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PILOT FITNESS, A SAFETY FACTOR IN AVIATION

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IN our thinking as to the comparative importance of pilot fitness as a safety factor in aviation, it is well to keep in mind such views as have been expressed by Major-General James E. Fechet (Ret.), formerly chief of the U.S. Army Air Corps, who has devoted a great deal of time to the study of airplane crashes. Discussing the causes of airplane crashes he says that in more than half the number of cases these are due to personnel error or to undetermined causes. In the personnel group he includes the pilot, the weather man, the airline operations manager and the mechanic. Of these the pilot is of course a very important factor. A small percentage of these crashes—less than five, he says—is due to mechanical failure—engine malfunctions, breakage of some part of the plane or its essential accessories.¹ From this it seems that not the plane but its operation is chiefly at fault.

It is the purpose of this paper to describe an instrument for testing pilot fitness. We have called the instrument an electrical multiple-exposure tachistoscope. It was devised particularly for measuring the speed of adjustment of the eyes for change of distance, the speed of accommodation and the speed of adaptation,

FIG. 1.

Sectioned side elevation of multiple-exposure electrical tachistoscope.

FIG. 2.

A wiring diagram for the multiple-exposure electrical tachistoscope.

FIG. 3.

The electrical tachistoscope in operation at a test station in Chicago. The set-up is for measuring speed of adjustment for change of distance of object.

and for testing ocular and general fatigue. In designing the instrument special attention has been given to compactness of construction, ease of operation and ready portability. A picture of the instrument set up for operation, a sectioned side elevation and a wiring diagram are given in Figs. 1-3.

The instrument comprises a timing mechanism and three shutters, electromagnetically operated, so arranged as to expose in immediate succession a near test-object on the left, a far test-object in the median plane and near test-object on the right. The test-objects are the letter E which can be rotated into four different positions to give an objective check on the judgment. The far test-object is mounted in the same cabinet which contains the near test-objects, the shutters and the timing mechanism, as is shown in the sectioned side elevation (Fig. 1). A front surfaced mirror which is mounted at an appropriate distance from the rear of the cabinet serves to reflect into the viewing slit the image of the far test-object, thus reducing floor space requirements. The distance of the far test-object, the lateral separation of the two near test-objects and the illumination of all three can be varied at will.

The shutters are mounted on light aluminium arms which are attached to the armatures of three relays suitably positioned in the cabinet. The operate and release times of each relay are of the

order of 0.005 sec. On the outside of the cabinet the necessary switches are provided and a timing dial the pointers of which contact a commutator. The dial has 500 divisions each one of which is equal to 0.01 sec. when the commutator rotates at 12 r.p.m. By setting the pointers at the correct position on the dial, the operator may vary the exposure time of any test object at will, provided that the total duration of all the exposures does not exceed the period of one revolution of the commutator (in the above case, 5 sec.). The commutator is driven by a 1/80 h.p. universal governor-controlled D.C. motor with double worm-gear reduction. By varying the speed of the motor the commutator can be given a range of speeds from 6 to 30 r.p.m. The total duration of all the exposures can therefore be varied from 10 to 2 sec. At these limiting ranges the divisions on the dial will equal respectively 0.02 sec. and 0.004 sec. If still longer total exposure-times should be required, this can be arranged for in the reduction gearing of the motor. When alternating current is used, a synchronous motor can be substituted for the governor-controlled motor and a rectifier inserted to convert the current supplied to the shutters.

Uses of the Instrument and Test

The instrument makes possible: (a) The use of a set of very sensitive tests which take into account as no other tests do both the motor and the sensory functions of the eyes in just the proportion that they occur in the act of seeing objects in different directions and at different distances. Composite tests of this kind give by direct measurement information that cannot be obtained, and permit of conclusions that cannot be drawn, from any amount or kind of separate testing of functions.

(b) The testing of the dynamic speed of vision* with either the oculomotor or the accommodative feature emphasised. The test made with the accommodative feature emphasised gives the speed of accommodation as nearly as possible, it would seem, for that result to be obtained. Similarly, the arrangement of the conditions of the test so as to emphasise the importance of

* There are two types of test for speed of vision: a static test and a dynamic test. In the static test the eyes fixate and accommodate for a given selected distance and the test-object is exposed at that distance for the minimum time needed for its discrimination. Such conditions test only the speed of reaction of the sensorium. They give no information as to the motor functions of the eyes and the effectiveness of their co-ordination for the purpose of seeing. In the dynamic test for speed of vision on the other hand, the eyes are required to shift their regard from one object to another or to a series of objects and to discriminate them in turn during the time or times of exposure. These conditions test not only the speed of reaction of the sensorium but also the oculomotor facility and efficiency.

convergence and divergence in the results measures the speed of these functions as nearly in complete separation as can be accomplished.

(c) The measurement of the time to change from near to far and from far to near either in combination or separately. The measurement of the time required for these shifts separately in the form of the test in which the oculomotor functions are emphasised gives a sensitive comparison of the facility and condition of the converging and diverging mechanisms, which may be more significant and comprehensive than tests of the duction type. Such measurements also provide a way of making a quantitative determination of what the results of the duction tests mean in terms of typical oculomotor performances. In the form of the test in which the accommodative feature is emphasised, the measurement of the time required for the shifts separately gives a comparison of the time required for the action of the muscles of accommodation and the lens material in the change from near to far and from far to near, which may have both a practical and a theoretical bearing. All the aforementioned possibilities of measurement have, we believe, great value in relation to the examination of the eyes in the work of the clinic.

In addition to these clinical applications, the following further uses of the instrument and the measurements it makes possible may be discussed :

1. *A test of vocational fitness in all cases in which dynamic speed of vision is an important requirement.*—Most of the work requiring speed of vision is done with moving eyes. For such work a static test, which tests only the speed of reaction of the sensorium, is incomplete. A quickly reacting sensorium, it is true, gives a quick discrimination of the object and a quicker and more effective guidance of the movement of the eyes. However, it is not nearly so important for the quick use of the eyes in the greater part of work that persons are called on to do as are quick oculomotor and accommodative adjustments. There are many vocations for which a high standard of requirement in this respect is needed. In a machine age in which all industrial performances are quick and public and private conveyances travel at rates of speed that were formerly almost inconceivable, the demands put on the speed of the eyes' reactions have become increasingly rigorous. Further, the requirements of factory workers who operate machines are by no means low. It is our strong belief that ocular tests in which the factor of speed is not given great importance are not a safeguard against either inefficiency of performance or dangerous accident.

2. *A test of pilot fitness for aviation.*—Our first model of multiple-exposure tachistoscope was devised during the World

War to test pilot fitness for aviation.² We thought that the eyes of aviators should have a supernormal speed and precision of co-ordinated response in the three fundamental reactions: oculomotor, accommodative and sensory. Only the reaction of the sensorium is tested by static tests of speed of vision, and the important element of speed is entirely left out in all other types of ocular test. The incompleteness and lack of special fitness of the usual clinical and ophthalmological tests for this purpose should be obvious without further elaboration.*

In the early years of aviation, particularly during the World War, the need for testing the fitness of pilots for flying was duly recognised. In later years, however, the importance of testing pilot fitness was overshadowed by the development of instruments and the stress laid upon them as a guide for flying. In this a grave mistake may have been made. Recently there seems to be a growing conviction that the pilot is an important factor in the increasing number of airplane crashes. There is perhaps a good reason for this conviction. It may be that with the rapid improvement in facilities for aviation, the attitude of the pilot has changed with respect to the importance of his own qualifications, fitness and training and to the highly specialised nature of the services he was formerly called on to contribute and still has to contribute

* In connection with the testing of fitness for any work or performance it may be of interest to point out that where there is a composite test involving several functions, it is usually considered both the logical and a time-saving procedure to make that test the initial test and to make separate tests of the individual functions only when the composite test shows a deficiency or when individual tests are deemed advisable for other reasons. It is our experience that an adequate test of dynamic speed of vision is a very sensitive means of separating out those who have ocular and oculomotor deficiencies. Further, it measures directly the importance of these deficiencies in terms of the performance that has to be accomplished, namely the quick and accurate seeing of objects in different directions and at different distances. No amount of testing separate and individual functions can possibly do more than serve as a basis for estimating a candidate's ability to accomplish this performance. The testing of the separate functions would seem logically to be a later step in order to find out what function was at fault and what, if anything, could be done to correct the deficiency.

A well-known analogy is the visual acuity test as a test of fitness. The customary procedure is to give the composite test first and then if a deficiency is found to follow this up with tests of the component functions—the power to form correct images (refractive) and the power of sensory discrimination. In the selection of candidates as to fitness by the visual acuity test it is scarcely deemed necessary or expedient to perform the analytical tests unless a deficiency is shown by the composite test; nor could an accurate estimate of acuity of vision be made from the results of the analytical tests, refractive and sensory. Would it not seem to be equally exceptional to try to arrive at a rating of the ability to use the eyes for the quick and accurate seeing of objects in different directions and at different distances from any amount or kind of testing of the separate functions involved, ocular and oculomotor? That this should ever have been attempted is probably due to the lack of an adequate composite test.

in emergencies.* It may be also that not enough attention is paid to fitness in the selection of pilots and to making sure that they are in fit condition for service at all times when they are called on to render service. It seems strange that the plane should be carefully tested on every point of its construction and operation before each flight and little or no attention given to the pilot at that important time other than to see that he is on hand to fly. With the advance in scientific and mechanised control, the importance of the human factor has without question been thrust into the background.

Our first model of the tachistoscope, devised during the World War as stated earlier, was used at Mineola for studying the fitness of entrance candidates and later was taken to France by Dr. William Holland Wilmer, surgeon in charge of the Medical Research Laboratories, Air Service, A.E.F., for the purpose of studying the fitness of aviators already in the service for the various tasks required of them, particularly in combat flying. Since the war the instrument has been greatly improved and is now being manufactured by the Gaertner Scientific Corporation. As manufactured by this company the instrument has been still further improved. One of the earlier improved models was described in the Archives of Ophthalmology.³ In 1933-36 this model of this instrument was used by Comdr. C. J. Robertson (MC) U.S. Navy, for the study of fitness for aviation on such points as entrance requirements, disqualification for the service on account of age, fatigue in relation to number of hours in the air, individual susceptibility of fatigue, etc. Dr. Robertson has published his results in a series of articles in the U.S. Naval Medical Bulletin and the Archives of Ophthalmology.⁴

The instrument provides a test which is without doubt one of the most sensitive that has ever been devised for the detection of any imperfection in the oculomotor, accommodative or sensory functions or of any temporal disturbance in these functions. Common causes of these disturbances are fatigue, loss of sleep, worry and all mental states which distract attention, the variations in physical and mental efficiency and alertness common to every one in the course of time, illness, etc. Any of these may be sufficient to cause the aviator to fail or falter at a critical time in the high degree of service that is required of him. The profound effect of fatigue and other disturbances of bodily and mental

* In this connection it must be remembered too that the use of a greater number and complication of instruments has in itself become an ocular problem. The quick and accurate reading of instruments in addition to the quick seeing of objects outside the plane indeed constitutes an important requirement for speed in the use of the eyes and an important need for testing for age as a disqualifying factor. As a test instrument for all such needs and requirements, the tachistoscope described is admirably fitted.

efficiency on such highly organised and delicate muscular co-ordinations as are required in the speedy use of the eyes, is well recognised. Fatigue, for example, has to be tested through its effect on some function. Perhaps no more delicate means can be found for detecting fatigue than through its effect on speed in those uses of the eyes which require highly co-ordinated changes in muscular adjustment. The delicacy and accuracy of co-ordination that are required in these adjustments will be realised when one remembers that changes in the convergence of the eyes are made by six pairs of muscles which serve to support as well as to move the eyes, and that the breadth of the images on the two retinae which must be combined into one in seeing is, for the standard test-object, of the order of thousandths of a millimetre. Also in changing the vision from near to far and back again to near, the muscles of accommodation must act in perfect co-ordination with the muscles that move the eyes. Still further, the sensorium must function at a high level of efficiency.

In testing programmes the point which seems thus far to have been most frequently if not entirely overlooked is the importance of temporal disturbances in fitness, particularly in relation to the prevention of accidents. While it is true that a human being cannot be treated as a machine, we do know that the aviator is subject to many disturbances from day to day that render him unfit for those services which require a supernormal fitness and proficiency and involve a responsibility for human life and safety. It seems only reasonable, therefore, that the fitness of the aviator should be tested before each flight, at least before each more exacting flight is undertaken, as well as the fitness of the plane which he operates. It is surely not enough to require only an entrance test of fitness and then allow him to go on without further check, even without regulation of his conditions of living, until age or some mishap retires him from service.*

Our personal feeling is that a test should be made of each aviator immediately before and after each flight. We have the following reasons to offer for this:

(a) The test before the flight should be used to prevent the

* We understand that some improvement in this respect has already been made or is in contemplation. The following, for example, is quoted from the article by Major-General Fechet referred to earlier in the paper: "Striving to promote continued pilot fitness, we developed a new profession in the Army—that of Flight Surgeon. He has paid us handsome dividends. We found that annual or semi-annual examinations were not enough. We needed a smart medico to keep the pilots under daily observation . . . Flight Surgeons paid off in reducing airplane crashes. I commend that thought to commercial airline operators." He says further: "Health is mental as well as physical. I think the mental side plays a bigger rôle in air pilot health than the physical. A man who is worried and preoccupied about domestic discord or financial extremities may be more unsafe than one subject to fits or fainting spells."

aviator from going into the air when he is clearly and dangerously unfit for service. It is neither fair nor good public policy that a knowledge of his fitness should depend upon his own report. In combat flying in particular he might well be prevented from making such a report through fear of being called a slacker or because of patriotism or personal pride. In commercial service, too, many reasons might operate to deter him from making a report of unfitness. The responsibility for making such report should be taken out of his hands and consigned to a competent examiner. A surgeon, however long his experience and however well demonstrated his ability, voluntarily subjects himself to a test of steadiness of hand and keenness of eye before undertaking a critical operation. Surely in these offices requiring services equally responsible for life and safety, there should be some test of fitness immediately before the service is undertaken. Such precautions might be considered extreme had not the frequency of airplane crashes demonstrated that something is radically wrong in modern aviation.

(b) The test at the end of the flight would indicate how well the aviator has stood the strain of his service. It would give valuable information as to his susceptibility to fatigue and make it possible to assign him to the length and kind of service he is capable of performing. It would also give a great deal of valuable general information as to the number of hours in the air and the amount of strain which aviators, taken collectively, can reasonably be expected to stand.

(c) From the results of the tests, graphs or curves can be plotted which will give a splendid picture of the aviator's fitness, his endurance, his susceptibility to fatigue, the consistency of his service, etc. In short, these records would serve as the basis for a high type of personnel service in aviation. From these graphs it can also be readily seen when the aviator is becoming incapacitated for service through age or some other cause. This alone should be sufficient reason for adopting some such programme.

(d) A feasible test and instrument are available. The test does not require more than ten minutes to perform and the result can readily be given a numerical rating. The instrument is easy and convenient to operate and the entire programme well within the technical capabilities of the average flight surgeon.

Two forms of the test may be suggested: (1) The time required for the discrimination of the object at near, the change to far and back again to near may be measured in each test; or (2) in a series of preliminary tests the median or average times required for these performances may be determined for each aviator and these be taken as his standard of performance. In the routine procedure of

testing, the instrument should be set to give these times of exposure. The test may consist of ten or some suitable number of trials to ascertain in what percentage of cases the aviator can attain his standard of performance. This percentage may be accepted as the index of his fitness at that time.

3. *A specific performance test of fitness for night flying.*—As a part of the routine of night flying, the pilot must look back and forth from the comparatively highly illuminated cockpit and instrument panel to more distant outside objects under very low illumination. The ability to do this quickly and with a satisfactory discrimination of detail is perhaps the most important visual qualification of a night pilot. It involves a change in the adjustment of the eyes for both intensity of light and distance of object. The night flyer has quickly to adapt from light to dark and back again to light as well as at the same time change his adjustment for distance from near to far and back again to near. The time required for this combined action in a suitable test relationship can be measured with the instrument described in this paper. All that is required to make the additional measurement of speed of adjustment for change of intensity of light is obviously to illuminate the two near test-objects to an intensity different from that of the far test-object. The near test-objects, for example, could be given an intensity similar to that illuminating the cockpit and instrument panel, and the far test-object any suitable low intensity, preferably that approximating the outside illumination at night. To make this test the instrument should be installed in a dark or darkened room. A small curtained enclosure should be provided the back wall of which is the face of the instrument. The enclosure will simulate the cockpit and will be illuminated to an intensity suitable for a cockpit. In this the examinee will sit. The face of the instrument will, then, have the illumination of the cockpit, which illumination should also be given to the near test-objects. The far-test object as seen in the mirror should receive the low amount of light that is selected as representing that of objects outside the cockpit. The test will then be performed in the usual manner. The time will be measured to discriminate the near test-object and to change the adjustment from the near to the far test-object and back again to the near, both with respect to adaptation and muscle control. For this test a much larger far test-object will have to be used than is employed for measuring speed of adjustment for distance alone under medium intensities of light. In this respect it may be noted (a) that small objects could not be seen with the intensity of illumination and time of exposure that are provided, (b) that the objects which the night pilot is required to discriminate outside the cockpit are in the main large objects and (c) that the time in which he has to make the discrimination is usually short.

It may be noted further that the test situation presented by the instrument is extremely favourable for the control of the preliminary adaptation of the eyes. That is, the observer is seated facing the exposure shutters and the front panel of the instrument which receive the same intensity of light as falls on the near test-objects.* Thus in the natural course of the experiment he can very easily and conveniently be adapted for any length of time that is desired to the same intensity of light at which the experiment begins and ends—namely, the intensity usually found in the cockpit and on the instrument panel. The near test-objects could of course be given any value of illumination that is wanted, also the far test-object; that is, any experiments or series of experiments involving differences in the intensity of illumination of the near and far test-objects over a wide range could be performed. Since in the instrument described, the total exposure-time may be varied in continuous series up to 10 sec. or longer, the range of exposure-times provided is ample for the purpose.

Obviously the test can be made in three ways: (a) The maximum performance for each person may be determined. This would be the analogue of making tests of visual acuity, for example, in terms of the minimum visual angle that can be discriminated. This procedure is the longest because it requires a correct adjustment of the exposure-times for each observer, but it results in a much finer grading of performance. (b) Any suitable number of levels of performance may be chosen and the instrument set at once to give these levels. This method of testing would place persons in ranks or groups and is the analogue of the Snellen method of grading visual acuity. It is a quicker procedure than (a) but the grading is correspondingly rough. By a practised examiner, testing by this method should take but a few minutes. In forming such a graded scale in our preliminary work with the instrument in general,² we used steps of 0.02 sec. for the double excursion. These intervals have been found very suitable by Comdr. Robertson in his work with the instrument in classifying aviators as to fitness of performance for day flying.⁴ An alternate procedure would be to determine directly specific scales made up of the number and breadth of steps needed for the purpose in question. (c) Critical or limiting values could be established for any purpose for which such values are desired. The instrument could then be set for these values after the usual preliminary trials to familiarise the examinee with the test, and the determination made whether he could give the judgments required, which could be done with a single setting of the dials of the instrument.

* A convenient means of illuminating the exposure shutters and the front panel of the instrument and of varying the intensity of illumination over a wide range as may be desired, is the device we have called a variable illuminator.⁵

The above-mentioned three procedures are for a given intensity of light and given distances of the near and far test-objects. The test can be varied indefinitely by changing these intensities and distances.

In this test we have not only a scientific test of capacity, within the limits considered, but a specific performance test made under scientific conditions with accurate scientific controls. We call this a specific performance test because the actual visual task which the pilot has to perform in night flying is very closely copied. Speed of adjustment for change of distance of object and change of intensity of light is accurately measured—that for change of intensity of light (speed of adaptation) much more accurately, within the limits of the instrument, than is possible for example with any adaptometer that has yet been devised.

4. *A test of disturbance in fitness due to altitude.*—The instrument would seem to provide a very sensitive means of detecting and studying the effect of altitude, temperature and other variations in the physical conditions to which the aviator is subjected. In testing for the effect of altitude the test should be made when the plane is at the altitude in question, not after it has landed. The compactness of the instrument renders it admirably fitted for making tests on the plane. The instrument should be suitable too for studying the effect of oxygen deficiency and of changes in air pressure wherever these occur or may be produced, also equally suitable for testing individual differences in susceptibility to these effects as a part of the programme for testing fitness. Further, aviation is not the only vocation in which a prior knowledge of the individual's characteristic fitness in these respects would be of value.

As further evidence of the sensitivity and versatility of the instrument it may be noted that while an older model was in use at the U.S. Naval Station, at Pensacola, Florida, it was found that the results were affected by alcohol, tobacco and coffee, and that the unusually high speeds for the different age groups were obtained from those who abstained from the use of tobacco.⁶

5. *A limiting test for age as a factor in fitness.*—As the eyes grow older the importance of accommodation in a dynamic test for speed of vision increases until it becomes the dominant factor in the result. Speed of accommodation is not an important factor in the results for the young eye unless there is some accommodative abnormality. Accommodation is the first of the ocular functions to deteriorate with age and the one that shows the closest correlation with age. The earliest manifestation of what would ordinarily be called a deterioration in this function, that is, a deterioration of significant practical importance, is, so far as

measurements have been made, a decrease in speed. A comparative test of dynamic speed of vision of the eyes of the young and those of the middle-aged and near middle-aged furnishes striking and most conclusive evidence that the latter are under a special handicap in regard to all types of work that require speeds that are normal or supernormal for young eyes. For example, many automobile drivers in an early stage of presbyopia have advised us that they dare not take their eyes off the road for the length of time they require even to read the speedometer. Driving under conditions which do not permit of the inspection of the instrument panel is, it will be granted, somewhat hazardous.

There is also, of course, an important need for a limiting test for age in aviation. The aviator in combat flying and in landing, particularly on water, needs everything that can be had in the way of dynamic speed of vision. In the early days of aviation—for example, during the World War—such a test was not so greatly needed as now. The vocation was new and by far the greater number of aspirants were young men. Now the aviators of that time, such as have survived, have grown older. It is difficult to make them realise that they may no longer be fit for the service or all branches of it and hard, without definite and concrete evidence of unfitness, to make a case against them that will stand.

The chief value of the test as a limiting test for age is in its application to persons between the years of 30 and 45 or 50, the period for which a precise and sensitive test is most needed and most difficult to obtain.

6. *A means of measuring ocular fatigue and recovery, of testing individual susceptibility to fatigue and capacity to recover, and of detecting disturbances in fitness from other causes such as loss of sleep, worry and all mental states that distract attention, etc.*—The addition of speed or power to sustain, to any test performance gives greater sensitivity for the detection of fatigue. For example, in a study of ocular and oculomotor fatigue, the test of dynamic speed of vision can be made at suitable intervals during the performance of a task, and from the results a curve for fatigue can be plotted for each person tested. From these curves individual susceptibility to fatigue of persons in the same age group and of those in different age groups can be compared. There are great individual differences in this susceptibility which, it scarcely needs to be pointed out, is an important factor to be considered in determining ocular fitness for any type of work, especially for all performances requiring a high degree of fitness. Age, moreover, is a most important factor in this susceptibility. One would expect, therefore, that using the test of dynamic speed

of vision as a fatigue test would be a most sensitive way of determining the effects of age on ocular fitness.

In addition to determining ocular fitness and susceptibility to ocular fatigue, the instrument and test may be used for testing the rate of recovery from ocular fatigue. From a study of the curves for ocular fatigue and recovery, persons of the same age group and those of different age groups can be compared as to susceptibility to ocular fatigue and the capacity to recover. A greater difference due to age might be expected for the latter than for the former. Our experience and observation is that while older persons become fatigued more easily, the especially marked handicap of age is on the side of recovery.

An instrument that furnishes a means of measuring and making a quantitative comparison of both ocular fatigue and recovery, in addition to measuring speed of performance, should have both important scientific interest and a practical utility over a wide range. Such a means would be of value not only in the selection of persons in all vocations in which special ocular fitness is required but in checking up on the persons selected for their ocular fitness at any time to accomplish an assigned task. A record of the dynamic speed of vision and the rate of ocular fatigue and recovery for any person gives a comprehensive estimate of his ocular fitness. In addition to the particular service rendered, studies comprising such determinations give information of general value.

In connection with the discussion of ocular fatigue and recovery it should be borne in mind that oculomotor fatigue and depression sustain a general relationship to general bodily fatigue. This relationship is sufficiently close to suggest that a fairly comprehensive estimate may be had of the bodily condition by testing the combined ocular and oculomotor performance. Just how much work has been done in direct confirmation of this sympathetic relationship we are not prepared at this time to state. We may, however, make two citations at this time. Comdr. Robertson has used our test and instrument with success in determining and studying fatigue in aviators. Among other things he was able to compare quite easily the amounts of fatigue induced by 1, 2, 3 and 4 hours of flying.⁷ The second citation refers to experiments recently made in Russia, where a great deal of interest is being taken in physiological optics of the practical type we have been trying to develop. These experiments were conducted by J. J. Troumpaitz in the Laboratory for Lighting Research at the Leningrad Institute for Industrial Hygiene and Accident Prevention. The test of the ocular condition used was one devised by us for studying the effect of lighting conditions on ocular fatigue

by measuring the eyes' power to sustain clear seeing for a period of time.⁸ Bodily fatigue was induced by the operation of a device called a bicycle-ergograph, which was selected for the study because its operation required no fatiguing use of the eyes. Nevertheless, a close relationship was shown to exist between bodily fatigue as measured by the ergograph and ocular fatigue as measured by the test of power to sustain clear seeing.*

Also, as indicated in the heading of this section, the test for dynamic speed of vision can be used very effectively to detect disturbances in fitness due to other causes such as loss of sleep, worry and all mental states which distract attention, the variations in physical and mental efficiency and alertness common to every one in the course of time, illness, etc. This use of the test has been sufficiently discussed under the heading "A test of pilot fitness for aviation."

7. *As a means of training eyes to greater oculomotor and accommodative facility.*—The discussion should not perhaps be brought to a close without noting the possibility of using the instrument as a means of training oculomotor and accommodative facility. Its daily use for a suitable length of time might very well serve to raise eyes slightly or moderately subnormal to normal proficiency and normal eyes to a needed supernormal proficiency. Under the spur of a speed requirement it would seem that the co-ordination of so many individual performances might be facilitated to a significant amount by daily practice. We suggest this possibility of the benefit of a prolonged systematic use of the instrument as a means of training the eyes, particularly eyes with slight muscle defects, in spite of the fact that a minimum of practice effect is shown by normal eyes in the ordinary use of the instrument for making a test.

Summary

With the growing conviction that the pilot is an important factor in the increasing number of airplane crashes, it seems that more attention should be paid to fitness in the selection of pilots and to making sure that they are fit for service at all times when they are called upon to render service. It is strange indeed that so much care is taken to see that the plane is in perfect condition before a flight is undertaken and so little attention is given to the condition of the pilot. While it is true that a human being cannot be treated as a machine, we do know that he is subject to many disturbances from day to day that render him unfit for those

* From a report of work submitted personally to the authors by J. J. Troumpaitz. The purpose of the experiment was to show the loss of efficiency which the eyes sustained during a period of heavy physical work.

services which require a supernormal fitness and proficiency and involve a responsibility for human life and safety. These disturbances can be shown by test.

In the paper very sensitive tests of fitness and disturbances in fitness are proposed and a convenient instrument for giving these tests is briefly described. This instrument is an electrical multiple-exposure tachistoscope comprising a timing mechanism and three shutters electrically operated, so arranged as to expose in immediate succession a near test-object on the left, a far test-object in the median plane and a near test-object on the right. The test-objects are the letter E which can be rotated into four different positions to give an objective check on the judgment. The far test-object is mounted in the same cabinet which contains the near test-objects, the shutters and the timing mechanism. A front surfaced mirror which is mounted at an appropriate distance from the rear of the cabinet serves to reflect into the viewing slit the image of the far test-object, thus reducing floor space requirements. The distance of the far test-object, the lateral separation of the two near test-objects and the illumination of all three can be varied at will. The exposure-time of each of the shutters is controlled through the setting of the appropriate pointers of the timing dial. The total of all the exposures can be varied from 2 to 10 sec. At these limiting ranges the divisions on the dial equal respectively .004 and .02 sec. If still longer exposure-times should be required, this can be arranged for in the reduction gearing of the motor operating the timing mechanism.

In designing the instrument special attention has been given to compactness of construction, ease of operation and ready portability.

The instrument makes possible: (a) the use of a set of very sensitive tests which take into account as no other tests do, both the motor and the sensory functions of the eyes in just the proportion that they occur in the act of seeing objects in different directions and at different distances, (b) the testing of the dynamic speed of vision with either the oculomotor or the accommodative feature emphasised and (c) the measurement of the time required to change from near to far and from far to near in combination or separately.

The following practical uses of the instrument and test procedure are discussed: (1) a test of vocational fitness in all cases in which dynamic speed of vision is an important requirement; (2) a test of pilot fitness for aviation; (3) a specific performance test of fitness for night flying; (4) a test of disturbance in fitness due to altitude; (5) a limiting test for age as a factor in fitness; (6) a means of measuring ocular fatigue and recovery, of testing

individual susceptibility to fatigue and capacity to recover, and of detecting disturbances in fitness from other causes such as loss of sleep, worry and all mental states that distract attention, etc.; and (7) as a means of training eyes to greater oculomotor and accommodative facility.

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RARE OCULAR DEVELOPMENTAL ANOMALIES IN ASSOCIATION WITH CONGENITAL AND ACQUIRED BLINDNESS Clinical "proof" of vitreous development

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THE following history of a blind patient who attended my ophthalmic clinic illustrates the complexities which underlie certain types of cases presenting themselves for blindness certification.