability to cope effectively with the demands of his environment is decreased as a result of heightened anxiety (Spielberger, 1976).

How does anxiety manifest itself? Anxiety is not a single response but rather a complex response set that manifests itself across different domains, including the psychological, biological and physiological. Cattell (1961) used factor analysis to isolate anxiety from effort stress, general arousal and fear. He found the anxiety factor to correlate, among others, with heightened autonomic activity including changes in heart rate, blood pressure, and galvanic skin response (GSR) as well as emotional reactions such as a high susceptability to annoyance. Selye's original investigation of stress in animals and more recently the work of Mason (1975), have drawn attention to biochemical changes as indicators of the anxiety response. This form of the anxiety response is characterized by increased activity of the endocrin system which leads to secretion of corticosteroids by the adrenal cortex and catecholamines, most notably adrenalin, by the adrenal medulla. A variety of illnesses, such as gastrointestinal ulceration have been associated with elevated levels of these substances.

State vs. Trait Anxiety. A further refinement of the anxiety response was provided by Cattell (1966) when he drew a distinction between anxiety as a trait and anxiety as a state. Anxiety as a trait is a stable personality disposition: a chronic tendency to be anxious. Anxiety state on the other hand, denotes a temporary, situational anxiety reaction that fluctuates over time and depends on particular environmental conditions. Spielberger (1966,1976) further developed the state anxiety construct by defining it "in terms of the intensity of the subjective feelings of tension, apprehension, nervousness and worry that are experienced by an individual at a particular moment". Spielberger placed a strong emphasis on the subjective perception of the emotional symptoms of anxiety. Thus while it seems clear that when people are anxious, they exhibit a number of different responses, it is the actual "anxious" experience that uniquely characterizes the anxiety state; biochemical and physiological responses are not unique indicators of anxiety since they can be generated by a variety of different conditions including physical exercise (Baum, Grunberg & Singer, 1982). Spielberger developed the State-Trait Anxiety Inventory (STAI) to assess these two distict types of anxieties. The state component of STAI is a self-rating, Likert-type instrument that measures varying levels of tension, apprehension and nervousness over transitory periods lasting several minutes (Spielberger, Gorsuch & Lushene, 1970).

Anxiety Conditions.

After conducting an extensive review of anxiety related research, Epstein (1972) identified three conditions under which anxiety develops:

Primary Overstimulation. Assuming that an organism has some upper limit of stimulus processing ability, an anxiety response ensues when this limit is exceeded. Epstein identified two conditions which will result in this excess, both being a function of the perceived stimuli. Anxiety reaction can occur when the intensity of the stimulus is above some tolerable threshold. For example being subjected to a loud, sustained tone. Overstimulation may also be reached when a large number of competing stimuli are present or when the complexity of a stimulus is high. This view is consistent with cognitive theories (Norman, 1976) which are based on a premise of limited channel capacity in information processing.

Cognitive Incogruity. This basic concept involves the idea of a fundamental need for an organized mental model of the world that matches the real world experience. If an individual cannot organize information into a consistent and meaningful framework or use that framework as a predictive model for his environment, he experiences anxiety.

Response Uncertainty. Response Uncertainty covers a number of situations in which an individual is unable to carry out some particular response that may be necessary for achievement of a goal. These situations may arise when the response is not available in the individual's repertoire of actions or when a response cannot be implemented as rapidly as may seem necessary in order to reach the desired goal.

Computer Anxiety

The research in computer related anxiety has a relatively short history, dating back only about ten years. This may be one reason for the apparent lack of an accepted paradigm or at least an established framework for the study of anxiety reported by numerous data-entry personnel, programmers and computer science students. Reported in the literature are two distinct approaches to the study of computer anxiety: one that focuses on the *a priori* fear and apprehension of novice users towards operating unfamiliar computer equipment while the other deals with job related stress and anxiety reported by experienced computer personnel in the industry. The following section summarizes the work of both camps.

Computer Anxiety as a Fear of Computers

In their survey of computer anxiety research, Cambre and Cook (1985) identify a number of operational and conceptual definitions of computer anxiety. These definitions treated computer anxiety as a form of fear, apprehension, and threat of using computers. Raub (1983) defines computer anxiety as "the complex emotional reactions that are evoked in individuals who interpret computers as personally threatening." Maurer has a similar view when he defines computer anxiety as "the fear and apprehension felt by an individual when considering the implications of utilizing computer technology, or when actually using computer technology. " Almost an identical position is held by Rohner and Simonson (1981). They define computer anxiety as "the mixture of fear, apprehension, and hope that people feel when planning to interact or when actually interacting with a computer."

Computer Anxiety in the Workplace

A preliminary qualitative investigation into the problem of computer anxiety in the industry was presented by Brod (1985) in his text "Technostress". Brod conducted numerous clinical interviews with a variety of information processing personnel complaining of fatigue, irritability, tension, headaches, nightmares and other symptoms of stress and anxiety. He also noted that these individuals displayed a resistance to learning about the machines. Their work environment was described as lacking in variety and balance. Many clients, especially those working closely with computers felt that their family and social life suffered; in fact spouses of professional programmers were often refered to as "computer widows". Stress and anxiety symptoms were most evident in people who were required to interact closely and frequently with the computer. From such observations Brod coined the term "Technostress" to denote "a modern disease of adaptation caused by an inability to cope with the new technologies in a healthy manner". A precursor to technostress is what Brod calls a "techno-centered state". Computer workers in this state can be described as fact-oriented, focused on speed and accuracy and exhibiting a low tolerance for ambiguity of human behavior and communication.

Ivancevich, Napier and Wetherbe (1985) investigated job related stress in information systems personnel of 18 major corporations. Using a survey questionnaire they first compiled a list of stressors (factors underlying stress) that were frequently cited by data processing personnel. Following a factor analysis seven stressors were identified, including communication problems, role ambiguity, reward inadequacy and work relationship patterns. The main stressor was cited as time-pressure/work overload. The authors did not provide a description of this factor, however they report that it was found to correlate significantly with two criterion measures, namely the number and the severity of health disorders for subjects exhibiting the type A stress behavior pattern which they defined as "an action-emotion complex observed in people aggressively involved in a struggle to achieve more and more in les and less time." The disorders covered by their survey instrument included temper tantrums, lack of energy and dizziness; all being common symptoms of anxiety. Their study raised some important but unanswered questions regarding the nature of the time-pressure/work overload factor. For example, is this factor due to the the job structure of data processing departments or does it stem from the actual process of interacting with the computer equipment?

The only study found that attempted to measure operator anxiety associated with actual computer interaction was done by Powers, Cummings and Talbott (1973). Four physiological correlates of anxiety were recorded while subjects used a querry language to retrieve information from a data base. These were heart rate, systolic blood pressure, diastolic blood pressure and an galvanic skin response (GSR), a technique used to infer the presence of stress and anxiety by measuring skin conductivity which is affected by the amount of moisture produced by sweat glands. The subjects were first coached in the use of the database system and immediately after that they were instructed to conduct a search for a specific item in the database. Their physiological responses were recorded several times during the session. The results showed that the greatest increase in physiological response occured during the first ninety seconds on the terminal. The amount of prior computer exposure had no significant effect on the anxiety levels. The authors did not include data obtained on subsequent interactions with the system, such as waiting for output, responding to feedback and re-entering input. No reason was given for this incomplete data analysis. A computer expert was present at all times to answer any questions the subjects may have had regarding the operation of the computer system they were using. In most natural situations this type of assistance is rarely available. The authors report that the physiological correlates of anxiety were unreliable, particularly the GSR measure They do not elaborate on why these measures are unreliable but a variety of behaviors can lead to the same physiological responses. For example running up a flight of stairs will affect all of these indicators.

The Human-Computer Interaction Process

Wickens and Kramer (1985) conducted an extensive review of research in user/machine interaction, but they did not focus on specific interaction events and processes. A few models of human-computer interaction exist for specific task domains, particularly text editing tasks (Card, Moran, Newell, 1983), but at the present time no comprehensive theoretical framework exists for describing, in general, human-computer interactions. Yet, as Norman (1983) points out, "If we intend a science of human-computer interaction, it is essential that we have principles from which to derive the manner of the interaction between person and computer." According to Norman (1983), using the computer system consists of forming an intention, choosing an action, specifying the action to the system and evaluating the outcome. This view resembles a general model of problem solving behavior developed by Newell and Simon (1972) called the General Problem Solver (GPS). GPS is essentially a means-end analysis heuristic where one specifies a goal and the means to achieve that goal, generating sub-goals in the process.

The interation process is discussed in more detail in the next section where the development of the computer interaction anxiety model is presented. In the following section it is argued that a number of specific processes and events that occur when people interact with computers may constitute the types of anxiety-provoking conditions identified by Epstein.

III. The Computer Interaction Anxiety Model

Introduction

The model presented here provides a theoretical basis for investigating computer interaction anxiety. By integrating existing anxiety research on the one hand, particularly Spielberger's state-anxiety construct and Epstein's anxiety-inducing conditions, with Norman's model of the human-computer interaction process, factors relevant to computer interaction anxiety research are identified and a relationship between them is hypothesized. Specifically, the model identifies a number of observable events that arise in the interaction process which are hypothesized to cause anxiety responses in computer operators. The complete model is illustrated in Figure 1.

Anxiety in the Model

A number of different responses are exhibited by anxious people: subjective experiences of tension and nervousness, sweating, increased heart rate, and adrenalin secretions are a few. Which of these responses then should be considered in defining anxiety? The literature does not provide a definitive answer, but given that the purpose of this study is to develop a model useful for examining why people *feel* anxious when they work with computers, the definition of anxiety adopted here must necessarily be stated in terms of an individual's subjective, emotional experience. Therefore, for the purpose of this study, *anxiety is defined as a temporary, fluctuating state of tension, apprehension, nervousness and worry subjectively experienced by an individual during a particular time interval.* The preceeding definition is the one proposed by Spielberger (1966,1976) for the state-anxiety construct.

Given this definition of anxiety, under what computer-use conditions can this form of anxiety be expected to occur? In order to properly answer this question it is first necessary to examine the interaction process that takes place between people and computers more closely.

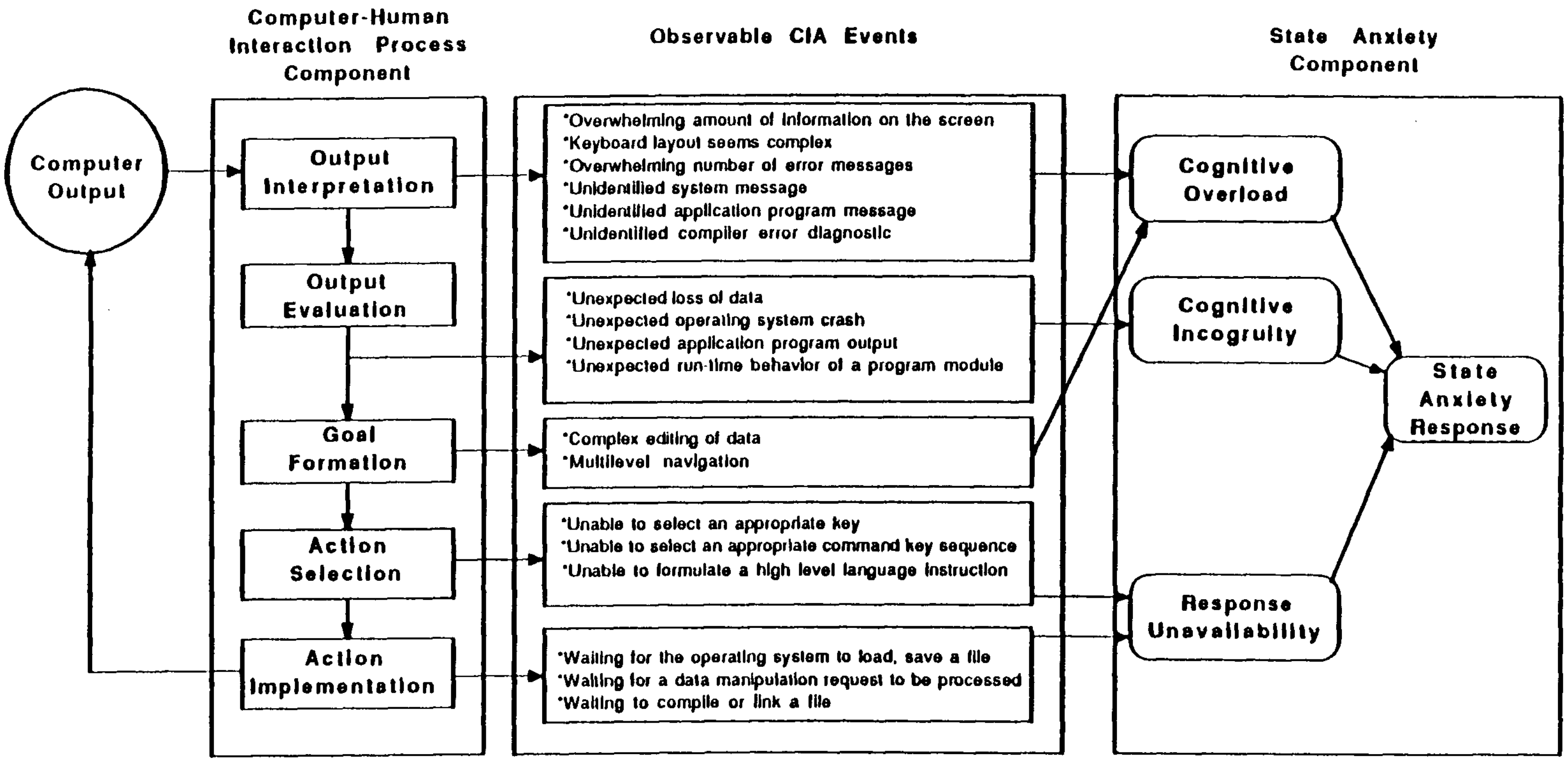

Figure 1. The Computer Interaction Anxiety Model

Human-Computer Interaction in the CIA Model

In order to identify specific events that may arise while working with a computer and that may be representative of the anxiety conditions identified in the anxiety section of the literature review, the human-computer interaction process must be analyzed in greater detail. The interaction that takes place between a human operator and a computer is not easy to define because it encompasses a broad spectrum of activities. The activities range from writing low-level machine code to setting up macro instructions for an electronic spread sheet to mouse-controlled text-editing tasks.

When attempting to characterize the interaction process, a description of user behavior as well as the behavior of the computer system is necessary. Both Norman as well as Simon & Newell base their descriptions of the interaction process on an iterative transition from some current state to a specified goal state by the application of suitable operators that reduce the discrepancy between the current and the goal states. The interaction process can also be viewed from a simple behavioristic perspective. The computer acts as a source of stimuli which cause the user to generate either appropriate or inappropriate responses. Again such behavior is directed toward some particular goal. The stimuli correspond to specific states of the computer while the responses constitute the operator's behavior. Thus the entire interaction process can be characterized by a goal directed sequence of stimulus-response pairs (Wise 1981). By utilizing the systems approach of Norman and Simon & Newell within a behavioristic context, the interaction component of the CIA model emerges:

Goal-Formation. A goal is defined as the desired state of the computer system. The exact specification of a particular goal state resides, of course, within the operator as a subjective mental image of the desired outcome. It is the user's expectation of the final outcome of his actions. Furthermore, a given task may involve the formation and subsequent completion of many sub-goals before the final goal state can be reached.

Stimulus Interpretation. This is the initial perception and interpretation of computer output, including screen text and graphics as well as printed messages and sounds.

Output Evaluation. The current state of the system is compared with the expected or desired goal or sub-goal state. If it matches the goal state the interaction process terminates. Otherwise a sub-goal is generated and the interaction proceeds.

Action-Selection. From long-term memory, the operator selects strategies for implementing the current goal. The process depends on the size of the action repertoire as well as on the access to it (Anderson, 1973).

Action-Implementation. The chosen strategy is implemented in a form that is understandable to the computer system. This involves varying degrees of control-sequence construction, depending on the complexity of the task.

The interaction process component of the CIA model combines behavioristic and cognitive approaches within a means-end analysis context. Stimulus in the form of computer output is evaluated in terms of the operator's goal. If the output does not correspond to the desired goal, a series of responses is initiated. These include selecting some action from a repertoire of a number of possible candidates that may lead to the desired result. Assuming that a selection has been made, the action must then be implemented in a way that conforms to the computer system's protocol. If the operator lacks either the appropriate knowledge or access to that knowledge, reaching the desired goal may not be possible. If, on the other hand, the implementation is successful, the action will produce a new computer state (ie. a new stimulus) which can subsequently be evaluated again. The entire process thus iterates until the final goal is reached or until the operator terminates the session. Examples of typical interaction events in terms of specific task activities are presented in Table 1.

Table 1. Examples of Observable Interaction Events

INTERACTION PROCESS	OPERATOR TASK		
	Keystroking	Using an Application	Programming
Output Interpretation	Orienting on the keyboard	Interpreting application software messages, calculations or graphics	Interpreting error diagnostics
Output Evaluation	Checking data entry accuracy	Evaluating screen output Monitoring the operating system state	Evaluating run-time behavior of program
Goal Formation	Using function keys	Moving to another module within an application	Moving to another level in the program code
Action Selection	Selecting keyboard characters	Selecting command key sequences	Selecting a high level language instruction
Action Implementation	Entering characters	Running the application	Running the program

Can activities such as goal-formation, output evaluation and action selection lead to anxiety-inducing conditions described earlier, namely cognitive overload, cognitive incongruity and response uncertainty? In this final and crucial step in the development of the CIA model, a link is hypothesized between the interaction process and the anxiety response, as defined earlier. Specifically, it is proposed that a subset of activities that may occur in the course of an interactive computer session represent instances of cognitive overload, cognitive incongruity and response uncertainty. These activities were termed computer interaction anxiety events (CIA events). It should be noted however, that the term *event* is used in a broad sense; more complex activities or processes such as unsuccessful memory searches are, in the model, regarded as events. The events considered in this study are listed in Table 2, and the rationale for their selection is discussed below.

Table 2. CIA events contributing to each anxiety condition

<u>Cognitive Overload</u>

1. Screen appears cluttered and disorganized
2. Keyboard layout appears complex
3. Performing complex file editing
4. Receiving an overwhelming number of error messages
5. Working with multiply-nested program modules

<u>Cognitive Incongruity</u>

6. Sudden, unexpected loss of files or data
7. Sudden, unexpected system crash
8. Fixing the last bug but finding that the program still does not run as expected
9. Unable to locate a bug
10. Receiving a confusing message from the system

<u>Response Uncertainty</u>

11. Forgetting commands
12. Difficulty with formulating programming statements
13. Waiting for files to load, save or copy
14. Waiting for program instruction(s) to execute
15. Waiting for program to compile

The events presented above were derived from a list of about 30 events that was compliled by the experimenter over a two year period while working as a programmer and a systems analyst in various data-processing environments. The original list included a number of event descriptions that represented similar situations. (For example "unexpected loss of data" and "unexpected loss of files"). Redundancy was reduced by shortening the list to the 15 event labels appearing in Table 2.

Cognitive overload events. Cognitive overload can arise when the amount of information contained in a particular computer output exceeds the operator's information processing capability. Thus, while learning to operate a new system, the number of new keystroke commands may be too large to hold in memory; or when programming, keeping track of diagnostic error messages may overload memory capacity. The operator may also be required to formulate many sub-goals adding to the information load. Multiple sub-goals may have to be formulated during complex data editing or when navigating between several levels of an application program such as in a hierarchical data base.

Cognitive incongruity events. Cognitive incongruity is the inability to incorporate new information into existing knowledge structures. An operator may experience cognitive incongruity in the form of unexpected or confusing feedback from the system or in encountering confusing error diagnostics. This general discrepancy between the expected and the observed state of the computer system is a direct consequence of the output evaluation taking place within the interaction process component.

Response uncertainty events. Finally, response uncertainty occurs when an operator is unable to reach a goal (or a sub-goal) because he/she is either unable to select or to implement an appropriate action. For example he/she may not be able to recall a particular command key sequence or may be unfamiliar with the instruction set of a programming language. The operator may also be forced to wait for the system to respond. As Epstein (1972) stated, having to wait before responding can be viewed as one form of inability to implement a response. Therefore being forced to wait for the computer system, be it a compiler, linker, or the operating system itself, to process instructions constitutes an observable CIA event in the response uncertainty category.

Summary of the CIA model

In summary then, the anxiety response in the CIA model is similar to the interpretations of computer anxiety as a fear of computers in that the anxiety is viewed as a temporary, fluctuating state rather than a permanent personality trait. In the CIA model however, the conditions that give rise to state anxiety are not a result of perceiving the computer as threatening but emerge instead directly from the interaction process itself.[1]

The CIA model predicts that when computer operators experience events which contribute to cognitive overload, cognitive incongruity or response uncertainty, they experience an increased level of subjectively-perceived state-anxiety response. Conversely, no increase in anxiety responses is predicted by the CIA model for operators performing a computer-based task that is free of any CIA events. This hypothesis was tested in the present study.

[1] For if people were indeed fearful of computers, their anxiety level would be expected to fall off with prolonged computer exposure, but as Powers (1973) found, the amount of prior computer exposure had no significant effect on anxiety levels. Furthermore, fear has previously been shown to be distinct from the anxiety response itself (Cattell, 1961; Lazarus, 1966)

Statement of Hypothesis

The experimental hypotheses emerge directly from the prediction of the CIA model and can be stated as follows:

1. If people experience one or more CIA events during an interactive computer session, then their level of state-anxiety will be higher compared to their anxiety level in the absence of these events.

2. When people are engaged in an interactive session free of CIA events, their anxiety is not significantly higher than their anxiety level during a relaxation period away from the computer.

IV. METHOD

Subjects and Design

Participants in this study were volunteers from three sections of an introductory computer studies course (CSED 217) offered by the Faculty of Education at the University of British Columbia. Participation in the study consisted of completing several forms of a written questionnaire which was distributed to all three sections of the course by the experimenter. A total of 50 questionnaires were distributed, 35 were returned and of those 4 were rejected because they were not properly completed resulting in a total of 31 student volunteers that completed the study. All instructions to the subjects were provided within the questionnaire. (see Appendix A)

In order to test the prediction that specific interaction events will cause state anxiety levels to increase, the absence/presence of the observable interaction events identified in the CIA model were chosen as the independent variable. All of the CIA-Events considered in the model were operationally defined. The operational definitions were in the form of simple descriptions presented to the subjects as part of the questionnaire.

Anxiety Test Instrument. Anxiety level, as measured by the A-State scale of the State-Trait Anxiety Inventory (STAI) constituted the dependent measure. The A-State scale contains 20 items that ask people how they feel by rating themselves on a Likert-type, four point scale. (see Appendix B) It measures tension, apprehension and nervousness along a continuum of increasing levels of intensity. This instument is a sensitive indicator of transitory anxiety over time intervals as short as only a few minutes. The A-Scale may be given on several occasions for which state anxiety measures are needed (Spielberger, Gorsuch & Lushene, 1970).

Pilot Study. A pilot study was carried out in order to gain a better understanding of the behavior of the independent variable (presence or absence of CIA events). Approximately 50 computer science students were observed by the experimenter as they performed various programming and editing tasks. (None of these students were included in the actual sample used for the study). Particular attention was paid to the frequency and sequencing of typical CIA events. Through these observations it became apparent that CIA events do not distribute themselves evenly across an interactive session. Instead, they tend to occur in clusters of about five to ten events lasting altogether about 15 minutes. These 15 minute event periods were then followed by about 30 minute (on the average) event-free periods where the students' work progressed smoothly. Based on these preliminary findings, the length of the time interval in which the presence or absence of the independent variable was to be recorded, was chosen to last approximately 15 minutes.

Given the operational definitions of the variables in the model, three experimental conditions were defined: (a) *Condition E.* An interactive programming session lasting approximately 15 minutes, in which one or more observable CIA events as defined above took place; (b) *Condition NE.* An interactive programming session lasting approximately 15 minutes, in which no observable CIA events, as defined above, occured; and (c) *Condition R* which was defined as relaxation away from the computer. This condition was used to establish a baseline anxiety level. Given the operational definitions of the variables in the CIA model along with the specification of the treatment conditions, the specific research hypotheses can be restated as follows:

1. *The level of state-anxiety as measured by the A-State scale experienced by subjects in the E condition will be significantly higher ($p < .01$) than in either of the NE or R conditions.*

2. *There will be no significant difference in anxiety levels ($p < .01$) between the NE and the R conditions.*

The Task. The subjects were performing a programming task which constituted their final project in the course. The individual projects varied among the subjects but all tasks involved entering, running and debuging BASIC or Pascal programs of intermediate level of sophistication. The level of programming was determined from the entrance requirements and content of the course. A regular classroom task was chosen because a laboratory task may not constitute a realistic, motivating goal. Therefore even if something was preventing the subjects from reaching a goal that was created by the experimenter, the affective response might be minimal. In other words, it is essential for the subjects to have a goal worth reaching. It was assumed that completing their individual assignments would constitute such a motivating goal.

In the questionnaire, the subjects were asked to select a time during which they expected to work at the terminal on their individual programming projects for at least one hour without any interruptions. A period of at least one hour was chosen to allow enough time for both conditions (E and NE) to take place. The subjects were also presented with the operational definitions of the CIA-Events. They were instructed to monitor their programming session, keeping track of events that matched the CIA event descriptions. If they experienced one or more of these events for about 15 minutes, they were instructed to pause in their work and to immediately complete the A-State form. Following this they were to resume their work and carry on until their activities at the terminal were free of any CIA-Events, again for a period of about 15 minutes. Following this, 15 minute event-free period (condition NE), they were once again instructed to pause and immediately fill out a duplicate A-State form. No other data was collected for the remainder of the terminal session.

Immediately after the subjects completed their computer session they were asked to indicate the type and the frequency of CIA-Events that they encountered. They did this by placing a check mark next to the operational definition of the CIA event that took place. If a particular event occured more than once, a corresponding number of checkmarks was placed next to the event description. And lastly, anxiety data for the baseline condition was obtained by asking the subjects to complete a third duplicate of the A-State scale while they were at home relaxing.

V. RESULTS

Analysis of anxiety responses.

The means and standard deviations of anxiety responses for the three conditions appear in Table 3.

Table 3. Mean anxiety response and standard deviation under three instructed conditions by 31 subjects

Condition	n	Mean	Standard Deviation
CIA-Events	31	56.87	10.39
No Events	31	30.55	7.18
Relaxation	31	35.10	8.57

Anxiety levels for the three conditions were compared using a repeated measures analysis of variance (ANOVA). There was a significant difference in anxiety responses between the three conditions, $F(2,60) = 92.72$, $MSe = 66.18$, $p < .0001$. Two orthogonal contrasts (E vs. NE and E vs. R) were then carried out to test the experimental hypothesis. The first contrast, comparing the E and NE anxiety levels (mean difference = 56.87

vs. 30.55) was significant, $F(1, 60) = 81.14$, $p<.05$. This result indicates that when CIA events occured during the programming session, there was a significant increase in the subjects' anxiety levels. The second contrast compared the anxiety level in the NE condition with the baseline level in the R condition (mean difference = 30.55 vs. 35.10). This contrast was not significant, $F(1,60) = 2.42$, $p<.05$. This means that there was not a significant difference between anxiety level experienced by subjects in the event-free portions of the programming session and their anxiety level during relaxation.

Analysis of CIA Events Profile

The CIA model identified a number specific anxiety-inducing events that are likely to occur during a typical interactive session. While these events were selected to cover a wide variety of situations, it was expected that not all of them would necessarily occur and that some would occur more frequently than others. This is in fact what happened.

Table 4. Frequencies of CIA events that occured during the session by event category.

CIA Events		FREQUENCY
Cognitive Overload		
1. Screen appears cluttered and disorganized		7
2. Keyboard layout appears complex		5
3. Performing complex file editing		20
4. Receiving an overwhelming number of error messages		28
5. Working with multiply-nested program modules		1
	Total	61
Cognitive Incongruity		
6. Sudden, unexpected loss of files or data		32
7. Sudden, unexpected system crash		3
8. Fixing the last bug but finding that the program still does not run as expected		71
9. Unable to locate a bug		91
10. Receiving a confusing message from the system		27
	Total	224
Response Uncertainty		
11. Forgetting commands		9
12. Difficulty with formulating programming statements		33
13. Waiting for files to load, save or copy		44
14. Waiting for program instruction(s) to execute		10
15. Waiting for program to compile		46
	Total	142

As can be seen from Table 4, the most frequently occuring CIA event was the inability to locate a program bug. A closely related event was the premature expectation of finding and correcting a bug only to discover that the program still did not run properly. It occured with the second highest frequency. Events that did not take place very often all involved low level keyboard commands. This result was to be expected since all the subjects were familiar with the computer system. In addition, the overall frequency of each event category was calculated (see Table 4). The results indicate that cognitive incongruity events occured most frequently while response uncertainty events occured about twice as often as events in the cognitive overload category. The raw data alone, including the high frequency of the cognitive incongrity events along with the highly significant increase in anxiety responses suggest (but in no way establish), that incongruity events in particular, are associated with high levels of anxiety. This would not be an unreasonable finding given that the mismatch between people's internal and subjectively logical representation of a situation and the actual state of the world, can be intrinsically threatening to the ego.

Before concluding this section, it is necessary to briefly discuss potential sources of error in this experiment. The primary source of error stems from a limited control over the subjects' actions, since the subjects themselves timed the 15 minute intervals and monitored the occurence of the CIA events. As a result, not all the intervals were the same length and some important CIA events may have been missed. Furthermore, because the subjects decided on their own, when to pause and fill out a form, in spite of the instructions given, their anxiety levels at the time of completing the anxiety forms might not have been indicative of their actual anxiety responses as induced by the CIA events. Another source of uncontrolled variability resulted from the heterogeneous nature of the programming tasks. Not all subjects performed tasks of equal complexity and not all of the programming assignments were at the same level of completion. Therefore given two subjects, one just about to finish his project while the other just starting, they might react differentialy to the similar CIA events. More reliable data could be obtained if all subjects performed the same task and if the experimenter observed each subject's individual progress throughout the session, monitoring the computer screen as well as the subject's behavior, and administering the anxiety measure precisely when typical CIA events took place.

VI. DISCUSSION AND CONCLUSION

The purpose of this study was to develop and test a model that could explain computer anxiety as the result of activities emerging directly from integrating with a computer. The existence of computer interaction anxiety has not been firmly established in the literature because computer anxiety investigations up to this point have concentrated on assessing and explaining fear and apprehension of inexperienced computer users on the one hand, or correlating stress and anxiety symptoms of data-processing personnnel with job related factors such as work deadlines and management pressures on the other hand. The CIA model is set apart from both of these approaches because it explains computer anxiety as a result of specific activities emerging directly from the human-computer interaction process.

In the model, anxiety can occur under three conditions arising from the interaction process: a. when the processing of the computer output exceeds the operator's information processing capacity (Cognitive overload), b. when the actual and the expected output do not match (Cognitive incongruity), and c. when the operator is unable to either formulate or implement the necessary action to achieve the desired goal (Response uncertainty). In the CIA model, each anxiety-inducing condition is manifested by a number of specific, observable events, called CIA events. They range from forgetting key command sequences to looking for but not finding a programming bug.

The model predicted that the occurence of one or more of these events would be accompanied by an increased level of anxiety. The results clearly support this hypothesis. The portions of the programming session in which CIA events occured were associated with significantly higher anxiety levels than parts of the same session free of these events. Furthermore, the event-free segments of the session were shown to be no more anxiety-inducing than relaxation base levels. In fact, the mean anxiety scores were lower in the event-free condition than scores during relaxation, although this difference was not found to be significant. One plausible but post hoc explanation for this result would be that when people perform a task and their work progresses smoothly, attention is diverted from possible anxiety provoking thoughts or images. Therefore, while it may be true that some people find computers anxiety-provoking, as some computer anxiety theorists propose (Raub 1981, Rohner & Simonson,1981), the present findings suggest that working with computers is not inherently stressful but is instead a function of specific interaction events. What then, are the implications of the present findings?

Whether a CIA event will occur or not, depends on the actual computer output and on the declarative and procedural knowledge possesed by the operator (some examples are discussed below). Computer interface design can influence the former while computer instructors are expected to develop the latter. The CIA model suggests that instructors, documentation writers and interface designers can reduce computer anxiety by reducing cognitive overload, cognitive incongruity and response uncertainty. Some examples of just how this might be done are the following:

Reducing response uncertainty. Many users get "stuck" because they cannot remember an instruction or command format, and spend a great deal of time searching, in frustration, through page after page of documentation. One way to avoid this situation is to provide instructional manuals that group all the available commands according to their function rather than listing them in alphabetical order, thus reducing search time. Another way is to provide *informative* feedback, as in an error diagnostic that also includes a suggestion of a possible action to take. For example the Pascal compiler error "incompatible assignment" could be extended to include the more helpful message "check data type declaration for variables V1 and V2". The inability to implement a response often means being forced to wait for a system to compile, link or transfer files. While system delays cannot be eliminated, one way of reducing anxiety associated with such delays would be to make them more predictable. Indeed people seem to prefer delays that have minimal variability (Rubinstein & Hersh, 1984).

Reducing cognitive overload. Keeping the amount of information that a user needs in short term memory to a minimum is one way of preventing cognitive overload. But how the information is represented must also be considered. A good example can be found in file management within MS-DOS, a widely used microcomputer operating system. Files are stored in directories which are contained in other directories which in turn can be nested within yet other directories. In order to transfer, load or save files between directories, the hierarchical nesting structure must be kept in memory. Commands such as " copy \dir5\dir4\dir3\dir2\dir1\fileF to \dir5\dir4\dir6" are not uncommon. The user's memory capacity would be much less taxed, and fewer errors would result if a hierarchical tree structure was displayed on the screen and a cursor or a mouse was used to navigate up and down the tree.

Reducing cognitive incongruity. To minimize cognitive incongruity, system feedback should be consistent with the actual state of the computer, as affected by the operator's actions. For example, the CIA event "I thought I lost some files" may occur when a "file does not exist" message is displayed and the operator interprets this as meaning that the file he needs has been erased. But often operating systems only lose access to directory files. Restarting the system or running a disk utility package often restores the access path. Another example can be found in most Pascal compilers. In Pascal, a missing ";" can result in dozens of error messages, depending on where in the program the omission occured. The reason is that everything beyond the error is incorrectly parsed by the compiler. To a programmer who has carefully and logically assembled his program, such an error message is completely unexpected and inconsistent with the rules of Pascal syntax. It is not surprising that daily encounters of this type might lead to job stress and general work dissatisfaction as reported by Brod in Technostress (Brod, 1985).

The CIA model is only the first step towards understanding and controlling computer interaction anxiety. Further work needs to be done on the relative effect on the operators' anxiety levels of the various CIA events taking place in a computer session. From the perspective of the CIA model, trying to locate a complex bug within a large program would put a greater burden on the operator's cognitive capacities than trying to remember a particular key command (ie. more sub-goals need to be formed, and more complex system feedback evaluation may be necessary). The increased cognitive overload would increase the chance of experiencing anxiety. On the other hand, programmers who debug frequently may have developed better coping mechanisms for reducing their anxiety. Thus operator characteristics, such as their experience and cognitive style must also be considered in further research. The CIA model offers an initial framework within which solutions to these problems can be sought. It identifies specific interaction events which cause people to experience anxiety, and it describes a possible mechanism underlying this process. Hopefully this will pave the way to a more humane computer interface design.

VII. REFERENCES

Anderson, J. R. (1976). Language, memory and thought. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Baum, A., Grunberg, N.E., & Singer, J.E. (1982) The use of psychological and neuroendocrinologocal measurements in the study of stress. Health Psychology, 1(3), 217-236.

Blank, S. S., & White, B. (1984). Teachers and technological innovation. B.C. Journal of Special Education, 8(1), 71-79.

Brod, (1985). Technostress. Engelwood Cliffs, N.J.: Prentice-Hall.

Cambre, M. A., & Cook, D. L. (1985).Computer anxiety: definition, measurement, and correlates.Journal of Educational Computing, 1(3), 37-54.

Card, S. K., Moran, T P. & Newell, A. P. (1983). The psychology of human-computer interaction. Hillsdale, N.J.: Erlbaum Associates.

Cattell, R. B. (1966). Anxiety and motivation: theory and crucial experiments. In C. D. Spielberger (Ed), Anxiety and behavior (pp.23-66). Academic Press.

Cattell, R. B., & Scheier, I. H. (1961). The meaning and measurement of neuroticism and anxiety. Ronald Press.

Dalbey, J. & Linn, M. C. (1985). The demands and requirements of computer programming:a literature review. Journal of Educational Computing Research, 1(3),253-270.

Epstein, S. (1972). The nature of anxiety with emphasis upon its relationship to expectancy. In C. D. Spielberger (Ed.), Anxiety:current trends in theory and research (pp.40-66). Academic Press.

Frankenhaeuser, M., & Collins, A. (1976). Underload and overload in working life: outline of a multidisciplinary approach. Journal of Human Stress, 2, 35-46.

Ivancevich, J. M., Napier, A. H., & Wetherbe, J. C. (1985). An empirical study of occupational stress and health among information systems personnel. Information & Management, 9, 77-85.

Lazarus, R. S. (1966). Psychological stress and the coping process. McGraw-Hill.

Newell, A. & Simon, H. A. (1972). Human problem solving. Engelwood Cliffs, N.J.: Prentice-Hall.

Norman, D. A. (1983). Design rules based on analyses of human error. Communications of the ACM, 4, 254-258.

Powers, W. G.,Cummings, W. H., & Talbott, R. (1973, April). The computer anxiety. Paper presented at the International Communication Association Convention, Montreal, Canada.

Raub, A. C. (1981). Correlates of computer anxiety in college students. Unpublished doctoral dissertation, University of Pennsylvania.

Rohner, D. J. & Simonson, M. R. (1981,April). Development of an index of computer anxiety. Paper presented at the annual convention of the Association of Educational Communication and Technology, Philadelphia.

Saranson, I.J. (1972). Experimental approaches to test anxiety:attention and the uses of information. In C. D.

Spielberger (Ed.), Anxiety:current trends in theory and research (pp.40-66). Academic Press.

Spielberger, C. D. (1972). Anxiety: current trends in theory and research. (2nd ed.). Academic Press.

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). Manual for the State-Trait Anxiety Inventory. Palo Also, Calif. Consulting Psychologist Press.

Warrick, D. D., Gardner, D. G., Couger, D. J. & Zawacki, R. A. (1985). Stress. Datamation, 31(8), 15-22.

Wickens, C. D., & Kramer, A. (1985). Computers and automation:the interface and the logic. Annual Review of Psychology, 36, 328-348.

Wise, W. S. (1982). Improving the user-machine inteaction. AEDS Journal, 15, 23-30.

APPENDIX A

Instructions to the Subjects

INSTRUCTIONS FOR COMPLETING THE ATTACHED FORMS

step 1

Select a time during which you expect to work on a computer for at least one hour without any significant interruptions such as staff meetings, attending lectures, etc.

As you work at the terminal things may or may not go smoothly. For example your program might crash or you might receive an unexpected message from the system. This type of situation will be called **S1** and will be defined broadly as any situation where:

a. something unexpected or undesirable happens OR
b. something unclear or confusing happens OR
c. you are repeatedly forced to wait for the computer to do something

(Look over form **FE** which describes some situations of this type.)

The opposite situation, called **S2** can be characterized as smooth, steady progress in your work.

A typical work session then, may consist of some combination of these two situations. You will be asked to indicate your feelings in each situation as you encounter it.

When you are ready to begin your computer work session follow step 2.

step 2

Begin your work and keep working until you experience either situation **S2** or situation **S1**. After experiencing either of the two situations continuously for about 15 minutes, pause and fill out form **FA1** right away.

When done resume your work and keep working until you experience the opposite situation from the one you have just gone through. After about 15 minutes of being in this opposite situation, pause and fill out form **FA2** right away.

When done just carry on until you are ready to quit your computer session.

step 3

When you finish the work fill out form **FE**.

step 4

Fill out form **FA3** when you are at home relaxing.

APPENDIX B

The A-State Scale

FORMs FA1,2,3

Circle the situation you have just experienced experienced: S1 S2

A number of statements which people have used to describe themselves are given on each of the FA forms. ***Read each statement and then circle the number to the right of the statement to indicate how you feel right now , that is , at this moment.*** There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

1= not at all 2= somewhat 3=moderately so 4=very much so

I feel calm	1	2	3	4
I feel secure	1	2	3	4
I am tense	1	2	3	4
I am regretful	1	2	3	4
I feel at ease	1	2	3	4
I feel upset	1	2	3	4
I am presently worrying over possible misfortunes	1	2	3	4
I feel rested	1	2	3	4
I feel anxious	1	2	3	4
I feel comfortable	1	2	3	4
I feel self confident	1	2	3	4
I feel nervous	1	2	3	4
I am jittery	1	2	3	4
I feel "high strung"	1	2	3	4
I am relaxed	1	2	3	4
I feel content	1	2	3	4
I am worried	1	2	3	4
I feel over-excited and "rattled"	1	2	3	4
I feel joyful	1	2	3	4
I feel pleasant	1	2	3	4

APPENDIX C

Instructions for Recording CIA-Events

FORM FE

INSTRUCTIONS:

Each box on the following two pages describes some event which you may have just experienced or that you are presently experiencing. Read each statement carefully and select those descriptions that fit the events in your S2 situation.

Place a checkmark next to the descriptions you have selected. If you have experienced some event more than once, indicate so by the corresponding number of check marks.

eg: If the computer crashed four times within the last 15 minutes, put four check marks next to the statement,
"The system crashed".

APPENDIX D

ANOVA Table For a Repeated Measures Design of 31 Subjects' Anxiety Responses

Source	df	SS	MS	F	p
Between Subjects	30	3019.25	100.64	.38	.99
Treatments	2	12272.71	6136.36	92.72	.0001
Residual	60	3970.62	66.18		
Total	92	19262.58			