AVIATION psychology

Gower

Edited by
RICHARD S. JENSEN

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Edited by
RICHARD S. JENSEN
Department of Aviation
The Ohio State University

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AVIATION PSYCHOLOGY

To:

Mark and Rachel

Preface

Aviation psychology can be defined as the study of human behavior in the design and operation of aviation systems. As such, it is a multi-disciplinary field depending upon contributions from four academic disciplines: Engineering, Psychology, Education, and Physiology. From the early days of WW I, aviation psychology has been focused on pilot selection. However, in recent years, the field has changed direction, concentrating on such issues as cockpit design, crew decision making, training, workload, and physiological factors such as fatigue, stress, and substance abuse.

The contents of this book are the result of the efforts of sixteen prominent researchers in the field of aviation psychology brought together by the Ohio State University's Biennial Symposium on Aviation Psychology held in Columbus, Ohio. It is divided into four sections representing the four academic disciplines mentioned above.

Engineering is frequently the driving force behind the rest of the field because it defines the role played by the operator. As we enter the era of the "Super Cockpit" (See Chapter 1), new concerns are raised requiring the expertise of the aviation psychologist in the design stages of these systems. The objective of the engineer in the field of aviation psychology is to design safe, effective, and reliable aircraft systems that minimize the need for operator selection and training (Roscoe, 1980).

Psychology includes problems that have been considered "soft" science in the past but are taking on new importance due to the changing role of the flight crew as managers and decision makers rather than continuous manipulators of the controls. Within psychology, the primary focus is on normal human behavior including: perception, cognition, information processing, and learning. Although personality is an important aspect in aviator selection, there is little interest or contribution from other areas of the field.

Education is important to aviation psychology because it's function is to "complete the job left undone by the engineer" (Roscoe, 1980) in system safety, effectiveness, and reliability. The educational program then is developed to fit the needs of the learner. The field of simulation for training is also an important part of this contribution.

Physiology is important to aviation psychology because of the impact it has on the performance of the pilot. For years it was the main focus of human performance in aviation. It remains important today because of the problems of fatigue in long-haul flights, g-induced loss of consciousness in many military flights, effects of many other factors such as alcohol, drugs, nutrition, stress, etc.

R.S. Jensen

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Contributors

Adams, Richard J., Advanced Aviation Concepts, Inc., Jupiter, Florida

Biegalski, Lt.Col. Conrad S., United States Air Force, Travis Air Force Base, California

Collins, Dr. William E., Federal Aviation Administration, Civil Aeromedical Institute, Oklahoma City, Oklahoma

Diehl, Dr. Alan E, Head Quarters, United States Air Force Inspection Safety Center, Norton Air Force Base, California

Dolgin, Dr. Daniel L., Naval Aerospace Medical Research Laboratory, Pensacola, Florida

Gawron, Dr. Valerie J., Flight Research Department, Arvin/Calspan, Buffalo, New York

Gibb, Dr. Gerald D., Embry-Riddle Aeronautical University, Daytona Beach, Florida

Hopkin, Dr. V. David, RAF Institute of Aviation Medicine, Farnborough England

Hubbard, Dr. David C., University of Dayton Research Institute, Williams Air Force Base, Arizona

Jensen, Dr. Richard S., Department of Aviation, The Ohio State University Columbus, Ohio

Kegg, Dr. Pamela S., Federal Aviation Administration, Civil Aeromedical Institute, Oklahoma City, Oklahoma

Manning, Dr. Carol A., Federal Aviation Administration, Civil Aeromedical Institute, Oklahoma City, Oklahoma

Miller, Dr. James (Jay) C., Chief, Human Factors Branch, United States Air Force Flight Test Center, Edwards Air Force Base, California

Moore, Dr. Thomas J., Armstrong Aerospace Medical Research Laboratory Wright-Patterson Air Force Base, Ohio

Rockway, Dr. Marty R., University of Dayton Research Institute, Williams Air Force Base, Arizona

Roscoe, Dr. Stanley N., ILLIANA Aviation Sciences, California

Samel, Dr. Alexander, DFVLR-Institute for Aerospace Medicine, Koln, West Germany

Schiflett, Dr. Samuel G., United States Air Force, School of Aerospace Medicine, Brooks Air Force Base, Texas

Stark, Dr. Edward A., Singer-Link, Binghamton, New York

Stinnett, Thomas A., Defense and Electronics Center, Westinghouse Electric Corporation

Taylor, Dr. Robert M., RAF Institute of Aviation Medicine, Farnborough, England

Telfer, Dr. Ross, Institute of Aviation, University of Newcastle, Australia

Tsang, Dr. Pamela S., Department of Psychology, Wright State University, Ohio

Vidulich, Dr. Michael A., Human Engineering Division, United States Air Force, Wright-Patterson Air Force Base, Ohio

Waag, Dr. Wayne L., United States Air Force, Williams Air Force Base, Arizona

Wegmann, Dr. Hans-Martin, Institute for Aerospace Medicine, West Germany

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THOMAS A. STINNETT

INTRODUCTION

The role of the human factors engineer in the design and development of the super cockpit, will be crucial for the future of human factors engineering as well as the super cockpit. The communication between human factors engineers and other engineering disciplines has been poor. Engineering disciplines, other than human factors specialists, tend to neglect the importance of the man-machine interface. Human factors engineers tend to concentrate their efforts on conducting paper studies and laboratory experimentation. This criticism is not directed towards those human factors personnel who are solely engaged in basic research. Rather, it is directed more towards those who are engaged in applying human factors techniques to the design and development of systems programs. However, even those engaged in basic research, should strive to make it easier to relate the results of their efforts to applied human factors. This is usually very difficult to do. The tendency to play a criticizing rather than a creative engineering role has relegated most human factors engineering staffs to participate as minor contributors to systems program conception, design, and development engineering activities. To succeed, the super cockpit must overcome many formidable systems engineering problems related to software, hardware, and human factors engineering. Since the pilot and cockpit interface is the focal point of the super cockpit, human factors must play a significant role in the systems integration engineering team. The most prominent problems are related to pilot acceptance, multisensor and display information fusion, the helmet-mounted display (HMD), and artificial intelligence/expert systems (AI/ES). A coordinated systems design engineering team effort will be required to achieve the stated goals of the super cockpit as specified by the Human Systems Division, Air Force Systems Command (AFSC). This chapter provides a general background of the evolution of the man-machine interface leading up to the super cockpit, identifies the most prominent problems, and discusses recommended technical approaches to resolve them.

BACKGROUND

The interaction between man and machine from the first club, stone, or tool selected by prehistoric man to extend his physical capability to the present development of computers, robots, and sensors to extend his mental as well as his physical capabilities, has been beset by neglect and oversight. One of the major reasons for this casual attitude is that humans are extremely adaptable with an inherent ability to compensate for deficiencies and inadequacies in the interface between man and machine. Displays and controls have tended to be considered by scientists and engineers as not being very technically challenging and therefore not deserving of the same degree of attention as other aspects of system design. The old saying, 'he can fly the crate it came in', or, 'they can learn to use it', aptly reflects this line of thinking. It was not until World War II when weapons had become more sophisticated and complex, did displays and controls, the primary means with which humans interact with machines, begin to take on some import. Today, the current state-of-the-art of technological achievement and the severe or catastrophic consequences of system failure due to human error, has resulted in an awareness of the necessity to design and develop the most efficient displays and controls possible. Nuclear power plant, industrial, and air traffic control catastrophic accidents caused by 'human error', have heightened public awareness of the importance of the man-machine interface. The proliferation of first, computer games, and then, personal and business computers, has also influenced this awareness. The general public has become acutely aware of the importance of the human factor and the man-machine interface. 'User friendly' has become a byword in the public vocabulary.

In the affairs of national defense, the numerical superiority in conventional weapons enjoyed by the Threat, has forced us to compensate by developing superior performance weapons by the application of advanced technology or 'high tech'. The super cockpit concept is the culmination of the awareness of the criticality of the man-machine interface. It's implications are relevant to industrial and commercial applications as well as military airborne and surface based crew stations. Technological spin-offs for unforeseen applications can be expected as well. Whether all of these spin-offs will prove to be beneficial to society in general remains to be seen. The super cockpit is one of the higher priorities of the system objectives defined by the United States Air Force Forecast II study which was conducted to prepare for the 21st Century by identifying future systems technological requirements (Super Cockpit Industry Days, 1987). Table 1.1 lists the ten technologies that are directly oriented towards human factors research and engineering development. The U.S. Army has conducted a similar study entitled, Air-Land Battle Concept 2000. The time-frame covers the years 2000 through 2015 (termed Army 21).

Table 1.1
RADC Staff forecast II: Technologies related to human systems

ID#	DESCRIPTION	ID#	DESCRIPTION
PT-36	KNOWLEDGE-BASED SYSTEM	PT-34	ROBOTIC TELEPRESENCE
PT-40	VIRTUAL MAN-MACHINE INTERACTION	PS-27	MANNED SPACE STATION
PT-44	AIRCREW COMBAT MISSION ENHANCEMENT (ACME)	PS-39	THEATRE AIR WARFARE C^3I
PS-48	BATTLE MANAGEMENT PROCESSING & DISPLAY SYSTEM	PS-44	SUPER COCKPIT
PT-07	RAPIDLY RECONFIGURABLE CREW STATION	PS-46	BATTLE MANAGEMENT WORKSTATION

Caution should be exercised in drawing inferences from these studies since they attempt to project military combat operational requirements into the future by 10 to 20 years. Since the average design and development time of most military systems is about 10 to 15 years, it is necessary to make such predictions. However, technical advances are unpredictable and dramatic breakthroughs and reversals can be expected to occur altering the direction of system design and development, opening new unforeseen horizons, and diminishing or eliminating others. By the time most systems are deployed, their operational nature has also been drastically modified. A good example is the F-16 which was conceived as a highly maneuverable, low-cost, austere, air-combat dogfighter (the low end of the low-high cost weapons mix). Today, it has a complex, expensive, avionics suite and also performs air-to-ground weapons delivery as well as air combat missions. Such projections, if historical precedence has any meaning, are invariably inaccurate. It is impossible to predict, with any reasonable degree of accuracy, the national, international, political, and sociological changes that will occur. The world is dynamic, in a constant state of flux, and military requirements are influenced by all of these variables. There is also the question; which should be the driver for establishing the baselines of future system design and development programs; technology or operational requirements? Ideally, it should be a combination of both, each drawing upon each other, taken in small incremental steps to ensure compatibility and acceptance on both sides.

Another possible reason for the lack of attention given to the man-machine interface, is the lack of communication and coordination between human factors, and the electronic, mechanical, and software design engineers, who have traditionally been responsible for system definition, design, and development. The fault lies with both parties: design engineers view the human factor to be insignificant or of a low priority, and human factors engineers have tended to function as criticizers rather than as creators. There seems to be a narcissistic tendency for human factors engineers to work, preach, and publish, within their own group: a tendency to function in isolation and independent of those actively engaged in the conception, design, and systems development process. In order for the human factors community to effectively participate in the super cockpit program, it will be necessary for it to play a more prominent role. Also, technical publications and presentations issued by human factors personnel tend to be oriented towards an audience of peers; stilted, pedantic, and filled with terms and jargon familiar only to those actively engaged in the field. Very few design engineers read the Human Factors Journal. An overabundance of references conveys the impression that human factors engineers devote most of their time to writing study reports, analyzing other human factors studies, e.g., conducting literature searches while not offering creative or original thoughts of their own. This preaching to the choir makes it very difficult, if not impossible, to apply human factors experimental results or studies to actual design and development programs. This situation has led most systems program managers and technical staffs to view human factors with a jaundiced eye.

Fault also lies with the excessive documentation requirements dictated by customer specifications. To meet these requirements, human factors engineers are forced to spend an inordinate amount of time and effort filling out compliance sheets, task analysis reports, etc., which prevents them from playing a more creative role. Human factors engineers rapidly find themselves engulfed in producing a blizzard of specification required paperwork. This situation results in a productive time-lag between the schedules of human factors, and program design and development engineering. Therefore, most human factors program engineers are tolerated as a burden placed upon program managers by the necessity to ensure compliance with required human factors military specifications and standards.

Bearing this in mind, human factors personnel must redirect and re-orient their technical and communication approaches to be of interest and value to those actively engaged in the program engineering design and development arena. Once a system baseline has been established, it is extremely difficult to modify it. The advent of the super cockpit concept makes it imperative that human factors engineers strive to become an integral part of the design engineering team. This will require a willingness and the courage to rely on intuition, technical judgment, and experience, when there is no time nor funding to conduct extensive, time consuming, experimentation and analysis.

The Implications of High Technology

The advent of the concept of the 'super cockpit' has implications that reflects a quantum leap forward in the ways that humans will interact with machines and systems in the future. These implications can only be imagined and are dependent upon conjecture. The dramatic technological advances being made in sensor, signal, information, and display and control capabilities are virtually impossible to keep up with. The result is a proliferation of technical disciplines, each of which is constrained by training and interests, making it more difficult than ever to achieve comprehensive and efficient systems integration. Therefore, it is vitally important that human factors engineering becomes a recognised and integral part of the systems engineering design team. Human factors engineering must participate actively and energetically in the conception, design, and development process. The tendency to function only in a critic's role must be abandoned. It is far easier to criticize than it is to create and develop. The evolution of most systems is typically dependent upon a small nucleus of program systems engineers, who usually operate by themselves in a closed conference, to hammer out the system configuration concept. These confabs may be considered to be 'skunk works' where technical experience and engineering intuition play a key role. There is no time to painstakingly construct and analyze operational sequence, task, and timeline analyses. This is not to say that such analyses, along with experimentation and simulation, should be abandoned; they should be exercised in a manner and within a time-frame that is responsive and valuable to the systems design and development effort. They should be employed as design tools, rather than as substantiating documentation.

The current emphasis placed on high technology and it's attendant activities such as artificial intelligence (AI), expert systems, computer science and technology, etc., is fraught with peril for the human factors discipline as well as for those concerned with human welfare. Displays and controls have traditionally tended to be the responsibility of electromechanical engineers. With the advent of the digital computer, software engineers have begun to play significant roles and in many cases, predominate ones. This emerging predominance can be expected to dramatically increase during the evolution of the super cockpit concept. It is therefore necessary that human factors personnel place more emphasis upon information integration, i.e., the sensing, processing, and display of information to the operator (Figure 1.1), rather than confining it to the aspects of hardware mechanization that has been common to the practice of human engineering (ergonomics). The definition of the word 'information' has been difficult to pin down. It is a matter of semantics and depends upon it's application and technical orientation of the person using it.

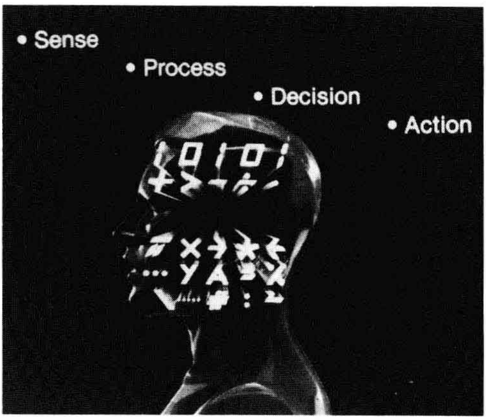

Figure 1.1 The human factor system interaction

Claude Shannon, in his famous Bell Labs paper, A Mathematical Theory of Communication, established the discipline of information theory which was the genesis of electronic transmission and processing of signal data or information (Shannon, 1948). Shannon and others tried to coin or select a word more representative of his theory, but 'information' continued to be used. Shannon's technical definition of information, which is essentially a quantitative measure of transmitted and received electrical pulse messages that are encoded and decoded, was quite different from the conventional definition and common usage of the word by semanticists and the general public. This unfortunate appropriation and twisting of a common conventional word by the technical community has also occurred with the word 'intelligence', as applied to artificial intelligence, or AI, which also has been misused and misunderstood. Software engineers are very inept at conveying information in the traditional sense of the word and it will be up to the human factors engineers to provide the lead or at least a bridge between systems, software, and hardware design engineers, and the operational user community. The recent genesis of knowledge engineering is based upon this premise.

There are as many different definitions of AI as there are people who employ it. These range from the 'thinking computer' to 'computer-aided.' The term computer-aided is preferred by many design engineers who are more realistic in it's potential for application to large, complex, non-structured operational programs. There is more general interest in the merits of expert systems which as an adjunct of AI, is closer to reality and easier for humans to relate to. Expert systems are virtually identical to computer-aided systems which have been in existence for time immemorial, depending upon one's definition of the word computer. Mechanical computers have existed for centuries. The abacus is an example, as are the fingers of the human hand (probably the first computer), which made the base ten as the arithmetic foundation for all human calculations. If AI is to become more than a short-term fad or a buzzword applied to all types of nonsensical applications, it must be converted from academic study into applied engineering systems design. This is proving to be extremely difficult to do.

As with Shannon, Norbert Wiener held deep concerns about the misuse of cybernetics which he expressed in his study, The Human Use of Human Beings, written as a popularized version of his classic 1948 work, Cybernetics (Wiener, 1948a; 1948b). This concern of the misuse and potential for an adverse impact on society was also earlier expressed in a Broadway satire entitled, The Adding Machine, written by Edgar Rice and produced in 1923 (Rice, 1923). The protagonist, Mr. Zero, was a bookkeeper who painstakingly scribed with pen and paper the accounts of the company he worked for. When a new mechanical adding machine was implemented, he became a slave to it, sitting there for hours, punching keys on a keyboard. Kurt Vonnuget Jr. wrote a novel published in 1960, entitled Player Piano, which also expressed similar concern (Vonnuget, 1960). His reference to a third industrial revolution where thinking machines take over all government, military, and civilian industries and enterprises, is chilling to contemplate. The restructuring of the world's human inhabitants into the technical elite and the lower servitudes who are technical illiterates seems to be already in process.

Impetus for the Super Cockpit

The primary impetus for the super cockpit is the expanding complexity and number of subsystems and associated interfaces which has placed an unacceptable burden upon human decision-making within extremely short reaction times. In addition, the realization and acceptance that humans are