Chapter 12

FATIGUE IN AEROSPACE OPERATIONS

The achievement of global strategic and tactical capability has magnified many professional problems for the Flight Surgeon, but perhaps none more than the problem of aerospace crew fatigue. The perfection of in-flight refueling techniques and the extension of aircraft range through better design and engineering have resulted in vastly more prolonged operations than those encountered in the past. The Flight Surgeon of today finds himself confronted with fatigue problems from every conceivable operational source, whether it be prolonged B-52 flights, oversea tactical deployment of fighter aircraft, around-the-clock troop carrier and MAC support of far-flung operations, missile launch control duty or planning the daily routine of the astronaut.

The Flight Surgeon needs to be able to recognize and manage the fatigue problems which occur within his sphere of control. The Directorate of Flight and Missile Safety Research is convinced that many of the faulty decisions that contribute to aircraft accidents at the end of long missions can be ascribed to fatigue. An equally critical consideration is the fact that fatigue-induced performance decrements might cripple a mission on which the safety of our nation may depend. Such considerations make it obligatory to review the general subject of fatigue to assist the Flight Surgeon toward a better understanding of its etiology, prevention and control.

RESEARCH ON THE PROBLEM

There has been no lack of conscientious inquiry into the problem of fatigue in aerospace operations. The almost endless number of fatigue-producing factors present in man and his environment, and the number of these factors which cannot be simulated in the laboratory have made this area of research one amply endowed with frustration. Nevertheless, we have gained considerable insight into a number of facets of the problem. A thorough, critical review of the research efforts in this area is beyond the scope of this chapter, but one will be well repaid if he scans some of the references listed at the end of this chapter. From the early work of F. C. Bartlett in 1942 with the "Cambridge Cockpit" up through the latest review of fatigue by O. B. Schreuder in 1966, many investigators have added to our knowledge of what fatigue is, when one should suspect its presence, how one recognizes it, and what one can do about it. Unfortunately, none of the studies, including the biochemical determinations of various "stress catabolites," are able to give us a reliable answer to our basic question: "When is a crew member too fatigued to fly safely and proficiently?" Before reviewing some of the studies listed at the end of this chapter, one should be forewarned that, at present, there are no practical and objective tests to answer the key question asked above.

The present treatment of the subject of fatigue will be disappointingly vague because the size and complexity of the problem far exceed the available knowledge. However, a delineation of what little is known will serve a useful purpose, and a realization of what remains to be discovered may stimulate the careful observer to contribute significant observations from his day-to-day professional practice. A reasonable approach to the problem might well involve:

a. First, the consideration of a practical, working definition of fatigue and a description of the types of situations likely to engender significant amounts of fatigue.

b. Second, a discussion of the kinds of observations which support a diagnosis of fatigue, and an attempt to provide theoretical perspectives within which these observations can be evaluated. Finally, some of the actions available to the Flight Surgeon for the prevention and relief of fatigue will be suggested.

WHAT IS FATIGUE?

The word "fatigue" arose from the Latin *fatigare,* meaning "to waste away." Viewed in this sense, the term has enjoyed a very general descriptive usefulness by many scientific and technical disciplines to denote a change in some natural property from a stronger to a weaker manifestation. Unfortunately, these widespread applications of the word "fatigue" have resulted in many variations, both in its *specific* meaning and in the inciting causes implied by its use. To understand what is meant by "fatigue," one must know the scientific discipline of the user. To the exercise physiologist, "fatigue" implies decrements in muscle strength associated with depleted energy-producing compounds and increases in anerobic breakdown products, such as lactic acid. To the metallurgist, "fatigue" implies a progressive deterioration in the strength of a metal associated with crystalline changes in its structure as a result of repeated stresses. To the psychologist, "fatigue" may imply a mental state characterized by decreasing motivation, an elevated threshold for stimuli and a decrease in accuracy and speed in solving problems or carrying out psychomotor tasks. To the Flight Surgeon, who is more interested in the "whole man" and his capability to perform as an integrated part of a weapon system, we can best define "fatigue" as that condition characterized by a detrimental alteration or decrement in skilled performance related to duration or repetitive use of various skills. Physical, physiological, and psychological stresses may singly or in combination accentuate the fatigue state.

It is thus clear that, to determine the etiological basis of fatigue in aerospace operations, one must learn to distinguish carefully between various factors that might induce or aggravate a decrement in performance. Each instance must be regarded as having its own etiological chain, along which physical, physiological, and psychological factors may assume importance. This caution merely recognizes that behavior can deteriorate in many different ways and for many different reasons. The task of the Flight Surgeon is to discover the reasons for a particular deterioration, pursue all possible means to arrest it, and restore full performance capability. In so doing, the Flight Surgeon will often find himself dealing with factors and circumstances far removed from traditional notions of fatigue. Ideally, the Flight Surgeon will attempt to recognize those potential factors which may lead or contribute to fatigue, and prescribe the necessary corrective measures to prevent the problem.

VARIETIES OF FATIGUE

Flying fatigue is generally identified in two overlapping categories: Acute Skill Fatigue and Chronic Flying Fatigue. A third classification of physical or muscular fatigue on rare occasions, may be important in the flying environment. Generally, the physical exertions of flying are not great enough to create the muscular fatigue encountered in prolonged manual labor. However, prolonged sitting, encumbered by personal equipment of varying degrees of discomfort, may cause static muscular discomfort as a result of stasis and local pressure point hypoxia.

Acute Skill Fatigue

Acute skill fatigue or "single mission skill fatigue" is that tendency towards decrement in either quality or quantity of skilled work output which occurs concomitant with the prolonged application of oneself to a demanding task.

The etiology of this type of fatigue is primarily psychological. Monotony of the task, particularly one that requires close, continued attention and carries considerable personal responsibility for the consequences of any lapses in attention, is an important cause. Apprehension, boredom, relative immobility, and *lack* of apparent threat to life or limb all contribute to a progressive disinclination to observe and critically evaluate what is going on around the operator. As would be expected, physiological factors such as mild hypoxia, hypoglycemia, dehydration, and recent illnesses all can contribute to a lessened ability of the operator to resist the psychological factors. Environmental factors such as weather and turbulence, high noise levels in the cockpit or in the headphones, and discomfort from inadequate cockpit temperature controls will further lessen the operator's resistance to the stultifying psychological factors.

Symptoms and signs of acute skill fatigue fall into three general areas:

a. *Decrement in psychomotor functions* manifested by decreased coordination and over and under controlling of stick and rudders;

b. *Narrowed span of attention* resulting in a tendency to "leave out" important elements of sequential tasks, failure to scan the whole instrument panel, slowing of the "cross check" of primary flight instrument and a tendency to "fix" on one instrument to the neglect of other equally important instruments; and

c. *Acceptance of a lowered standard of performance* and increasing preoccupation with and distraction by minor discomforts.

Much of this symptomatology is reversible, at least for some time intervals. The occurrence of any event that breaks the monotony of the task may bring the operator's skill and attention almost up to its unfatigued level. An inflight emergency, a "near miss" or even the preparations for landing will normally wipe away much of the fog which appears to cloud the flier's mind in this type of fatigue.

Our description of acute skill fatigue should include reference to an allied phenomenon which has come to be known as *vigilance* decrement, that is, a loss in one's readiness to perceive and respond to the signal inputs of watchkeeping tasks. This phenomenon is customarily measured in terms of errors of omission and prolongation of response times. Losses in vigilance are perhaps most common among radarscope observers, but they are also seen among pilots and flight engineers engaged in monitoring instrument displays. Such losses occur most readily under conditions of low signal rate in which there are unpredictable intervals between signal inputs, but other factors inherent in the design of the display system and the surrounding conditions of work cannot be ignored. The operational importance of this phenomenon can be inferred from laboratory studies which have shown that vigilance losses of 50% or more can occur within the first half hour of watchkeeping, and the existence of this problem under actual field conditions is well established.

The length of time required before acute skill fatigue becomes a hazard is extremely variable. The Royal Air Force found that significant degrees of acute skill fatigue were observable after 10 hours of flight in piston-type aircraft and after only three 1-hour sorties in jet fighters. The fatigue response was quite variable among different pilots and appeared to be more severe in night flying. Obviously, the stamina and reserve of the crew member at the time he is exposed to an acute skill fatigue will affect his ability to fight off the deleterious effects on his performance capability.

The wide variation in capability to resist the effects of acute skill fatigue which exists in various persons and within the same person at different times, makes the prediction of the onset of skill fatigue difficult at best. Only by knowing each crewmember's stamina and reserve at the time of exposure and the magnitude and quality of the fatigue-inciting events to which he is exposed, can the Flight Surgeon hope to prognosticate the time at which the crewmember will become significantly fatigued.

Chronic Flying Fatigue

Chronic flying fatigue is the term applied to the "staleness" or lowered "fatigability threshold" that results from the accumulation of residual fatigue left over from incompletely compensated recurrent acute skill fatigue.

Single episodes of acute skill fatigue can usually be corrected by a suitable rest period which gives the crewmember time to replenish his psychological and physiological reserves. For most healthy Air Force personnel, a good night's sleep is sufficient time in which to accomplish this "reknitting of the ravelled sleeve of care." However, when operational requirements dictate recurrent maximum effort missions over prolonged periods with insufficient rest and recreation to allow complete recovery from the preceding mission before undertaking the next mission, the crewmember's reserves become steadily more depleted. Acute skill fatigue tends to occur earlier in each mission and with less provocation as the crewmember becomes enmeshed in a tightening spiral of circumstances which deplete his resistance to fatigue at a steadily increasing rate.

The same etiologic factors that cause acute skill fatigue are active in chronic flying fatigue, but the crewmember's tolerance is lessened. This lessened tolerance amplifies the deleterious effects of environmental factors that were not previously significant into major stresses which take further toll of the crewmember's reserves. This is manifested by an increased awareness of discomfort, irritability, "grousing" and visible decrements in the quality of task performance and a tendency to "cut corners."

MANAGEMENT OF FATIGUE

In the ideal, and, hence, theoretical situation, fatigue is undesirable in any degree. Unfortunately, this ideal situation does not exist and we must accept the fact that fatigue is a natural and concomitant result of any demanding activity. Since the unit cannot accomplish its mission without such activity, we must accept certain minimum amounts of fatigue as a natural and implacable result of mission-oriented activity. What the Flight Surgeon must try to do is minimize the associated fatigue by minimizing or eliminating the environmental stresses that increase the amount of fatigue, but which are not absolutely necessary to the mission. It is equally important that the Flight Surgeon emphasize and advocate the factors that increase the crewmember's ability to minimize the effects of fatigue on task performance. Determining which factors are unnecessary to the mission and which can be eliminated without affecting the mission requires good judgment and close cooperation between the Flight Surgeon and the nonmedical staff members of the unit. A few of the factors that have been identified in previous studies as having positive and negative affects on fatigue levels are listed in table 12-1.

TABLE 12-1. FACTORS TO BE CONSIDERED IN ESTIMATION OF FATIGUE POTENTIALS

a. *Length of Flights:* false starts; delayed flights; waiting periods at intermediate stops.

b. *Layover Facilities:* beds; sleeping conditions; messing; recreation and diversion; ground station organization.

c. *Reliability of Radio Aids* (particularly in the arctic and around the border of hostile countries).

d. *Uncomfortable personal equipment* (oxygen masks; pressure suits; anti-immersion suits).

e. *Weather:* anticipation of bad weather; rough flying with auxiliary crew on the verge of airsickness.

f. *Physical Condition:* lack of exercise and general body tone; poor eating habits; drinking the night before flying and during intermediate stops; smoking.

g. *Human Factors Design Engineering:* seat comfort; flight-deck design; sleeping facilities; working area lighting; reliability of the aircraft; adequacy of heating and ventilating systems for arctic and tropical flights; facilities for good in-flight meals; noise and vibration levels; instrument arrangements.

h. *Toxic Factors* such as prolonged flying at 10,000 feet and slightly over without supplemental oxygen; carbon monoxide and excessive carbon dioxide in the cabin.

i. *Leadership and Team Spirit:* Relationships with aircraft commanders and with superiors on the ground; adequate support and backup;

TABLE 12-1. Continued

amount of paperwork; effectiveness with organization; amount of individual responsibility; on and off-duty responsibilities.

j. *Personal Factors:* amount of flying experience (earlier flights in a career tend to be more fatiguing); domestic difficulties; financial security; personality of the individual; motivation and conscientiousness.

k. *Diurnal Rhythm Factors.*

l. *Unforeseen Emergencies.*

A study of these factors will reveal a number of situations and conditions that can be minimized or eliminated if they are fatigue-inducing or encouraged and strengthened if they are fatigue-resisting.

In addition to his generalized, unit-wide efforts to prevent the effects of fatigue, the Flight Surgeon has an additional and awesome responsibility, namely, to identify individual crewmembers who are fatigued to the point that their performance is likely to be unsafe. Successful identification of such crewmembers requires the Flight Surgeon to have a detailed knowledge of how each crewmember normally behaves so that the earliest, minimal changes in behavior which are suggestive of fatigue can be noted and acted upon. A detailed knowledge of each crewmember's normal behavior under different environmental conditions and types of stress is gained only by continued and close association between the Flight Surgeon and the crewmember. Only in this way can the Flight Surgeon accurately perceive when the flier "just isn't himself" and thus, can identify abnormal behavioral patterns long before the customary clinical or medical laboratory tests show any abnormality.

The conscientious Flight Surgeon must try to walk the narrow line between the error of allowing dangerously fatigued crewmembers to continue flying and the error of grounding crewmembers who still can perform their tasks safely. In this latter error, overcautiousness by the Flight Surgeon causes the remaining crews to have to shoulder the additional loads of the grounded crewmembers which may result in an increased over-all "failure rate."

At all times, the Flight Surgeon should adhere to the concept that each person's fatigue problem is unique and worthy of special study in terms of the personal and situational factors which lie beneath it. This stems from the fact that no two persons react alike under the same prevailing circumstances. No other approach will go as far toward revealing the changes that may be required in the habits, attitudes, and motivational structure of the person or the environmental circumstances under which he is operating.

The role of the Unit Commander in fatigue prevention may be less scientific than that of the Flight Surgeon, but it scarcely can be regarded as less direct. Command leadership instills mission orientation, defines operational objectives, establishes level and quality of mission support, and allocates various rewards and privileges available within the natural setting of the operation. The commander is as interested as the Flight Surgeon in preventing crippling fatigue; he is receptive to professional advice on the subject and any carefully considered recommendation for environmental control that might lie within his purview. *For example,* the commanders of MAC and SAC, acting on the advice of the Flight Surgeon, improved crew facilities aboard aircraft and provided additional crewmembers to permit rotation of duties and longer rest periods. These measures resulted in more effective performance during prolonged missions.

Finally, the Flight Surgeon should employ every means available to him to consider human factors and their relationship to safe and efficient job performance. (Research facilities and personnel proficient in human factor analyses are available in the Aerospace Medical Division of the Air Force Systems Command. When required, the services of these facilities and personnel can be obtained, upon request, through normal medical channels.) The quality and consistency of work output are profoundly dependent upon equipment and work space design. Competent equipment design can be achieved only through exhaustive studies of human capabilities and limitations. Much has already been accomplished to improve comfort, range of motion, simplicity of display, organization of control complexes, and computational aids, but there is still room for improvement. The Flight Surgeon can make a valuable contribution to this effort by publicizing, through the medium of the Unsatisfactory Report or the Aerospace Medicine Report, the comments and criticisms made by aircrewmembers concerning their equipment and work methods.

It has been found that intensive training will build up confidence and permit more relaxed flying responses. As a result, inflight emergencies and the ground controlled approach (GCA) at destination become less troublesome to the trained crewmember. In the case of simulators, indoctrination on skill fatigue leads to significant performance improvement. Frequently, fatigue simply signals the need for a few moments of variety and change to restore performance. In industry, when workers have been given breaks, output has been found to be superior to that produced by working continuously.

Coffee should be reserved for the last half of a flight since many people get a postcaffeine letdown. Similarly, meals should be balanced rather than relying on pure carbohydrate, since an insulin over-shoot may produce delayed hypoglycemia. The person in a good physical condition has greater ability to tolerate fatigue, experiences less postural tiring, and recovers faster after the mission.

Dextroamphetamine has been administered to a large number of aircrews without an accident attributable to the drug. However, side reactions have occurred in flight. To cite a case, one F–100 pilot who had been pretested as required and showed no side effects, took his first 5 mgm dexedrine before a refueling over the mid-Atlantic. He experienced a feeling of euphoria with a narrowed span of attention and complained that he could think of only one procedure at a time. Others have noted agitation and hyperactivity. Attention to crew rest facilities in larger aircraft has obviated the requirement for stimulants on many missions and constitutes a much better approach to the problem.

Unquestionably, fatigue will be a major problem in future space operations. The prolonged nature of such missions, coupled with periods of unpowered orbital flight en route, a minimal input workload and associated monotony, will create fatigue problems of considerable magnitude.

Although fatigue is a basic response of the human to continued stress, it can be minimized through a system of crew and environmental controls. The Flight Surgeon should be vitally interested in operational problems and their investigation and should serve as an advisor to the operational commander in the planning and evaluation of systems application to man.

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