SPEED STRESS AND THE AIRCRAFT PILOT

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ABSTRACT

When the human component in a man-machine system is pushed beyond the limits of human capacity in grasping information presented to the senses or in executing a series of actions correctly, a condition of "speed stress" may be said to occur. Conditions encountered by aircraft pilots, particularly those engaged in operating fighter aircraft at high speeds, make a consideration of the forms of speed stress, and of the measures to alleviate them, extremely important.

Introduction

In nearly every conceivable type of skilled performance nowadays, the necessity to adapt one's capacity to perceive signals for action, and to coordinate the effector aspects of skill with rapid changes in the situation is unquestionably the key factor in achieving the end served by the skill. This basic requirement of skilled performance has been stated by Professor Sir Frederic Bartlett in the following way: "Each component of the coordinated effort must come in exactly when it is required ...... If it finishes too soon, there will be irritating and disordering gaps. If it finishes too late, there will be interference. Either way, there will be clumsiness"[1]. There is sufficient evidence to show that the inherent problems of jet fighter warfare are the inevitable result of the tremendously high speeds at which jet aircraft operate. Under such flight conditions, it is extremely difficult for defending fighter forces to locate enemy aircraft, even when skies are clear, and there is bright sunlight. Combat speeds of 500 to 600 knots have almost doubled the speeds to which pilots have been accustomed. Not only has the pilot difficulty in locating the enemy, but he has equally serious difficulty in knowing his own position in space. Indeed, as General E. E. Partridge of the U.S. Air Force points out, "Once an airplane gets off the air, it is a projectile. It travels faster than a bullet. Flying at 10 miles per minute, the pilot can no longer do any accurate plotting of his own position" [2].

Demands of High Speed Flying—Facts which are coming to light with regard to flight conditions in which combat operations are carried out make it amply evident that the modern aircraft pilot has to exercise extreme alertness in spotting the enemy and taking necessary action. Since action and movement are so swift, it is well nigh impossible for any one person to be able to observe and report all that is going on. The spaces traversed in aerial combat today, may range around 30 miles or more and the heights at which the aircraft operate may be anything above 35,000 feet. The vulnerability of aircraft operating under such conditions cannot be exaggerated. D.C. Heimburger, an expert on air battles, states: "High speed flight requires a greater degree of concentration, since many operations are accelerated. More planning ahead of the airplane is necessary, and in cases of malfunction or emergency, more rapid reaction and thinking are essential. The 'anxiety factor' increases with speed, because of this increased mental tension, and the fact that chances of successful escape are greatly reduced with high speed and altitude" [3].

The safe and efficient operation of high performance aircraft poses several intricate problems to the aviator, which can be grouped under two main heads. First, there are the difficulties arising from growing complexity in the action which has to be taken under normal conditions and during an emergency. Secondly, there are many important questions concerning the effects of the speeds at which the aircraft pilot may be required to operate. With the former group of problems, we are not concerned in this paper. Since it is well known that there are optimum limits to human efficiency in dealing with changes occurring at high speeds, the problem under discussion may be stated in the following way: What are the optimum limits of human tolerance to speed? How does high speed performance affect the physiological and psychological capabilities of the aircraft pilot? What are the practicable measures which can be taken in order to alleviate the stresses resulting from high speeds?

The purpose of this paper is to analyse the psychological factors involved in the operation of military aircraft flying at high speeds.

The Concept of Speed Stress

Stress and its Measurement—Any condition of work assumes the nature of a stress when its principal characteristics or attributes are such that there results a significant interference with or serious disruption of the tempo and quality of human operation carried out under that condition. Looking at it from the point of view of the human operator, a stress would be described as a condition of work which in the course of some sudden or gradual change in its impact on the operator, surpasses the limits of his tolerance. It has been customary to express the degree of stress in terms of the relationship between a measureable quantity of change in objective conditions and some quantity such as work units turned out in a given period of time, or the frequency of errors and omissions, or changes in the effector processes such as pressure on controls, speed of responses, breakdown of action and the like.

Definition of Speed Stress—By the term 'Speed Stress' is meant the operational condition in which the human component in a man machine system is pushed beyond the normal limits of human capacity in grasping information which is presented to the senses, or in executing a series of actions, or both. This extraordinary push comes from outside the human operator, whereas its adverse effects are felt within the organism, either in the form of lapses of what is required to be perceived or inaccuracies in decisions which have to be taken, or the disorganisation of behaviour patterns established by training and past experience.

Kinds of Speed Stress Effects—It would follow from this that the influences of speed stress are capable of being felt in one or more of three ways:

(*a*) First, it may involve failure to perceive rapidly occurring changes in the environment. The missing of signals occurring in a swiftly moving stream of items is a case in point.

(*b*) Secondly, speed stress may sometimes cause serious breakdowns in the reliability of judgment on account of abnormal increases in the incidence of errors in decision taking by the operator. Given adequate time, the operator's decision taking in a simple situation ought to be error free. When the time available for decision taking is progressively reduced, the proportion of his mistakes, notwithstanding his proficiency, becomes alarmingly high.

(*c*) Thirdly, speed stress often disrupts the smooth and streamlined sequence of action which constitutes the effector aspects of the skill.

During the past few years, a series of studies has been carried out on pilots and technical personnel serving in the Indian Air Force. The findings of these studies, undertaken by scientists of the Defence Science Organisation will be discussed here, in so far as they relate to human performance under conditions of high speed.

Effect of Speed Stress on Perceptual Grasp

Synthetic Test of Perception—A special test arrangement was devised in a recent study, carried out on aircraft pilots and signal operators of the Indian Air Force,[4] in order to measure the effects of increasing speed on the perceptual efficiency of operators. The test display consisted of different kinds of signs such as dots, lines, and single digit numbers, presented in a stream. Speed Stress was synthetically imposed by reducing the interval between successive stimulus items. The signals to be perceived were inscribed on a long strip of paper, and mounted on a revolving drum. They were visible to the operators through a slit in a screen, placed in front of the drum. The speed of the drum as well as the positioning of successive signals on the band of paper were varied. Signals were thus presented at five different speeds, namely at 20, 40, 60, and 120 signals per minute. The action required by the pilots and signal operators was to move a stylus up or down, according to instructions by the experimenter. This was recorded on another band of paper, moving at the same speeds as those of the band displaying the stimulus items.

Types of Tasks—Three types of tasks were set for those who were put through these tests:—

(*a*) *Perceptual Discrimination*—In the first run, the stimulus consisted of a single dot, either above or below a base line running horizontally through the centre of the display. The subject had to keep his eye on the base line, and watch out for a dot which might be visible above or below the line. He was instructed to move the stylus up when he saw the dot above the line, and to move the stylus down when he saw the dot below the line.

(*b*) *Rapid Counting*—In the second condition of this test, the stimulus consisted of a group of dots which had to be counted by the subject.

None of these groups contained more than five dots. The stylus had to be moved upwards for odd numbers and downwards for even numbers.

(c) *Quick Addition*—The third type of task required quick addition of two single digit numbers. If the total was an odd number, the stylus had to be moved up, and if the total was an even number, the stylus had to be moved down.

In each of the above mentioned test runs, a set of twenty items had to be dealt with by the operator. These three types of tasks were chosen because they resembled, in a considerably simplified form, the kinds of things which pilots have to see and do while flying, for instance, the perception of aircraft at a distance, or the identification of markings on a target, or combining information emerging from two signal sources.

Effects of Increasing Speed on Perceptual Efficiency—The general finding in these experiments was as follows. Tasks requiring mere discrimination of the spatial position of a signal could not be adequately performed at signal frequencies exceeding 60 per minute. Tasks involving rapid counting were performed adequately only when the signal frequency was below 40 per minute. Tasks entailing quick addition could not be carried out at signal speeds of over 20 per minute.

Conditions for Rapid Decision Taking—On the highly complex, high speed modern aircraft, there are two important preparatory adjustments which the aircraft pilot has to make when an emergency arises. First, there is the recognition of the symptoms which might lead to an emergency. Secondly, there is the identification of the emergency which occurs without warning. In the conditions of high speed flight, these two factors influence the action which the pilot will take in order to avert a likely catastrophie. Since the time available to the pilot is narrowly limited, the all important consideration is the pilot's liabilities to make a wrong decision. The experimental setting adopted in this test of pilots, flying instructors and flight cadets, was intended to simulate such flight situations.

The Flight Plan Test—The procedure adopted in this test was to present each subject with a set of cards containing symbols representing certain features in a flight plan. Each flight plan contained six symbols, and each symbol represented one of two alternative features in a simulated flight situation. For example, plus sign indicates fuel state good, and a minus sign signifies poor fuel state. The task of the pilot consisted in making quick comparisons between two flight plans—one fixed on a blackened screen in front of the person, and the other mounted on a moving belt, visible through a slit in the screen. The pilot was required to tell off how many flight characteristics the two patterns had in common. The fixed flight, patterns were changed after every run of twenty moving patterns. Every pilot was given five test runs in which the mobile flight patterns appeared respectively for durations of 10, 8, 6, 4 and 2 seconds per pattern. Decisions based on the grasp of information under these test conditions were recorded and subsequently checked for accuracy. These tests were administered to groups of pupil pilots, fighter pilots, and flying instructors of the Indian Air Force.

Influence of Speed Stress on Decision Taking—Three points of psychological interest emerge from the analysis of the data of this experiment:

(a) First, it was found that accuracy of decision broke down seriously when speed in decision taking exceeded the rate of six decisions per minute. In other words, when two cards displaying symbols had to be compared, and the number of points they had in common was to be declared at least ten seconds needed to be allowed for each such decision.

(b) Secondly, although the rate of six per minute was found to be the general requirement for reasonable accuracy in decision taking, there was a noticeable difference in the performance of pupil pilots, flying instructors and jet fighter pilots. Jet pilots showed a markedly higher tolerance to speed stress which is obviously due to their being used to conditions of high speed.

(c) Thirdly, it was noticed that the three types of personnel tested differed in the types of error which they most frequently committed under speed stress. With pupil pilots, errors of overestimating the points in common between the flight patterns compared, were very numerous. Flying instructors and jet pilots, on the other hand, committed comparatively fewer errors of overestimation and more errors of underestimation.

Psychological Significance of Decision Taking—The techniques for the measurement of the effect of speed stress on decision taking have been developed on an extensive scale by Dr. N. H. Mackworth of Cambridge University. Mackworth used single and multi-channel displays on a large number of subjects and found that, particularly under multi-channel display conditions, the proportion of missed signals far exceeded the proportion of wrong decisions when there was signal overlap, involving speed stress. Summing up the psychological implications of his experiments, Mackworth observes; "There must be a fixed maximum to the rate at which a man can think effectively when making comparisons between sets of objects..........The suggestion is that this upper limit can be exceeded in two quite different ways. The obvious and the usual way is when time is short throughout a given task—when the average number of decisions required per minute is in general too high. This form of speed stress is best expressed by the average number of seconds per signal. This index is particularly suitable when the signals are presented through a single channel display and are more or less evenly spaced in time"[5].

The Stresses of High Speed on Response Time

Studies of Jet Fighter Pilots—When a pilot is actually engaged in flying a jet aircraft, it is not possible to make any direct measurement of the exact way in which the effector aspects of his skill are affected by the stress of high speed. One has therefore to rely on the pilot's testimony, or better still, in measurements made before and after the sortie. Any disorganisation of skill which might occur under conditions of flight, however potentially dangerous, does not as a rule last long enough to be detectable after the sortie has been completed. Either it results in an accident, or the pilot recovers from a temporary upset and regains his mental composure. In a recent study carried out on a group of young pilots, in a jet fighter squadron of the Indian Air Force[6], simple and choice reaction times were taken before and after flying, every day during a period of five weeks. Since the pilots were engaged in different kinds of flying sorties, it was also possible to classify their flying tasks in order of difficulty, according to the testimony of the pilots themselves. Three levels of difficulty were distinguished—easy, somewhat difficult, and hard. Exercises such as formation flying were classed as hard, cloud flying as somewhat difficult, and dry RP and front gun attack as easy.

Relation between Reaction Time Values and Level of Difficulty of Sorties—The mean response times for difficult sorties were significantly different from those for easy sorties. This, as will be evident from the figures in the table below, was quite pronounced both as regards simple and choice reactions :

(*Preflight Mean Reaction Time is taken as 100*)

Level of Difficulty	Simple RT	Choice RT
Easy Sorties	106	98
Somewhat difficult Sorties	107	107
Hard Sorties	112	111

Even though the sorties before and after which these measurements were taken did not last for more than 45 minutes, the postflight response times of the pilots tested showed an increase of 10 to 15 per cent over pre-flight values in the case of hard sorties. This was quite consistently observed in all pilots.

Transient Fatigue Resulting from High Speeds—The measurement of reaction time taken week after week on these jet fighter pilots, were analyzed to see if there was any retraction in their values which could be attributed to improvement by practice. Although it was noticed that the mean values of response times dropped from week to week, indicating improvement as a result of practice, the mean values of post-flight response times were consistently higher than those of preflight response times. If practice has the effect of reducing reaction time, there should be no reason why the postflight values should be in excess of preflight values. This difference has been explained by maintaining that the lengthening of postflight response time is an indication of transient fatigue. Under adverse meteorological conditions, combined with strenuous flying, the pilot's responses tend to slow down and this effect persists for a while, even after the completion of the flying sortie. Although the actual difference between post-flight and preflight response time is not very great, what has been observed under experimental conditions should be regarded as a pointer to skill impairment in operational conditions, involving rigorous battle strain. Under battle stresses, or pitched against highly ambiguous flying situations, even competent pilots may record marked increases in reaction time.

Discussion

Stresses Encountered in High Speed Flying—It is highly important to correlate the simple findings of the studies described above, with the kinds of demands which are ordinarily made on pilots who have to operate high performance aircraft. The reason underlying this is that the Indian Air Force is going in more and more for these new types of aircraft. "The modern aviator", as A.A. Burrows points out, " is a highly selected worker, doing a job which is among the most complex man can devise. In doing it, he is often subjected to stresses exceeding in number and degree those met in any other vocation. It is part of the psychologist's task to select personnel; but before doing this, it is necessary for him to study the aviator's world, and if possible, to assist him to meet the unfriendly environment in which he works"[7]. With great speed, the effects of high linear, angular, and radial acceleration are encountered. Apart from direct physical effects, noise and vibration are elusive enemies of efficient flying. Jet pilots are also liable to feel the bodily effects of sudden reduction in pressure while ascending. Reaction times increase, movement is restricted, feel is distorted, confusion and visual disorientation occur. The almost complete demands on the pilot's perception, thought and skill result in the nearly indefinable states of fatigue, with their vulnerable and elusive effects upon performance. The worst difficulty arises from the fact that concessions in time or efficiency are marginal today. The large number of accidents written off as 'pilot error' admit of no compromise

Vision at High Speed and Altitude—The high performance aircraft allows the pilot very little freedom for direct observation. At high altitudes, the horizon, which is the pilot's main visual point of reference of attitude appears like an atrophied disc. The range of his vision is restricted by the aircraft designer's need to minimize the protruberance of the Cock pit canopy. He cannot judge distance, height and speed aright, because he has hardly any clues to work on. He must therefore rely on readings of aircraft instruments which tell him what is going on around him. Recently, aviation medicine experts of the U.S. Air Force have estimated that if the pilot of a high speed aircraft, flying, for instance, at a speed of 520 knots, takes a reading on his Air Speed Indicator, the time required for saccadic eye movement will be about 280 milliseconds, by which time he will have flown about 250 feet. The plane will have flown yet another 1,200 feet while he was reading the instrument. If at that time, he was passing over a target to be bombed, he will have passed well away from it by the time he completes reading just one instrument. Let us consider another example. Touch down speeds of jet aircraft nowadays are well above 105 knots. While the pilot is making the visual adjustment necessary for a correct reading, he will have flown some 275 feet or more. During this interval, he cannot watch the runway or consult his landing aids. "While his attention is thus distracted, and while not being able to perceive distinctly, he may readily undershoot or overshoot the landing strip, or collide with some unseen obstacle on the ground"[8]. The perils of the pilot are just as great in the air as they are while he is approaching the ground. "At high altitudes and except when the sun's rays are glancing directly off the airplane, the reflection of the deep blue sky serves as an effective camouflage. If the eyes are not ranged exactly upon the aircraft distance, no sighting is made. Attacking aircraft can slip in without recognition until they are dangerously within closing range"[9].

Time Lags Under Conditions of High Speed Flying—The length of time elapsing between an actual occurrence and the time an individual is aware of his perception of it depends on the amount of time required for light to reach the eye and also on conduction time in the visual pathways and brain tracts. The speed of light being exceedingly high, the amount of time needed for light to reach the eye is negligible. The lag in the visual mechanism is, however, appreciable, and at supersonic speeds, it is potentially menacing. Recent ERG and EEG studies on this subject have shown that the latent time for perception covers the period required to stimulate the receptor and to conduct the sensory nerve current to its excitation level in the cerebral cortex. This has been accurately measured and has been found to vary with the intensity of the stimulus, the part of the retina being stimulated, and the state of attention of the person. The latent period of perception may be anything between 0·036 second to 0·300 second. These sensory conduction times are particularly important at supersonic speeds because of the considerable distances travelled by the aircraft during these periods. Recognition time, decision to act, and the time needed for motor impulses to reach the muscles have to be added before a reaction occurs. Recognition of unexpectedly seen objects would require more time, as this would in effect mean more distance covered. Recent studies carried out by Aviation Medicine experts in the U.S.A. indicate that mental processes such as comprehension, discrimination or recognition involve sensory latencies of a 'high' order, whereas direct visual perception, mechanical adjustment of the visual organs and indirect visual perception involve sensory latencies of a comparatively 'low' order. "The elapsed time of latencies of the higher order", says Dr. H. Sturghold, an U.S.A.F. Medical Specialist, "varies considerably. It may vary from two tenths of a second to several seconds. The chains of latencies of the higher order, are, as far as they come into play, more or less fixed. The system—extrafoveal perception, mechanical adjustment, foveal perception—shows no overlapping but a well defined succession of the partial processes. It does not permit acceleration, since it works at optimal speeds under normal conditions"[10].

Flying Hazards due to Perceptual Delays—The severe limitations imposed on the performance of pilots of high speed aircraft on account of these perceptual latencies can be appreciated when one considers the recent accident of an interceptor fighter, which crashed head on into the wing of a bomber[11]. The interceptor fighter was closing in on a bomber at the rate of 1,100 feet per second. For the fighter pilot that meant taking 110 feet in the one tenths of a second to see the bomber, and another 5,500 feet during the five seconds spent deciding how to line up, plus a further 440 feet in the four tenths of a second to react. All in all, it meant that he had flown about 7,000 feet towards the bomber by the time he lined up. Since he was about 3 miles away from the bomber when he first saw it, he had reduced the distance of 16,000 feet to a mere 9,000 by the time he lined up. But then, since the bomber was also flying at some speed, he did not have sufficient time to squeeze the trigger and break away. It takes approximately four seconds to squeeze the trigger, and a little more than five seconds to effect a runaway. The time lag of the pilot must be added on to the time required for the aircraft to respond to the operation of the controls—to move the rudder, to stretch the cables, to change the airflow over the controls. Time ran out, much to the detriment of the interceptor pilot. Quite apart from such problems as tolerance of acceleration, or fighting against illusions encountered in high speed flying, the utilization of the severely restricted time available for offensive action and escape is the key problem in high-speed flying.

Adaptation to Speed Stress—There can be no doubt that the experienced pilot will possess greater capacity to stand up to the stresses resulting from high speed flying than one who is not experienced. Exactly what processes help in making adaptation to speed stress possible is not as yet fully known. When a series of actions has to be carried out, the little intervals of time between each action and the next, known as 'change over' or 'resting' time is what needs to be carefully studied in this connection. Professor Sir Frederic Bartlett says that "there is some evidence that most people are more intolerant to marked increases in change over or resting time than marked decrease"[12]. This being so, it would follow that performance efficiency would suffer more when some skilled action has to be performed at a slower than the accustomed rate, than at a rate higher than that to which one is accustomed. It may be that the theory of "Central Organising time", recently advanced by Mr. A. T. Welford of Cambridge offers the best psychological explanation of this potentiality to tolerate accelerations in skilled performance. According to Welford's estimates, the time between the onset of a stimulus and the beginning of a response movement is of the order of 0·2 seconds. The time required for organising sensory data fed back from either the beginning or the end of the response movement is 0·15 second. This would imply that when stimuli arrive at intervals of less than 0·5 seconds, as they occurred in some of Welford's tracking experiments at Cambridge, there has to be "overlapping of organising time, thus making it theoretically possible for an operator to cope with rapid acceleration of movement". Welford therefore suggests that "the data from a stimulus, which arrives when the central mechanisms are dealing with data from a previous stimulus have to be 'held in store until the mechanisms have been cleared"[13]. If this were true, this would explain how it is that certain individuals continue to give error free responses even when the speed at which the stimuli are presented exceeds the usual or accustomed rate of performance.

Speeding up of Responses by Training—Although it has been established that discrete responses to successive stimuli requires intervals of not less than 0·5 second between stimuli, recent research on this subject has shown that in many skilled tasks, rapid patterns of movement are executed and the elements succeed each other at rates much higher than this[14]. This is made possible when the stimuli for the movement can be apprehended in groups and the responses may be similarly grouped. The only limiting factor in this case would be the rate at which the limb could be moved. In a series of experiments on RAF aircrew and RN petty officer tradesmen, Miss M. Vince of Cambridge, set tapping tasks in response to grouped dots presented in accelerating and decelerating series, at random intervals ranging between 0·5 and 0·1 second between successive stimuli. Although breakdowns were found to occur when intervals were of the order of 0·1 second, the response rate, particularly in free tappings tasks were of the order of 7 responses per second. When the stimuli were presented in large and sufficiently clear groups, the response rate approximated to the maximum free tapping rate[15]. Trained morse operators, for instance, have been noticed to 'copy behind' and take down words, phrases, or even sentences while listening to the succeeding phrase or sentence.

Anticipatory Tendencies—Another important psychological factor, which minimizes the adverse effects of speed stress is perceptual anticipation. When relevant information is presented to the aircraft pilot in advance, for example through such media as ground radar or the radar set operated by the navigator in the interceptor fighter aircraft, the pilot's use of this information will be *receptor* anticipation. When, on the other hand, no advance information is available, but the pilot is able to deduce the nature of a forthcoming situation from what he observes, and with the help of the background of his past experience, his use of this information may be called *perceptual* anticipation. Laboratory experiments designed by Dr. E. C. Poulton of Cambridge investigated this aspect of the anticipatory response in considerable detail[16]. The subjects in Poulton's experiments had to carry out a two pointer matching task, in which one pointer had to be kept in line with a second pointer which moved in a single vertical dimension in a simple harmonic or complex harmonic course, the subject always held the response handle or wheel so that an upward response movement raised the corresponding display pointer. Poulton found that in eight practice attempts, his subjects improved the timing of their matching of the completely predictable simple harmonic course. Even for the less predictable complex harmonic course, they were able to learn to anticipate, though not completely. The striking fact about these experiments was that at the two fastest display speeds, the error scores of the subjects were surprisingly low. It goes without saying that the cultivation of mental qualities such as anticipating and judging correctly will be a wise investment for the demands which future military operations will make on the skills of pilots.

Selection and Training of Pilots—The present method of selecting pilots for the Indian Air Force is based on experience gained during World War II and the main emphasis has been on the measurement and assessment of aptitude for flying. How far the tests which are at present in use give a true measure of pilot aptitude as such is very difficult to say. All that can be said with certainty is that those who have secured high scores in the pilot aptitude battery have been successful in completing their flying training. This has been confirmed by extensive follow up studies undertaken by the Psychological Research Wing. Whether there is more to pilot aptitude than is evident from the test records available at the Selection Boards is a matter on which hardly any authenticated information is at present available. There is, nevertheless some reason to believe that the reduction of pilot wastage does not in itself constitute the main ground for the peak of efficiency in combat operations, particularly those which involve considerable flying hazards. The problems of the service aircraft pilot, in fact, begin only when he completes his flying training. His first problem arises when he has to adapt his flying skill to the multifarious requirements of operational flying. Much of course will depend on what the pilot has learned during the period of his initial training. As Dr. W. E. Hick points out, "the basic skills inculcated must be reasonably lasting and not readily obliterated by changed circumstances. When the pupil pilot first leaves the ground, he will have little or no conscious recollection of what he has learnt.......In short, the pupil must be well drilled in those fundamentals which he is bound to need"[17].

Conclusion

To sum up, when the human component in a man-machine system is pushed beyond the limits of human capacity in grasping information presented to the senses or in executing a series of actions correctly, a condition of speed stress may be said to occur. Conditions encountered by aircraft pilots, particularly those engaged in fighter aircraft operation, make a consideration of the forms of speed stress and measures to alleviate their adverse effects very important.

Three forms of speed stress merit attention: first, the failure to perceive rapidly occurring changes in the environment. Psychological experiments have shown that in a swiftly moving succession of test items, a high proportion of stimuli are missed when the time intervals between successive items is less than 0·5 second. Secondly, serious breakdowns in the accuracy of decisions occur when the time available for making decisions is reduced below 10 seconds for a simple decision. Thirdly, speed stress disrupts the smoothness of skilled action which constitutes the effector phase of the skill. Protraction of response times to the extent of 10 to 15% above normal has been observed in fighter pilots at the end of hard flying sorties.

Of the various demands which high speed flying makes on the aircraft pilot, the stresses resulting from travelling at high speeds are easily the most exacting, since high speed flying allows the pilot very little freedom for direct observation. Even the little time spent over such actions as interpreting aircraft instruments or aligning the aircraft with a target lay pilots open to serious flying hazards.

The latent period of perception, which may extend to 300 milliseconds or more, and the time required for decision taking, which will involve a delay of nothing less than five seconds are significant time lags in supersonic flying.

Some mitigation of the adverse influence of speed stress is possible on account of the pilot's capacity to get used to flying at high speeds, by his cultivation of the experience of dealing with groups of stimuli rather than whith single stimuli and by learning to utilize his capacity for perceptual anticipation. It is of paramout importance that in the selection of aircraft pilots the several demands made on the pilot by high speed flying should be accorded due weight.

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Discussion

The paper was opened to discussion after it was read. Squadron Leader Jones drew attention to the importance of reaction time in flying and suggested that it should be introduced on the selection boards. He inquired whether some tests to assess reaction time were available and suggested that some method to develop speed of reaction at the training centre ought to be devised. Dr. Adiseshiah agreed that reaction time is a very important factor in flying and pointed out that some of the present tests in flying aptitude battery take into account speed of reaction in the person tested. Further, experiments have been carried out in the U.K. on anticipation. The results showed that one can be taught to anticipate things and the striking feature of these experiments was that the error scores of the subjects were surprisingly low. Squadron Leader Jones inquired whether greater weight could be given to reaction time in the case of pilots who are selected for jet flying.

Wing Commander Bobb pointed out that pilots are selected not for jet flying only, but on the basis of their capacity and aptitude to fly. Selection for various types of aircraft is done after the pilot passes through his flying training at the air force college. Captain Batra asked whether conditions in the laboratory simulate those in actual manoeuvres. Dr. Adiseshiah pointed out that reasonable amount of control is possible inside the laboratory but the operational situation cannot be duplicated one hundred per cent. At best the findings of laboratory experiments can be only a guide to what is capable of being achieved in real life conditions.

Col Sartaj Singh inquired whether it is possible to determine the optimum at which a human being can operate. The chairman stated that this has been a difficult problem on which several commonwealth countries have carried out extensive researches. The Canadians, for instance, have recently produced a guide book for use by design engineers. But, in actual practice, it has always been found necessary to make some kind of a compromise. In the last analysis the decision regarding aircraft design is the responsibility of the producer rather than of the psychologist. Col Sartaj Singh agreeing with the opinion expressed by the chairman stated that it was very essential to bear in mind the principle that the aircraft should be built around the pilot and not the **pilot** around the aircraft. Dr. Asthana inquired whether speed stress is studied in comparison with other conditions of stress encountered in flying. Dr. Adiseshiah replied that there are aero-medical research units working in collaboration with the personnel of the Defence Science Laboratory. There is some amount of co-ordination between those who are engaged in research on the problem of flying personnel. Recently, an Aviation Medicine School has been started in Bangalore which provides useful information on findings of their research work for the benefit of those who are engaged in flying.