Summer 1996

The Influence of Time Pressure and Information Load on Rule-Based Decision-Making Performance

Brooke Browne Schaab
Old Dominion University

THE INFLUENCE OF TIME PRESSURE AND

INFORMATION LOAD ON RULE-BASED

DECISION-MAKING PERFORMANCE

By

Brooke Browne Schaab
A.S. May 1964, Cape Cod Community College
B.S. August 1969, Old Dominion College
M.S. May 1973, Old Dominion University
M.Ed. May 1981, College of William and Mary

A Dissertation submitted to the Faculty of
Old Dominion University
in Partial Fulfillment of the
Requirement for the Degree of

DOCTOR OF PHILOSOPHY

INDUSTRIAL/ORGANIZATIONAL PSYCHOLOGY

OLD DOMINION UNIVERSITY
August 1996

Approved by:

Glynn D. Coates (Director)

Raymond H. Kirby (Member)

J. Raymond Comstock, Jr. (Member)

ABSTRACT

THE INFLUENCE OF TIME PRESSURE AND INFORMATION LOAD ON RULE-BASED DECISION-MAKING PERFORMANCE

Brooke Browne Schaab
Old Dominion University, 1996

Director: Dr. Glynn D. Coates

Performance was evaluated under varying levels of time pressure and information load to determine their influence on simple rule-based decision-making. Consistent errors, biases, and heuristics found in human decision-making have been attributed to attempts to reduce attentional demands and to the limitations of working memory. Do these same mistakes occur when little or no demand is placed on working memory and the decision is made by following a set of simple rules? Using a simulation of a radar operator's task, 96 participants monitored a display for 24 min. Time pressure was manipulated by increasing or decreasing the number of aircraft to be monitored. Information load was controlled by the amount of information required to make a decision on whether the aircraft was a "friend" or an "enemy." Increases in time pressure resulted in a decrease in reaction time (RT) and an increase in the percent of aircraft identified correctly until the

highest level of stress where RT increased and percent of aircraft correctly identified decreased. Increases in information load resulted in longer RT and a decline in the percent of correct identifications in three of the four conditions. In general, performance improved as time pressure increased rather than decreased over the task. Overall, performance was best under low levels of information load, moderate levels of time pressure, and when the task progressed from low-to-high levels of time pressure, rather than the reverse. Support was found for anchoring or confirmation bias.

TABLE OF CONTENTS

PAGE

LIST OF TABLES vi

LIST OF FIGURES vii

SECTION

1. INTRODUCTION 1

Decision-Making Theory 2
Stress and Decision-Making 4
Time Pressure 7
Decision-making Complexity 9
Order Effects in Decision-Making 10
Summary 13

2. METHOD 16

Design 16
Subjects 17
Apparatus 17
Procedure 18

3. RESULTS 22

Performance Results 23
Time pressure.................. 24
Information load............... 26
Gender......................... 27
Performance by half of task..... 28
Time pressure and information load......................... 28
Time pressure and order of presentation.................... 29
Half and time pressure.......... 33
Half, time pressure, and order of presentation........... 33
Workload and Selected Independent Variables 35
Anchoring Bias 37

SECTION PAGE

4. DISCUSSION 39

Time pressure.......................... 39
Information load....................... 41
Time pressure and information load.... 43
Additional findings................... 44
Anchoring bias......................... 48

5. CONCLUSIONS.................................. 49

REFERENCES 52

APPENDIXES

A. Research Design 66
B. Representation of the Task 67
C. Directions to Participants 68
D. Analysis of Variance Results for the Total Number of Aircraft Displayed 69
E. Analysis of Variance Results for the Performance Measures 70

VITA... 75

LIST OF TABLES

TABLE PAGE

1. Main Effects for Time Pressure 24

2. Analysis of Variance Table for Significant Findings 25

3. Main Effects for Information Load 27

4. Main Effects for Gender 28

5. Main Effects for Half of Task 29

6. Anchoring Bias and the Number of Errors 38

LIST OF FIGURES

FIGURE PAGE

1. The interaction of time pressure and information load for the number of aircraft acquired and the number correct of those acquired. $p < .05$ 30

2. Interaction of time pressure and order of presentation. $p < .05$. 32

3. Interaction of time pressure and half of task. $p < .05$. 34

4. Three-way interaction of time pressure, half of task, and order of presentation (ascending or descending). $p < .05$. 36

INTRODUCTION

Researchers have identified a number of factors that contribute to human errors, including time pressure and information load. In an attempt to reduce errors, researchers have developed systems that can perform complex functions while providing a simplified human interface with the process. Decisions can be made by following a preestablished set of rules. Pilots routinely follow checklists to ensure that systems are functioning correctly, power plant operators follow written standard operating procedures for both routine and emergency situations, and the average consumer can follow on-screen instructions for programming a VCR. Operators of these systems make decisions by following simple rule-based decision-making routines, yet errors do occur, particularly when the operator is under stress. The ability of technology to improve performance is limited by human error (Billings, 1991; Billings & Reynard, 1984; Chappelow, 1989; Freeman & Simmon, 1991; Huntoon, 1985; Jonsson, 1991; Nagel, 1988; Wickens, 1992). Further reductions in errors will involve a more complete understanding of the human component.

Decision-Making Theory

The understanding of the decision-making process sometimes is confusing because of the diverse and independent fields that contribute to the knowledge base, including: clinical, psychophysiological, personality, and social psychology; human factors; and contemporary judgment and decision-making theory (Hammond, 1988). Furthermore, decision theory has undergone several dramatic changes since its beginnings with the development of Bayesian or normative decision theory. Normative theory addresses how to make the optimal decision, but the research demonstrates that humans do not make optimal decisions (Bell, Raiffa, & Tversky, 1988; Fishburn, 1988; Luce & Raiffa, 1957).

In 1957, Simon's investigations indicated that humans do not follow the normative theory when making decisions, which led to his hypothesis of the rational decision maker. Rational decision makers do not select the optimal choice but examined the alternatives until an option is found that meets his/her requirements. Rationality is tempered by time limits and the limited processing capacity of the decision maker (Simon, 1988).

Subsequently, investigators turned their attention to behavioral or descriptive decision-making, which emphasized the types of decisions made and the reasons behind these decisions (Beach, 1993; Bell et al., 1988; Payne, 1982; Tversky & Shafir, 1992; Woods & Roth, 1990).

These theories advanced the notion that seeking and processing information lies at the heart of decision-making. Human decision-making involves: (1) Acquiring and processing information; (2) making a decision based on the information acquired and the goals involved; and (3) carrying out that decision (Nagel, 1988; Wickens & Flach, 1988).

Throughout this extensive research on decision-making, little attention has been focused on making routine decisions. In routine or rule-based decision-making the information needed to make a decision is analogous to following a cookbook recipe, with no need for reasoning or planning (Rasmussen, 1983). Rule-based decision-making may appear to be a deceptively simple task. Degani and Wiener (1990, 1993) in their study of pilots following routine checklists, commented on the number of times participants questioned the need to examine something as "simple and straightforward" as normal checklists (p.2). Several studies supported the need for investigation. Freeman and Simmon (1991), in an analysis of 244 airline incidents, found that crew compliance with written checklists and standard operating procedures could have prevented an overwhelming majority of the errors reported. Schofield and Griffin (1982) had reached a similar conclusion. In 1989-90 three aviation accidents over a period of 15 months resulted from the misuse of checklists ("FAA revokes pilot licenses", 1990). More recently, failure to follow a checklist is reported to have contributed to the death of 160 people when an American Airlines plane slammed into a mountain in Colombia ("Crew was busy-chatting", 1995).

Although decision-making has been investigated extensively, little research has concentrated on routine, rule-based decision-making. Using a written set of rules to make decisions is a common activity in a variety of occupations as well as in everyday life. The problems identified in the aviation industry highlight the need for further investigation of routine, rule-based decision-making under a variety of conditions. The current study investigates errors made when following a prescribed set of criteria.

Stress and Decision-Making

A stressor is something perceived by the person to be stress inducing (Svenson & Edland, 1989). Stressors have been found to influence the decision-making process, generally by degrading performance (Bell et al., 1988; Ben Zur & Breznitz, 1981; Billings, 1991; Billings & Reynard, 1984; Broadbent, 1971; Einhorn & Hogarth, 1987; Hockey, 1986; Hogarth, 1989; Hogarth & Kunreuther, 1990; Kahneman & Tversky, 1979; Rasmussen, 1986; Tversky & Shafir, 1992; Wickens & Flach, 1988).

Many variables have been found to produce stress, including too little or too much time, (Ben Zur, & Breznitz, 1981; Coates & Schaab, 1990; Entin & Serfaty, 1990; Hockey, 1986; Janis & Mann, 1977; Weltman, Smith, & Egstrom, 1971), the amount and quality of information available (Broadbent, 1971; Corbin, 1980; Driskell & Salas, 1991; Keinan, 1987) and the type of information to be processed (Dressel, Logan, Groce, & Boucek, 1992; Hogarth, 1989; Hogarth & Kunreuther, 1988; 1990; Lee, 1991; Svenson & Edland, 1989; Tolcott & Marvin, 1988; Tversky & Kahneman, 1985; Tversky & Shafir, 1992; Wickens, Stokes, Barnett, & Hyman, 1988; Wickens, Stokes, Barnett, & Hyman, 1989).

The influence of various stressors on performance has been a prevalent topic in human factors and information processing research. The seminal law of Yerkes-Dodson (1908) proposed that both high and low levels of perceived stress degrade performance, with optimal performance occurring at some intermediate level. Low levels of stress resulted in low arousal, while high levels produced the narrowing of attention (Easterbrook, 1959). Much of the early research on stress centered on physical stressors (Broadbent, 1971; Easterbrook, 1959; Hockey, 1986). The predominant researchers in the area arrived at similar conclusions about the influence of stressors on performance. Broadbent (1971), Easterbrook (1959), and Hockey (1986) found that under stress:

1. less information was processed,
2. information was scanned in a nonsystematic manner,
3. reaction time decreased (premature closure),
4. errors increased,
5. working memory decreased,
6. and the most salient cues (cognitively or physically) were processed.

Other researchers report similar results, particularly those utilizing the heuristics of Kahneman and Tversky (1973), (Clothier, 1991; Cowen, 1952; Evans, 1979; Janis & Mann, 1977; Kahneman & Tversky, 1973; Keinan, 1987; Keinan & Friedland, 1987; Stokes, Barnett, & Wickens, 1987; Svenson & Edland, 1989; Watchel, 1967; Weltman et al., 1971; Wickens, 1992; Wickens, Stokes, Barnett, & Hyman, 1993; Wickens et al., 1988; Wright & Weitz, 1977).

Hogarth and Einhorn (1992) produced contradictory findings. They proposed that reaction time increased as the decision-making process became more difficult in terms of the amount of information to be processed due to an increase in sampling of the information in an unsystematic manner and a reluctancy to make a decision.

Despite the plethora of research on the influence of stressors on performance, most of these studies involved decision-making under uncertainty, used physical stressors, or they required the participants to provide subjective weights to different amounts of information. Again, there is limited information on human decision-making under varying levels of stressors when the rules for making a decision are stated explicitly.

Time Pressure

Svenson and Edland (1989) defined time stress as "a discrepancy between what a person would like to do or feels he/she should do and, what he/she actually finds time to do" (p. 225). Time pressure, like stress, can be subjective, with different persons experiencing different amounts of time pressure for the same task.

Svenson and Edland (1989) presented three possible strategies of cognitive processing when dealing with time pressure:

1. Speed up the process to complete the task;
2. Continue at the same rate of processing and not complete the task;
3. Alter the manner of processing the task in some way.

They found that most subjects altered their cognitive processing in some way under time pressure. Similarly, others have found that decision makers modified their cognitive processes under time pressure by simplifying information (Entin & Serfaty, 1990; Volta, 1986; Wright, 1974). They accomplished this by using fewer attributes, placing greater emphasis on negative attributes (Beach, 1993; Beach & Mitchell, 1987; Beach & Storm, 1989; Smith, Mitchell, & Beach, 1982;) and by selecting simpler and/or more erratic strategies to make the decision (Christen-Szalanski, 1980; Einhorn, 1971; Rothstein, 1986; Wallsten & Barton, 1982; Wright, 1974; Zakay, 1985). Also, the majority of subjects made a different decision when placed under time pressure, than when time was not a factor (Zacky, 1985). They attributed this change to the participants placing more weight on the negative aspects of the attributes, which allowed them to eliminate certain choices early in the decision-making process.

Research has not always supported the detrimental influence of time pressure on decision-making. Contrary to the findings above, subjects under time pressure have been found to process more rather than less information (Entin & Serfaty, 1990); to show no decline in performance on a cognitive matching task involving attention span (Rothstein, 1986); and to adapt their performance to the changes (Coury & Drury, 1986; Payne, Bettman, & Johnson, 1990). Restriction of time to complete a task may help focus attention and mobilize resources to complete that task.

The research suggests that there is no definitive answer to the influence of time pressure on performance. The subjective nature of what causes individuals to experience stress, as well as the multiple stressors used in research, may have contributed to these diverse findings. The question of how time pressure affects rule-based decision-making is unanswered.

Decision-Making Complexity

The amount of information that needs to be processed prior to making a decision has been found to be an aspect of the complexity of the task (Dawes, 1979; Rasmussen, 1986; Tversky & Shafir, 1992; Wickens, Pizarro & Bell, 1991; Wright, 1974). Also, information load is influenced by whether or not the information needed has to be externally retrieved, retained in memory, or is permanently displayed (Sundstroem, 1989).

Wickens et al., (1987) determined that working memory predicted performance on novel problems of decision-making, with no difference found in performance between the novice and expert, although the experts reported more confidence in their decisions. In a follow-up study, Wickens et al., (1993) confirmed that stress did not degrade the performance of experts when the decision required procedural knowledge or long-term memory. They did not explore performance differences on novel tasks that did not use procedural knowledge or did not place demands on working memory.

Order Effects in Decision-Making

Kahneman and Tversky's research on common heuristics and biases has had a considerable influence on decision-making research. Investigations of these pervasive heuristics and biases have shown consistent patterns of errors between individuals and tasks (Jonsson, 1991; Kahneman & Tversky, 1973; Tolcott, Marvin, & Lehner, 1989; Tversky & Kahneman, 1974). For example, it appears reasonable that they will make better decisions when provided with more information. Under time pressure and information load, people have been found to make poorer decisions as more information is provided (Wright, 1974). In another example, researchers proposed that we begin the decision-making process by developing a hypothesis or anchor, and that we modify that anchor based on new information. Once they form a hypothesis, people become fixed on one solution and seek information to confirm that hypothesis, ignoring contradictory cues, particularly under stress (Adleman, Tolcott, & Bresnick, 1991; Barnett, Stokes, Wickens, Davis, Rosenblum, & Hyman, 1987; Sheridan & Ferrell, 1974; Tolcott & Marvin, 1988; Tversky & Kahneman, 1971, 1974, 1985; Wickens, 1992). Therefore, if the first cue indicated that a certain response was required, people would be more likely to interpret subsequent cues as evidence for a response. Similarly, Tolcott et al., (1989) found this anchoring bias in their research using military personnel participating in "War Games." These professionals reported high confidence in their initial hypothesis and increased their confidence in that decision despite receiving new information that was contradictory. When the same information was presented in a different order, the personnel focused on a different hypothesis and again were confident in their decision. Schofield and Griffin's (1982) investigation of 244 airline incidents indicated that almost half the errors involved more than one crew member. They suggested that the initially reported information may have biased what the second crew member "saw."

Additional research related to the anchoring bias found that once a person made a decision they reported more certainty in their response than justified as additional and, sometimes disconfirming evidence, was presented (Arkes & Harkness, 1980; Cowen, 1952; Fischoff, 1977; Samuelson & Zeuckhauser, 1988). Wickens et al., (1988) reported contrary findings. They found that under stress people tended to have less confidence in their decisions.

Several studies suggested that the anchoring bias could be reduced or eliminated when all of the necessary information was displayed at one time in order to make a decision. Because there was no memory load, a person examined each piece of information equally and did not need to establish an anchor to reduce the information load (Hogarth & Einhorn, 1992; Payne, Braunstein, and Carroll, 1978).

Tversky and Kahneman's studies of heuristics and biases in decision-making indicated that persons gave prominence to the first piece of information received and gave less weight to subsequent information. Hogarth and Einhorn's (1992) theory proposed no order effects or anchoring if the information is presented in total rather than sequentially.

Summary

Factors that contribute to errors in rule-based decision-making have received limited attention in the research literature. Do the same types of errors and biases that transpire with complex decision-making occur with routine decision-making, when the person is not required to call on long-term or working memory, and when all of the information needed to make the decision is displayed continuously?

The purpose of this study was to examine performance on rule-based decision-making under varying levels of time pressure and information load. The task was novel: therefore, long-term memory of procedural knowledge was not a factor. Also, the information needed to make a decision was displayed continuously to minimize the load on working memory.

People modify the manner by which they make rule-based decisions under varying levels of time pressure and information workload. This study used a simplified air traffic controller simulation to study these variables. The task involved acquiring aircraft using a computer mouse and identifying them as a "friend" or as an "enemy."

The following hypotheses were proposed:

1. At high levels of time pressure, reaction time decreases. The number of aircraft acquired, the number identified correctly, and the percent of aircraft correctly identified decreases over time due to the reduced intake and/or processing of information.
2. At high levels of information load, reaction time increases over time, but the percent of aircraft identified correctly does not increase over moderate levels of information load. This is because there is no increase in working memory requirements.
3. High levels of time pressure and information load result in declines in performance under time

pressure, but no decline under high levels of information load. At low levels of time pressure and information load there is no difference in performance.

4. When using multiple criteria for making a decision, the first piece of information displayed influences the final decision more than other information. If the first piece of information supports a response while subsequent information indicates an alternate response is appropriate, more errors occur than if the additional criteria support the first response.

METHOD

Design

A factorial design included the following independent variables: four levels of time pressure (4, 8, 12, and 16 aircraft to monitor); four levels of information load (1, 2, 3, or 4 criteria used to determine the status of the aircraft); two levels of gender; two levels of time (first and second half); and two levels of order of presentation of the number of aircraft to be monitored (ascending or descending number of aircraft). The design is presented in Appendix A. The between-subjects independent variables were the number of criteria used for making a decision, gender, and presentation order (descending and ascending). The within-subjects independent variables were the number of aircraft displayed and the first and second half of the task. Dependent measures included the number of aircrft acquired, the number correctly identified of those acquired, the percent of aircraft acquired, the percent of aircraft acquired and correctly identified, and reaction time. Information on the total number of aircraft displayed, was obtained to confirm that the task was performing as intended. An ANOVA was performed to determine the influence of time pressure and information load on performance.

A second ANOVA examined the relationships between the same independent variables mentioned above, and the results from the TLX.

A chi-square statistic was used to indicate if anchoring bias occurred. If the first criteria indicated a "friend", but subsequent criteria indicated an "enemy", then the correct response would be "enemy." Would more errors occur than expected by chance when the first criteria indicated a "friend" when the final decision was an "enemy?"

Subjects

Ninety-six undergraduates (48 males and 48 females) participated in this experiment. They received extra credit points in their courses for participating. Vision was not tested, but all subjects reported normal-or-corrected to normal visual acuity. The university's Human Subjects Institutional Review Board reviewed and approved the use of human subjects. A copy of this approval is located in the Department of Psychology.

Apparatus

The task was presented using a 386-DX microcomputer with a 14-inch VGA color monitor. The computer recorded the level of the independent variables, which included the number of aircraft appearing on the display, the amount of information required to make a decision, subject's gender, and first or second half of the task. Also, the dependent or performance variables were recorded and compiled via computer.

The NASA-Task Load Index (TLX; Hart & Staveland, 1988) was administered at the midpoint and at the conclusion of the task, provided a subjective measure of a workload. The TLX is a multidimensional rating scale consisting of six subscales, mental demand, physical demand, temporal demand, performance, effort and frustration. The first three subscales are associated with the task, while the last three describe the interaction of the subject and the task.

Procedure

Individual students simulated radar "spotters" in a surveillance aircraft who monitored a computer display to identify aircraft in the area as a "friend" or an "enemy." A representation of the task and directions to the subjects are located in Appendix B and Appendix C, respectively. The center of the computer screen displayed a small red circle representing an aircraft carrier. Black squares, representing aircraft, traveled toward the carrier at a speed of .5 mm/sec. Participants used a mouse to click on these "aircraft." Acquiring the aircraft resulted in the appearance of a display box on the screen containing four criteria for making a decision: type of aircraft (Jet or Prop); altitude; speed; and identification number. The order of the information presented remained constant. The participant's task was to use either one, two, three, or four criteria displayed to make the decision on whether the aircraft was a "friend" or an "enemy." For each participant the number of criteria used to make a decision (one, two, three, or four) remained constant throughout the task, although all four criteria appeared. The criteria used was displayed on an index card throughout the session. An "enemy" was identified when all criteria used to make the decision indicated an "enemy." The number "1" key was pressed if the criteria were met for identifying an "enemy." If the criteria were not met, the number "2" key was pressed, indicating a "friend." Each respondent encountered 4, 8, 12, and 16 aircraft displayed on the screen for 3 min each. Every participant encountered both the ascending and descending condition of the number of aircraft displayed. Therefore, the order was 4, 8, 12, then 16 aircraft displayed or 16, 12, 8, 4 aircraft displayed. The order, ascending or descending, was counterbalanced. After 12 min, all four levels of the number of aircraft displayed (4, 8, 12, and 16 OR 16, 12, 8, and 4) were experienced. Participants took a short break then completed the TLX. The last 12 min of the task repeated the first 12 min except that the number of aircraft on the screen was presented in the reverse order. The TLX was readministered at the conclusion of the last 12 min segment.

Participants received feedback on their performance through two lines, one red and one green, in the lower left-hand corner of the monitor. Each time a plane reached the carrier without being acquired (clicked on with the mouse) the red line became longer, if a plane was acquired, the green line became longer. The lines did not indicate correct and incorrect responses. Additional feedback occurred from an auditory tone when an aircraft reached the carrier without being identified. The researcher remained in the room while the task was perfor for as long

as the l participants

did no inability to

use a

ving the

number (between-

subjec d by using a

diffe g the aircraft

as a s).

performed. Participants practiced the task for as long as they felt was necessary. Three potential participants did not complete the task because of their inability to use a mouse.

Time pressure was produced through varying the number of aircraft that required monitoring (between-subjects). Information load was manipulated by using a different number of criteria for identifying the aircraft as a "friend" or an "enemy" (within-subjects).

RESULTS

Decision-making performance was assessed in the present research using the dependent variables of (1) number of aircraft acquired, (2) percent of aircraft acquired of those displayed, (3) number of aircraft correctly identified, (4) percent of aircraft correctly identified, and (5) reaction time. These measures were examined as a function of the independent variables of (1) time pressure, (2) information load, (3) gender of the participant, (4) order of time pressure, and (5) half of the task session. The time pressure variable was manipulated by the number of aircraft presented to the participant with four levels of 4, 8, 12, and 16 aircraft. The information load variable was varied by the number of criteria required in making the decision with four levels of 1, 2, 3, and 4 criteria. Two levels or order of time pressure were presented as either "ascending," with 4, 8, 12, and 16 aircraft presented, respectively or "descending," with 16, 12, 8, and 4 aircraft, respectively. Participants received both orders in a counterbalanced presentation, with half of the subjects beginning with an ascending order and half with a descending order. Primary analysis was performed using a 4 (time pressure) x 4 (information load) x 2 (gender)x 2 (order) x 2 (half) mixed design ANOVA with gender, order, and information serving as between-subjects variables. Both time pressure and half, served as within-subject variables. Post hoc comparisons were computed using Tukey's hsd. Alpha levels of 0.05 were used throughout.

A second ANOVA examined the relationship between the independent variables cited above and a self-report of subjective workload obtained from the Task Load Index.

Anchoring or the tendency to place more emphasis on the first criterion received in making a decision was investigated. The chi-square statistic was used to learn if more errors than expected occurred when the first criterion evaluated suggested a response that differed from the final decision.

Performance Results

Appendix D shows that the total number of aircraft displayed increased with increases in time pressure and information load.

Only significant findings are reported in the results section of the text. The complete ANOVA tables are located in Appendix E.

Time pressure. Time pressure was varied by increasing or decreasing the number of aircraft that appeared on the display for identification. The ANOVAs revealed significant main effects between time pressure and (a) the number of aircraft acquired ($F(3,240)=188.16$, $p<.05$), (b) the number correct of those acquired ($F(3,240)=144.45$, $p<.05$), (c) the percent acquired ($F(3,240)=535.02$, $p<.05$), (d) the percent correct of those acquired ($F(3,240)=3.38$, $p<.05$), and (e) reaction time ($F(3,240)=20.74$, $p<.05$). The main effects and the Tukey's hsd results for time pressure are shown in Table 1 and the significant effects for the ANOVA are shown in Table 2.

Table 1

Main Effects for Time Pressure

Dependent Variables	Number of Aircraft Displayed			
	4	8	12	16
Number Acquired	52.94_a	60.30_b	64.58_c	63.92_c
Number Correct	49.33_a	56.28_b	60.05_d	58.91_c
Percent Acquired	98.51_a	92.39_b	82.03_c	70.08_d
Percent Correct	92.91_a	93.00_a	92.96_a	91.59_b
Reaction Time (s)	1.38_a	1.21_c	1.17_c	1.28_b

Note: Means in the same row that do not share subscripts differ at $p<.05$ in the Tukey hsd comparison.

Table 2

Analysis of Variance Table for Significant Findings

Number Acquired

Source	DF	Anova SS	Mean Square	F Value	Pr > F
NUMDEC	3	51342.1081	17114.0360	18.99	0.0001
HALF	1	23552.0951	23552.0951	421.62	0.0001
G	1	5901.8763	5901.8763	6.55	0.0124
NUMPLN	3	16404.6706	5468.2235	188.16	0.0001
NUMDEC*HALF	3	465.9831	155.3277	2.78	0.0463
HALF*G	1	2.4076	2.4C76	0.04	0.8361
NUMDEC*NUMPLN	9	815.0021	90.5580	3.12	0.0015
HALF*NUMPLN	3	1024.2122	341.4041	18.23	0.0001
NUMPLN*ODR	3	2309.4935	769.8312	26.49	0.0001
HALF*NUMPLN*ODR	3	5186.5768	1728.8589	92.31	0.0001

Number Correct of Those Acquired

Source	DF	Anova SS	Mean Square	F Value	Pr > F
NUMDEC	3	63228.8021	21076.2674	26.24	0.0001
HALF	1	21231.0469	21231.0469	348.94	0.0001
G	1	3960.3333	3960.3333	4.93	0.0292
NUMPLN	3	13312.7813	4437.5938	144.45	0.0001
NUMDEC*NUMPLN	9	926.9792	102.9977	3.35	0.0007
HALF*NUMPLN	3	977.19271	325.73090	14.62	0.0001
NUMPLN*ODR	3	2516.3594	838.7865	27.30	0.0001
HALF*NUMPLN*ODR	3	4310.88542	1436.96181	64.48	0.0001

Percent Acquired

Source	DF	Anova SS	Mean Square	F Value	Pr > F
HALF	1	0.33506892	0.33506892	82.12	0.0001
G	1	0.46345508	0.46345508	9.32	0.0031
NUMPLN	3	8.95211268	2.98403756	535.02	0.0001
HALF*NUMPLN	3	0.08492448	0.02830816	13.41	0.0001
NUMPLN*G	3	0.12343115	0.04114372	7.38	0.0001
HALF*NUMPLN*ODR	3	0.05328072	0.01776024	8.42	0.0001
NUMDEC*HALF*G	3	0.02772257	0.00924086	4.38	0.0051

Percent Correct

Source	DF	Anova SS	Mean Square	F Value	Pr > F
NUMDEC	3	0.89703353	0.29901118	24.34	0.0001
NUMPLN	3	0.02684801	0.00894934	3.38	0.0189
NUMPLN*ODR	3	0.02408035	0.00802678	3.03	0.0299
NUMDEC*HALF*G	3	0.02763378	0.00921126	4.01	0.0082

Reaction Time

Source	DF	Anova SS	Mean Square	F Value	Pr > F
NUMDEC	3	147.4788330	49.159611	34.03	0.0001
HALF	1	38.9939333	38.9939333	168.81	0.0001
NUMPLN	3	4.9859935	1.6619978	20.74	0.0001
NUMDEC*HALF	3	16.4486239	5.4828746	23.74	0.0001
HALF*NUMPLN	3	1.4630926	0.4876975	6.51	0.0003
NUMPLN*ODR	3	10.6603045	3.5534348	44.34	0.0001
NUMDEC*HALF*NUMPLN	9	1.3180303	0.1464478	1.96	0.0453
HALF*NUMPLN*ODR	3	20.9805606	6.9935202	93.36	0.0001
NUMDEC*HALF*G	3	0.6450520	0.215017	2.87	0.0371
NUMDEC*NUMPLN*ODR	9	5.8143230	0.646036	8.06	0.0001

Note. The abbreviated variables are defined as follows: NUMDEC= number of criteria used to make a decision (information load); NUMPLN= the number of aircraft displayed on the screen (time pressure); ODR= order of presentation (ascending or descending); G= gender; and HALF= the first or second half of the task. The complete ANOVA results are located in Appendix E. $p<.05$.

As time pressure increased, the number of aircraft acquired and the number correct increased until the highest level of time pressure, where performance did not change or it declined. The percent of aircraft acquired decreased as time pressure increased, but the percent correct of those acquired did not decrease until the highest level, where 16 aircraft were displayed. Reaction time was the longest when 4, then 16 aircraft appeared on the display to be identified, but no difference occurred between 8 and 12 aircraft displayed.

Information load. Information load was produced by requiring participants to use one, two, three, or four criteria when making a decision (between subjects variable). The ANOVA revealed that the main effects were significant for (a) the number of aircraft acquired ($F(3,240)=18.99$, $p<.05$), (b) the number of aircraft identified correctly of those acquired ($F(3,240)=26.24$, $p<.05$), (c) the percent correct of those acquired ($F(3,240)=24.34$, $p<.05$), and (d) reaction time ($F(3,240)=34.03$, $p<.05$). The significant main effects and post hocs are located in Table 3, while the ANOVA findings are presented in Table 2.

Overall, as the number of criteria needed to make a decision increased, a decrease was seen in the number of

Table 3

Main Effects for Information Load

Dependent Variables	Number of Criteria Used 1	2	3	4
Number Acquired	72.09_a	62.47_b	57.67_b	49.50_c
Number Correct	70.37_a	55.32_b	53.71_b	45.17_c
Percent Correct	97.73_a	88.37_c	93.22_b	91.14_b
Reaction Time (s)	0.73_d	1.02_c	1.39_b	1.90_a

Note. Means in the same row that do not share subscripts differ at $p<.05$ in the Tukey hsd comparison.

aircrafts acquired and the number correct of those acquired, while reaction time increased. Performance measures for the percent correct varied, with the highest percent correct when using a single criterion, followed by three and four criteria, while the lowest percent correct occurred with two criteria.

Gender. Significant differences were found in performance by gender (see Tables 2 and 4). Males (a) acquired more aircraft ($F(1,80)=6.55$, $p<.05$), (b) identified a higher number correct of those identified ($F(1,80)=4.93$, $p<.05$), and (c) acquired a higher percent of the aircrafts displayed ($F(1,80)=9.32$, $p<.05$) then did females.

An interaction of gender by the number of aircraft displayed occurred on the dependent variable percent acquired ($\underline{F}(3,240)=7.38$, $\underline{p}<.05$). The percent acquired for males was greater than for females in all except the lowest level of time pressure, where performance did not differ.

Table 4

Main Effects for Gender

Dependent Variables	Male	Female
Number Acquired	63.21	57.66
Number Correct	58.41	53.87
Percent Acquired	88.21	83.30

Note. $\underline{P} < .05$.

Performance by half of task. Performance differed between the first and the second half of the task in (a) the number of aircraft acquired ($\underline{F}(1,80)=421.62$, $\underline{p}<.05$), (b) the number correct of those acquired ($\underline{F}(1,80)=348.94$, $\underline{p}<.05$), (c) the percent acquired of those displayed ($\underline{F}(1,80)=82.12$, $\underline{p}<.05$), and (d) reaction time ($\underline{F}(1,80)=168.81$, $\underline{p}<.05$). Performance improved during the second half in all areas except percent correct of those acquired (see Tables 2 and 5).

Time pressure and information load. Significant interactions occurred between time pressure and information load and the dependent variables, the number of aircraft acquired ($\underline{F}(9,240)=3.12$, $\underline{p}<.05$) and the number correct of those acquired ($\underline{F}(9,240)=3.35$, $\underline{p}<.05$).

Table 5

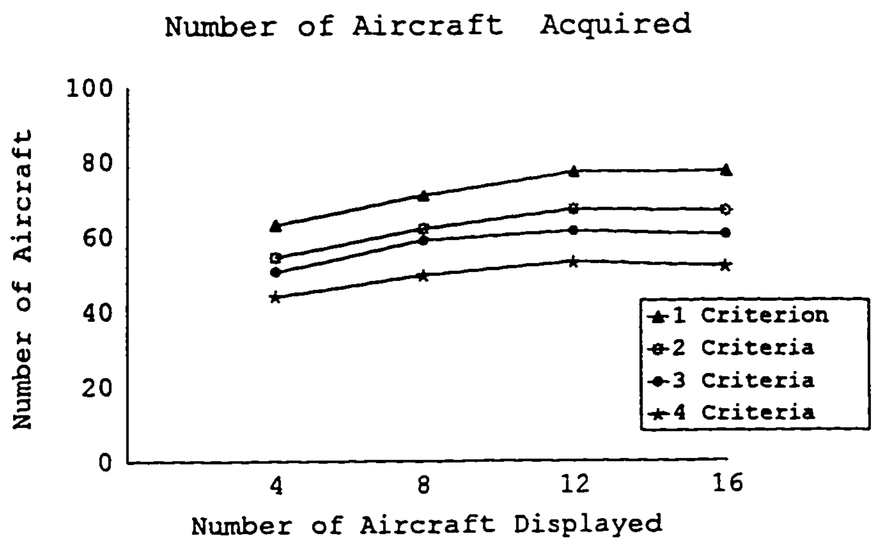
Main Effects for Half of Task

Dependent Variables	First Half	Second Half
Number Acquired	54.90	65.97
Number Correct	50.88	61.40
Percent Acquired	83.67	87.84
Reaction Time (s)	1.48	1.03

Note. $\underline{p}$ < .05.

Figure 1 shows that the number of aircraft acquired increased with increases in time pressure and decreased as the number of criteria used to make a decision increased, except for 12 or 16 aircraft displayed where there was little change in performance. In general, the number of aircraft identified correctly increased with increases in time pressure and decreases in information load except at the highest level of time pressure, where performance declined at all levels of information load. One exception occurred between two and three criteria needed to make a decision, where there was no difference in performance.

Time pressure and order of presentation. An interaction between time pressure and the order of presentation, ascending or descending, of the number of



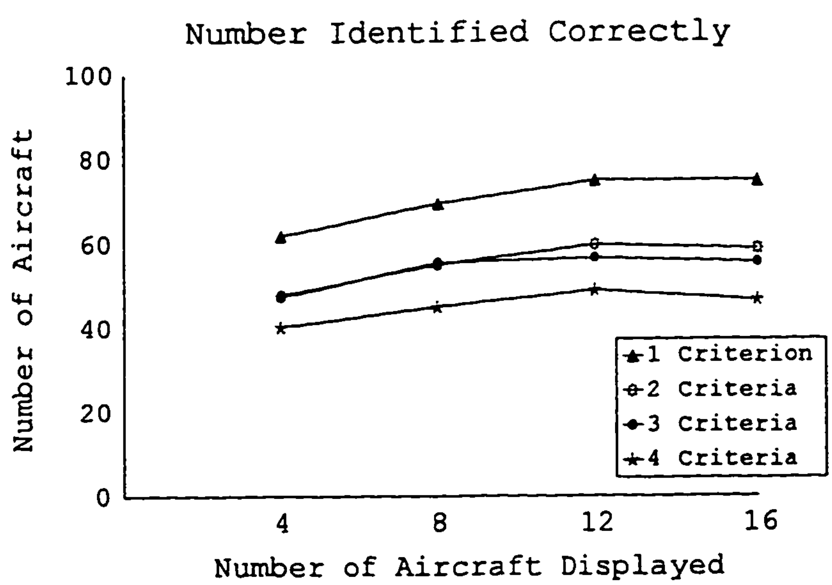


Figure 1. The interaction of time pressure and information load for the number of aircraft acquired and the number correct of those acquired. $p < .05$.

aircraft displayed occurred in (a) the number of aircraft acquired ($\underline{F}$=(3,240)=26.49, $\underline{p}$<.05), (b) the number correct of those acquired ($\underline{F}$(3,240)=27.30, $\underline{p}$<.05), (c) the percent correct of those acquired ($\underline{F}$(3,240)=3.03, $\underline{p}$<.05), and (d) reaction time ($\underline{F}$(3,240)=44.34, $\underline{p}$<.05).

When the number of aircraft displayed was presented in ascending order (4, 8, 12, 16 aircraft) both the number acquired and the number correct of those acquired improved over the first three levels then declined at the hardest level of time pressure. When the reverse order was presented, performance improved from 16 to 12 aircraft displayed, then declined (see Figure 2).

The percent of aircraft identified correctly of those acquired was higher at four aircraft displayed in the descending order condition, while the reverse occurred when 16 aircraft were displayed. In both the ascending and descending order, reaction decreased over the first three levels presented. In ascending order, reaction time decreased over 4, 8, and 12 aircraft displayed, while in descending order reaction time decreased over 16, 12, and 8 aircraft displayed. At the last level encountered, reaction time either increased (16 aircraft displayed) or showed a slight decrease (4 aircraft displayed).

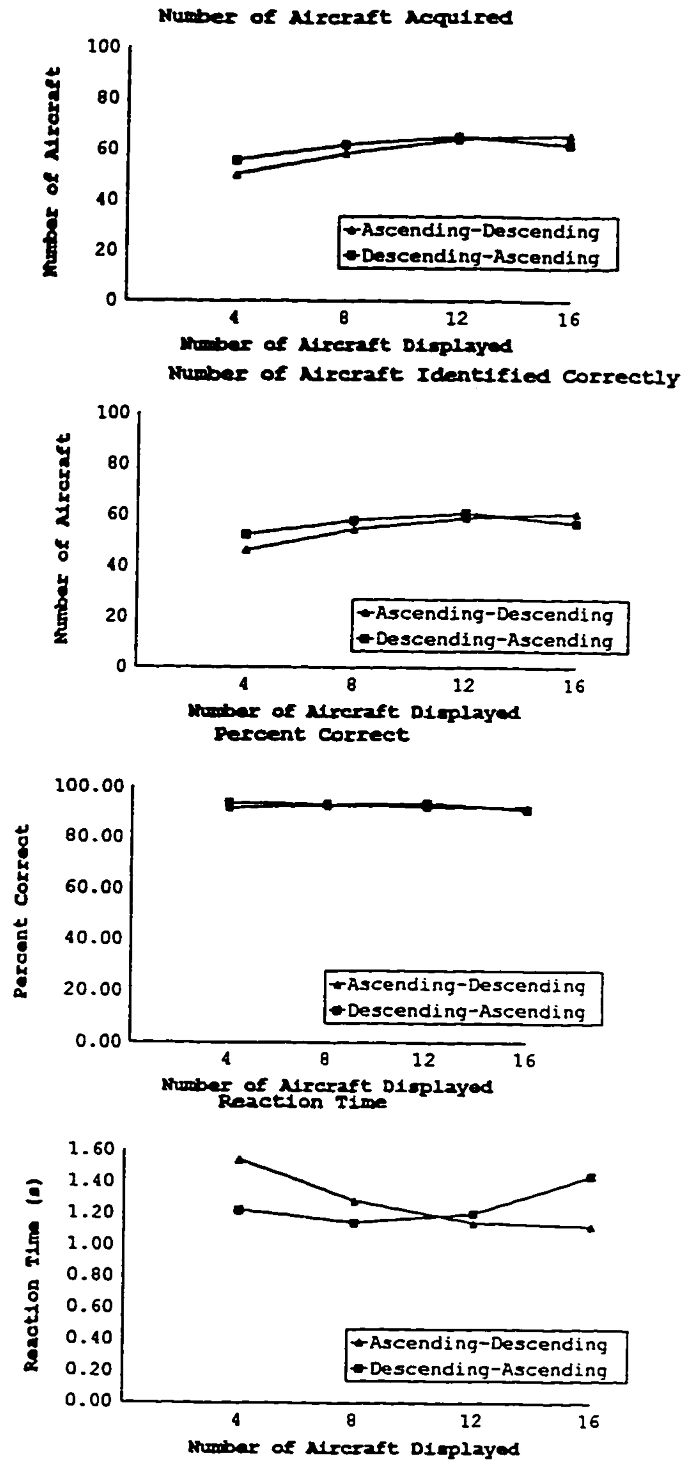


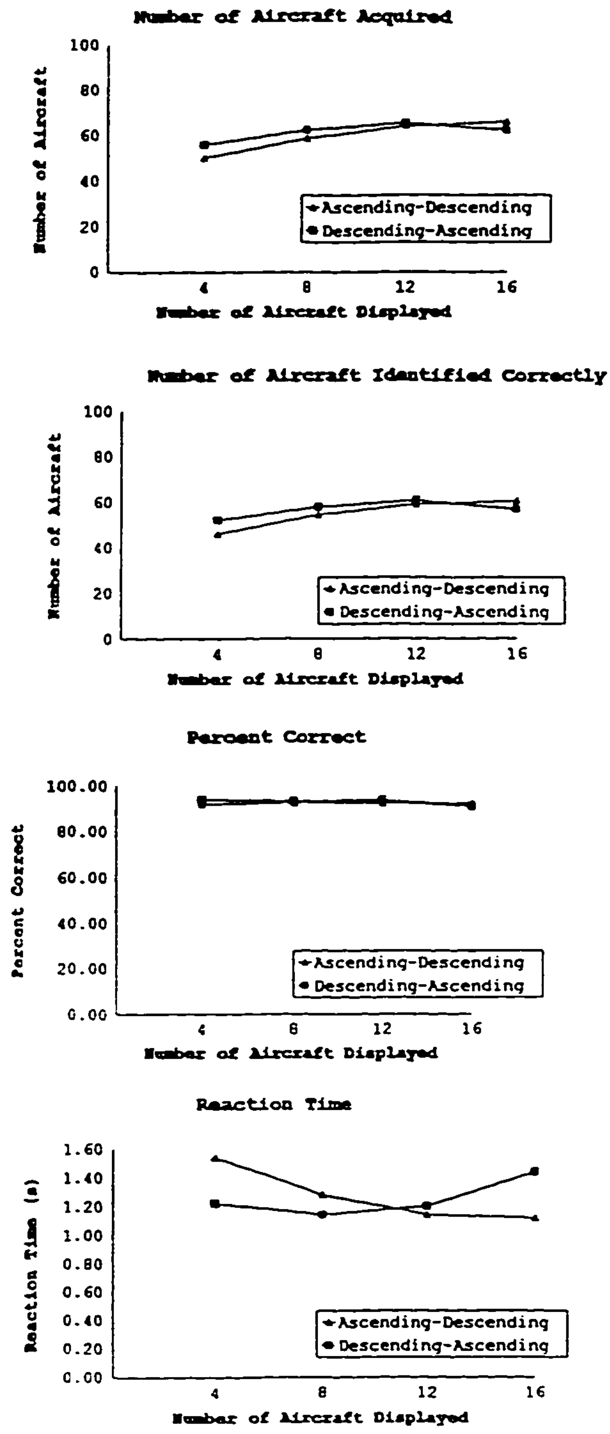
Figure 2. Interaction of time pressure and order of presentation. $p < .05$.

Half and time pressure. A half by time pressure interaction occured in (a) the number of aircraft acquired ($F(3,240)=18.23$, $p<.05$, (b) the number correct of those acquired ($F(3,240)= 14.62$, $p<.05$), (c) the percent acquired ($F(3,240)=13.41$, $p<.05$), and (d) reaction time ($F(3,240)=6.51$, $p<.05$).

Better performance occurred during the second half at all levels of time pressure except the percent of aircraft acquired under the lowest level of time pressure where performance did not differ (see Figure 3). Both the number of aircraft acquired and the number identified correctly indicated continuous improvement during the second half, while, in the first half, performance improved until the highest level of time pressure (16 aircraft displayed), where it declined. During the first half, reaction time decreased over the first three levels, but increased when 16 aircraft were displayed. The second half indicated consistent performance over the four levels.

No additional two-way interactions are presented here as they do not pertain to this research.

Half, time pressure, and order of presentation. One three-way interaction was examined as it provides additional explanation of the previous results.

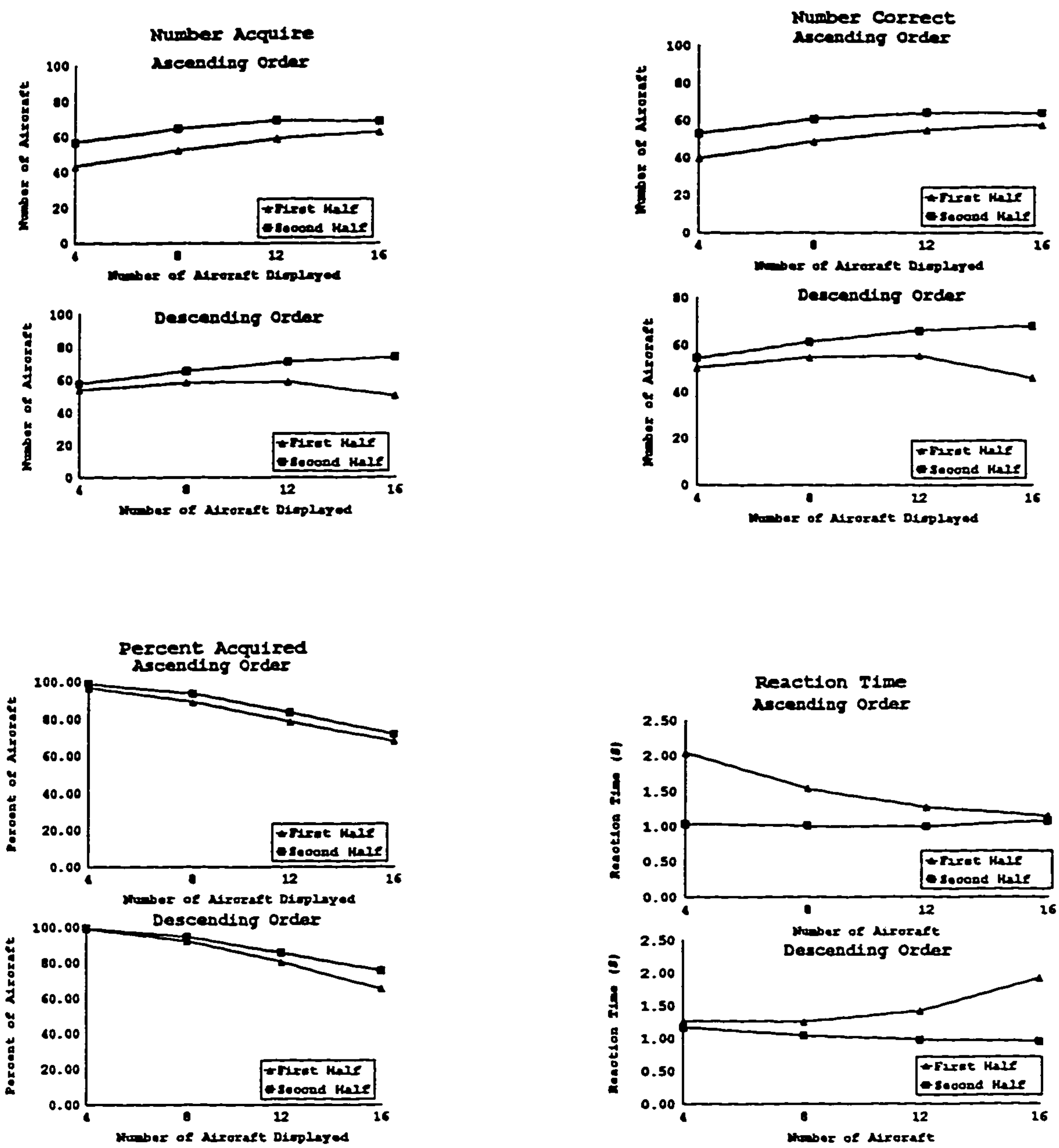


<u>Figure 3.</u> Inteaction of time pressure and half of task. $\underline{P} < .05$.

The interaction between half, time pressure and order of presentation (ascending or descending) was significant in (a) the number acquired ($\underline{F}(3,240)=92.31$, $\underline{p}<.05$), (b) the number correct of those acquired ($\underline{F}(3,240)=64.48$, $\underline{p}<.05$), (c) the percent acquired of those displayed ($\underline{F}(3.240)=8.42$, $\underline{p}<.05$), and (d) reaction time ($\underline{F}(3,240)=93.36$, $\underline{p}<.05$, see Figure 4).

Workload and Selected Independent Variables

The effects of workload, as measured by the Task Load Index, and the independent variables, order of aircraft (ascending or descending), half, and information load were investigated. The order of the aircraft and half were combined into a new variables with four levels: (a) first half, ascending; (b) second half, ascending; (c) first half, descending; and (d) second half, descending. The design precluded evaluating time pressure. A single main effect was found between the TLX's measure of time stress and the order/half variable ($\underline{F}(3,176)=6.43$, $\underline{p}<.05$), where a higher level of time stress was reported after completing the first half, ascending order. Subjects had just completed the task with the highest level of time pressure.



<u>Figure 4.</u> Three-way interaction of time pressure, half of task, and order of presentation (descending or ascending). $\underline{P}$ <.05.

Anchoring Bias

Anchoring bias occurs when the first criterion evaluated influences the final decision (see Table 6).

The chi-square statistic was used to determine if the number of errors made were above expectancy when the first criterion suggested a response that was contradictory to the final decision. Significant chi-squares where found when two criteria were used to make a decision (χ^2(3, N=192)=2693.61, $p<.05$), when three criteria were used to make a decision (χ^2 (8,N=192)= 1215.15, $p<.05$), and when four criteria were used in making a decision (χ^2 (15, N=4762.85, $p<.05$). As table 6 shows, more errors than expected occurred when the first criterion contradicted the final decision.

Table 6

Anchoring Bias and the Number of Errors

Two Criteria to Make a Decision	Number of Errors
Friend Friend	0 Errors
Friend Enemy	0 Errors
Enemy Enemy	57 Errors
Enemy Friend	1080 Errors
Three Criteria to Make a Decision	**Number of Errors**
Friend Enemy Enemy	20 Errors
Friend Friend Friend	54 Errors
Enemy Enemy Friend	258 Errors
Enemy Friend Enemy	300 Errors
Four Criteria to Make a Decision	**Number of Errors**
Enemy Friend Enemy Friend	12 Errors
Friend Friend Friend Friend	18 Errors
Enemy Friend Friend Friend	33 Errors
Enemy Enemy Friend Friend	51 Errors
Enemy Enemy Enemy Friend	119 Errors
Enemy Enemy Friend Friend	475 Errors

Note. The decision to identify the aircraft as an enemy is correct when ALL of the criteria indicate an enemy.

DISCUSSION

Four hypotheses are presented in this study. The first three address rule-based decision-making under varying levels of time pressure and information load. Performance was influenced by these independent variables but not always in the way predicted. The fourth hypothesis was supported as anchoring bias did influence performance in this study.

Time pressure. Time pressure was manipulated by increasing or decreasing the number of aircraft on the screen to be monitored (between-subjects). It was predicted that time pressure would result in a decrease in reaction time and a decline in the number of aircraft acquired, number correct of those acquired, and percent correct.

Reaction time was longest under the lowest (4 aircraft) level of time pressure, followed by the highest (16 aircraft) level (see Tables 1 and 2). The fastest reaction time occurred under the two intermediate levels. Although this appears to follow the Yerkes-Dodson law (1908), there is an alternate explanation. At the lowest level of time pressure, participants acquired 98.51% of the aircraft displayed and yet have the longest reaction time. This suggests that they adjusted their speed to accommodate the task.

As predicted, a decline in performance was found at the highest level of time pressure. No difference was found between the number of aircraft acquired at the two highest levels of time pressure. The number of correct identifications increased over 4, 8, 16, and 12 aircraft displayed, showing a decline at the highest level of time pressure as compared with the second highest level. The percent correct of those acquired did not differ at the first three levels, but decreased at the highest level of time pressure.

Past research indicated that time pressure can both improve or disrupt performance. Rothstein (1986) found that time pressure can focus attention and improve performance. Broadbent (1971) and Entin and Serfaty (1990) concurred that time pressure improved performance on simple or well-learned tasks. When time pressure increases to the point that it is unlikely that the task can be performed successfully, it has been found to result in (a) premature closure (Clothier, 1991), (b) faster reaction time (Hockey, 1986), and (c) working in a disorganized manner (Janis & Mann, 1977).

Premature closure and a faster reaction time were not seen at the highest level of time pressure, as reaction time actually increased at this level. Comments made by the participants during the task and debriefing suggested that time pressure resulted in their working in a disorganized manner. Some considered it as a challenge, while others viewed it as impossible and tended to "satisfice." Also, the tone that sounded when an aircraft reached the target without being acquired may have contributed to their perceived stress.

Information load. Information load, produced by increasing the number of criteria used (1, 2, 3, or 4) to make a decision, was predicted to result in increases in reaction time, but with no changes in the percent correct of those acquired.

As hypothesized, increases in information load resulted in increases in reaction time over all four levels of the task (see Tables 2 and 3). Reaction time increased by 29 sec when the second criterion was added, by .37 when the third was included, and by .51 with the addition of the fourth criterion. This suggests that subjects took the time necessary to process additional information.

Contrary to the hypothesis, the percent correct of those acquired did not remain steady over the four levels of information load. It was highest under one criterion used and lowest under two criteria used, with no difference between three and four criteria required (see Table 3).

This finding differs from those of several prominent researchers. Hockey (1986), in his review of the literature on the influence of stressors, concluded that demands on working memory were a major contributing factor to a decline in performance under stress. Wickens et al., (1993) also found that performance did not decline with increases in workload when working memory was not required. In the current investigation working memory was not required, yet performance varied under different levels of information load. There are several explanations for the findings. The poorest performance occurred when two criteria were used. It is possible that the second criterion, aircraft above 10000 feet, was more difficult to process than the other three criteria. Also, a ceiling effect may have been present when one criterion was used to make the decision. Further investigation is needed, with a different, and possibly easier, second criterion.

No difference was found between the percent of aircraft acquired under varying levels of information load, but differences occurred in the other performance measures. One explanation for finding no difference in the percent of aircraft acquired over increasing levels of information may be attributed to the complexity level of the two situations. Capturing the aircraft using the mouse is a motor task, but identifying the plane as a "friend" or an "enemy" is cognitive. Van Orden, Benoit, and Osga (1996) found a similar pattern of behavior when investigating the effects of cold air stress on performance. No differences were found between the control group and the stress group in a symbol recognition task, but differences were found on a cognitively complex task of scenario following.

Time pressure and information load. An interaction was predicted between time pressure and information load with performance. High levels of time pressure and information load were hypothesized to result in declines in performance under time pressure, but not information load. No difference was predicted a low levels of time pressure and information load.

The predicted interaction was not seen for reaction time or the percent correct of those acquired, but differences did occur in the number of aircraft acquired and the number identified correctly of those acquired.

Time pressure did result in a decline in the number of aircraft acquired and identified correctly at the highest level. Time pressure did not interact with information load on the dependent variable, the percent correct of those acquired, therefore, the expected interaction did not take place.

Performance using one criterion to make a decision resulted in more aircraft being acquired at all levels of time pressure and under all levels of information load. If the level, one criterion used to make a decision, was removed, the interaction for the number of aircraft acquired is not significant. Therefore, this interaction may be due to the ceiling effect found at the lowest levels of the independent variables.

The interaction between time pressure and information load with the number of aircraft identified correctly, suggests that performance using two or three criteria is similar over all levels of time pressure. The supports the possibility that the second criterion was more difficult to process.

Information load and reaction time do interact, but the interactions may be attributed to the research design.

<u>Additional findings.</u> Several main effects and

interactions occurred that were not hypothesized. The main effects for gender indicated that males acquired more aircraft, identified more aircraft correctly, and acquired a higher percent of the aircraft displayed than did females (see Table 4). Acquiring the aircraft using a mouse is a visual-spatial task, and some researchers have found that males perform better on spatial tasks (Swabb & Fliers, 1984). An interaction was present between gender and time pressure, where males acquired a higher percent of aircraft than females except the lowest level of time pressure, where no differences were found.

No half by gender interactions occurred, suggesting that males and females made similar gains during the second half of the task.

A possible learning effect occurred as performance was better during the second half of the task than the first in the number acquired, the number correct, the percent acquired, and reaction time (see Table 5).

The interaction between time pressure and half indicates that the highest level of time pressure had a more detrimental influence in the first half than in the second half of the task (see Figure 4). This suggests that time on task or practice may alleviate the decline in performance during high time pressure.

An interesting interaction occurred between time pressure and the counterbalancing of the order of presentation (ascending or descending). These findings are presented in the three-way interaction between time pressure, order of presentation, and half of task (see Figure 4), and provided additional insight into how the manipulation of the level of difficulty from high-to-low or from low-to-high influences performance.

Overall, performance improved when the number of aircraft displayed increased in ascending order, with more aircraft acquired with each increase, more identified correctly, a larger percent acquired correctly, and a decrease in reaction time. Performance showed a similar pattern in the first and second half, although overall performance was better in the second half.

Performance differed depending on whether the descending order of the number of aircraft displayed occurred during the first or second half of the task. If descending order was encountered during the first half, the number of aircraft acquired and the number acquired correctly were the lowest when 16 aircraft were displayed, there was a slight increase with 12 aircraft displayed, then a gradual decline is with 8 and 4 aircraft displayed. In contrast, when the descending order occurs during the second half, the 16 aircraft displayed condition resulted in more aircraft acquired and acquired correctly than in any other condition. Performance then showed a gradual decline with 12, 8, and 4 aircraft displayed. Regarding reaction time, when the ascending order was presented first and then the descending order, reaction time decreased with the ascending order and increased with the descending order. If the descending order was presented first, reaction time showed a decrease for 16, 12, and 8 aircraft, followed by a flattening out of performance. Fowler (1980) reported similar findings when investigating air traffic control accidents. He found that the highest number of incidents occurred under low levels of workload that followed a period of high activity.

The low level of performance, when the task began with the highest level of time pressure, may have contributed to this three-way interaction but it does not totally account for the results. When this task progressed from easy to difficult, performance improved. By contrast, when the task started as difficult and became easier, participants initially appeared to put more effort into the task but they began to reduce their effort as the task becames easier. Additional study of this issue is necessary before drawing any conclusions.

Anchoring bias. The presence of anchoring bias was supported. When two, three, and four criteria were used to make a decision, significant chi-squares indicated that more errors occured when the final decision was different from the one that would be appropriate based on the first piece of information or anchor. If the first criterion indicatds that the aircraft was a "friend" participants were more likely to make incorrect decisions based on subsequent information then if the first piece of information indicated that the aircraft was an "enemy." The strong influence of the first criterion encountered on the correctness of the decision suggests that, anchor bias was present on a simple rule-based decision-making task.

CONCLUSIONS

The purpose of this research was to examine performance when making simple rule-based decisions under varying levels of time pressure and information load and to determine if the types of errors that occurred followed patterns similar to those found in more complex decision-making research. Intuitively, following a simple set of rules to make a decision may be a rudimentary process, but these results suggest that this is not always so. The stressors, time pressure and information load, were found to influence performance differently. Also, several common biases that occur in complex decision-making are present in simple rule-based decision-making. Differences in performance were found by gender and by half.

This investigation shows that time pressure improves performance by reducing reaction time and increasing the percent of aircraft identified until the highest difficulty level, where performance drops dramatically. Unlike time pressure, information load does not influence the percent of aircraft acquired, which remained at about 86% over the four levels. Increases in information load did result in increases in reaction time and somewhat erratic performance in the percent of correct responses.

One interesting finding is that the order in which the task is presented, increasing or decreasing levels of time pressure, influences performance. Performance improves when the number of aircraft presented increases rather than decreases over time. This occurs irrespective of the half in which the ascending order occurs. When the number of aircraft decreases over the task, performance generally declines as time pressure is reduced. While overall performance declines in the descending order, more aircraft are acquired and identified correctly under the lower levels of time pressure. This implies that when a task entails high levels of time pressure a "warm up" period at a low level of the task may be beneficial in improving performance. Furthermore, beginning a task under high levels of time pressure may improve performance a lower levels.

Anchoring bias is evident, despite the lack of load on working memory. The first piece of information received influences how subsequent information is processed. The anchoring bias has been demonstrated repeatedly in research, but using more subjective criteria (Slovic & Lichtenstein, 1971, Tversky & Kahneman, 1982). Even in a simple rule-based decision, where all of the information to make a decision is available, persons are biased by the initial information. The anchoring bias appears to be quite robust.

This investigation demonstrates that providing simple step-by-step criteria to make a decision may not be sufficient to prevent errors or accidents. The same types of errors that occur on more complex tasks were found to arise under time stress and information load. Further investigation is needed to determine ways to reduce this error.

REFERENCES

Adleman, L., Tolcott, M. A., & Bresnick, T. A. (1991). Examining the effect of information order on expert judgment. Alexandria, VA: U. S. Army Research Institute.

Arkes, H., & Harkness, R. R. (1980). The effect of making a diagnosis on subsequent recognition of symptoms. Journal of Experimental Psychology: Human Learning and Memory, 6, 568-575.

Barnett, B., Stokes, A., Wickens, C. D., Davis, T., Rosenblum, R., & Hyman, F. (1987). A componential analysis of pilot decision-making. Proceedings of the Human Factors Society-31st Annual Meeting Santa Monica, CA: Human Factors Society, 842-846.

Beach, L. R. (1993). Broadening the definition of decision-making: The role of prechoice screening of options. Psychological Science, 4, 215-220.

Beach, L. R., & Mitchell, T. R. (1987). A contingency model for the selection of decision strategies. Acta Psychologica, 66, 201-220.

Beach, L. R., & Storm, E. (1989). A toadstool among mushrooms: Screening decisions and image theory's compatibility test. Acta Psychologica, 66, 201-220.

Bell, D. E., Raiffa, H., & Tversky, A. (1988). Descriptive, normative, and prescriptive interactions in decision-making. In D.E. Bell, H. Raiffa, & A. Tversky (Eds.), Decision-making: Descriptive, normative, and prescriptive interactions (pp. 1-32). New York: Cambridge

Ben Zur, H., & Breznitz, S. J. (1981). The effects of time pressure on risky choice behaviour, Acta Psychologica, 47, 89-104.

Billings, C. E. (1991). Human-centered aircraft automation philosophy: A concept and guidelines (Tech Memorandum 103885). Ames: NASA.

Billings, C. E., & Reynard, W. D. (1984). Human factors in aircraft incidents: Results of a 7-year study. Aviation, Space, and Environmental Medicine, 960-965.

Broadbent, D. E. (1971). Decision and stress. New York: Academic Press.

Chappelow, J. W. (1989). Causes of aircrew error in the Royal Air Force. (AGARD-CP-458) In Human behaviour in high stress situations in aerospace operations, I1-I8.

Christen-Szalanski, J. (1980). A further examination of the selection of problem solving strategies: The effects of deadlines and analytic aptitudes, Organizational Behaviour and Human Performance, 25, 107-122.

Clothier, C. C. (1991). Behavioral interactions across various aircraft types: Results of systematic observations of line operations and simulations. In R. S. Jensen (Ed.), Proceedings of the Sixth International Symposium on Aviation Psychology (pp. 332-337). Columbus, OH: The Ohio State University.

Coates, G. D., & Schaab, B. (1990). Single and dual vigilance performance using the Mackworth Clock and a verbal analog of the Mackworth Clock. Poster presented at the 34th Annual Meeting of the Human Factors Society, Orlando, FL: Human Factors Society.

Corbin, R. M. (1980). Decisions that might not get made. In T. S. Wallsten (Ed.). Cognitive processes in choice and decision behavior (pp. 47-67), Hillsdale, NJ: Erlbaum.

Coury, B. G., & Drury, C. G. (1986). The effect of pacing on complex decision-making inspection performance. Ergonomics, 29, 489-569.

Cowen, E. L. (1952). The influence of varying degrees of psychosocial stress on problem-solving rigidity. Journal of Abnormal and Social Psychology, 47, 512-519.

Crew was busy-chatting-before crash, recordings show. (1995, December 23). The Virginian Pilot, p. A1.

Dawes, R. M. (1979). The robust beauty of improper linear models in decision-making. American Psychologist, 34, 571-582.

Degani, A., & Wiener, E. L. (1990). Human Factors of flight-deck checklists: The normal checklist. (Grant NCC2-377) NASA.

Degani, A., & Wiener, E. L. (1993). Cockpit checklists: Concepts, design, and use. Human Factors, 35, 345-360.

Dressel, K. M., Logan, A., Groce, J., & Boucek, G. S., (1992). Pilot errors: A function of task complexity, background, communication load, and task urgency during line-oriented simulation. Paper presented at the 36th Human Factors Society Annual Meeting, Atlanta, GA.

Driskell, J. E., & Salas, E. (1991). Group decision-making under stress. Journal of Applied Psychology, 76, 473-478.

Easterbrook, J. A. (1959) The effect of emotion on cue utilization and the organization of behavior. Psychological Review, 66, 183-201.

Einhorn, H. J. (1971). Use of nonlinear, noncompensatory models as a function of task and amount of information. Organizational Behavior and Human Performance, 6, 1-27.

Einhorn, H. J., & Hogarth, (1987). A theory of diagnostic inference (AD#179786). University of Chicago: Center for Decision Research.

Entin, E. E., & Serfaty, D. (1990). Information gathering and decision-making under stress (TR-454). Arlington, VA: Office of Naval Research.

Evans, G. W. (1979). Behavioral and physiological consequences of crowding in humans. Journal of Applied Psychology, 9, 27-46.

FAA revokes pilots licenses of captain involved in USAir 737 crash at LaGuardia (1990, April 2). Aviation Week and Space Technology, p.53.

Fischoff, B. (1977). Perceived informativeness of facts. Journal of Experimental Psychology Human Perception and Performance, 3, 349-358.

Fishburn, P. C. (1988). Normative theories of decision-making under risk and under uncertainty. In D. E. Bell, H. Raiffa, & A. Tversky (Eds.), Decision-making: Descriptive normative, and prescriptive interactions (pp. 78-98). New York: Cambridge.

Fowler, F. D. (1980). Air traffic control problems: A pilot's view. Human Factors,22, 645-654.

Freeman, C., & Simmon, D. A. (1991). Taxonomy of crew resource management: Information processing domain. In R. S. Jensen (Ed.), Sixth international symposium on aviation psychology (pp. 391-396). Columbus, OH: The Ohio State University.

Hammond, K. R. (1988). Judgment and decision-making in dynamic tasks. Information and Decision Technologies, 14, 3-14.

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), Human mental workload (pp. 139-183). Amsterdam: North Holland.

Hockey, G. R. J. (1986). Changes in operator efficiency as a function of environmental stress, fatigue, and circadian rhythms. In K. R. Boff, L. Kaufman, & J. P. Thomas (Eds.), Handbook of perception and human performance (Vol.II). New York: Wiley.

Hogarth, R. M. (1989). Ambiguity and competitive decision-making: Some implications and tests. In P. C. Fishburn & I. H. LaValle (Eds.), Annuals of Operations Research 19, 51-78.

Hogarth, R. M., & Einhorn, H. J. (1992). Order effects in belief updating: The belief-adjustment model. Cognitive Psychology, 24, 1-55.

Hogarth, R. M., & Kunreuther, H. (1988). Risk, ambiguity, and insurance. Journal of Risk and Uncertainty, 1, 459-488.

Hogarth, R. M., & Kunreuther, H. (1990). Decision-making under uncertainty: The effects of role and ambiguity. (No: R & T4425080). Office of Naval Research. University of Chicago: Center for Decision Research.

Huntoon, R. B. (Feb, 1985). Displays, Deja Vu. Aviation, Space and Environmental Medicine, (131-137).

Janis, I. L., & Mann, L. (1977). Decision-making. New York: Free Press.

Jonsson, J. E. (1991). The role of behavioral decision theory for cockpit information management. In R. S. Jensen (Ed.), Sixth international symposium on aviation psychology (pp. 72-77). Columbus, OH: The Ohio State University. Kahneman, D. (1973). Attention and effort. Englewood Cliffs, NJ: Prentice Hall.

Kahneman, D., & Tversky (1973). A. On the psychology of prediction. Psychological Review, 80, 251-273.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. Econometrica, 47, 263-291.

Keinan, G. (1987). Decision-making under stress: Scanning of alternatives under controllable and uncontrollable threats. Journal of Personality and Social Psychology, 52, 639-644.

Keinan, G., & Friedland, N. (1987). Decision-making under stress: Scanning of alternatives under physical threat. Acta Psychologica, 64, 219-228.

Lee, A. T. (1991). Aircrew decision-making behavior in hazardous weather avoidance. Aviation, Space, and Environmental Medicine, 158-161.

Luce, R. D., & Raiffa, H. (1957). Games and decisions. New York: Wiley.

Nagel, D. C. (1988). Human error in aviation operations. In E. L. Wiener & D. C. Nagel (Eds.), Human factors in aviation (pp.263-303). San Diego: Academic Press.

Payne, J. W. (1982). Contingent decision-making. Psychological Bulletin, 92, 382-402.

Payne, J. W., Bettman, J. R., & Johnson, E. J. (1990). The adaptive decision-maker: Effort and accuracy in choice. In R. M. Hogarth (Ed.), Insights in decision-making (pp. 129-153). Chicago, IL: University of Chicago Press.

Payne, J. W., Braunstein, M. L., and Carroll, J. S. (1978). Exploring predecisional behavior: An alternative approach to decisional research. Organizational Behavior and Human Performance, 22, 17-22.

Rasmussen, J. (1983). Skills, rules, and knowledge: Signals, signs, and symbols, and other distinctions in human performance models. IEEE Transactions on Systems, Man, and Cybernetics, 13, 257-266.

Rasmussen, J. (1986). Information processing and human-mane interaction: An approach to cognitive engineering. New York: North-Holland.

Rothstein, H. G. (1986). The effects of time pressure on judgment in multiple cue probability learning. Organizational Behavior and Human Decision Processes, 37, 83-92.

Samuelson, W., & Zeuckhauser, R. (1988). Status quo bias in decision-making. Journal of Risk and Uncertainty, 1, 7-59.

Schofield, J. E., & Griffin, W. C. (1982). An analysis of aircrew procedural compliance. Aviation, Space, and Environmental Medicine, 964-969.

Sheridan, T. B., & Ferrell, L. (1974). Man-mane systems. Cambridge, MA: MIT Press.

Slovic, P., & Lichtenstein, S. (1971). Comparison of Bayesian and regression approaches to the study of information processing in judgment. Organizational Behavior and Human Performance, 6, 649-744.

Simon, H. A. (1957). Models of man. New York: Wiley.

Simon, H. A. (1988). Rationality as process and as product of thought. In D. E. Bell, H. Raiffa, & A. Tversky (Eds.), Decision-making: Descriptive, normative, and prescriptive interactions (pp. 58- 77). New York: Cambridge.

Smith, J. F., Mitchell, T. R., & Beach, L. R. (1982). A cost-benefit mechanism for selecting problem-solving strategies: Some extensions and empirical tests. Organizational Behavior and Human Performance, 29, 370-396.

Stokes, A. F., Barnett, B. J., & Wickens, C. D. (1987). Modeling stress and bias in pilot decision-making. Proceedings of the Annual Conference of the Human Factors Association of Canada. Montreal, Canada.

Sundstroem, G. A., (1989). Information search and decision-making: The effects of informational displays. In H. Montgomery & O. Svenson (Eds.), Process and structure in human decision-making (pp. 225-236). chester: John Wiley & Sons.

Svenson, O., & Edland, A. (1989). Change of preference under time pressure: Choices and judgments. In H. Montgomery & O. Svenson (Eds.), Process and structure in human decision-making (pp.225-236). chester: John Wiley & Sons.

Swabb, D. F., & Fliers, E. (1984). Sex differences found in human brains. Science News, 8, 322-331.

Tolcott, M. A., & Marvin, F. F. (1988). Reducing the confirmation bias in an evolving situation (Technical Report 88-11). Reston, VA: Decision Science Consortium, Inc.

Tolcott, M. A., Marvin, F. F., & Lehner, P. E. (1989). Expert decision-making in evolving situations. IEEE Transactions on Systems, Man, and Cybernetics, 19, 606-615.

Tversky, A., & Kahneman, D. (1971). Belief in the law of small numbers. Psychological Bulletin, 76, 105-110.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. Science, 185, 1124-1131.

Tversky, A., & Kahneman, D. (1982). Judgment under uncertainty: Heuristics and biases. In D. Kahneman, P. Slovic, & A. Tversky (Eds.) Judgment under uncertainty: Heuristics and biases (pp. 3-33). Cambridge: Cambridge University Press.

Tversky, A., & Kahneman, D. (1985). The framing of decisions and the psychology of choice. In G. Wright (Ed.), Behavioral decision-making. New York: Plenum.

Tversky, A., & Shafir, E. (1992). Choice under conflict: The dynamics of deferred decision. Psychological Science, 6, 358-361.

Van Orden, K. F., Benoit, S. L., & Osga, G. A. (1996). Effects of cold air stress on the performance of a command and control task. Human Factors,38, 130-141.

Volta, G. (1986). Time and decision. In E. Hollnagel (Ed.), Intelligent decision support in process environments. Berlin Springer-Verlag. NATO ASI Series F21.

Wallsten, T. S., & Barton, C. (1982). Processing 65 probabilistic multidimensional information for decisions. Journal of Experimental Psychology: Learning, Memory, and Cognition, 8, 361-384.

Watchel, P. L. (1967). Conceptions of broad and narrow attention. Psychological Bulletin, 90, 89-101.

Weltman, G., Smith, J. E., & Egstrom, G. H. (1971). Perceptual narrowing during simulated pressure-chamber exposure. Human Factors, 13, 99-107.

Wickens, C. D. (1992). Engineering psychology and human performance. New York: Harper Collins.

Wickens, C. D., & Flach, J. (1988). Human information processing. In E. Wiener & D. Nagel (Eds.), Human factors in modern aviation. New York: Wiley.

Wickens, C. D., Pizarro, D., & Bell, B. (1991). Overconfidence, preview, and probability in strategic planning. Proceedings of the Human Factors Society, 35th Annual Meeting, Santa Monica, CA: Human Factors Society, 1556-1560.

Wickens, C. D., Stokes, A. F., Barnett, B., & Davis, T., Jr. (1987) Componential analysis of pilot decision-making (Final Technical Report ARL-87-4/SCEEE-87-1). Savory, IL: University of Illinois.

Wickens, C. D., Stokes, A. F., Barnett, B., & Hyman, F. (1988). Stress and pilot judgment: An empirical study using MIDIS, a microcomputer-based simulation. Proceedings of the Human Factors Society- 32nd Annual Meeting Santa Monica, CA: Human Factors Society, 175-177.

Wickens, C. D., Stokes, A. F., Barnett, B., & Hyman, F. (1989). The effects of stress on pilot judgment in a MIDIS Simulator. AAMRL-TR-88-057.

Wickens, C. D., Stokes, A. F., Barnett, B., & Hyman, F. (1993). The effects of stress on pilot judgment in a MIDIS simulator. In O. Svenson & A. J. Maule (Eds.), Time pressure and stress in human judgment and decision making (pp. 271-292). New York: Plenum Press.

Woods, D. D., & Roth, E. M. (1990). Cognitive system engineering. In M. Helander (Ed.), Handbook of human computer interaction (pp. 3-44). New York: North-Holland.

Wright, P. (1974). The harassed decision maker: Time pressures, distractions, and the use of evidence. Journal of Applied Psychology, 59, 555-561.

Wright, P., & Weitz, B. (1977). Time horizon effects on product evaluation strategies, Journal of Marketing Research, 16, 429-443.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit formation. Journal of Comparative Neurological Psychology, 18, 459-482. (cited in Wickens, 1992).

Zakay, D. (1985). Post-decisional confidence and conflict experienced in a choice process, Acta Psychologica, 58, 75-80.

Appendix A

Research Design

Within Factors

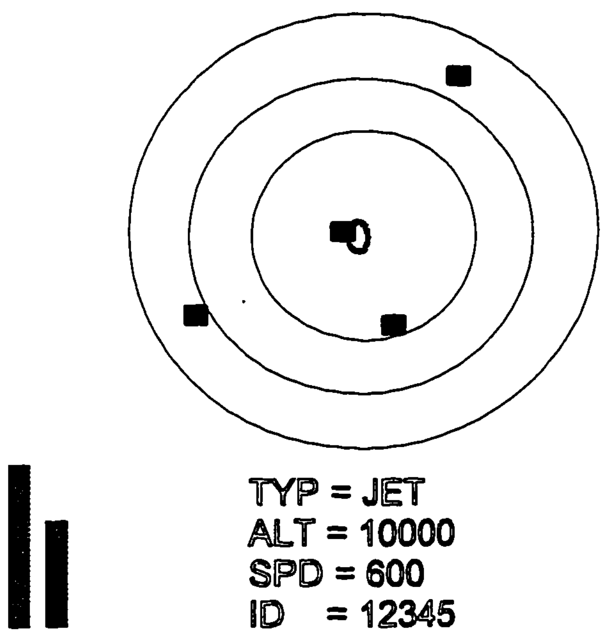
	4 Aircraft Displayed	8 Aircraft Displayed	12 Aircraft Displayed	16 Aircraft Displayed
First Half	1-96	1-96	1-96	1-96
Second Half	1-96	1-96	1-96	1-96
TLX:First Half	1-96	1-96	1-96	1-96
TLX:Second Half	1-96	1-96	1-96	1-96

Between Factors

	1 Decision	2 Decisions	3 Decisions	4 Decisions
Male	1-12	13-24	25-36	37-48
Female	49-60	61-72	73-84	85-96
AD-DA Order	1-12	13-24	25-36	37-48
DA-AD Order	49-60	61-72	73-84	85-96

Appendix B

Representation of the Task



Appendix C

Directions to Participants

Your job is to protect an aircraft carrier (point at red circle) from potential enemy attack. You are in an aircraft circling the area. The aircraft flying around the carrier are represented on your display by these black squares (point). You need to determine if these aircraft are friendly or if they are enemy aircraft. You do this by using the mouse and clicking on the "aircraft" (demonstrate). Identification information appears that assists you in making the decision on whether this is a friend or enemy. It tells you the following information:

1) Prop or Jet
2) Altitude
3) Speed
4) Identification number

(Use one of the scenarios below depending on the number of criteria the subject is required to use to make a decision.)

I. If the aircraft is a JET, it is an enemy. Select #2 If the aircraft is a PROP it is friendly
Select #.1 Remember, for friend select #1 and for an enemy select #2. .(Point to the permanently displayed criteria for selection.) (Demonstrate. Practice.)

II. If the aircraft is a JET **AND** flying ABOVE 10,000 feet, it is an enemy. Select #2 Otherwise, it is friend. Select #1 If the aircraft is a Jet and the altitude is above 10000 feet,
select #2 for enemy. Remember, the aircraft must be both a JET and the altitude must be ABOVE, not at, 10,000 feet, to identify it as a #2 or enemy. If it does not meet these criteria, select #1 because it is a friend. (Point to the permanently displayed criterion for selection.) (Demonstrate. Practice.)

III. If the aircraft is a JET **AND** flying above 10000 feet **AND** is flying above 600 mph it is an enemy, select #2. Remember, the aircraft must be all three, a JET, with an altitude
above 10,000 feet, and flying over 600 MPH. The altitude and speed must be above NOT at these levels. If it does not meet these criteria select #1 because it is a friend.
(Point to the permanently displayed criterion for selection.) (Demonstrate. Practice.)

IV. If the aircraft is a JET, **AND** flying above 10,000 feet **AND** is flying above 600 mph **AND** its identification number is even, it is an enemy. Select #2. Remember, the aircraft must be all four, a JET, with an altitude above 10,000 feet, flying over 600 MPH, AND have an even identification number. If it does not meet these criteria select #1 because it is a Friend. (Point to the permanently displayed criterion for selection.) (Demonstrate. Practice.)

You will be assisted by other radar operators during your watch. You will not see these operators but, you will notice an increase or a decrease in the number of aircraft displayed as additional operators come on or come off the task.

At the bottom of the screen (point) are a red and a green line. Every time an aircraft reaches the carrier without your identifying it as either a friend or an enemy the red line will grow. Every time you identify an aircraft before it reaches the carrier the green line will grow. This will show how well you are protecting the carrier. It does not indicate if your response was correct or incorrect.

Remember, your goal is to identify the aircraft before they reach the carrier.
DO YOU HAVE ANY QUESTIONS?
(Demonstrate the task again several times. Repeat the criteria being used. Allow the subject to practice.)

Appendix D

Analysis of Variance Results for Total Number of Aircraft Displayed

Source	DF	Anova SS	Mean Square	F Value	Pr > F
NUMDEC	3	59751.4727	19917.1576	43.13	0.0001
HALF	1	16511.3555	16511.3555	413.86	0.0001
G	1	782.0638	782.0638	1.69	0.1969
NUMPLN	3	148018.098	49339.3660	1340.77	0.0001
ODR	1	6.9388	6.9388	0.02	0.9027
NUMDEC*HALF	3	1011.0977	337.0326	8.45	0.0001
NUMDEC*G	3	3970.6810	1323.5603	2.87	0.0417
HALF*G	1	5.1680	5.1680	0.13	0.7199
NUMDEC*NUMPLN	9	2093.241	232.5820	6.32	0.0001
HALF*NUMPLN	3	533.86849	177.9562	11.29	0.0001
NUMPLN*G	3	936.702	312.2340	8.48	0.0001
NUMDEC*ODR	3	903.0768	301.0256	0.65	0.5841
HALF*ODR	1	82.0326	82.0326	2.06	0.1555
ODR*G	1	778.0326	778.0326	1.68	0.1980
NUMPLN*ODR	3	3743.243	1247.7480	33.91	0.0001
NUMDEC*HALF*NUMPLN	9	250.57422	27.8415	1.77	0.0754
HALF*NUMPLN*G	3	55.80599	18.6020	1.18	0.3179
NUMDEC*HALF*ODR	3	131.3372	43.7791	1.10	0.3552
NUMDEC*ODR*G	3	124.2956	41.4319	0.09	0.9655
HALF*NUMPLN*ODR	3	5087.85807	1695.9527	107.59	0.0001
NUMDEC*HALF*G	3	205.63930	68.5464	1.72	0.1699
NUMDEC*NUMPLN*G	9	247.11600	27.4570	0.75	0.6664
HALF*ODR*G	1	37.18800	37.1880	0.93	0.3372
NUMDEC*NUMPLN*ODR	9	141.72000	15.7470	0.43	0.9194
NUMPLN*ODR*G	3	17.40000	5.8000	0.16	0.9247
NUMDEC*HALF*NUMPLN*G	9	101.86589	11.3184	0.72	0.6922
NUMDEC*HALF*ODR*G	3	34.66020	11.5534	0.29	0.8328
NUME*HALF*NUMPL*ODR	9	867.33464	96.3705	6.11	0.0001
NUMDEC*NUMPLN*ODR*G	9	117.50100	13.0560	0.35	0.9550
HALF*NUMPLN*ODR*G	3	13.86849	4.6228	0.29	0.8302
NUMD*HALF*NUMP*ODR*G	9	78.09505	8.6773	0.55	0.8365
SUBJ(NUMDEC*ODR*G)	80	36944.56250	461.8070	.	.
HAL*SUBJ(NUMD*ODR*G)	80	3191.64580	39.8956	.	.
HA*NUM*SUBJ(NUM*ODR*G)	240	3783.10417	15.7629	.	.
NUM*SUBJ(NUMD*ODR*G)	240	8831.85400	36.7990	.	.

Appendix E

Analysis of Variance Results for the Performance Measures

Analysis of Variance Results for Number Acquired

Source	DF	Anova SS	Mean Square	F Value	Pr > F
NUMDEC	3	51342.1081	17114.0360	18.99	0.0001
HALF	1	23552.0951	23552.0951	421.62	0.0001
G	1	5901.8763	5901.8763	6.55	0.0124
NUMPLN	3	16404.6706	5468.2235	188.16	0.0001
ODR	1	535.0013	535.0013	0.59	0.4432
NUMDEC*HALF	3	465.9831	155.3277	2.78	0.0463
NUMDEC*G	3	6861.9727	2287.3242	2.54	0.0624
HALF*G	1	2.4076	2.4076	0.04	0.8361
NUMDEC*NUMPLN	9	815.0221	90.5580	3.12	0.0015
HALF*NUMPLN	3	1024.2122	341.4040	18.23	0.0001
NUMPLN*G	3	77.4727	25.8242	0.89	0.4476
NUMDEC*ODR	3	1187.6810	395.8937	0.44	0.7255
HALF*ODR	1	65.9180	65.9180	1.18	0.2806
ODR*G	1	1346.7305	1346.7305	1.49	0.2251
NUMPLN*ODR	3	2309.4935	769.8312	26.49	0.0001
NUMDEC*HALF*NUMPLN	9	113.2304	12.5811	0.67	0.7341
HALF*NUMPLN*G	3	65.89974	21.9665	1.17	0.3207
NUMDEC*HALF*ODR	3	267.5977	89.1992	1.60	0.1967
NUMDEC*ODR*G	3	210.2227	70.0742	0.08	0.9719
HALF*NUMPLN*ODR	3	5186.5768	1728.8589	92.31	0.0001
NUMDEC*HALF*G	3	307.44140	102.4805	1.83	0.1475
NUMDEC*NUMPLN*G	9	426.19920	47.3555	1.63	0.1075
HALF*ODR*G	1	0.0326	0.0326	0.00	0.9808
NUMDEC*NUMPLN*ODR	9	202.9284	22.5476	0.78	0.6389
NUMPLN*ODR*G	3	86.0977	28.6992	0.99	0.3993
NUMDEC*HALF*NUMPLN*G	9	100.1054	11.1228	0.59	0.8016
NUMDEC*HALF*ODR*G	3	10.2539	3.4180	0.06	0.9801
NUME*HALF*NUMPL*ODR	9	542.0117	60.2235	3.22	0.0011
NUMDEC*NUMPLN*ODR*G	9	125.7201	13.9689	0.48	0.8869
HALF*NUMPLN*ODR*G	3	51.6706	17.2235	0.92	0.4320
NUMD*HALF*NUMP*ODR*G	9	90.4804	10.0534	0.54	0.8470
SUBJ(NUMDEC*ODR*G)	80	72085.1458	901.0643	.	.
HAL*SUBJ(NUMDE*ODR*G)	80	4468.8958	55.8612	.	.
NUM*SUBJ(NUMD*ODR*G)	240	6974.7708	29.0615	.	.
HAF*NU*SUB(NUM*ODR*G)	240	5186.5768	1728.8589	.	.

(appendix continues)

(continued)

Analysis of Variance for the Number Correct

Source	DF	Anova SS	Mean Square	F Value	Pr > F
NUMDEC	3	63228.8021	21076.2674	26.24	0.0001
HALF	1	21231.0469	21231.0469	348.94	0.0001
G	1	3960.3333	3960.3333	4.93	0.0292
NUMPLN	3	13312.7813	4437.5938	144.45	0.0001
ODR	1	701.5052	701.5052	0.87	0.3528
NUMDEC*HALF	3	257.1927	85.7309	1.41	0.2463
NUMDEC*G	3	5093.9479	1697.9826	2.11	0.1050
HALF*G	1	0.2552	0.2552	0.00	0.9485
NUMDEC*NUMPLN	9	926.9792	102.9977	3.35	0.0007
HALF*NUMPLN	3	977.19271	325.73090	14.62	0.0001
NUMPLN*G	3	98.9271	32.9757	1.07	0.3610
NUMDEC*ODR	3	982.3594	327.4531	0.41	0.7479
HALF*ODR	1	21.3333	21.3333	0.35	0.5554
ODR*G	1	1446.5052	1446.5052	1.80	0.1834
NUMPLN*ODR	3	2516.3594	838.7865	27.30	0.0001
NUMDEC*HALF*NUMPLN	9	101.06771	11.22975	0.50	0.8710
HALF*NUMPLN*G	3	161.65104	53.88368	2.42	0.0669
NUMDEC*HALF*ODR	3	128.4896	42.8299	0.70	0.5525
NUMDEC*ODR*G	3	509.4010	169.8003	0.21	0.8882
HALF*NUMPLN*ODR	3	4310.88542	1436.96181	64.48	0.0001
NUMDEC*HALF*G	3	215.52604	71.84201	3.22	0.0233
NUMDEC*NUMPLN*G	9	463.3750	51.4861	1.68	0.0954
HALF*ODR*G	1	0.0208	0.0208	0.00	0.9853
NUMDEC*NUMPLN*ODR	9	72.7760	8.0862	0.26	0.9837
NUMPLN*ODR*G	3	54.9844	18.3281	0.60	0.6178
NUMDEC*HALF*NUMPLN*G	9	283.4010	31.4890	1.41	0.1830
NUMDEC*HALF*ODR*G	3	15.5937	5.1979	0.09	0.9678
NUMDE*HALF*NUMPL*ODR	9	488.3750	54.2639	2.44	0.0115
NUMDEC*NUMPLN*ODR*G	9	233.6094	25.9566	0.84	0.5754
HALF*NUMPLN*ODR*G	3	15.3646	5.1215	0.23	0.8756
NUMD*HALF*NUMP*ODR*G	9	167.7708	18.6412	0.84	0.5831
SUBJ(NUMDEC*ODR*G)	80	64260.4583	803.2557	.	.
HAL*SUBJ(NUMD*ODR*G)	80	4867.5417	60.8443	.	.
NUM*SUBJ(NUMD*ODR*G)	240	7372.7083	30.7196	.	.
HA*NU*SUB(NUM*ODR*G)	240	5348.2917	22.2846	.	.

(appendix continued)

(continued)

Analysis of Variance for Percent Acquired

Source	DF	Anova SS	Mean Square	F Value	Pr > F
NUMDEC	3	0.12685199	0.04228400	0.85	0.4706
HALF	1	0.33506892	0.33506892	82.12	0.0001
G	1	0.46345508	0.46345508	9.32	0.0031
NUMPLN	3	8.95211268	2.98403756	535.02	0.0001
ODR	1	0.03635227	0.03635227	0.73	0.3952
NUMDEC*HALF	3	0.00052585	0.00017528	0.04	0.9881
NUMDEC*G	3	0.24402960	0.08134320	1.64	0.1878
HALF*G	1	0.00280908	0.00280908	0.69	0.4092
NUMDEC*NUMPLN	9	0.05106268	0.00567363	1.02	0.4267
HALF*NUMPLN	3	0.08492448	0.02830816	13.41	0.0001
NUMPLN*G	3	0.12343115	0.04114372	7.38	0.0001
NUMDEC*ODR	3	0.04397594	0.01465865	0.29	0.8291
HALF*ODR	1	0.00285825	0.00285825	0.70	0.4051
ODR*G	1	0.03436573	0.03436573	0.69	0.4083
NUMPLN*ODR	3	0.00736101	0.00245367	0.44	0.7247
NUMDEC*HALF*NUMPLN	9	0.00893363	0.00099263	0.47	0.8937
HALF*NUMPLN*G	3	0.00571109	0.00190370	0.90	0.4408
NUMDEC*HALF*ODR	3	0.01300673	0.00433558	1.06	0.3698
NUMDEC*ODR*G	3	0.00697569	0.00232523	0.05	0.9865
HALF*NUMPLN*ODR	3	0.05328072	0.01776024	8.42	0.0001
NUMDEC*HALF*G	3	0.02772257	0.00924086	4.38	0.0051
NUMDEC*NUMPLN*G	9	0.07816312	0.00868479	1.56	0.1290
HALF*ODR*G	1	0.00002552	0.00002552	0.01	0.9372
NUMDEC*NUMPLN*ODR	9	0.02557240	0.00284138	0.51	0.8671
NUMPLN*ODR*G	3	0.01745364	0.00581788	1.04	0.3742
NUMDEC*HALF*NUMPLN*G	9	0.01365164	0.00151685	0.72	0.6915
NUMDEC*HALF*ODR*G	3	0.01092711	0.00364237	0.89	0.4487
NUMDE*HALF*NUMPL*ODR	9	0.00837428	0.00093048	0.44	0.9119
NUMDEC*NUMPLN*ODR*G	9	0.02720953	0.00302328	1.00	0.8430
HALF*NUMPLN*ODR*G	3	0.00440672	0.00146891	0.70	0.5553
NUMD*HALF*NUMP*ODR*G	9	0.01374708	0.00152745	0.72	0.6869
SUBJ(NUMDEC*ODR*G)	80	3.97916295	0.04973954	.	.
HAL*SUBJ(NUMD*ODR*G)	80	0.32641032	0.00408013	.	.
NUM*SUBJ(NUMD*ODR*G)	240	1.33858940	0.00557746	.	.
HA*NU*SUB(NUM*ODR*G)	240	0.50650915	0.00211045	.	.

(appendix continues)

(continued)

Analysis of Variance for Percent Correct

Source	DF	Anova SS	Mean Square	F Value	Pr > F
NUMDEC	3	0.89703353	0.29901118	24.34	0.0001
HALF	1	0.00807564	0.00807564	2.05	0.1565
G	1	0.00953160	0.00953160	0.78	0.3811
NUMPLN	3	0.02684801	0.00894934	3.38	0.0189
ODR	1	0.00707981	0.00707981	0.58	0.4500
NUMDEC*HALF	3	0.01066048	0.00355349	0.90	0.4448
NUMDEC*G	3	0.04262026	0.01420675	1.16	0.3317
HALF*G	1	0.00096975	0.00096975	0.25	0.6215
NUMDEC*NUMPLN	9	0.03518208	0.00390912	1.48	0.1567
HALF*NUMPLN	3	0.01673863	0.00557954	2.43	0.0658
NUMPLN*G	3	0.01681826	0.00560609	2.12	0.0984
NUMDEC*ODR	3	0.01385760	0.00461920	0.38	0.7706
HALF*ODR	1	0.00153228	0.00153228	0.39	0.5350
ODR*G	1	0.01490018	0.01490018	1.21	0.2741
NUMPLN*ODR	3	0.02408035	0.00802678	3.03	0.0299
NUMDEC*HALF*NUMPLN	9	0.02558430	0.00284270	1.24	0.2719
HALF*NUMPLN*G	3	0.01370373	0.00456791	1.99	0.1160
NUMDEC*HALF*ODR	3	0.01074811	0.00358270	0.91	0.4411
NUMDEC*ODR*G	3	0.03224068	0.01074689	0.87	0.4579
HALF*NUMPLN*ODR	3	0.00365159	0.00121720	0.53	0.6618
NUMDEC*HALF*G	3	0.02763378	0.00921126	4.01	0.0082
NUMDEC*NUMPLN*G	9	0.01217881	0.00135320	0.51	0.8656
HALF*ODR*G	1	0.00110448	0.00110448	0.28	0.5983
NUMDEC*NUMPLN*ODR	9	0.03262244	0.00362472	1.37	0.2023
NUMPLN*ODR*G	3	0.00454512	0.00151504	0.57	0.6335
NUMDEC*HALF*NUMPLN*G	9	0.03176453	0.00352939	1.54	0.1352
NUMDEC*HALF*ODR*G	3	0.00380210	0.00126737	0.32	0.8101
NUMDE*HALF*NUMPL*ODR	9	0.03257557	0.00361951	1.58	0.1226
NUMDEC*NUMPLN*ODR*G	9	0.02249373	0.00249930	0.94	0.4868
HALF*NUMPLN*ODR*G	3	0.00534675	0.00178225	0.78	0.5080
NUMD*HALF*NUMP*ODR*G	9	0.01125196	0.00125022	0.54	0.8408
SUBJ(NUMDEC*ODR*G)	80	0.98298209	0.01228728	.	.
HAL*SUBJ(NUMD*ODR*G)	80	0.31571705	0.00394646	.	.
NUM*SUBJ(NUMD*ODR*G)	240	0.63485485	0.00264523	.	.
HA*NU*SUB(NUM*ODR*G)	240	0.55073136	0.00229471	.	.

(appendix continues)

(continued)

Analysis of Variance for Reaction Time

Source	DF	Anova SS	Mean Square	F Value	Pr > F
NUMDEC	3	147.478833	49.159611	34.03	0.0001
HALF	1	38.9939333	38.9939333	168.81	0.0001
G	1	0.253040	0.253040	0.18	0.6767
NUMPLN	3	4.9859935	1.6619978	20.74	0.0001
ODR	1	0.057574	0.057574	0.04	0.8423
NUMDEC*HALF	3	16.4486239	5.4828746	23.74	0.0001
NUMDEC*G	3	5.675815	1.891938	1.31	0.2771
HALF*G	1	0.4118941	0.4118941	1.78	0.1856
NUMDEC*NUMPLN	9	1.1824756	0.1313862	1.64	0.1048
HALF*NUMPLN	3	1.4630926	0.4876975	6.51	0.0003
NUMPLN*G	3	0.2537202	0.0845734	1.06	0.3688
NUMDEC*ODR	3	5.469853	1.823284	1.26	0.2931
HALF*ODR	1	0.0645590	0.0645590	0.28	0.5985
ODR*G	1	4.671514	4.671514	3.23	0.0759
NUMPLN*ODR	3	10.6603045	3.5534348	44.34	0.0001
NUMDEC*HALF*NUMPLN	9	1.3180303	0.1464478	1.96	0.0453
HALF*NUMPLN*G	3	0.3720270	0.1240090	1.66	0.1773
NUMDEC*HALF*ODR	3	1.5334287	0.5111429	2.21	0.0930
NUMDEC*ODR*G	3	1.748541	0.582847	0.40	0.7509
HALF*NUMPLN*ODR	3	20.9805606	6.9935202	93.36	0.0001
NUMDEC*HALF*G	3	0.645052	0.215017	2.87	0.0371
NUMDEC*NUMPLN*G	9	0.801289	0.089032	1.11	0.3555
HALF*ODR*G	1	0.552134	0.552134	2.39	0.1260
NUMDEC*NUMPLN*ODR	9	5.814323	0.646036	8.06	0.0001
NUMPLN*ODR*G	3	0.163469	0.054490	0.68	0.5651
NUMDEC*HALF*NUMPLN*G	9	0.403003	0.044778	0.60	0.7984
NUMDEC*HALF*ODR*G	3	0.303155	0.101052	0.44	0.7268
NUMDE*HALF*NUMPL*ODR	9	9.947177	1.105242	14.75	0.0001
NUMDEC*NUMPLN*ODR*G	9	0.323960	0.035996	0.45	0.9069
HALF*NUMPLN*ODR*G	3	0.344605	0.114868	1.53	0.2065
NUMD*HALF*NUMP*ODR*G	9	0.582191	0.064688	0.86	0.5585
SUBJ(NUMDEC*ODR*G)	80	115.580918	1.444761	.	.
HAL*SUBJ(NUMD*ODR*G)	80	18.479405	0.230993	.	.
NUM*SUBJ(NUMD*ODR*G)	240	19.232765	0.080137	.	.
HA*NU*SUB(NUM*ODR*G)	240	17.978076	0.074909	.	.

VITA

Brooke Browne Schaab
974 Kelso Court
Virginia Beach
Virginia 23464-0038

(804) 467-2745 (Home)
(804) 427-4381 (Work)

Objective

Old Dominion University has provided me with an outstanding education in the areas of research and quantitative analysis. My goal is to apply and expand this knowledge in a variety of situations.

Educational History

Bachelor of Science, Old Dominion College, Norfolk, Virginia
Major: Elementary Education Honors: Graduated Cum Laude 1969

Masters of Science, Old Dominion University, Norfolk, Virginia
Major: Special Education Honors: Graduated Magna Cum Laude
Thesis: Comparison of Programmed Learning versus Tradition Reading Programs 1973

Masters of Education, College of William and Mary, Williamsburg, Virginia
Major: School Psychology Honors: Graduated Summa Cum Laude 1981

Doctor of Philosophy, Old Dominion University, Norfolk, Virginia
Major: Industrial/Organizational Psychology Honors:Graduated Summa Cum Laude 1996
Dissertation: The Influence of Time Pressure and Information Load on Rule-Based Decision Making Performance.

Papers Presented

Coates, G. D., & Schaab, B. (1990). Single and dual vigilance performance using the Mackworth Clock and a verbal analog of the Mackworth Clock. Poster presented at the 34th Annual Meeting of the Human Factors Society, Orlando, Florida.

Coates, G. D., & Schaab, B. (1990). Comparison of cognitive and sensory performance in vigilance tasks as a function of signal probability, location, single vs. dual presentation, and a self-reported measure of arousal. Poster presented at the 36th Annual Meeting of the Southeastern Psychological Association. Atlanta, Georgia.

Fulop, A., Schaab, B., & Quinn, K. (1990). A task analysis of airline departure agent. Paper presented at the Virginia Psychological Association, Virginia Beach, Virginia.

Rogers, K., Thoburn, H., & Schaab, B. (1990). Vigilance performance correlations with a self-reported measure of arousal. Paper presented at the Virginia Psychological Association, Virginia Beach, Virginia.

Schaab, B. (1995). Values then and now: What's changed over the past 30 years? Paper presented at the Psychological Society, New York.

Schaab, B., & Coates, G. D. (1993). Vigilance as a function of stress and arousal. Paper presented at the First Mid-Atlantic Human Factors Society, Virginia Beach, VA.

Schaab, B., & Coates, G. D. (1990). The effects of eye and hand dominance on the detection of verbal and spatial visual signals. Poster presented at the 36th Annual Meeting of the Southeastern Psychological Association, Atlanta, Georgia.

Schaab, B., & Coates, G. D. (1989). Vigilance on cognitive and sensory tasks as a function of gender. Paper presented at the meeting of the Virginia Psychological Association, Lynchburg, Virginia.

Stern, K., & Schaab, B. (1991). Personal identification verification using signature dynamics. Unpublished test report. IBM Charlotte Human Factors.