The Medical Aspects of Skill

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Air crew are selected on an educational, intelligence, and medical-fitness basis, and thereafter all training and continuation training is devoted to the development and maintenance of flying skill, which can be defined as the ability to produce a calculated reaction to a stimulus or series of stimuli. The many factors that can adversely affect this acquired skill must be considered in relation to air crew. The aim of aviation medicine is to investigate these factors and their effect on skill, and to advise the aircraft designer, engineer, and operators how best to eliminate or greatly reduce them.

Aviation Medicine is that branch of occupational medicine concerned with the many tasks associated with the operation of aircraft. Inevitably the pilot of an aircraft is the crew member of greatest interest and the number of factors which may affect his well-being all ultimately affect his skill as a pilot. The principal aim and purpose therefore, of Aviation Medicine, is to advise the designer and engineer of the particular physiological, psychological and medical factors which exist and how best to eliminate or greatly reduce them, and so maintain the environment and conditions of flight that the pilot can function to his best advantage at all times and be able to exercise his acquired skill to ensure maximal safety.

In the particular context with which we are interested it is the skill of flying a modern aircraft with which this paper is concerned. Skill can be defined in a number of ways depending on the art to which it is applied, but in relation to the art of flying it could perhaps be defined as the ability to react in a correct and calculated way to a single stimulus, or to a complex variety of stimuli and to ignore false and irrelevant stimuli, and to be able to forsee, and thereby often forestall, an undesirable situation.

The skill acquired in this particular art is the learning, through a long and complex training, of the implications of single or multiple stimuli and using the particular ability of the human mind to store such information to produce the correct response, not instinctively, but as a result of a considered action. Thus most of us are reasonably skilled in one or other of the many arts. Anyone can go out on a golf course and hit a golf ball, but it takes many hours of study of the art of golf and practice to become a really first-class player whose skill enables him to weigh up all the factors to be considered in any particular situation and to produce the desired result, which so few of us can. In the art of flying the degree of skill which any pilot achieves depends initially on the basic background of that individual. Some ability in the general art of learning is a prerequisite for selection for flying training, as the acquisition of skill is itself a process of learning, and once this process has been completed the maintenance of skill depends on the practice of the art and on the process of refresher and continuation training, without which any acquired skill and ability will rapidly recede.

The complexity of the modern aircraft with its multiple systems, the size of the aircraft passenger load, the density of air traffic and the need for rapid handling of traffic into and out of airfields, places a great responsibility on the captain. He must be able to react correctly to any situation and it is the degree of skill which he can acquire and exercise which will directly influence his reaction. Such reactions can be assessed by simulator training where emergencies can be presented to him and his reaction to them confirmed and compared with his previous performance in response to similar stimuli. Thus the pilot of today, and the airline pilot in particular, must be an individual whose skill and capability are on the top line at all times.

In this paper I shall endeavour to consider medical factors which affect the specific skill of flying. These factors are many. Almost every external distraction and variation will have an adverse effect and I am not aware of any single factor which can improve skill other than those which I have already mentioned. The presence of a training captain beside an airline pilot may well stimulate him to exercise a higher degree of skill, although I think this is the exception and not the rule, and not infrequently this may produce the opposite reaction through nervousness, displaying a lack of confidence by a pilot in his own ability, so that the practice of all airline pilots flying with a training captain at regular intervals is obviously a good one.

I would like now to discuss personal factors, the first of which is health, defined by the World Health Organisation as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. The airline authorities and the licensing authorities spend much money and effort on ensuring that pilots in particular are fit and likely to remain so, and it is incumbent upon air crew to ensure that they keep themselves fit, as their livelihood depends upon their ability to fly. The annual medical examination to which airline pilots and air crew are subjected is extensive and uses all known modern techniques to investigate their systems, but nevertheless incidents do occur where pilots have died in the air as a result of a sudden medical incident and the number of potentially lethal conditions which are discovered as a result of post-mortem examinations of young and apparently healthy individuals is alarming. Nevertheless, the keeping of medical records and the periodical check on individuals involved in flying is worthwhile even if it only results in the elimination of a very few, perhaps ageing, air crew in the interests of safety, their own and of their passengers and crew. To a great extent the medical authorities must rely upon the honesty of air crew themselves to report known deficiencies, even though this might result in the loss of their livelihood. Better that than the loss of their life. Air crew should be encouraged to take mild regular exercise, preferably of a type which they can organise on their own without involving many other individuals and, of the recognised exercises, golf and squash are probably predominant, although there are others.

It is almost impossible for air crew to maintain a regular living rhythm as they are moving around the world and their natural rhythm is being constantly disturbed. This is a factor which some get used to but in the maintenance of full body efficiency and in the elimination of fatigue, effective sleep is the most important single factor. There is no known indication of fatigue, there is nothing that can be measured on an individual to say that that man is tired beyond his work capability; individual variations are so enormous that although it is reasonable to lay down standard working periods under varying conditions it cannot be said that all individuals will be fatigued at the end of that period, some may be able to go on for several hours with complete safety; but there is only one factor which overcomes fatigue and that is sleep and effective sleep at that. Individual requirements of sleep vary, but as a general principle this should exceed six hours in twenty-four but should not exceed more than about eight and a half, and it is important that this sleep should be natural and uninterrupted.

I have said that sleep must be natural sleep, but in any situation where a pilot has a particularly arduous task ahead of him his ability to relapse into natural sleep may be impaired by other factors, such as worry and the fact that he is in a strange environment and perhaps out of his normal rhythm; under these conditions I think that the use of selected, short-term acting and rapidly eliminated hypnotics is desirable to enable the induced sleep to extend into a natural sleep. There is a great deal of controversy about this subject, but the personal selection of hypnotics is essential, as individual reaction to different preparations varies widely and it is essential to know the individual reaction, as this can affect subsequent performance. Much of the work which has been done on comparing performance with withheld sleep, with natural sleep and with induced sleep has been invalidated by poor design of experiment and by lack of controls. The body's need is for sleep and if this does not come naturally it should be induced, otherwise that individual will be unfit for the task which is before him.

In the maintenance of a high degree of professional skill in the art of flying, age must be considered, as obviously a young and inexperienced pilot cannot have had the experience of older pilots and it can be argued that the older pilot cannot react as rapidly as the younger. In my definition of skill I stated that this was the calculated reaction to a stimulus and therefore the rather more mature pilot with a greater background and greater degree of experience is in a far better position to produce this calculated reaction than the young and relatively immature. At this present time there are flying in our airlines a very large number of pilots who learned their flying before the Second World War or during it, and who now have some thirty years or more experience of professional flying. These pilots have advanced with the times through their primary trainers to conversion on to operational types of aircraft, to conversion again on to early types of piston engine passenger aircraft, to propjets, to jets and, some of them may shortly be progressing to the era of supersonic transport aircraft.

The question is often asked 'For how long should a pilot go on flying?' and to this I think there is really no known answer. It must depend on the individual. Cardiovascular and cerebral incidents are nearly as common in air crew of age bracket 35 to 45 as they are in the older brackets, and the elimination of aircraft pilots at too young an age would obviously be undesirable both from the point of view of the pilot's career and from the financial side. Other factors which affect the pilot personally are his own home background and happiness and whether or not he has any problems and worries which can inject themselves into his working life. These could be financial and that, to an extent, is eliminated by paying airline pilots well; it could be family problems and these easily crop up due to the comparatively large proportion of time an airline pilot spends away from home. He may be concerned about the normal things which affect us all, such as whether his children are making progress at school, what their future is likely to be, and all this leads up to the need to ensure a stable and happy home and a secure pilot, devoid of worries, who is alert and fully aware of the importance of his job.

The environment in which a pilot is working will have a direct effect on his ability to work well. Environment is a factor which can change rapidly in a normal climate and even more rapidly with a change of aircraft position and flight state. The control of environment has been achieved in a large number of aeroplanes, the aim of such control being to ensure physical comfort. This physical comfort should be achieved first and foremost for the crew who fly the aircraft, rather than for the passengers who provide the income.

Three controllable variables affect the degree of thermal comfort in the cockpit. These are the actual temperature, the relative humidity of the air and the rate of the air movement. These three factors have been combined together by the environmental physicists to provide a measurement of effective temperature, the temperature which the body feels in any particular situation. The actual temperature, the temperature recorded by the thermometer in that situation, can be controlled by cabin conditioning, heat can be added or extracted from an aircraft cabin.

The relative humidity can be controlled by adding water vapour to the cabin air and this is usually accomplished in large passenger aircraft by the passenger load themselves, their contribution to the comfort of the aircraft. They are breathing out large quantities of water vapour all the time and in a low humidity situation expired water vapour may contribute more than 50% to the total humidity in the aircraft. Airline operators tend to be reluctant to add water to their cabin conditioning systems as the weight of water involved for an eight hour flight can be considerable, several hundred pounds, and this is lost load. Once the aircraft reaches the point of top of descent and starts to descend, humidity will increase progressively and if it has been maintained at a comfortable figure during the entire period of flight the atmosphere within the aircraft will become saturated late in the descent and massive condensation on cold parts of the aircraft structure can occur; this is highly undesirable as it may mist transparencies and short circuit electrics. It has been suggested that set minimal rates of humidity should be accepted and that to overcome the problem of condensation during descent the humidification system should be turned off half an hour before the known time of commencement of descent; in that way the humidity would be maintained during the greater part of flight and would only reach very low figures during the last half hour at cruise altitude, shortly before the humidity is about to rise again during descent. The effect of a dry, low humidity atmosphere is to produce dryness of the lips and eyes and this can become uncomfortable at humidity levels below 20% and extremely uncomfortable if this level is not maintained for periods exceeding an hour, and progressively worse for longer periods.

Control of the air movement can be effected by positioning louvres around the cockpit so that the rate of air movement in any particular zone can be controlled at will, the louvres being controllable in direction and in flow. High air flow produces rapid evaporation of sweat from skin, which is the method by which the body controls its temperature, and chilling. Chilling produces a reduction of blood flow through the skin so that the amount of sweat produced is reduced and heat lost by evaporation can thus be controlled. Most aircraft cockpits leave much to be desired in environmental control and if peak efficiency of crew is to be expected then this is an area in which an increase in efficiency from the aircraft designer could be expected.

Over the past few years the noise levels in the cockpits of aircraft have progressively been reduced. In the immediate post-war era transport aircraft were dependent on piston engine powerplants with noisy exhaust systems. Some of these were excessively noisy and levels of 110/120 dB in the cockpit zone were possible. Anything in excess of around 115 dB produces discomfort. In the line of the engines themselves even higher noise levels were experienced. Such high noise levels were not maintained throughout flight but were experienced in certain parts of the aircraft during peak engine power periods, but even under cruise conditions noise levels remained around 100 dB. Long exposure to such an intensity will induce early fatigue and skill will thereby be affected. Associated with noise, vibration in piston type aircraft was sometimes an aggravating factor. With the advent of the propjet and of the pure jet, noise levels within the aircraft have considerably reduced over the past few years and it is now possible to fly most modern jet aircraft without the need for helmets and ear defenders, and to carry on normal conversation within the cockpit area. Aerodynamic noise can become a factor in the very high speed aircraft and communication may become difficult at very high speeds due to this factor. Vibration has also been greatly reduced with the advent of the propjet and jet, but turbulence is an added disturbance which can be reduced by aircraft design and by avoidance of areas of rough air wherever possible.

Aircraft seating requires careful consideration to maintain optimal comfort over the range of sizes of pilot; the adjustment of seating and rudder pedals and of controls themselves to suit the range of size of air crew is essential, so that each and every pilot can operate all the essential controls when fully harnessed and reach all the accessories which he may have to operate, without strain and rapidly if and when the situation arises that demands this rapid action.

Much work has been done over the past 25 years on the presentation of information to the pilot and in the placing of controls logically in relation to the instruments which they affect. The grouping of the essential flight instruments in a position immediately in front of the pilot so that he can see exactly what is going on has resulted in a nearly standardised type of flying panel and these instruments are duplicated for both pilots. The complexity of modern aircraft systems has produced a situation where it is impossible to expect a single pilot to be able to scan all the instruments involved, and in larger aircraft it has become the task of a flight engineer to control the powerplant and accessories as necessary, and to monitor many instruments for the pilots.

The failure of any system can be indicated by a warning light, but when the number of warning lights becomes excessive the usefulness of this as a warning device becomes limited. So often warnings are false, they are a failure of indicating mechanisms rather than of a failure of part of the system which they are supposed to be reporting to the pilot and, when such failures become frequent, warnings tend to be ignored. The earliest form of warning was the klaxon horn interconnected with the undercarriage and airspeed indicator, but even this failed, on a number of occasions, to warn a pilot that he was landing wheels up. Auditory warnings as well as visual warnings are fed into some aircraft systems, fire for instance being indicated by the jangling of fire bells. But rather than having reliable warnings it is more important to have reliable systems. The reliance of the pilot on his systems and the improving reliability of systems goes a long way to ensure pilot confidence in the aircraft and we are all aware that such confidence increases with the number of hours of experience each pilot has on a particular type, and on the total number of hours which that aircraft has flown world-wide. When a new type of aircraft comes into service nobody knows how it will react in certain circumstances in the hands of an ordinary commercial airline pilot. Everything has been done during its acceptance trials in the hands of test pilots to ensure that all its vices have been removed, nevertheless when a new aircraft comes into initial use, certain defects usually arise and these are rapidly fed back through the system by the cross-feed of information which exists world-wide so that problems can be eliminated rapidly and corrective action taken wherever that particular type of aircraft may be operated.

The effects of decreased barometric pressure have been largely overcome by the use of pressurised cockpits and cabins. In the past the problem of exposure to altitude was one which could only be overcome by the use of additional oxygen to the inspired air and for this purpose it was necessary to use a helmet and oxygen mask. The effects of oxygen lack can be demonstrated on healthy air crew as low as 4000 ft and on the not so healthy passengers at much lower levels. With the pressurisation of modern aircraft to an altitude of around 3000 ft, hypoxia does not constitute a serious hazard to the maintenance of skill until decompression of the aircraft occurs; then it has one of the most marked effects of all extraneous factors. Individual susceptability varies widely; the general effect is of a rapid deterioration of mental and physical capability at altitudes in excess of 10,000 ft and at higher altitudes the rate of onset becomes rapid to a few seconds at 40,000 ft and almost immediate unconsciousness at any higher than this. The balance can be restored by the use of oxygen to maintain a gas mixture capable of producing blood saturation of the alveoli of the lungs, but at altitudes in excess of 33,000 ft even breathing 100% oxygen, efficiency, in the absence of additional pressurisation will decrease and at 40,000 ft breathing 100% oxygen, the degree of blood saturation is equivalent to flying at around 12,000 ft without additional oxygen. The use of oxygen equipment involves masks and tubes, and a helmet or harness on which to fit the mask to the face. This becomes a distraction and although physical and mental efficiency may be maintained in a possible emergency, the discomfort and distraction of wearing a mask for an emergency, which experience has shown is extremely unlikely to occur, is such that pilots may prefer to accept the risk and to use the facility of putting on a mask and head harness if and when this decompression occurs.

Decompression sickness or bends can be prevented by maintaining the pressure around the body by means of the aircraft pressure cabin. Therefore, it is essential that in the event of explosive or rapid decompression, descent should be made at the maximum rate of which the aircraft is capable.

Thus the effect of altitude on the skill of the pilot can be possibly more marked than any other single factor, but it is an effect which can be protected against by the use of pressure cabins. In the event of the integrity of this failing, rapid and correct action is necessary to recover the aircraft and prevent an occurrence of a major catastrophe.

The maintenance of physical comfort, control of the environment, the reduction of noise levels, the comfort of the cockpit workspace and the ability to see forward and downward from the cockpit are all aimed at maintaining the pilot in the best possible physical shape so that he can exercise his art for the expected duration of his working day, which may involve several flights during that day, and still be immediately aware of any emergency arising and immediately be able to take corrective action when this is necessary.

In the investigation of pilot work load it has become obvious that two zones of maximal work load exist. The first of these is the period immediately leading up to, during and immediately following, take-off. Second is the reverse, associated with the return of the aircraft to the runway at the end of a sector, and clearance of the runway to the dispersal area. In both these situations maximal effort and concentration is required, normally for a short period but one which may not infrequently extend up to 30 or 40 minutes. The intensity of the work load is high during the whole period of ground handling from pre-flight inspection, through the start-up period, taxiing and line-up and does not decrease until the aircraft is well and truly airborne and clear of high density traffic areas. Nevertheless, at any time during flight a high work load intensity may arise through an emergency or in high air traffic densities. It is to enable pilots to deal with such spells of high intensity work load, with the possibility of superimposed emergencies, that the high degree of training and ability to interpret emergencies which becomes skill, is demanded of them. In recent investigations of pilot work load recordings have been made of pulse rates and these have been found to be consistently higher during the pre-flight and take-off phases and during the actual approach to descent on to the runway, and highest possibly of all around threshold. The fact that a recent newspaper report noted that a pilot's pulse rate increased when the stewardess was presenting him with a cup of coffee is an indication that his personal systems were working correctly and that he was reacting to an age-old stimulus in the correct way.

In all the survey work which has been carried out to determine pilot work load and to try to determine when fatigue starts to affect the efficiency of pilots' activities, no single factor has emerged which can be used as an index of fatigue, but there is an indication that the maximal hours which have been laid down by International Regulations are justified and that these should not be exceeded. Under certain circumstances there are indications that when the work load is excessively high during certain periods of flight, usually associated with high intensity traffic zones and involving frequent changes of flight information regions, and when some of the factors which I have mentioned earlier are unfavourable, that the permitted hours should be somewhat reduced or a different system should be introduced for the scoring of sectors to the appropriate work load and environmental conditions normally associated with them. Such a system has recently been introduced into British European Airways following a suggestion from a team which investigated pilot work load within British European Airways five years ago. Although this points scheme for any particular sector is not entirely satisfactory, it is an indication of the possible means of ensuring that pilot work load in any period does not exceed a certain maximum and that thereby the safety of aircraft, crews and passengers can be improved.

Thus the maintenance of flying skill is many-sided. The first and most important is a good basic background and training and, having been trained and acquired a good degree of skill, to be able to maintain that skill through continued practice of that art, through continued training, through keenness on the job, in a comfortable, controllable environment the systems of which are as simple as possible to comprehend and to operate. I have endeavoured to outline some of the more obvious factors which can affect skill; the slightly under-confident pilot is probably better able to produce the correct reaction than an over-confident one, but one who has not the knowledge or ability will never reach the required degree of skill which I prefer in the pilot who happens to be flying me.

Discussion

A. D. Baxter (Bristol Siddeley Engines, Filton, Bristol, U.K.): It is clear from the paper that, although it is primarily concerned with aviation, its subject matter is of much wider interest and application. It is, I am sure, an excellent example of the 'fall-out' which can benefit mankind in all walks of life.

I connection with the subject of sleep, may I ask why eight and a half hours' sleep is regarded as a maximum for efficient operation? Does one's ability decline due to excessive sleep or does it remain constant beyond a certain period of rest? Can one accumulate the excess period as a reserve against shorter sleep periods? Also, are shorter periods of sleep, such as on a short train journey or after lunch, effective if accumulated to a total of 8 hours in a day?

Professor D. Keith-Lucas (College of Aeronautics, Cranfield, Bedford, U.K.): Have you any evidence on whether there is a correlation between fatigue and anxiety on the one hand and susceptibility to disorientation on the other?

Group Capt. Barwood: In the discussion which followed this paper a questioner asked what effect sedation had on the suppression of dreams, as this had been reported to produce adverse psychological effects and personality changes. The point was made, and emphasised, that in the context with which the use of sedation had been advocated this would be sporadic use, and that the use of sedation on a routine or continuous basis could not be contemplated under any circumstances. The point had also been made that careful selection of the type of sedative for each individual would be necessary and there were a number of suitable sedatives available which did not affect dreams and this was therefore not considered to be an entity.

In reply to Mr. A. D. Baxter it was suggested that excessive sleep probably produced little benefit and that the main need was for a period of effective, fully restful, and uninterrupted sleep. It was largely a matter of habit how long that period of sleep required to be and the effectiveness of sleep also controlled the amount required, but individual variation was great. Some fortunate people can recuperate greatly by a cat-nap but the habit of dropping off during the day may affect their ability to get to sleep at night and also, the efficiency of their main sleep. King Alfred advocated eight hours' work, eight hours' play and eight hours' sleep and this is really still applicable. Sir Winston Churchill was reported to have been able to work phenomenally long hours with short periods of rest and deep sleep between periods of hectic mental and sometimes physical activity — he was one of the lucky ones.

In reply to Professor Keith-Lucas it was said that anxiety was thought to be likely to have definite influence in the production of disorientation and that fatigue, by slowing reaction, could produce an incorrect and not logically calculated reaction to a stimulus and might thus tend to worsen a potential incident.