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# THE USE OF IN-FLIGHT EVALUATION FOR THE ASSESSMENT OF AIRCREW FITNESS

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

PREPARED FOR

NORTH ATLANTIC TREATY ORGANIZATION

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# The Use of In-flight Evaluation for the Assessment of Aircrew Fitness



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# THE USE OF IN-FLIGHT EVALUATION FOR THE ASSESSMENT OF AIRCREW FITNESS

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Papers presented at the Aerospace Medical Panel Specialists
Meeting held at Ankara, Turkey, 24 October 1975

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## PREFACE

The topic of The Use of In-Flight Evaluation for the Assessment of Aircrew Fitness was the inducement that resulted in the assembly and presentation of seven papers. The importance of in-flight assessment cannot be emphasized too greatly inasmuch as in-flight performance and pathophysiological status and events are the ultimate determinants of fitness to perform safely and effectively in the aerial environment. This is particularly true because such evaluations are frequently the last opportunity to preserve experienced aircrew whose contributions would be forfeited by a less comprehensive and finally definitive analysis of integrated ability.

Many aspects of in-flight determinations of physical, psychological, physiological and bioaeronautical suitability and fitness of aircrew were considered. These included some in-flight and simulation techniques, examination methods, bioinstrumentation and procedures for fitness studies as well as results of assessment of the ability to fly safely with orthopedic injuries, amputations, and visual deficiencies, plus a few other physiological and psychological situations. Also included are assessments of paratroopers and non-pilot aircrew in their performance of duty.

# TECHNICAL EVALUATION REPORT

The Use of In-Flight Evaluation for the Assessment of Aircrew Fitness was the topic on the morning of 24 October 1975 during the AGARD/NATO Aerospace Medical Panel Specialists' Meeting held in Ankara, Turkey. The prompt submission of papers by all the speakers allowed the publication of AGARD Conference Pre-print No. 182. This provided the opportunity for all attendees to study the text before its presentation in order to assimulate the material with greater accuracy. This should also have contributed to more precise comments and questions during the general discussion period. Seven papers were presented and a lively general discussion followed.

Two presentations were broad in scope, reporting the results of in-flight evaluations with a wide spectrum of conditions. The first series was about 132 military personnel and the second series was about 51,433 civilians in a society where the citizens feel that their being allowed to fly as a pilot is a "right" rather than a "privilege". This perception requires much less restrictive policies than in a military population and, therefore, could be looked at as a large experimental study group from the military viewpoint. Thus, the experience and observations from this civil group of pilots could provide for better extrapolations and judgments in the cases of military aircrew. The sample sizes in this civil paper appear large enough to draw the statistical conclusions that individuals with deficient distant vision, deficient color vision without any operational flying limitations (i.e. no waiver), and those with blindness or absence of either eye are increased risks to flight safety.

An especially outstanding psychological description and isolation of the various aspects and stresses of parachuting was presented in one paper. Two other papers presented methods of studying problems and reaching conclusions; a comparison of binocular with monocular visual activity revealed little difference in many cases and a night vision device that decreases visual acuity plus eliminating color vision decrements measures of performance.

Simulation is not a true indicator/predictor of in-flight response under some circumstances as demonstrated by another paper. The last paper proposed the theory, with observations supporting the hypothesis, that increased atmospheric electricity effected blood electrolytes and is related to accidents.

In-flight evaluation for the assessment of aircrew fitness was shown to have multiple facets. This modality demonstrated its application and usefulness for evaluating the integrated adaptation and ability to compensate for decreased or absent function, plus its utility in focusing on a specific, narrow capability as an invaluable research tool. In-flight evaluations appear to be the only appropriate method of studying performance and the fitness for flying of allegedly handicaped individuals. It is the only reasonably cost effective and economical method of assessing the final productivity in a diversity of problems that can not be evaluated at a lower, less integrated level of function. However, questions that require more illumination include: (1) When would a simulator be more accurate? (2) What clinical measurements or tests are sufficiently sensitive to make in-flight evaluations unnecessary? (3) What are realistic physical standards? (4) What are the criteria that will allow accurate prediction of those who will fly competently and safely?

Assessment of aircrew fitness by in-flight evaluation has proven worth. However, the above questions are areas that would be productive topics for future Aerospace Medical Panel activities.

CONTENTS

# US ARMY MEDICAL IN-FLIGHT EVALUATIONS: 1965-1975

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ABSTRACT

One hundred thirty-two in-flight evaluations were reviewed. Information from the records and reports reposited at the US Army Aeromedical Center, Fort Rucker, Alabama, was read, extracted and synthesized. Evaluation methods used, plus the results of compiling case classifications and the subsequent medical recommendations for duties involving flying are presented and discussed. Specific categories of individuals presented in detail are lower extremity amputees, "one-eyed" aviators, and color vision defective aviators.

## INTRODUCTION

In November 1964, an Army aviator sustained a crushing injury to his right foot necessitating a Syme's amputation. After recovery and rehabilitation, he was referred to the Army Aeromedical Consultation Service for evaluation as a test case. His success lead to the referral of others for evaluation and this report presents an accumulation of these cases. Many of these aviators required waivers to remain on active duty prior to or concommitant with the determination of their fitness for continuation on flying duty. The US Army had recognized that the services of many experienced but disqualified aviators would be lost unless a method was established to comprehensively investigate an individual's adaptation and complete capability. Coincident with this recognition was a rapid build-up in Army aviation and a critical shortage of aircrewmen. A potential resource was aviators who had been injured in combat or aviation related activities who desired to return to flying duty but were physically unfit by regulation standards. It was decided to give some of these men an in-flight trial of their ability. "Check-rides", which have long been a part of aviation, were applied to examining selected "unfit" individuals. In-flight evaluations have subsequently become a common means to scrutinize medical fitness to fly by the US Army.

## METHOD

Procedures governing the requesting and conducting of aeromedical consultations with in-flight evaluations have been established by US Army Regulations. These regulations are applicable to all Army aviators who are unfit for flying duties. The local flight surgeon can make the determination that an aviator still possesses a capability for flying duty, with possible restrictions, after the aircrewman has received maximum benefit of hospitalization with all available types of therapy and convalescence. The aviator's flight surgeon sends the request for aeromedical consultation/in-flight evaluation to the US Army Aeromedical Center at Fort Rucker, Alabama, where an Aviation Medicine Consultant reviews the case. If no further consultations at the local medical facility are necessary, the Aeromedical Consultation Service coordinates the request with the personnel managers in the aviators branch (e.g. infantry, artillery, armor). If the personnel operators determine they have a need that could be fulfilled by the capabilities of an aviator with the applicant's branch, rank, experience and possible restrictions, the individual is sent to the US Army Aeromedical Center, Fort Rucker, Alabama. Temporary flight status orders are issued which allow the individual to perform flying duties during the period of the evaluation, usually two weeks.

The individual undergoing evaluation has his history reviewed before being given a comprehensive physical inspection and medical examination. This usually includes screening studies such as the following: laboratory tests (e. g., urinalysis, hematology, serology, enzymes, chemistries, lipid phenotype and serum electrophoresis), X-rays, (e.g., chest, abdomen, sinuses, and spine), performance tests (e.g., pulmonary functions and treadmill), and speciality consultations (e.g., dental, cardiology, otolaryngology, ophthalmology, and neuropsychiatry, plus others when indicated).

The aviator examinee is required to demonstrate his ability to safely and efficiently perform all the normal functions associated with piloting the aircraft in which he was qualified. The experienced flight surgeon who is responsible for conducting the evaluations confers with a standardization instructor pilot in each type aircraft before each flight. The peculiar characteristics of the aircraft and the examinee's handicap are discussed in order to identify functions and maneuvers that may present an unusual challenge to the individual. During this consultation a special flight test profile and schedule is synthesized to supplement the usual check-ride grading sheet. Particular attention is given to stressing the weakened function to determine ability, capability, and stamina to safely and satisfactorily perform all activities that might be expected during a full flying schedule. Both the instructor pilot and the flight surgeon observe all aspects of the evaluation, except for flights in the few Army aircraft which cannot seat a flight surgeon. The ability to adequately preflight the aircraft by climbing to check such things as the wing tanks and rotor heads must be performed adequately as well as passing all in-flight emergency procedures such as engine and hydraulic failures. Techniques on landing, taxing, and stopping are also stressed in order to catch any subtle deficiencies. Problem areas are identified with each instructor pilot and the flight surgeon making written reports on all aspects of the in-flight evaluation.

After completion of all aspects of the evaluation, the case is presented to a Consultant Board of Flight Surgeons, plus a qualified instructor pilot as a voting member. This board makes a determination of the ability of the aviator to perform flying duties safely and efficiently. It may advise further reevaluation, suspension, restricted flying duty, or full duty. The conclusions and recommendations of the board, along with any dissents or minority opinions, is forwarded to the US Army Headquarters in Washington, DC, where final action determining the type of duty status if made and the individual is officially notified by the personnel managers. This method was initially established to evaluate injured individuals following hospitalization after injury, but it has now been expanded to investigate other permanent impairments such as defective color vision.

## RESULTS

The material which follows describes some of the observations of 132 of the evaluations done in a decade at the US Army Aviation Center, Fort Rucker, Alabama. Causes for evaluation are given in Table I by year.

TABLE I

CAUSES FOR EVALUATIONS BY YEAR

| Year | Injury Resulted From: Hostile Action | Injury Resulted From: Accident | Color Vision | TOTAL |
|---|---|---|---|---|
| 1965 | 6 | 1 | 0 | 7 |
| 1966 | 4 | 4 | 0 | 8 |
| 1967 | 7 | 2 | 2 | 11 |
| 1968 | 13 | 1 | 1 | 15 |
| 1969 | 7 | 3 | 4 | 14 |
| 1970 | 12 | 2 | 3 | 18* |
| 1971 | 10 | 3 | 9 | 23* |
| 1972 | 3 | 1 | 3 | 7 |
| 1973 | 3 | 1** | 5 | 9 |
| 1974 | 1 | 1 | 14 | 17* |
| NA | 0 | 1+ | 2 | 3+ |
| TOTAL | 66 | 20 | 43 | 132 |

* Total includes one evaluation for other reasons.
** Cause of below the knee amputation not recorded in records.
NA Means year of evaluation was not in waiver file.
\+ Includes a monocular aviator evaluated in April 1975.

One hundred and seventeen (117) of the individuals evaluated were pilots. One hundred and nine (109) of these 117 were returned to some type of flying duties. Eighteen (18) of these returned to flying duties were dual rated (i.e. capable of piloting both fixed and rotary wing aircraft).

Followup data concerning the current status of all 129 (two (2) were evaluated twice) is not available. Some of the conditions evaluated were static; therefore, special periodic status reports were not required. Also, some of the individuals studied are no longer in the Army and the followup is, therefore, quite difficult.

Three sub-groups, Lower Extremity Amputees, "One-Eyed" Aviators, and Color Vision Defectives are discussed in more detail in the following pages.

LOWER EXTREMITY AMPUTEES:

A true spectrum of lower extremity amputees was seen by the Aeromedical Consultation Service. Of the 12 amputees evaluated, there were 8 below-the-knee, one (1) above-the-knee, one (1) Syme's (disarticulation of the distal tibio-talar joint with removal of medical and lateral malleoli), one (1) Chopart (midtarsal), and one (1) toes (3, 4, 5) and metarsals (3, 4) associated with an ankle fusion. Their ages ranged from 20-37 years with ranks of Warrant Officer to Major at the time of amputation. Experience ranged from 300-4600 flying hours. Seven (7) amputations involved the left extremity, while 5 were right sided.

During the clinical evaluation, special care was taken to evaluate the amputation stump. The absence of incisional breakdown, ulceration, dermatosis, neuroma or tenderness was assured. Range of motion of joints and strength were then noted. Finally, prosthesis fit and adaptation when applicable, were evaluated. The type of prosthesis was functionally appraised to anticipate the nature and technique of its use during in-flight evaluation.

Every effort was made to attempt maneuvers that would severely stress the deprived extremity. The performance of each maneuver was noted, particularly the technique of execution.

In fixed wing and rotary wing aircraft, the performance of the pre-flight was evaluated. In rotary wing especially, the aviator must deftly and acrobatically mount the rotor head to evaluate transmission and rotor systems. Conditions of weather and local turbulance must be considered for surefootedness. In fixed wing aircraft, the operation of rudder and braking controls were stressed. This is best accomplished in taxing, stopping, take-offs and landings (especially cross wind) and rudder controlled stalls and slips. Reach of controls is evaluated, especially under constraints of the yoke or stick. Finally, in dual engine fixed wing, single engine procedures are stressed.

Rotary wing evaluations become even more extensive due to their maneuverability. Again, pedal control (antitorque) is stressed, especially with hydraulic failure in assisted systems. All rotary wing power changes require reciprocating change in antitorque, thus stressing lower extremity function. Wheeled rotary wing aircraft evaluations are similar to fixed wing at least as far as the use of brakes is concerned.

OBSERVATIONS: Of the eight (8) below-the-knee amputees, five (5) were rotary wing only. Each of the five (5) had no difficulty during in-flight evaluation in skid-mounted, rotary wing aircraft. None were current in wheeled rotary wing aircraft, although one had a Federal Aviation Agency fixed wing certificate to fly restricted to aircraft with hand operated brakes (this restriction was later removed after demonstrated proficiency). In all cases, the Aeromedical Consultation Service recommended restricted flying duty in skid-mounted rotary wing aircraft. An additional restriction for two of the five was a flight with a fully qualified aviator in the aircraft flown. This was recommended in one case because of an indicator of potential future stump difficulty requiring revision. In the other because of an incidentally identified cortical (central) deficiency of stereopsis (failed visual tested apparatus and Verhoeff stereopters). In each case the restriction was imposed to provide a period of secure, but operational in-flight evaluation. Upon review by the Office of The Surgeon General, the Department of the Army approved five (5) of the Aeromedical Consultation Service recommendations pertaining to below-the-knees unchanged. They indefinitely suspended one aviator, a Warrant Officer with a high below-the-knee amputation (a knee disarticulation prosthesis of the hinge type with hydraulic assist) and limited flying experience (366 hours). Despite the fact that he demonstrated exceedingly good performance in flight, this above-the-knee-like configuration and limited experience considered in light of reduced service needs, deterred his return to military flying duty. One of these aviators (restricted flying duty with fully qualified aviator in skid-mounted rotary wing) developed repetitive incisional skin breakdowns after 12 months of flying and he was medically separated. Followup on the remaining three returned to flying is in progress (one is definitely known to be flying).

Two of the below-the-knee amputees were dual rated fixed wing/rotary wing. Each flew exceptionally well in both fixed and rotary winged aircraft despite the fact that shifting of the foot to apply heel pressure was required to initiate braking action (the SACH foot cannot be voluntarily pivoted when static). The Aeromedical Consultation Service recommended both for restricted flying duty with a fully qualified aviator in rotary wing/fixed wing. Upon review by the Office of The Surgeon General, the Department of the Army approved both for return to flying duty, one without restriction, the other restricted to skid-mounted rotary wing and fully qualified aviator (despite demonstrated proficiency and 3264 hours experience). One was medically separated after 19 months of flying due to recurrent furunculosis, especially during hot humid weather. However, he still flies fixed wing civilian aircraft.

The last below-the-knee amputee evaluated (March 1973) was a highly skilled and trained aviator (dual rated with 3000 flying hours). He also flew the wheeled rotary wing aircraft, CH-54 Skycrane, as well as fixed wing multi-engine aircraft. In both flight and ground evaluation, he experienced no difficulty with any aircraft maneuver. Unfortunately, during the course of the evaluation, his stump ulcerated due to a surgically unacceptable result. His indefinite suspension was continued. The amputation stump was later revised, but he became disillusioned with lack of suitable assignment opportunities and never returned for reevaluation. He was recently seen by one of the authors in medically retired status while endeavoring to acquire a job as a civilian instructor pilot for the military.

An above-the-knee amputee was a rotary wing rated medical evacuation pilot whose gait was exemplary utilizing a total contact suction socket with hydrocadence knee and SACH foot prosthesis. He was actively dancing, playing tennis, water skiing and driving a stick shift sport car prior to evaluation. His in-flight evaluation revealed little difficulty with normal or emergency maneuvers. He had difficulty dismounting one model aircraft due to the placement of the step wells. Nevertheless, his slithering dismount was reasonably prompt and safe. In one evaluation, he preflighted the aircraft in the rain after crossing a muddy field. In control of the anti-torque pedals he used flexion and extension at the thigh in conjunction with the reciprocal action between legs through the pedals. An incidental observer could not have distinguished this movement from normal pedal control. Coming off and on the controls, he used hand assistance to locate the pedal promptly and securely. This took one-two seconds. Although never required, even during hydraulics off maneuvers, his good leg was available to shift to the appropriate pedal if added force was needed (a technique used by a civilian instrument pilot flying with an above-the-knee amputation). The Aeromedical Consultation Service recommended return to restricted flying duty with a fully qualified aviator in skid-mounted rotary wing aircraft with possible removal of the fully qualified aviator after reevaluation in one year. The Department of the Army imposed indefinite suspension.

The above-mentioned aviator was reevaluated in February 1974. During that evaluation, he was observed during a standard nap-of-the earth introduction flight, considered the most demanding of modern Army aviation. Environmental conditions the day of the flight included winds of 12 knots gusting to 14. Maneuvers performed included nap-of-the earth downwind takeoff and approach, nap-of-the-earth hovering out of ground effect, nap-of-the-earth flight, masking and unmasking and nap-of-the-earth normal approaches and takeoffs. In all evaluations, he performed exceptionally well. Since he had adjusted long term to his above-the-knee prosthesis without significant medical intervention, the Aeromedical Consultant Board strongly recommended return to restricted flying duty. Unfortunately, this recommendation arrived at the Department of the Army in a more restrictive and less favorable personnel climate than before. The indefinite suspension was continued.

The Syme's amputee was dual rated, but had great difficulty, initially, in fixed wing aircraft, shifting his heel from rudder to braking position. His control on landing in anticipation of hard braking left much to be desired. The Aeromedical Consultation Service recommended return to restricted flying duty with a fully qualified aviator in rotary wing aircraft only. The Department of the Army concurred, restricting him from wheeled rotary wing aircraft. Five (5) years later, the aviator returned for evaluation and possible removal of the restriction. This time he demonstrated no difficulty with fixed wing brakes. The Aeromedical Consultation Service and the Department of the Army concurred in return to full flying duty without restriction.

The Chopart amputee was also dual rated. He performed without difficulty in both fixed wing and rotary wing aircraft. The Aeromedical Consultation Service and the Department of the Army concurred in his return to full flying duty without restriction.

Finally, the toe amputee had no difficulty with performance in rotary wing flight. He did, however, lack plantar flexion at the time of evaluation. Thus, the Aeromedical Consultation Service and the Department of the Army concurred in return to restricted flying duty in skid-mounted rotary wing aircraft without other restrictions.

DISCUSSION: What factors must be evaluated before the determination of fitness for flying can be reached? First, the pilot must be in otherwise excellent health. Other significant conditions which might compromise flying safety or personal health must be excluded. His amputation stump must be in excellent condition without evidence of incisional breakdown, ulceration, dermatosis, neuroma or tenderness. Two members of this series had to be eliminated from military aviation for these reasons. Next, his in-flight ability must be tested and demonstrated in all aircraft in which he is qualified or anticipates flying. Special attention must be given to minor, but significant deviations in cockpit design which can hamper foot or leg movement in-flight. The characteristics of the prosthetic device are also important.

SYNOPSIS: Of twelve (12) lower extremity amputees, nine (9) were restored to various forms of productive flying duty. These have served for varying lengths of time despite the fact that two (2) are known to have departed the service due to stump complications.

TABLE II (A)

AEROMEDICAL CONSULTATION SERVICE RECOMMENDATION

| TYPE | BK | AK | SYME'S | CHOPART | TOES META | TOTAL |
|---|---|---|---|---|---|---|
| RFD/SMRW | 3 | 0 | 1 | 0 | 1 | 5 |
| RFD/FQA/SMRW | 2 | 2* | 0 | 0 | 0 | 4* |
| RFD/FQA | 2 | 0 | 0 | 0 | 0 | 2 |
| FFD | 0 | 0 | 1* | 1 | 0 | 2* |
| INDEF/SUSP | 1 | 0 | 0 | 0 | 0 | 1 |

RFD = Restricted Flying Duty
FQA = Flight with fully qualified aviator in the aircraft flown
SMRW = Skid-mounted rotary wing aircraft
FFD = Full flying duty (unrestricted)
INDEF SUSP = Indefinite Suspension from flying duty
* Reevaluated one case (substract)

TABLE II (B)

DEPARTMENT OF THE ARMY DISPOSITION OF LOWER EXTREMITY AMPUTEES

| TYPE | BK | AK | SYME'S | CHOPART | TOES META | TOTAL |
|---|---|---|---|---|---|---|
| RFD/SMRW | 2 | 0 | 1 | 0 | 1 | 4 |
| RFD/FQA/SMRW | 3 | 0 | 0 | 0 | 0 | 3 |
| FFD | 1 | 0 | 1* | 1 | 0 | 3* |
| INDEF/SUSP | 2 | 2* | 0 | 0 | 0 | 4* |
| TOTAL EVALUATIONS | 8 | 1 | 1 | 1 | 1 | 12 |

RFD = Restricted Flying Duty
FQA = Flight with fully qualified aviator in the aircraft flown
SMRW = Skid-mounted rotary wing aircraft
FFD = Full flying duty (unrestricted)
INDEF SUSP = Indefinite Suspension from flying duty
* Reevaluated one case (subtract)

RECOMMENDATIONS: Reid and Baker, when reporting earlier on the first six (6) amputee cases in this series, recommended guidelines for determining the return of these disabled aviators to flying duty. They felt that services needs, type of amputation, motivation and interest, and age, hours experience and time in service should all be considered together. Service needs have certainly played a strong administrative role in this decision, but as stated by Reid and Baker, "We must not become so rigid in our systematic regulation-oriented process of decision making that we ignore the human element."

"ONE-EYED" AVIATORS:

Of all man's endowments, vision is the most indispensable. Without vision, successful and sustained manned flight would most certainly be impossible. The extent to which this is so becomes clear when one reflects upon the flexibility and maneuverability of rotary wing aircraft. Performance of both normal and emergency maneuvers require the pilot's trained as well as inate ability to visually interpret clues to depth, distance and relative speed. The epitome of man's visual requirements in these aircraft is well understood when observing the performance of the autorotative maneuver, especially when applied to an unanticipated emergency landing to hostile terrain, complicated by slopes, gullies, tree stumps, foilage, elephant grass, rat holes and other obstacles.

Accurate depth perception or distance judgment has long been considered vital to safe flying performance in the civil and military aviation environment. There are many recognized clues to depth perception both binocular and monocular, the majority being monocular. The binocular clues have been stressed by Karlsberg, et al. They maintain that functional stereopsis exists to as great a distance as four miles. Regardless, no experimenter has established stereopsis as an essential capability to insure outstanding or even acceptable aerial performance. Despite this fact, all three US military services require passing scores on tests of stereopsis (binocular parallax) for selection for flight training. Accommodation and convergence have been considered unreliable if truly functional at all in operational depth perception.

Many authors have stressed the importance of the multiple monocular clues to depth perception in all around aerial performance. Rose emphasized the importance of the monocular clues of motion parallax and retinal image size in the landing of aircraft. The total list of monocular clues thought to be useful in distance estimation or perception of depth are linear perspective (including covergence of parallel lines, discrimination loss and gradient change), apparent foreshortening and vertical overlapping of contours (interposition of objects), retinal image size (know and relative size of objects), increasing size of objects, illumination perspective (lighting effects, shadows) and motion parallax. All of these are apparently used effectively by monocular or uniocular individuals and probably are the prime depth perception clues in the binocular individual. Pilots who use only one eye because of amblyopia, uncorrected anisometropia or loss of an eye have been reported by several authors to have good flying ability.

Since depth perception or distance judgment is considered vital in many phases of flight regardless whether rotary or fixed wing, what should one impose for standards as the maximum tolerable visual deficit consistent with personal and public flying health and safety? Karlsberg, et al, supposed that steroacuity is more than advantageous, it is a contributing factor in a pilot's ability to land an aircraft at minimums and to maneuver an aircraft in an unfamiliar environmental from as great a distance as four miles. They arrive at this deduction from mathematical analysis and the known capability of some men. Further, they imply that stereopsis is essential under conditions of less than clear weather and faciliary environs. Contrast this with the demonstrable findings of Lewis and Krier. They could discern little difference in the landing performance of an experienced group of test pilots when they were deprived of binocular vision.

Primarily as a result of eye injuries from hostile action, certain Army aviators requested evaluation for return to flying duty under the provisions of regulations establishing the Army

Aeromedical Consultation Service. Since these aviators were largely experienced and had adjusted physically and emotionally to their injuries, serious consideration was given to their evaluation. They included individuals who had sustained two (2) types of injury. The first were truly unilocular having been deprived of vision by trauma followed by enucleations. This paper reports Army procedures to evaluate these individuals, their ultimate disposition and a review of the important elements to consider in such a determination of fitness for flying duty.

OBSERVATIONS: Nine (9) physically disqualified aviators were evaluated during the period July 1966 to April 1975. Of the nine (9) aviators evaluated, three (3) were uniocular and six (6) monocular. Their ages ranged from 27-47 years with ranks of Warrant Officer to Colonel. Experience ranged from 286 to 4370 flying hours. Four (4) were dual rated (fixed and rotary wing), while the remainder were rotary wing only. The three (3) uniocular conditions resulted from surgical enucleations after penetrating fragment injuries from hostile fire. The monocular conditions resulted in one (1) case from idiopathic serous retinopathy, the others from direct or indirect injury to the globe with resulting scotoma or other visual interference. Three (3) of these resulted from hostile fire, the remainder from non-flying ground accidents.

Generally all nine (9) aviators performed satisfactorily in-flight. Some tended to hover high or pull collective pitch prematurely in autoratations in the initial phase of their evaluations. All but one (1) compensated well for this tendency by completion of the in-flight evaluations. Based on their findings, the Army Aeromedical Consultation Service recommended restricted flying duty with a fully qualified aviator in the aircraft flown for all but two (2) of the aviators initially evaluated. One (1) of the first of these cases was complicated by an established history of recurrent shoulder dislocations. Due to the combined defects, an indefinite suspension was recommended. This individual was later reevaluated after successful arthroplasty, using a more elaborate and definitive in-flight profile. He subsequently received a favorable recommendation from the Aeromedical Consultant Board. The second case, and last chronologically, had a successful in-flight evaluation but the Aeromedical Consultant Board was concerned that helicopter vibrations might compromise the remaining function of the damaged eye. The eye had a huge choroidal rupture with peripheral pigmentary degeneration and old vitreous blood. The examining ophthalmologist had felt that he would have a statistically greater chance of developing glaucoma or retinal detachment. Thus, a recommendation for indefinite suspension was made. It should be noted, however, that no conclusive prospective data exists on the effects of vibration on previously injured eyes.

Upon review, the Department of the Army indefinitely suspended three (3) initially. These included the two (2) cases mentioned above and the one (1) with some tendency to hover high. Two (2) of the monocular aviators were returned to restricted flying with a fully qualified aviator. To date, these two (2) aviators are known to have flown safely for 41 months. Two (2) dual rated uniocular aviators were returned to restricted flying duty with a fully qualified aviator, and further restricted to fixed wing only and daytime takeoffs and landings. A similar restriction was placed upon another rotary wing monocular aviator who died in a tractor accident, which was found to be unrelated to his visual deficiency.

The one (1) case who had been reevaluated by the service had his suspension reaffirmed by the Department of the Army despite rather enthusiastic and positive support by the Aeromedical Consultant Board. This decision was later appealed by the US Army Aeromedical Research Laboratory. This organization had assisted the Army Aeromedical Consultation Service in a departure to a specialized and intensive profile for in-flight evaluation. This evaluation was unique in that the individual was given a trial period of reinstruction and proficiency before undergoing the final "check-ride" with a Standardization Instructor Pilot. Further, he was evaluated and followed by scientifically sophisticated aviators and psychologists. Based on this appeal, the Department of the Army reconsidered and ordered the individual to restricted flying duty with a fully qualified aviator. He was further restricted to fly from the right seat (opposite his visual deficiency) to facilitate visual clearing. In addition, he was earmarked as a research subject for the US Army Aeromedical Research Laboratory and later assisted them in standardization of their flight recorder system. To date, this individual flies successfully and has acquired 30 months of accident-free flying. He has transitioned to the OH-58 ("Jet Ranger"), assisted as an instructor pilot and graduated from the Warrant Officer Advanced Course.

DISCUSSION: The potential problems in the utilization of "one-eyed" aviators is of interest. The first area of concern is that of visual field. Loss of one eye results in approximately 22% less coverage than the binocular field of vision. Target identification and ground observation requires more than vision. Experience is of considerable benefit. Vision within the aircraft is probably not significantly different whether "one-eyed" or binocular. Performance under scotopic visual conditions must also be considered. Stereoscopic acuity is markedly diminished under scotopic conditions. Thus, the normal individual becomes more dependent upon monocular clues to depth perception. However, some of these are also significantly diminished under night visual conditions. The student loss of night vision can be catastrophic for both the monocular and the binocular aviator. The aviator does not often have to cope with the blinding effect of approaching headlights, but he may on occasion be exposed to sudden bright light at night (a flare, loss of landing zone illumination, searchlights, etc.). In addition to these relative disadvantages of monocular vision, there is a remote possibility of a foreign body in one eye, when a spare is ordinarily available in the binocular pilot. This factor was considered along with the potential effects of glare at night in recommending restriction of "one-eyed" aviators to flight with another fully qualified aviator in the aircraft flown. Two (2) important aspects of flight not extensively tested among Army "one-eyed" aviators was their ability to safely perform formation, or nap-of-the-earth flying. It was the opinion of the Army Aeromedical Consultation Service that such in-flight evaluation would have been inconclusive and/or even hazardous when undertaken with aviators lacking proficiency as a result of prolonged periods of suspension from flying duty. However, in the one (1) case detailed above, an idealized and expensive exploration of this area was accomplished.

It demonstrated that at least one (1), highly motivated individual, was with proficiency, able to manifest flying skills that were potential and anticipated in his initial evaluation. Perhaps lastly, consideration must be given to potential emotional responses to "one-eyed" aviators on the part of their fellow contemporaries as well as their future passengers.

RECOMMENDATIONS: Taking these potential limitations into consideration, along with knowledge of clues to depth perception and distance judgment, certain criteria are established for the return of experienced "one-eyed" aviators to flying duty. First, the remaining eye should be capable of normal vision free of significant ocular pathology. Second, the aviator must be capable of satisfactorily performing normal and emergency procedures in the major types of aircraft in which he is qualified under day and night conditions.

Upon clinical and in-flight demonstration of the above and considering all constraints, it is prudent to restrict the aviator to flight with another fully qualified aviator in the aircraft flown. Annual followup including ophthalmologic examination is essential along with the provision for eye protection for the remaining functional sight. This is currently provided by use of safety glasses in aviator goggle (wire) frames to minimize additional interference with field of vision. The Federal Aviation Administration returned 4,327 applicants to flying with 20/200 or worse vision in their worse eye during the two (2) years prior to 1 January 1972. They denied certificates to an additional 175. Accident studies by the agency have not implicated these pilots as being associated with increased accident risk.

COLOR VISION DEFECTIVES:

The ophthalmology portion of the flight physical examination has classically been deemed to be of major importance. The aircrewman's facility to identify and characterize objects and signals is dependent upon the adequacy of his visual system. Furthermore, the proper identification and interpretation of a variety of aviation-related phenomena depends not only upon excellent visual acuity and perception of depth, but also on accurate discrimination and identification of colors or hues.

The need for adequate color perception of the Army aircrewman can be borne out by considering the consequences of errors in the following areas: Colored smoke is frequently used to mark both friendly and enemy targets. Any error in identification could easily result in destruction of friendly forces by their own aviation fire support. Colored smoke was used in Vietnam to call in medical evacuation helicopters. The enemy, at the same time, would deploy several colors of smoke, thus requiring the pilot to rapidly identify the correct color of smoke to avoid flight into a hostile area. The aviator must additionally be able to identify colored tower light signals when radio communications fail, interpret the green, yellow and red lights of tactical glide slope indicators and utilize various aeronautical maps and charts which employ various colors to depict terrain and other information. Failure to identify various grades and types of aviation fuel by color could rapidly lead to engine damage or failure.

In this age of nap-of-the-earth flying, the continuous demands placed upon the visual system to search, recognize and characterize in navigation and target acquisition will likely require the subtle advantages provided by adequate color discrimination under varying conditions of light and contrast.

A little more than 8% of unselected males have some degree of color perceptual difficulty. Among females, color perceptual deficiences comprise a small fraction of the total population. Color perceptual deficiencies vary from the mild anomalous trichromat condition where there is an altered sensitivity to one of the primary colors to the monochromat condition where color perceptual capabilities are theoretically absent.

The Army flight surgeon currently has previously used two standard tests to evaluate color perception: The Dvorine pseudoisochromatic plates commonly referred to as the PIP or VTS-CV and the Farnsworth Lantern or FALANT Apparatus. The fourteen-plate PIP test is very sensitive. The test will fail many individuals having even a mild red-green anamalous color vision deficit. This test, however, must be administered under the correct lighting (daylight blue or a Macbeth Easel Lamp) by RESPONSIBLE individuals to be valid. It was the only acceptable color vision test under the physical standards for entry into flight training until a change to the governing regulation was made in January 1974. This change authorized extension of the color vision standards to include using the Farnsworth Lantern and Color Threshold Tester for all flying classes. Unfortunately, the change had not been reviewed or sanctioned by the Aviation Medicine Consultant. Prior to 1974, the Farnsworth Lantern was the alternate test authorized under Army flying physical standards for those individuals who failed the PIP test. The Farnsworth Lantern was designed to "pass" those mild red-green anomalous trichromats who are otherwise unable to pass the PIP test. Theoretically, Army aviators who had undergone routine Class 2 flying duty medical examinations prior to January 1974 should have passed the PIP test and never required Farnsworth Lantern testing. Curiously enough, rated Army aviators have occasionally failed both the PIP and Farnsworth Lantern testing, and therefore, have required additional evaluation to determine suitability for continued flying duty with a waiver.

The correlation between clinical color vision testing and operational color vision requirements for the Army aircrewman has not been well defined. Due to the lack of information and correlation, Army aviators and aircrewmen who fail the PIP and Farnsworth Lantern test are referred to the Army

Aeromedical Consultation Service. Here they are given operational in-flight color vision evaluations to determine suitability for waiver. It is felt that evaluees must be able to identify both colored tactical smoke signals and Aldis lamp/Biscuit gun light sequences seen from a control tower with 1000% accuracy for favorable consideration of waiver.

SPECIAL PROCEDURES: Between September 1971 and February 1974 a total of eighteen (18) of the aircrewmen found to be color defective under Class 2 and 3 Army Flying Physical Standards were referred to the Army Aeromedical Consultation Service of the Army Aeromedical Activity, US Army Aeromedical Center, Fort Rucker, Alabama, for in-flight testing and recommendation of aeromedical disposition. The first eight (8) individuals underwent only repeat PIP and Farnsworth Lantern testing and operational in-flight evaluation. In March 1973, in-flight testing procedures were further standardized and extended. An ophthalmologic examination and a series of six (6) laboratory color vision tests were administered. The additional procedures were begun so that the evaluee's color perceptual deficit could be more clearly defined and results of clinical testing correlated with the in-flight evaluation results.

The six (6) clinical color perceptual tests which are conducted under rigidly controlled conditions are:

(1) Dvorine pseudo-isochromatic plates (PIP): This is a standard color vision test consisting of fourteen (14) test plates. On each plate is an arrangement of various sized colored dots. One range of colored dots forms the background while the other, a one or two digit number. Color defectives are not able to distinguish certain numbers from their backgrounds. The Dvorine pseudo-isochromatic plates are visualized at a distance of thirty (30) inches and illuminated by a Macbeth Easel Lamp in an otherwise darkened room. Individuals are not allowed to "trace" the figures and must give the proper responses within five (5) seconds to receive credit for a particular plate. The test is "failed" if five (5) or more errors are made in the fourteen-plate sequence. Scoring is accomplished by recording the number of errors as the numerator and the number of plates in the test as the denominator.

(2) Farnsworth Lantern (FALANT): This apparatus permits a successive presentation of nine (9) combinations of vertically aligned pairs of lights. The possible colors represented are red, green and white. The test is accomplished in a glare-free "normally lighted" room with the evaluee seated at a distance of eight (8) feet in front of the instrument. Following a period of adaptation and demonstration of red, green and white color combinations, the test is begun. The subject names the color of the top and then the bottom light in the presentation. If there is any error in identification of the nine (9) color pairs, the sequence is repeated twice more in succession. The test is failed if more than two (2) errors are made in the sequences of eighteen (18). Failure of the Dvorine pseudo-isochromatic plates and the Farnsworth Lantern Test is disqualifying in all classes of Army flying physical standards.

(3) American Optical - Hardy, Rand and Rittler (AO-HRR) Pseudo-isochromatic Plates: This is a test consisting of twenty (20) plates divided into four (4) sequences (demonstration, screening, red-green dificit quantifying and blue-yellow deficit quantifying). Each of the plates has an identical background composed of dots of varying size, brightness and shades of gray. The subject is required to identify symbols (circle, triangle or X). If the subject can correctly identify each of the six (6) screening plates, he is considered to have normal color perception. Again, lighting is very critical for this test. The test is conducted under a Macbeth Easel Lamp in a darkened room in a manner similar to the PIP test.

(4) The US Air Force (USAF) Color Threshold Test (CTT): The evaluee is presented with sixty-four (64) colored light combinations by means of two rotating discs, each with eight (8) positions. One rotating disc contains eight (8) colored filters and the other eight (8) neutral density filters, each being one-half as dense as the preceding filter. The sixty-four (64) presentations are from low to high light intensities. The sequence of eight (8) colors is alternated in direction for each successive neutral density filter to limit memorization of the color pattern. The test is accomplished in a darkened room with the subject seated ten (10) feet from the instrument. The subject is instructed to visualize the color presentations by looking between the two blue fixation dots. The test is begun following a demonstration of the various colored filters. A passing score is represented by not fewer than fifty (50) correct responses in the sequence of sixty-four (64), crediting the evaluee only with the number of correct responses for each color above and including the intensity for which no errors are made.

(5) Nagel - Type Anamoloscope: The subject is presented with a bipartite field, half of which contains yellow light of variable intensity and the other half of variable mixture of red and green (yellow when combined). The subject is tasked with matching the hue and brightness of yellow in both halves in the field. The type and degree of protan or deutan color deficiencies may be characterized by this technique.

(6) Lovibond Colour Vision Analyzer: This is a relatively new instrument which will separate defective from normal color perception and quantify specific types of color perceptual deficiency. The instrument contains a revolving wheel of colored filters (including a neutral filter) which surround a single neutral filter. The saturation of the peripheral filters and intensity of the central neutral filter may be varied. The subject is tasked with comparing each of the colored filters on the wheel with the central filter for colorimetric and brightness matches. Results are superimposed on a modified chromaticity diagram containing the red and green confusion loci.

The two field tests are conducted as follows:

(1) The Aldis lamp/Biscuit gun light sequences are visualized from the control tower while the evaluee is seated in the rear, side facing seat of a helicopter. Five pre-planned sequences can be called for from the control tower operator. Each color is shown for five (5) seconds with a three (3) to five (5) second pause between each color. The lights are viewed from a distance of approximately two kilometers. If there is traffic congestion or an inexperienced control tower operator, the test is conducted with the aircraft on the ground at similar distances. Otherwise, a wide circle is flown around the control tower during which time the evaluee identifies the sequence of lights (red, white and green) as presented. The accompanying flight surgeon and pilots of the aircraft must all be in agreement as to the correct sequence presented, otherwise the test is repeated. At least three (3) sequences (15 lights) are viewed during a particular test. Additional sequences are presented if the subject makes an error(s) to further substantiate his deficiency.

(2) The observer views a pre-planned random sequence of red, green, violet, yellow and white (two (2) of each included) smoke from the rear, side-facing seat of a helicopter. The tests are conducted during bright daylight hours. The helicopter circles the site altitude from 200 to 500 feet above ground level and a distance of 1.0 to 2.0 kilometers as an assistant on the ground detonates the smoke grenades one by one in a prearranged sequence. The evaluee is required to write down the color of each smoke seen. If he later "changes his mind," the response is counted as missed, but the change is written in the margin adjacent to the first impression. An accuracy of 100% is required for passage of the test.

OBSERVATIONS: The eighteen (18) aircrewmen included in the special study period (Sep 71 to Feb 74) included fifteen (15) rated Army aviators, two (2) civilian flight instructors, and one (1) Staff Sergeant crew chief. The Dvorine pseudo-isochromatic plates and the Farnsworth Lantern tests were failed by all evaluees, which resulted in their referral to the US Army Aeromedical Consultation Service for disposition. The latter eight (8) individuals underwent more extensive study as explained above. All individuals who failed to properly identify tower lights and/or colored patches of smoke during in-flight evaluation were identified as color defective by Dvorine pseudo-isochromatic plates, the Farnsworth Lantern, American Optical Hardy, Rand and Rittler plates and Nagel anomaloscope testing. Color defective individuals identified by Dvorine pseudo-isochromatic plates and Farnsworth Lantern testing were further characterized by Nagel anomaloscope and Lovibond Colour Analyzer evaluation. The Nagel anomaloscope and Lovibond Colour Analyzer results were in agreement with the exception of one (1) case. In this instance, Nagel anomaloscope testing revealed a more serious degree of deuteranamalous trichromacy than did the Lovibond Colour Analyzer. This individual did fail his in-flight testing, failing both the colored tower lights and tactical smoke. A most interesting observation was that of seven (7) individuals with passing scores on the CTT, four (4) did not pass the in-flight evaluation. The CTT, therefore, resulted in a greater than 50% false-negative rate in this limited series of evaluations.

DISCUSSION: These early results and the results of other investigators do not support the CTT as a reliable indicator of operational aviation performance when compared with either the Aldis lamp/Biscuit gun or the smoke grenade tests. The Aldis lamp/Biscuit gun and smoke grenade tests represent military aviation requirements necessary for aircrewmen supporting tactical ground operations. Due to the limited number of evaluees in this series with unstandardized use of controls and conditions, the statistical significance of the findings cannot be discussed. Nevertheless, it has raised the question that the CTT may "pass" individuals incapable of distinguishing red, green or white signal lights from a control tower or smoke colors used for tactical ground operations. The CTT is now considered an acceptable test of color vision for US aircrewmen. It is conceivable that aircrewmen passed under this standard may not safely support tactical ground operations when adequate individual color perception is required.

In a Federal Aviation Agency report (Lewis & Steen, 1971) the results of a series of seven (7) color vision tests given to 198 color defectives were compared with recognition of aviation color signal light flashes. The CTT was classed as "unsatisfactory for screening airmen applicants." This was due to the high percentage of subjects who passed the CTT test and subsequently missed colored signal light tests. From a safety standpoint, this could be a tragic error to make. In this same study, the Farnsworth Lantern was classed as a "superior predictor of performance on the practical test". This was again substantiated in this current series.

A second study by the same authors (Steen and Lewis, 1972) correlated the seven (7) clinical tests with the aviation signal lights at night as well as during daylight. There were fifty-five (55) color defectives included in this study. The ranking of the CTT did not improve from the previous daylight only study.

CONCLUSION: Experience reveals that screening tests performed by paramedical personnel on flying physical examinations must be simple to administer and score to avoid erroneous and misleading results. The color testing equipment should require minimal calibration and maintenance, be of low unit cost and readily available from suppliers and give reliable testing results. The US Air Force-CTT proves to be a rather complicated and time-consuming test, requiring periodic calibration by trained maintenance personnel. It is generally unavailable at various physical examination stations and gives an unacceptably false-negative rate when compared to perational test results.

Although the Farnsworth Lantern appears to be an adequate test even for initial applicants, it is not recommended for the following reasons: (a) It is a highly prived instrument (roughly $1,000.).

To utilize it for selection of aircrewmen would require its purchase by all recruiting agencies of the Army Recruiting Command and other Army agencies. (b) It takes a good amount of skill, care and time to prepare, administer and score the test situation.

The other color vision test apparatus such as the Nagel-type anomaloscope and Lovibond Colour Vision Analyzer, could serve as useful standards for aeromedical evaluation of "rated" aircrewmen at various centers should further study substantiate the proper correlation with actual operational flight requirements.

Renewed emphasis should be placed on operational in-flight testing of a variety of visual skills, especially color discrimination. Clinical tests must bear up to operational expectations and should be sufficiently realistic to consider the normal, average man's competence and physiological sensitivity. (For instance, can an Aldis Lamp beam be consistently interpreted even by a normal trichromat at operational distance, i.e. pattern altitudes, etc?; can smoke grenade colors be standardized nation-to-nation and be hue and saturation selected to reduce the risk of misinterpretation even by moderately affected color defectives?)

It is evident that operational requirements of aircrewmen can only be defined following intensive study of the various aviation-related requirements for color perception and careful evaluation under varying mission, environmental and lighting conditions. The demands of modern warfare and the advant of helicopter nap-of-the earth or terrain flight for Army aviation will likely require the application of subtle and yet untested visual skills of man. To date, aeromedical science has defined operational requirements for color vision in the most gross and obvious terms. The requirement for subtle discriminations remains a mystery and seemingly defies simple investigation.

Individuals referred to the Army Aeromedical Consultation Service for evaluation of color vision deficiencies now undergo a complete visual evaluation. Disposition is deliberated on the basis of clinical and in-flight testing. The Army Aeromedical Consultant Board has consistently agreed that an unconditional waiver should be considered only when no errors in identification or tactical smoke or Aldis Lamp/Biscuit gun sequences are made. When experienced aviators (500 plus hours) fail the operational test, they are given a waiver that restricts them to fly with another fully qualified aviator who possesses normal color vision.

## SUMMARY

Many individuals with physical handicaps have distinguished themselves in numerous active careers. Aviation is no exception, having individuals such as Wiley Post, Douglas Bader, and John "Pegleg" Hoskins. These men, like most of those studied in this report, were exceptionally outstanding individuals with unique qualities. They had the motivation and adaptability to modify performance in order to compensate for their impairments by integration of all their capacities. The net result was an overall ability to cope with their usual environment and flying. This allowed them the pride and satisfaction of knowing they were productive, contributing members of society.

There are some who would imply that permitting evaluation of these individuals misleads them, gives them false hopes, permits them to postpone depression only to suffer it at a later date. In Reid and Baker's study, their respondents felt that rehabilitation was accelerated because they were looking forward to returning to duty and flight status. In all likelihood, hope enhances the rehabilitation process. Whether returned to flying duty or not, it is likely that the in-flight evaluation restores the individual's confidence in himself and his capabilities.

TABLE III

SUMMATION BY TYPE OF DISABILITY

| Type of Disability | Medical Recommendation* FFD | RFD | DNIF | TOTAL |
|---|---|---|---|---|
| Orthopedic ** | 45 | 24 | 6 | 75 |
| Ophthalmologic | 1 | 10 | 1 | 12 |
| Color Vision | 40 | 0 | 3 | 43 |
| Other | 1 | 0 | 1 | 2 |
| TOTAL | 87 | 34 | 11 | 132 |

*FFD = Full Flying Duty with no followup required other than routine periodic physical examination.

RFD = Restricted Flying Duty: Must meet specific conditions in order to pilot an aircraft (e.g. have a copilot).

DNIF = Duty Not Involving Flying (i.e. suspended "grounded").

** "Orthopedic" includes amputation, limitation of motion, shortening, and loss of function as a result of peripheral nerve trauma. Peripheral nerve injuries are included in "Orthopedic" because the primary concern is with the function of the extremities rather than the neurosurgical procedures which prepared the patient for evaluation.

The high percentage of those returned to some type of flying duties in the reported population should not be considered as representative of the potential of all handicapped persons. All of those evaluated were well screened and selected to have a chance at succeeding by themselves, their flight surgeon, and those reviewing the request. Except for a few in the defective color vision group, all were experienced aviators who had previously proven their ability as successful pilots.

The restrictions on some of the aviators with waivered conditions limits their flying to situations where they must comply with stipulations such as: another aviator in the cockpit (proficient in the aircraft and with access to the controls); pilot only certain types of aircraft; and wear specific prosthetic devices (e.g. braces, artificial limbs, contact lens). This reduces the utilization of these specific aviators. However, by applying their knowledge and experience to aviation-related tasks, it releases another fully qualified pilot for unlimited assignments.

The aviators returned to flying duties represent about $6,625,496 in initial training costs if a monetary amount can be placed on their value. If a price could be estimated for their experience since graduation from flight school, the dollar amount would be much greater. However, the use of these men's experience, maturity, and judgment as aviation commanders and staff officers is invaluable. Another intangible with possibly greater value is the morale factor of returning these men, usually perceived as physically handicapped, to their chosen profession. Their individual benefit is a positive example for other aircrewmen and soldiers that produces dividends in mission accomplishment. There is no record of a waivered US Army aircrewman having been injured in an aircraft accident.

The unresolved question is the capability of disabled men following an aircraft accident. It has not been possible to evaluate these men when challenged with that situation. The philosophical question concerns the risk to the individual in escaping from the aircraft if he sustains injuries and the disadvantage he may have in evading a ground threat after the crash. Some would say it unfair to permit a "disabled" individual to accept that risk. Others are mostly impressed by the fact that it is the "Will to Survive" that is important.

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The opinions or assertions contained in this paper are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the US Army or the United States Department of Defense.

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# ACCIDENT EXPERIENCE OF CIVILIAN PILOTS WITH STATIC PHYSICAL DEFECTS

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SUMMARY

The U.S. Federal Aviation Administration (FAA) is committed to establishment of airman physical standards and certification policies that are as liberal as possible without compromising aviation safety. Through the years, medical flight test results, research, and consultant opinions have resulted in relaxation of medical standards and policies and current FAA certification of 4,704 pilots with blindness or absence of one eye, 14,421 who wear contact lenses, 15,779 with deficient color vision, 15,543 with deficient distant vision and smaller, but significant, numbers with paraplegia, deafness, and amputations. Limitations are placed on flying activities when appropriate. Routine aircraft accident investigations seek to determine the presence of physical problems in the involved airmen and any probable association of the defect with the accident cause. The FAA experience with these civilian pilots who have static physical defects was examined and accident rates were calculated for several categories of pathology for comparison with the overall accident rates in general aviation activities. Three categories exceeded expectations significantly: blindness or absence of one eye, deficient color vision with a waiver, and deficient distant vision. However, these groups reported much higher median flight times than a non-accident airman population and accident airmen without any of the pathology selected for this study. Analyses of available data proved inconclusive but increased exposure may account for most or all of the increased accidents observed for airmen with these three pathologies. None of the accidents was related to the pilots' physical condition in the reports.

It has been reported[1,2] that 90 percent of the British Royal Flying Corps aviators who were killed during the first year of World War I died because of their own individual deficiencies and that 60 percent of the deaths were found to have been directly due to physical defects. Medical standards and care reportedly dropped this incidence to 12 percent 2 years later.[2] (However, the earliest reference usually given for these figures[9] actually speaks of "fliers lost to active flying service," 90 percent due to the "physical condition" of the pilot and "...a considerable proportion of the physical defects leading to accident are the immediate or late effects of strain on the circulation under the influence of low oxygen tension in the air." No mention is made of the 60 percent or 12 percent who were killed due to physical defects.)

Cooper[2] in 1930, Herbolsheimer[5] in 1942, Harper[4] in 1964, Rohde and Ross[7] in 1966, and Dougherty and Harper[3] (who reexamined Harper's 1964 data) in 1968 all have reported significantly higher accident rates for civilian pilots who were medically certificated with physical defects. However, Harper found that pilots with corrected defective distant visual acuity, whether corrected by spectacles or contact lenses, did not have a significantly greater frequency of accidents and Rohde and Ross found a decreased risk of accident with several medical conditions including wearing contact lenses, deafness, and trauma and deformities. Rohde and Ross also studied a number of other medical conditions including monocularity for which they found an inconclusive association with accident risk.

The duties assigned to the FAA by the Federal Aviation Act of 1958 included one to promote safety and another to encourage and foster civil aeronautics and air commerce. Very rigid physical standards might result in some improvement in safety but, if only perfect physical specimens were permitted to fly, growth, economic benefits, and enjoyment would be markedly reduced. Medical judgment is therefore necessary to balance these two, at times antagonistic, charges.

The Federal Aviation Regulations, Part 67, Medical Standards and Certification, provides that a medical certificate of the appropriate class may be issued to an applicant who does not meet the medical standards set forth in this Part. The Federal Air Surgeon may at his discretion find that a special medical flight or practical test, or a special medical evaluation, should be conducted to determine whether the applicant can perform his duties under the airman certificate he holds, or for which he is applying, in a manner that will not endanger safety in air commerce during the period the certificate would be in force. Upon such a finding, the Federal Air Surgeon; a Regional Flight Surgeon; or the Chief, Aeromedical Certification Branch, Civil Aeromedical Institute, may authorize the conduct of that test or evaluation. If the applicant shows that he can perform the duties satisfactorily, a medical certificate of the appropriate class is issued. The Federal Air Surgeon may also consider the applicant's operational experience for this purpose.

Any operational limitation on, or limit on the duration of, a certificate that is issued under this section and that the Federal Air Surgeon determines is needed for safety is specified on the airman or medical certificate held by, or issued to, the applicant. No additional tests are required during later physical examinations of holders of statements of demonstrated ability unless there is significant progression of the physical deficiency.

Medical participation in aircraft accident investigation, an active program in which 78 percent of FAA-designated Aviation Medical Examiners participate voluntarily, helps the National Transportation Safety Board (NTSB) determine accident causes and thus identify the significant problems in aviation safety; checks on the adequacy of medical standards, the certification process, and medical flight tests; and provides information to improve human engineering and crash survivability design of aircraft.

Growth of the civil airman population to 762,604 at the end of 1974 with application of the established medical standards, medical flight or practical tests results, judgments about the applicant's operational experience, consultants' opinions, and research findings have resulted in the following numbers of active airmen with static physical defects (pathology categories) of concern for this study:

| Pathology Category | No. of active airmen |
|---|---|
| Blindness or absence of either eye (includes uncorrectable distant visual acuity of 20/200 or worse, one eye) | 4,704 |
| Wears contact lenses | 14,421 |
| Deficient color vision (has taken signal light gun test and passed) | 5,157 |
| Deficient color vision (restriction: not valid for night flight or color signal control) | 10,622 |
| Deficient distant vision (uncorrected distant vision poorer than 20/100 for first or second class, or does not correct to standards for any class) | 15,543 |
| Paraplegia | 154 |
| Deafness (restriction: not valid for flying where radio is required) | 87 |
| Amputation (restriction: must wear artificial limb while flying, or requires special controls on airplane) | 745 |

This study was designed as a first effort using readily available information to compare the accident experience of the airmen in each of these eight static physical defect categories with expectations based upon their representation within the active airman population. The 762,604 airmen who held current medical certificates on December 31, 1974, and the records of 4,600 airmen who were involved in aircraft accidents during 1974 were used in the analysis. The overall results are shown in Table I.

Three categories stand out as exceeding expectations based on the observed to expected ratios as well as chi-square results. These categories are blindness or absence of either eye, deficient color vision with a waiver, and deficient distant vision. The other categories were either not significant or could not be calculated because of small expected values.

It is interesting to note that, for the categories without increased accident rates, either corrective devices were required or operational limitations were imposed. This is true for only one of the significant categories (deficient distant vision).

In an effort to consider exposure to risk, reported flying times for the 6-month period immediately preceding the latest physical examination before the accident were analyzed for the 416 accident airmen with a selected handicap, for each of the three significant categories, for the 4,184 other airmen who had accidents, and for a sample of 1,020 from the active airman population. Hours flown during the 24 hours and 90 days preceding each aircraft accident are contained in FAA aircraft accident investigation reports but these data are not readily available nor are they available for the airman population sample.

The distribution of 6-month flight times for accident airmen were significantly different (greater) than those for the active population sample and the flight times for airmen with selected handicaps were significantly greater than for the other accident airmen. Table II shows the increased proportion of handicapped airmen who reported higher levels of flying activity.

The separate defect categories were further compared and analyzed using the chi-square test, trend analysis, and other standard parametric techniques with inconclusive results as to the potential contribution of exposure to the experience realized.

The median flight times are presented below and are considered more representative than other summary statistics due to reporting problems and extreme influences which affect other measures.

| | |
|---|---|
| Active airman population sample | 13.9 hours |
| Accident airmen (4,184) without selected pathology | 38.4 hours |
| Blindness or absence of one eye | 74.9 hours |
| Deficient color vision without restriction | 61.7 hours |
| Deficient distant vision | 107.8 hours |

It seems possible that increased exposure may account for a large part of the increased accident rates observed for these pathologies. If so, it is most likely in the case of defective distant vision (107.8 hours) and possible also for blindness or absence of one eye (74.9 hours) and deficient color vision without restriction (61.7 hours) when these are compared to the other accident group exposure of 38.4 hours. Calculation of accident rates per 100,000 flying hours for each category would be ideal, if possible, and could change the relationships observed here.

Because of the three categories which were significant involved visual problems, the FAA reports of these accidents (which are unofficial; the NTSB determines the official cause) were examined to determine the time of day and phase of flight for each. Mid-air collisions, landing accidents, and nighttime and special operations were of particular concern. The results of this analysis are presented in Table III. Because of small numbers and the obvious trends reflected in Table III, no statistical treatment was considered appropriate.

Pilots with only one eye and those with deficient color vision without any operational limitations had more (33 and 50 percent, respectively) than the usual (9.4) percent of their fatal accidents at night. All three categories had more (89, 67, and 74 percent) than the expected 27 percent of their fatal accidents during the cruise phase of flight and more (53, 52, and 47 percent) than the expected (21 percent) of the non-fatal accidents during landing. There were only two mid-air accidents but 31 of the accidents involved agricultural operations where accidents which occurred during spray runs and turns were counted as "cruise." Agricultural operations accounted for 15 percent of the non-fatal accidents for the monocular and deficient distant vision groups. (Aerial application usually accounts for about 10 percent of all general aviation accidents.) Two-thirds of the ag accidents occurred during actual spray operations but only one ag accident was fatal so this operation did not contribute to the high percent of fatal accidents during cruise nor to the high percent of non-fatal landing accidents which was observed for all three of the visually handicapped groups. Increased future attention to ag accident reports is indicated to determine if there is any obvious operational/physical defect relationship.

The preliminary determination of the probable cause of each accident was also checked. Human factors causes were cited in 60 percent of those with blindness or absence of either eye and of those with deficient color vision without restriction, and in 48 percent of those with deficient distant vision--all below the usual finding of about 85 percent of general aviation accidents due to human factors causes. None of the accidents was related to the pilot's physical condition in the reports. Four of the monocular pilots struck objects (one collided with another aircraft in flight, two struck wires, and one hit a calf on takeoff) as did five of those with deficient distant vision (three struck the ground during turns and one hit power lines and another struck cattle on takeoff).

Relatively few studies have been performed over the years to compare airmen physical standards and deficiencies with accident experience. Fewer still examples are known where the findings in such studies have influenced medical standards and policies. An exception is the Harper study,[3] which probably influenced the FAA (in 1965) to relax the distant visual acuity standards for first- and second-class medical certificates (from 20/50 to 20/100) and establish a more liberal policy on waivers for poorer acuity, before correction, and for contact lens acceptance. The Rohde and Ross study, the most thorough of those referenced and reported here, has influenced medical standards and policies for several conditions including monocularity.

Few studies have been conducted of inflight performance of pilots with static physical defects. Roman[8] and Lewis[6] did not find any significant increase in landing errors by pilots flying jet aircraft after the loss of binocular vision.

Because all U.S. civilian medical certification and aircraft accident data are now contained in the same computer system in Oklahoma City, analyses of the data to determine the effects of static physical defects and known active diseases on pilot performance and aviation safety are now more feasible despite the large numbers of airmen and accidents involved. Inflight performance research should be conducted when appropriate.

In this preliminary analysis of the accident experience of pilots in eight categories of static physical defects, there is evidence that handicapped pilots fly significantly more hours than do accident and non-accident pilots without known defects. Where devices or operational limitations are available to compensate for physical deficiencies, the accident rate usually was not found to be significantly higher than for pilots without physical problems. The extra interest, effort, and determination required to learn to fly and to obtain medical certification with a significant physical handicap may result in an increased number of actual flying hours as found reported. Overreporting is, of course, possible and, except for the agricultural operations, we know very little about the type of aircraft, weather, time of day, congestion, or other risks typically encountered by the handicapped groups. The general dependability and the will to compensate for serious handicaps is frequently recognized for those in several of the pathology categories considered here.

Analyses of the data that were available for this study have proved very interesting but inconclusive with regard to a final explanation for the higher accident experience of these three groups. There is a strong likelihood that increased exposure to flight accounts for the increased accidents. Further future examination of individual accident reports may identify specific operational problems or important missing information which warrant additional emphasis in accident investigation, data analysis, and research. The findings of expanded studies such as this can influence medical standards and policies, clinical examination procedures, flight test content and reliability, limitations, educational materials, research priorities, and the use of color in aviation. These analyses should continue on a regular basis and should be extended to common active diseases such as diabetes treated by diet alone and hypertension which are of current professional interest and concern. Our workload and available resources have not permitted these studies as frequently or as profoundly as we feel they are indicated.

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TABLE I

AIRMEN AND ACCIDENT FREQUENCIES AND RATES FOR SELECTED PATHOLOGY CATEGORIES

| Pathology Category | Freq. Active Airmen Pop. | Rate/ 1,000 | Expected Accident Airmen--1974 | Observed Accident Airmen--1974 | No. Observed / No. Expected | Observed Accident Rate/1,000 | Chi-Square Test |
|---|---|---|---|---|---|---|---|
| Blindness or Absence of Either Eye | 4,704 | 6.17 | 28.4 | 45.0 | 1.58 | 9.78 | 9.86** |
| Contact Lenses (Path. Code 161) | 14,421 | 18.91 | 87.0 | 99.0 | 1.14 | 21.52 | 1.70* |
| Deficient Color Vision (waiver cause Code F) | 5,157 | 6.76 | 31.1 | 52.0 | 1.67 | 11.30 | 14.21*** |
| Deficient Color Vision (Restrict. 17) | 10,622 | 13.93 | 64.1 | 53.0 | 0.83 | 11.52 | 1.95* |
| Deficient Color Vision (Total) | 15,779 | 20.69 | 95.2 | 105.0 | 1.10 | 22.82 | 1.04* |
| Deficient Distant Vision (waiver cause Code D less Path. Code 162) | 15,543 | 20.38 | 93.7 | 165.0 | 1.76 | 35.87 | 55.60*** |
| Paraplegia (Path. Code 639) | 154 | 0.20 | 0.9 | -- | -- | -- | + |
| Deafness (Restrict. 22) | 87 | 0.11 | 0.5 | 1.0 | 2.00 | 0.22 | + |
| Amputations (Restrict. 10 or waiver cause Code 1) | 745 | 0.98 | 4.5 | 5.0 | 1.11 | 1.09 | + |

\+ Expected value too small--cannot run $X^2$
* Not significant at 0.05
** Significant at 0.01
*** Significant at 0.001

TABLE II

FLIGHT TIME DATA

| Airman Category | Preceding 6 Months Flight Time (Hours): 0 | 1-10 | 11-50 | 51-200 | 200+ | Total |
|---|---|---|---|---|---|---|
| With Selected Handicap | 33 | 48 | 117 | 140 | 78 | 416 |
| Percent | 7.9 | 11.5 | 28.1 | 33.6 | 19.0 | 100.1 |
| Other Accident Airmen | 656 | 707 | 1,066 | 1,047 | 708 | 4,184 |
| Percent | 15.7 | 16.9 | 25.5 | 25.0 | 16.9 | 100.0 |
| Total Accident Airmen--1974 | 689 | 755 | 1,183 | 1,187 | 786 | 4,600 |
| Percent | 15.0 | 16.4 | 25.7 | 25.8 | 17.1 | 100.0 |
| Active Population Sample | 220 | 273 | 236 | 152 | 139 | 1,020 |
| Percent | 21.6 | 26.8 | 23.1 | 14.9 | 13.6 | 100.0 |

$X^2$ (total accident airmen vs. active population sample) = 121.24 4 d.f. Sig. @ 0.001

$X^2$ (airmen with selected handicap vs. other accident airmen) = 34.62 4 d.f. Sig. @ 0.001

TABLE III

TIME OF DAY AND PHASE OF FLIGHT OF ALL ACCIDENTS AND THOSE IN THREE SIGNIFICANT PATHOLOGY CATEGORIES

| | All Accidents | Blindness or Absence of either eye (1): 9 Fatal | 34 Non-fatal | Deficient Color Vision (2): 12 Fatal | 40 Non-fatal | Deficient Distant Vision (3): 19 Fatal | 146 Non-fatal |
|---|---|---|---|---|---|---|---|
| **Time of Day** | | | | | | | |
| Day | 85% | 67% | 88% | 50% | 85% | 84% | 85% |
| Night | 9.4% | 33% | 6% | 50% | 2.5% | 11% | 6% |
| Dawn | 1.1% | -- | -- | -- | 2.5% | -- | 3% |
| Dusk | 4.3% | -- | 3% | -- | 10% | -- | 3% |
| Unknown | 0.2% | -- | 3% | -- | -- | 5% | 3% |
| **Phase of Flight** | | | | | | | |
| Takeoff | 19% | -- | 29% | 25% | 23% | 5% | 21% |
| Cruise | 27% | 89% | 12% | 67% | 20% | 74% | 24% |
| Approach | 23% | -- | -- | 8% | 2.5% | 5% | 3% |
| Landing | 21% | 11% | 53% | -- | 52% | 16% | 47% |
| Ground Operation | 3% | -- | 3% | -- | 2.5% | -- | 1% |
| Unknown | 3% | -- | 3% | -- | -- | -- | 3% |

(1) Includes 1 mid-air (day), 6 ag (1 fatal)

(2) Includes 1 mid-air (day), 4 ag (0 fatal)

(3) No mid-air, 21 ag (0 fatal)

# STRESS AND PSYCHIC FUNCTIONS: OBSERVATIONS OF FLIGHT CREWS AND PARATROOPS DURING PARACHUTE OPERATIONS

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## SUMMARY

Observations were made of the behaviour of a considerable number of parachutists and flight crews during parachute operations. Such operations are marked by a series of phases or pre-arranged manoeuvres which involve both the higher processes and simple motor mechanisms.

The author is a trained parachute officer and a "jump master" of the Italian Air Force; he noted the stresses which occur in the various phases and especially the involvement of the higher psychic processes. It appears that the emotive-affective complex is especially exposed to operational stress in this situation.

Hypotheses are advanced on such issues as these, with special reference to the psychological content and to the effect of drill and discipline on stress.

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For some time, various authors (Hill and Williams, Barwood, Simonov, Pimenova) have dealt with the correlation between operational stress and psychic processes, and there is agreement in studies of military behaviour that such stress is greater with regard to the higher mental functions than the simpler motor-perception mechanisms.

Since one of the operating conditions in which stress is at its most intense is parachute jumping, both for the technical and emotional characteristics which distinguish it, I have considered it worthwhile to give observations made on paratroops and flight crews during the course of operations, evaluating the prevalence of stress. Up to the present time, parachuting has been the object of interesting studies and research concerning both somatophysiological aspects for the greater part, and those psychological and neurological. I would quote, among others, the works of Reid and coll., Fenz and Epstein, Schane and Slinde, von Renemann and coll., Leger, Gauthier and coll., Galban and coll. Furthermore, in 1968 at the NATO-AGARD Study Group Meeting in Brussels on the subject of "Aeromedical Aspects of Troop Transport and Combat Readiness", one of the papers presented was that by Rota which dealt specifically with military parachutists; we also learn that the French Naval Research Centre for Applied Psychology has performed various electro-encephalographical tests on paratroops.

It is interesting to note that the major part of the research shows that various modifications in heart, brain, vegetative, humour, psycho-motor, etc. activities are in more or less direct correlation with the emotive component of stress and with the psycho-physiology of the individual. Another reason for which I feel that this contribution has value is that as a psychiatrist I carried out observations on paratroopers' comportment in line with a mainly psycho-dynamic orientation, thus reflecting, in accordance with Cobb's definition, not only "what a subject does" but "the reason why he behaves in a certain way". Boring affirms "Psychology deals not only with the comportment of man as it appears from his reactions, so much as and above all with the consciousness which is discovered in his immediate experience; no scientist has been able to study a disembodied consciousness".

Finally, another motive is the fact that the observations have been directly executed in action during the various phases of parachute operations. Being a parachute officer of the Italian Air Force, I have always taken an active part in the moments and conditions I describe, living the situations of operational stress with their emotional impact and their influence on the higher mental processes. I have thus been able to verify on myself the actual effect on the mechanism and its incidence. This - my double role of participant-observer - is, in my view, perhaps the most significant aspect of the work, and also the most unusual encountered in such operations.

Clinical observations were made based on direct interrogation and immediately recorded observations of behaviour and changes occurring during the various phases of the jump operation. No data is given of types or numbers of missions executed, of aircraft, of paratroops, of equipment employed, nor of the Armed Force and its relative sector, or any other information which could be classified for military security.

Operative steps of military parachute operations using the "engaged rope" system can be set out as follows (I have found this personally-devised summary the most useful for this work) :

I - PRE-JUMP

a. Preparation : This includes all actions starting from entrance to the airfield
   1. Fitting the parachute and ancillary equipment
   2. Control checks by the individual and by the jump master
   3. Embarkation, installation, and take-off.

b. Flight, towards jump zone :
   1. Ascent, straightening out, approach
   2. Hooking onto engaged rope and control checks, identification of jump area by aircraft crew, coordination between first jump master and the guide patrol on the ground, switching on the green light for "go".
   3. Approach to aircraft door and assumption of exit position.

II - JUMP (1)

1. Exit
2. Parachute opening shock
3. Unfolding of canopy (2)

III- POST-JUMP

1. Descent
2. Landing
3. Action (operational training).

Obviously, as is widely acknowledged, the whole of these phases and operations activate the various sensitive-perceptive mechanisms that, by means of the stimulation of particular sensory organs, give rise to consequent motor reactions. In substance, it is a process which, though very complex, is automatic and results from conditioning when, following the findings of modern neurophysiology, it is not exclusively one or more specific sensory organs which condition the reaction but the whole in which other integrated sensations play their part. This is the sphere of "rational psychological comprehension" where analytical investigations of personality are omitted and a completely impersonal situation remains. Less evident, and certainly less clear in primary causes and in motivational elements conscious and unconscious, is the activation of the whole of the higher psychic processes.

In the first phase (Pre-jump) two higher mental processes are called into play, i.e. attention and affection ('affettività'). It should be pointed out that, even before the commencement of the various phases, emotional stimulation already occurs in each individual as soon as he is aware of inclusion in the jumping team. It is, in fact, the prefiguration in the creative imagination of an event of which, at bottom, no one can predict the outcome. It is a non-objective phase because of lack of reference points in comparison with the actual experience which comes after, during the jump, when all emotions and anxieties make their appearance freely. Merely entering the airfield with its open and extensive horizon gives the anticipation of an even wider and boundless dimension which will be realized during jump and descent.

Attention is a term to which are attributed many significantly different meanings, even from a descriptive point of view. To some it has the ability to heighten consciousness (Wundt), to render various mental states clearer and more lively (Ebbinghaus, Titchener, Warren) as far as identification with the highest degree of lucidity of consciousness (Pieron). More recently, Baudin has distinguished "waiting attention" in which consciousness becomes activity, tension or effort directed at an object not yet in its possession, from "concentrated attention" which is beamed on a specific object or subject. Jaspers has indicated, in a deeper phenomenological analysis, three similar but not identical elements which co-exist in the concept of "attention", (a) the feeling of actively addressing mental activity to a determined object or subject (das Erlebnis des Sich-hin-wenden); (b) the clarity and vivacity of the contents of the consciousness; (c) the effects of the first two phenomena on the natural course of psychic processes in toto, e.g. the facilitating of actions in a determined sense, and this is the element which permits the objective study of attention.

In the course of parachute operations, during Phase I and particularly at steps a/1 (fitting of parachute and other equipment) and a/2 (checks by the individual and the jump master), I was able to subject paratroops to some easy attention tests such as the Bourdon test (in which a certain letter must be erased in a passage in an unknown language) and that of Toulouse-Pieron (where a specific figure is to be underlined in a list which includes randomly mixed geometric shapes). The results, in most cases, showed a marked trend to exhaustion of the generic attention process, evidenced by longer time taken to execute the test and a greater number of errors, roughly 20-22% more than would be encountered under normal conditions in individuals similar in age, intelligence, social, environmental and working backgrounds. This would demonstrate

(1) The word "jump" includes all phases up until the stabilization of descent speed.
(2) Unfolding may be complete (with constant descent speed) or partial (malfunctioning) with relative increase in speed.

that generic attention in the course of fatigue tends to follow the so-called "interest-law" which regulates the selection of objects or subjects on which the attention focusses. As Baudin affirms, "it is a general fact that we give attention only to what concerns us or moves us directly or indirectly, from near or afar".

In the pre-jump phase, generic attention tends to be replaced by a "waiting attention" projected towards the still-future event (the jump) and by a "concentrated attention" directed at the event to follow (the landing). Paratroops in this phase appear to concentrate greatly and almost exclusively on the jump and everything that relates to it; this is particularly notable in moments a/1 and a/2 when the fitting of the parachute and the control checks give a first physical, bodily, sensation connected with the jump. On the clinical level, it is probable that this attention displacement from the general to the specific represents an equivalent state of unconscious anxiety.

Bumke, and in general all authors in classical German psychiatry, use "Affekte" or "Gemütsbewegungen" to describe the intense feelings which, in degrees of strength, accompany somatic reactions and which influence the entire psyche. In particular, "affective reactions" are characterised by the arousal of a feeling of specific aspect in understandable relation (Schneider) with external events. Linked to the concept of affective reaction is that of "emotive reaction" or "emotion" (3) which can be used to define an affective reaction of particular intensity. According to Gemelli and Zununi, for every feeling there is a corresponding emotion which is its exaggeration. German specialists use the term "state of humour" (Stimmung) to indicate the entirety of feelings present in a specific state of consciousness.

Thus, still in Phase I of pre-jump, the sphere of affection (affettività) is involved in operative stress in each of its components and at each second. In this phase clinical data acquisition is limited to observation, examination and interview of participants, and activation in them of projective mechanisms; the evaluation of the collective "psychic pulse".

Moment a/1, that of putting on the parachute and similar material, already necessarily induces a particular state of mind in that, as already pointed out, it is the starting point of the jump operation. A general state of subdued excitement is observed, characterised by an increase in vivacity and pleasant feelings of well-being. Jumping causes specific attention to be focussed on it, since it is a goal to aim at and therefore determines a feeling of expectation and of happy restlessness which is heightened by being part of a team. There is a common feeling of fellowship, of participating in a joint endeavour, so that individual personalities may be left aside in order for identification in a wider, protective collective personality.

During phase a/2, the humour tone tends to shrink as the control checks alert the consciousness to the inherent risk in the manoeuvre and of the importance of containing the risk by accurate control checks of all the equipment used. But it is in moment a/3 that a disappearance of this characteristic is witnessed, and its replacement by a state of "thymic silence" ("troubled mental state"); this is at the stage of entering the aircraft, arrangement in it of the paratroops, and aircraft take-off. By this, I do not mean that there is a lack of feeling, or affective indifference, rather that a particular state of mind is signified between the passive acceptance of the factual approach of a situation unconsciously recognized as anti-preservative and a feeling of separation from the reality of the earth as a mother-element.

This is not yet a separation in the complete sense as there is still the indirect contact phase when the body of the aircraft, remaining on the ground, serves as a link. It is, however, realized at the moment of take-off when, for the first time during the operation, the parachutist feels his isolation from the ground. The indirect contact becomes a break. The thymic silence then extends its expression to behaviour and gestures, and continues in moment b/1 of Phase I, that of flight towards the jump area, climbing, levelling and approaching. At step b/2 the pre-jump phase enters its most significant moment. The jump masters commence giving various orders in preparation for the act of abandoning the aircraft which is to occur approximately six minutes later. The relationship between the parachutist and the jump master has a special psychological significance. The fact of depending, in this phase, on their orders can give rise to an unconscious correlation between remote childish models and images in which common archetypes and structures dissolve, integrating with specific elements and individuals in the life history of each person. The first and second jump masters may often be identified with a powerful guardian father-figure, and this process can also involve the flight crew even though they are at a distance and physically separated by the cockpit-fuselage screen which makes their presence less felt.

At this stage, control checks are repeated by both individuals and the jump master, and parachutists hook the engaged rope to the static line. The gesture has a significance only to be understood by those who have experienced it several times. It constitutes a compensatory act in anticipation of the anti-physiological event of the jump by means of establishing an umbilical cord through which assurance, protection and guardianship

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(3) Many English authors extend the appellative "emotion" generically to all emotivity.

are received; these terms should be appreciated beyond the actual direct meaning. In psychoanalytical terms, the interpretative hypothesis can be advanced of a new beginning of a "mother relationship", the engaged rope representing the "need-satisfying object" and fulfilling the role of "the good mother", "the ideal mother", the "ordinarily devoted mother" (4).

The parachutist firmly grasps the line, following it as it slides along the length of the aircraft, and approaches the door. Then, in his turn, he stands at the door, adopts the correct exit posture, and lets go. Whether it is a matter of course because he has become used to it, or whether it is instinctive, he does it with decision and energy almost as if to get away as quickly as possible and overcome "separation anguish". It is this feeling which arises at the prospect of being separated from a being recognised as necessary for survival; in this two factors enter : fear of an unspecified danger either external or from growing inner tension, and fear of losing the object capable of providing comfort and protection.

Moreover, step b/2 also involves the flight crew members. For them, particularly the pilots, it is the period of identifying the jump zone, of interphone coordination with the first jump master and the ground guide patrol, of the rapid switch-on of the green light which permits the manoeuvre to proceed. The emotional state involves the whole sphere of affection giving rise to a form of anxiety signal, understood as the reply of the ego to the increase in instinctive or emotional tension which alerts the ego of a threat to its equilibrium. Its function is to enable the ego to institute defensive measures, and can be considered as a form of direct internal vigilance. A similar phenomenon affects the first and, even more so, the second jump masters. The fact that the chief pilot and the leading jump master are in direct collaboration, and that the latter acts directly on information received from the former is such that reciprocal transmission of tension level can be realized and the corresponding antidote given by the anxiety signal.

The second of the phases into which the manoeuvre has been divided is that of jump itself. The operational stress involves, in this phase, the whole complex of higher mental processes. In step 1 - exit - will is summoned up in which various factors - instinct, affection and intellection - play a part. Exit from the plane door expresses a level of energy in the form of a controlled and willed push towards a determined, foreseen, action and freely-chosen purpose after a conscious act of judgement.

Emotive affection is involved in the process of "relation to a mother" with regard to the engaged rope, and one sees in this phase the continuation and extension, i.e, the mother-child separation. The process ends and gives place to a cathartic mechanism as the normal unfolding of the canopy eliminates the various anxiogenic components.

In the act of exit, attention is indubitably involved as the paratrooper who, already at the door, had reached the highest concentration of energy, puts into being a state of vigilance and alertness by means of which he can follow as rapidly as possible the jump sequences. There is a global increase in attention characterised by the fact that the parachutist simultaneously awaits more than one stimulus without fixing attention specifically on any one; the sudden and violent contact with the air, the sensation for some seconds of falling freely in the atmosphere, maintenance of the correct body position with hands on the emergency parachute forming a feeder of security and protection. The complex of cognitive function: recognition, evaluation, discrimination, criticism, gives place to a behaviour different from that guided by instincts, i.e, to an "intelligent" behaviour. The central nucleus of intelligence is one of the elements in particular which is activated in moment 2 - shock of chute opening - and moment 3 which is the unfolding of the canopy. The parachutist must then evaluate extremely rapidly the normal sequence of events so that in the case of malfunction he can operate the emergency parachute with the utmost speed. In such an event, perception-evaluation-decision are the functions and sequence which constitute the unique and simultaneous mental process.

I have been able to study cases, rare as they are, which often involve first-time jumps, of malfunction of parachute, and to compare theory and reality. Since I, myself, experienced two consecutive cases of parachute malfunction in jumping from helicopters, I have my own first-hand evidence to offer. Certainly, such a double event is extremely rare, and to have undergone the experience qualifies me, I believe, to offer the following observations.

The first of the two consecutive parachute failures was my first experience of a malfunction and, naturally, stress was at a high level. On perception, there was a "surprise" phase which expressed itself in a brief block of the psycho-motor which then reasserted itself and was followed by evaluation-decision. The second failure of the parachute to open occurred thirty minutes later. It did not provoke the "surprise time" - the mental process perception-evaluation-decision was so closely linked as to be a single spontaneous event. The operational stress of the first jump, in effect, so stimulated the complex of functions and higher thought processes

(4) This definition has been introduced by Winnicott to indicate the mother who offers her child maternal care adequate for its development and who is capable of "primary maternal activities".

represented by attention, vigilance, emotion and affection-evaluation plus critical decision, that the same elements remained active in the second situation, with the exception of the emotional-affective sphere which had already encountered a mechanism of exhaustion as regards the "surprise" components. From this, an interpretation may be derived of the positive function of operational stress on the psychological processes during this sort of activity, and interesting inferences as regards training may be drawn.

The danger in this jump phase - particularly for those making a first jump - is that of the dominance of the emotive-affection on other functions and processes. Thus a thorough conditioning is desirable involving operational stress on the functions by means of frequent, repeated and most realistic simulations of the emergency.

The third phase post-jump, involves three steps, descent, impact and action. Descent represents the agreeable, even romantic, aspect of parachuting. However, in military jumping it has a high operational role. Emotion and affection undergo intense stimulation. This is expressed by affective somatic sensations (Leibgefühle) or "vital feelings" (Vitalgefühle or Lebensgefühle) and "ego sentiment" (seelischegefühle) according to the definition by Scheler, or "feelings of condition" (Zustandsgefühle) according to Schneider's classification, i.e. profound feelings or sentiments - in this case, pleasing and of considerable depth. In this phase, consciousness is greatly involved either as "consciousness made objective" (Gegenstandbewusstsein = everything in our presence can be understood, thought, recognised not only by senses butalso by the "inner eye" of self-observation and introspection) or as "ego consciousness" (Ichbewustsein = how the ego is conscious of itself) according to Jaspers' concept. At the same time, operational stress brings in other processes : attention - the psychological complex of evaluation-discrimination that with others constitute the "central intelligence core" of which we have already spoken - and decision. Beyond feelings and emotions which stimulate, descent is the phase in which the parachutist executes various manoeuvres, controls his position relative to other parachutists, takes possible anti-collision measures, arranges laterally the emergency parachute, selects the most suitable impact area. He steers himself towards the landing, unhooks the appropriate equipment, manoeuvres to avoid obstacles (trees, electricity wires, etc.) Clearly, all this requires that the afore-mentioned processes be jointly involved to the highest degree and to a high level of reciprocal integration.

The moment of impact is above all emotive-affective. The parachutist re-finds the earth from which he ascended. In the preceding seconds he prepares for the landing, assuming the position and degree of tension prescribed by training. The tension, however, is mental as well as muscular and it expresses the "desire and will to return". He wishes to "feel" this return through the scraping of his boots and other parts of the body touching the ground. We are here, as in the descent phase, in a full sphere of affective somatic sensations which combine in a particularly agreeable "state of humour". Psychologically analysed, it is a direct and immediate consciousness of his own ego and his corporal image. The action represents the last moment of the third phase of the jump. Since the operational stress involved concerns nearly all the higher mental processes, a paratrooper may commence ground action in a flexible mental state. The relative inferences from literature are diverse : Rota, in the wake of his research, holds that no real reduction in operational efficiency occurs, although he has some reservation as regards a possible actual combat situation; Galban and coll. in their investigation have seen some aspects of efficiency diminish, and others instead increased, and they conclude that it is relevant to greater military experience on the part of the individual.

My personal observations lead me to agree with the latter assertion, extending it to the specific experience of jumping and interpreting it as an expression of a more conservative possibility of use of the psychic energy charge. With this expression, I refer to the Freudian concept of energy which postulates "bound energy" as a characteristic of structurised parts of the psychic apparatus, i.e. the psyche or ego and of secondary processes, and a "free or mobile energy" characteristic of non-structurised parts of the psychic apparatus, i.e. the "Id" and of primary processes. The concept is valid referred to problems of attention displacement, of interest and attachment of one person to another or one activity to another.

In conclusion, effects of operational stress during the various steps of a jump are considerable, involving the whole complex of higher mental mechanisms and processes and, in particular, the emotive-affective sphere. The subject is of interest in respect of operational and training implications to be derived, and also the psychological and psychiatric selection of candidates or trainee parachutists.

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# COMPARISON OF VISUAL PERFORMANCE OF MONOCULAR AND BINOCULAR AVIATORS DURING VFR HELICOPTER FLIGHT

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## SUMMARY

This study describes a methodology for assessing the inflight visual performance of six binocular Army aviators and one monocular Army aviator during various maneuvers in a JUH-1H helicopter. The methodology described is a corneal reflection technique using both video tape and 16mm film as a recording medium. Information on the use of 13 visual sectors is provided for a number of maneuvers to include normal takeoffs and landings and hovering maneuvers. The aircraft windscreen was divided into eight sectors while the side windows and chin bubbles comprise an additional four sectors. The thirteenth visual sector represents the inside cockpit area. Data presented include percentage of total time spent in each sector, average dwell time per sector and sector transition (permutation) values. Comparison data are provided between the six binocular pilots and the monocular pilot. These data reveal that in many cases there was little difference between binocular and monocular visual activity. In addition to the objectively recorded data, information concerning monocular visual cues is presented.

## INTRODUCTION

There is little question that helicopters have become an integral part of the U.S. Army's tactical structure. Also, there is little question that mission accomplishment and safe flight of the helicopter is dependent in large measure on external visual information received by aircrew personnel. Evidence that minimum adequate visual information is currently afforded Army aviators is substantiated by the very fact they can, and do, fly the machines. However, little is known with regard to what areas of the windscreen aviators most often use, how long they dwell in these areas, what dynamic response patterns they utilize to transition from area to area, where and what they view external to the aircraft, or how these parameters change as a function of variables, such as aircraft flown, maneuvers flown, level of training, or physiological state. Knowledge concerning these parameters is perhaps a first step in gaining information concerning what visual cues are predominate in helicopter flight control.

Though the visual sensory modality is considered, almost without exception, to be highly critical to helicopter flying, few research studies have been conducted measuring where the pilot looks during actual rotary wing flight. Two studies[1,2] were performed some years ago but were primarily concerned with establishing the minimum acceptable visual envelopes for aircraft. These studies examined visual performance, in various aircraft over a number of maneuvers, in terms of the frequency with which aviators utilized certain visual areas. While attempting to establish these visual envelopes, the investigators did study some visual performance of aviators while flying helicopters. It might be added that these particular studies appear to have been overlooked when one views the military standards concerning visual envelopes for helicopters. Since these studies, a number of new helicopters have been added to the Army inventory, the function and flight envelopes of helicopters have expanded, and the technology for recording visual performance has advanced, providing more measures with greater accuracy.

More recently, two other studies[3,4] investigated a number of maneuvers gaining data by way of interview techniques as well as in-flight recording of visual performance for two aviators. The in-flight visual data was examined by using three lateral areas referenced to the windscreen and four vertical categories referenced to the earth's surface. The major emphasis of the inflight visual performance, however, was directed at measuring performance in maneuvers flown IFR (instrument flight rules). These efforts provided some needed information as to what instruments are used, how long they are used, and their order of usage.

With regard to VMC (visual meteorological conditions) rotary wing flight several studies have just been conducted concerning visual performance.[5,6,7] Though information has been added to visual performance data, much yet remains to be established for this sensory modality which is so critical to safe flight.

Additionally, there may be information relative to visual flight rules to be gained from studying monocular visual performance during helicopter flight. Perhaps the major binocular cue which a monocular aviator loses is that of retinal disparity which perhaps can be useful to a distance of between 490 - 700 yds.[8] This however does not appear necessary for the conduct of adequate flight control, a fact attested to by a number of successful one-eyed helicopter pilots. However, there is little information available as to whether or not these monocular pilots tend to gain their flight control cues from the same areas which appear to be visually "rich" for binocular aviators.

The purpose of this investigation was to gain data concerning visual performance during VMC conditions while executing a number of maneuvers in a UH-1 helicopter. For purposes of comparison, data was acquired for one monocular aviator and six binocular aviators.

METHOD

The binocular subjects were six Army aviators with a mean age of 29.4 years. Their flight experience ranged from 300 hours to 2500 hours with a mean of 1621 flight hours. The monocular aviator was a 34 year old male who is currently on flight status. His eye loss was the result of a facial injury due to hostile fire on a combat flight mission. These facial injuries resulted in enucleation of the left orbit in May of 1967. Prior to his injury he had flown a total of 652 hours of which 439 were combat mission hours. This injury was disqualifying for a Class II flight physical. This aviator (seeking a return to flight status) requested and received a medical evaluation in 1968. The medical evaluation did not recommend a return to flight status. This determination was based on a condition of recurrent subluxation of the right shoulder rather than the monocular condition. A Magruson-Stack procedure was performed on the right shoulder joint in February of 1969 and since that time there has been no history of dislocation. Again, in 1972, he requested another medical evaluation in an attempt to return to flight status. His case was evaluated by the Aeromedical Consultation Service located at Ft Rucker, Alabama. This evaluation was favorable medically and it was determined that the subject should undergo an ungraded evaluation flight (prior to his final graded evaluation flight) to determine if additional flight training would be necessary because of the length of time since he had flown. The informal in-flight evalution was performed on 12 April 1972 and administered by the Flight Standards Division. Several deficiencies were noted and are as follows: (a) At approximately 100 feet AGL "ballooning" was noted on normal approaches. The evaluee tended to fixate on the ground and would apply rearward cyclic pressure as the apparent ground speed suddenly increased. (b) Landings were consistently made to the right side of the runway. (c) Takeoffs were always accompanied by 20° to 30° of right yaw in climbout. (d) Hovering altitude tended to be somewhat higher than the desired three feet. (e) During autorotations, the evaluee tended to initiate his final pitch pull 10 - 15 feet higher than normal. It was the opinion of the Standardization pilot that much of the evaluee's difficulty was due to his lack of recent flight experience (last flight was 21 May 1967) and difficulty in adjusting to obtaining flight control cues with one eye. It was felt that a period of "retraining" was necessary to develop the use of the visual cues and flight proficiency prior to a final evaluation flight. This additional flight training was provided in a UH-1H helicopter with a well qualified instructor pilot provided by the U.S. Army Aeromedical Research Laboratory at Ft Rucker.

The retraining began on 18 April 1972 and lasted for two weeks. This training encompassed all standard helicopter maneuvers to include: hovering turns, rearward flight, maximum performance takeoffs, confined area operations, slopes, pinnacles and formation flight. Non-standard and emergency maneuvers practiced were autorotations to include standard autorotations (both day and night), low level autorotations, and 180° turn autorotations. Other flight maneuvers practiced were low level flight, Nap-of-the-earth flight and recovery from unusual attitudes. During this training, daily after flight debriefings were conducted. These after flight discussions were recorded and transcribed in chronological order.

Numerous variations were noted and discussed during this training period. Some of the areas of significance were: (a) It was pointed out by the instructor pilot (IP) that the monocular aviator tended to land the aircraft right of the center line with a right yaw of 10° to 15°. When questioned about this the subject stated that he was aligned with the runway and that he was not in a right yaw position. The subject was instructed to exit the aircraft, walk away from it, and then to look at its alignment. Returning to the cockpit he stated that it was clearly to the right of the center line with a right yaw. The aircraft was then aligned with the center line to give the subject another view. Subject stated that the aircraft appeared to be left of center and yawed left. Additional practice of this maneuver enabled this situation to be corrected. The subject stated he had shifted from referencing his body to an external referent to using fixed points on the aircraft and relating these to an external referent. (b) When instructed to maintain a stationary three foot hover above a point the pilot tended to randomly drift and gain altitude without his being aware of these deviations. The subject was asked what he was using for an external referent. He replied he would look at a tree line that was located approximately 100 meters from the aircraft. The subject was instructed to use cues closer to the aircraft (5 to 10 meters distance) as these objects would provide the finer visual cues necessary to maintain a precise hover. When the subject used cues which were closer, his performance improved rapidly. He had a slight tendency to fixate but quickly recognized this tendency led to over control and therefore started using a visual scan pattern. This flight training aided the pilot in establishing new visual perception cues and also added greatly to his confidence that he could again fly with skill and precision. This included the ability to manage all of the in-flight ancillary tasks associated with flight. On 4 May 1972 the subject was administered his graded evaluation ride with a check pilot from the Department of Standards. All normal flight maneuvers were performed as well as non-standard and emergency maneuvers. The subject experienced no difficulty in performing any of the maneuvers. No evidence of any visual difficulty presented itself during this evaluation. It was the opinion of the Department of Standards check pilot that the subject was adequate in ability and proficiency for safe flight. A final evaluation check ride grade of 85 was given for the entire flight. On 18 August 1972 the Aeromedical Consultation Service recommended that the subject be returned to Class II flying duty subject to the following restrictions:

(a) Flight with another aviator fully qualified in the aircraft flown.

(b) Flight from the right seat (opposite his visual deficiency) to facilitate clearing the aircraft in turns.

(c) Re-evaluation and testing at the Aeromedical Consultation Service annually and/or whenever transition to another type or series aircraft is contemplated.

(d) Identification as a research subject to facilitate re-evaluation, gathering of information, and administrative handling of his case.

This recommendation was accepted and the individual was returned to flight status with the above mentioned restrictions.

APPARATUS AND PROCEDURES

Visual performance of all subjects was measured via a modified NAC Eye Mark Recorder used in conjunction with either a video recording system (30 frames/sec) or 16mm motion picture camera (16 frames/sec). The NAC recorder utilizes corneal reflection and has a field of view of 60° in the horizontal and 43.5° in the vertical. The optically focused reticle which is reflected from the eye and superimposed on the image is approximately .5mm. Mounting modifications were required to assure accuracy during in-flight measurements. Figure 1 shows an aviator wearing the modified NAC.

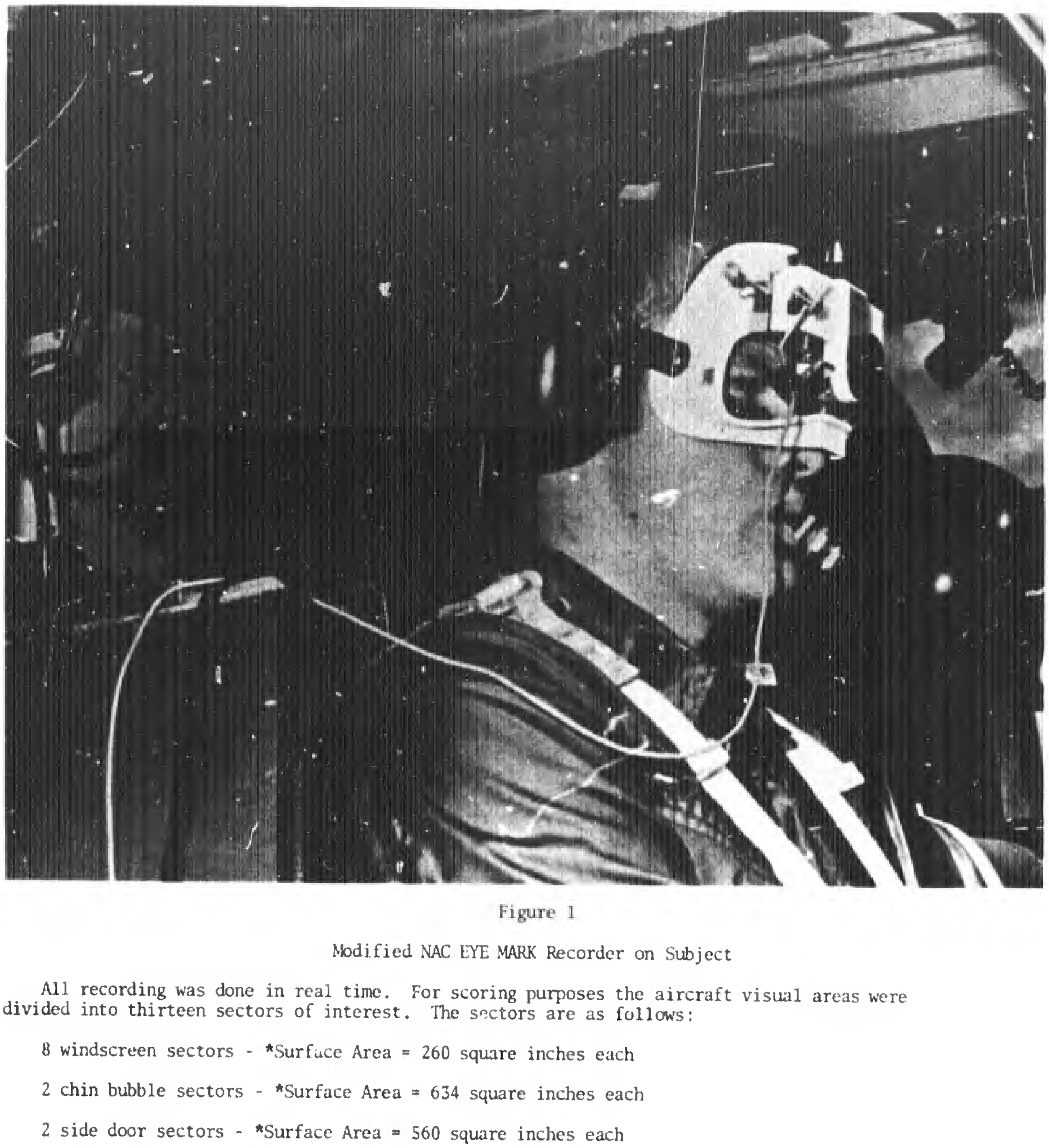

Figure 1

Modified NAC EYE MARK Recorder on Subject

All recording was done in real time. For scoring purposes the aircraft visual areas were divided into thirteen sectors of interest. The sectors are as follows:

8 windscreen sectors - *Surface Area = 260 square inches each

2 chin bubble sectors - *Surface Area = 634 square inches each

2 side door sectors - *Surface Area = 560 square inches each

1 inside cockpit sector

*Note that sectors within each group are of equal surface area but not necessarily equal viewing area.

Figure 2 shows a visual plot of the viewing area of the UH-1H model helicopter. This plot provided by the Bell Helicopter Company, Fort Worth, Texas, was generated using water line 64.05 and station 470.90. The black vertical and horizontal superimposed lines on this plot represent the divisions of the various windscreen sectors used in this investigation.

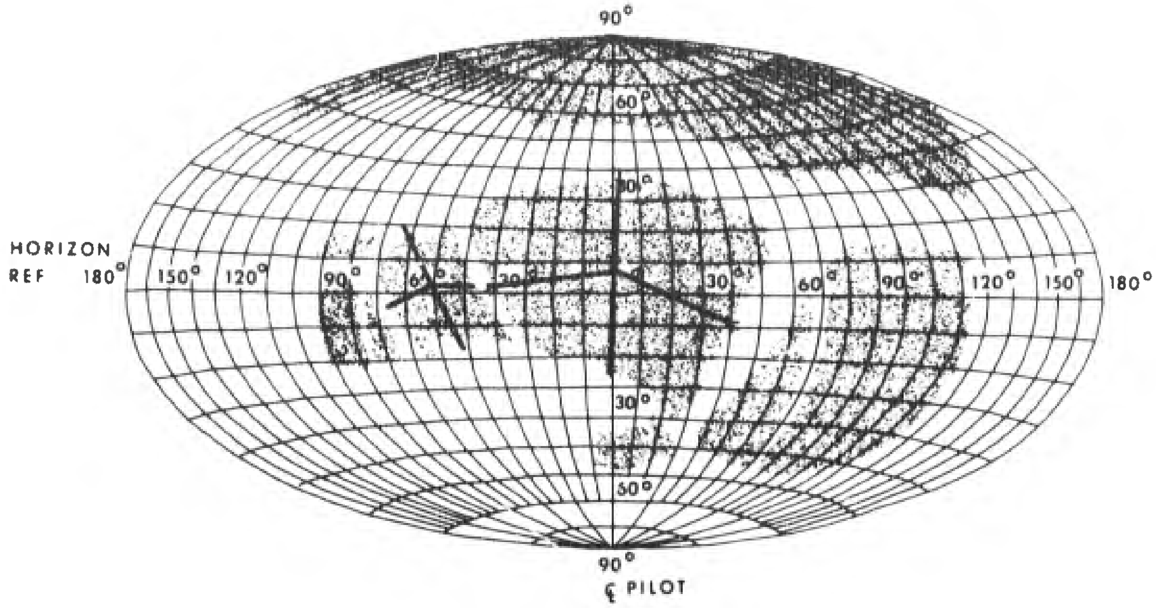


Figure 2

Visual Plot, UH-1H

Each subject, prior to flying the helicopter, was fitted with the NAC recorder in the laboratory and checked for accuracy. He then proceeded to the aircraft for final hookup and additional calibrations. The subjects flew from the right seat (the normal pilot's position in a helicopter) adjusted to his own comfort. After each flight, each subject was again checked for accuracy to assure that the NAC had not shifted. Throughout the test no shifts in the NAC were found to exist.

Each subject performed a standardized set of eleven maneuvers common to helicopter operations. These were as follows: 1. Lift off to Stabilized Hover, 2. Forward Hover, 3. Rearward Hover, 4. Hover Turn Left (90°), 5. Hover Sideward (Left), 6. Hover Sideward (Right), 7. Hover Turn Left (360°), 8. Hover Turn Right (360°), 9. Hover Turn Right (90°), 10. Normal Take Off and Normal Approach to a Hover (Left Traffic Pattern), 11. Normal Take Off and Normal Approach to Touchdown (Right Traffic Pattern).

DATA ANALYSIS

After all data had been recorded, the tapes and/or film were brought back to the laboratory for scoring. Time scoring was performed while playing the tapes back at one-half speed, and consisted of recording the time spent in each sector. The timing system permitted accuracy to 50 msec. Time per sector for each maneuver for the six subjects was scored by two investigators and was accomplished by pressing microswitches mounted on specifically designed boards to accommodate the fingers of each hand. Each board contained six switches with the thirteenth sector being represented by a foot switch. Each switch closure performed three functions. It provided a unique voltage to a digital voltmeter, caused a counter (time base) to stop and reset, and signaled the computer to accept both values. The voltage served to provide a unique core address for each sector, and the computer was programmed to add the incoming values to the appropriate sector location. After all data was entered, the computer then performed the subsequent analysis required. All timing was forced, i.e., all flight time had to be accounted for by one of the sectors.

Perhaps the primary limiting factor of scoring time in this manner involves the reaction time of the scorers. However, the error introduced by this factor is considered minimal in that one can reasonably expect to record some time in any sector which was frequented by the eye for any period of time 100 msec. or greater. This exists because, at the scoring speed, a 100 msec. deviation appeared for 200 msec., which is within reaction time capability. The data supported this contention because scores were found in the 100 msec. range. Measurement to this resolution can be considered adequate when one considers the response time in terms of ability to gain information. This scoring method will, of course, introduce some error when the eyemark is not visible to the scorer, since all time had to be accounted for by one of the sectors. When this event occurred, time was accumulated in sector one or time spent inside. However, error introduced by this situation was negligible since the scorers did not often lose sight of the eyemark. Eyeblinks theoretically could cause loss of the eyemark and result in time accumulated in sector one, but were not considered a problem inasmuch as they were in most cases below the scorer's response threshold. Eyeblinks, as recorded during helicopter flight, have been reported to occur with average frequencies ranging from 18 to 24 per minute.[9] Durations of these blinks have ranged from under 20 msec. to over 113 msec. with 89% occurring below

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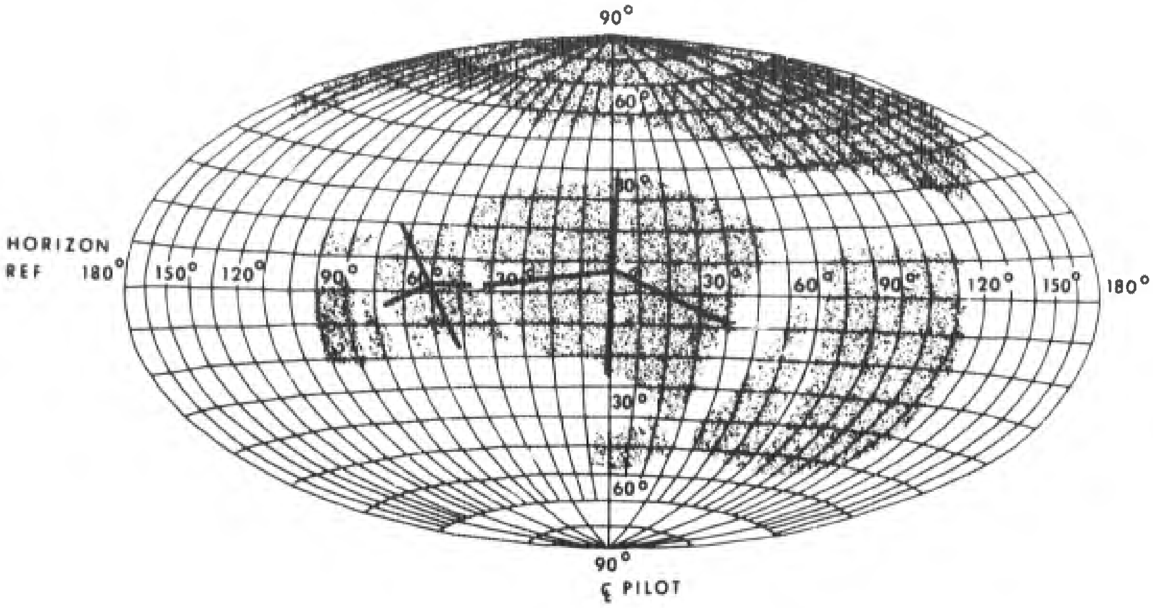


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56 msec.[10] With regard to saccadic movements influencing the data to any extent, this again, in the opinion of the authors, was minimal because saccadic movements for the visual angles involved would be of very short duration. Previous literature has stated that pilot head movements must be considered any time eye movement is greater than 15° [1] in any direction from the centrofoveal position.

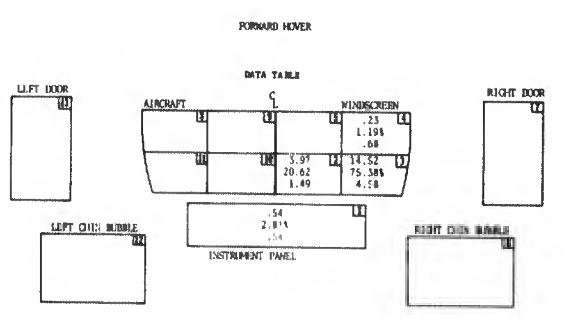
The sector transition measure consisted of a frequency count for transitions from one sector to another. Since there were 13 sectors, this yielded 156 permutations, e.g., sector one to sector three, sector three to sector one, sector one to sector five, sector five to sector eight, etc. As with the timing scores, the switch closures provided voltages that the computer manipulated such that each permutation was assigned a unique core address and a simple counter was set up to provide the frequency of occurrence. After all data was entered, the computer then performed the subsequent analysis required. For this measurement score reaction time was not critical in that frequency was all that was important, thus permitting the scorer to lag if necessary to record.

## RESULTS AND DISCUSSION

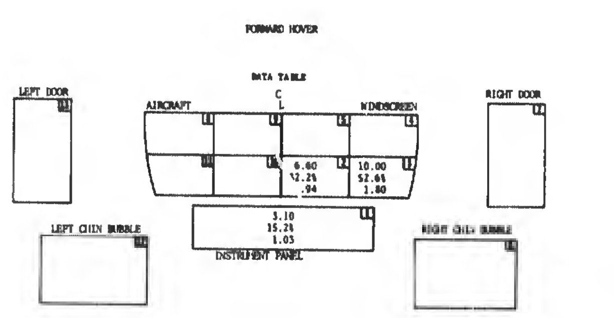
Because of space limitations the results of only four maneuvers will be presented and discussed. These typical helicopter maneuvers are: Forward Hover, 360° Hover Turn Left, 360° Hover Turn Right, and Takeoff with normal traffic and landing. The data for each maneuver are presented individually with one figure and one table per maneuver. The data appearing on the left side of the figures and left side of the tables are data for the binocular group of aviators. The data appearing on the right side of the figures and the tables are for the monocular aviator. The figure represents the thirteen scored visual sectors. The aircraft windscreen was divided into eight visual sectors. The two side door windows and the two chin bubbles added four additional sectors. The inside area of the aircraft was the thirteenth sector. The numbers in the top right corner of each sector are for sector identification. The three values appearing in the sectors represent the following: (1) Total time spent in that sector in seconds, (2) Percent of total maneuver time spent in the sector, (3) Mean visual dwell time for that sector. Dwell time was established by dividing the total time spent in the sector by the number of visual exits recorded for that sector. The data presented in the tables are self-explanatory with the possible exception of the Mean Sector Transitions/Minute measure. This measure was derived by taking the total number of sector transitions made by each subject, dividing it by the time it took him to complete the maneuver, multiplying by 60 and then computing a mean.

Forward Hover. The first maneuver to be compared is the forward hover. The maneuver began from a stationary three foot hover from which the subject pilot was instructed to hover forward for a distance of 60 feet and stop.

As can be seen in Figure 3 the binocular group spent only 2.81% of the total maneuver time inside the cockpit while the monocular aviator spent 15.2% of the total time inside. This was the only maneuver of the eleven recorded maneuvers in which the monocular aviator had a greater percentage of cockpit time than the binocular aviator. It can also be noted that there existed a more even distribution between sectors 1 & 2 for the monocular aviator and his dwell times were typically shorter. Table 1 indicates that the difference between the monocular aviator and the binocular group in time to complete the forward hover was negligible. The mean number of sectors used was found to be essentially the same but the monocular aviator was much more active (higher number of sector transitions) than the binocular group on the average, with almost as many sector transitions as the most active binocular aviator. This is demonstrated by his 16 sector transitions (permutations) which better than doubled the mean of 7.17 transitions for the binocular group. The monocular aviator's high visual activity was again reflected in the mean sector transitions/minute data. In summary, it may be fair to state that within the total visual areas of concern the monocular aviator, in general, used the same sectors of the windscreen as did the binocular aviators. However, he did not use the sectors the same percentage of time as the binocular group nor did he dwell there as long. As mentioned above, the monocular aviator spent more time in the cockpit than the binocular group and when looking inside, he stayed inside longer before going back to the windscreen than did the binocular aviators.




Binocular Means




Monocular Values

Figure 3

Forward Hover

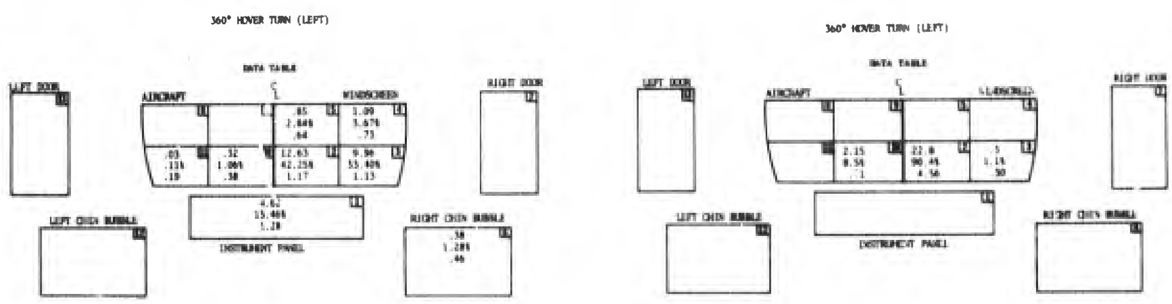
Table 1

Forward Hover

| | Binocular Means | Range | Monocular |
|---|---|---|---|
| Total Time (Secs) | 19.27 | (9.20-29.0) | 20.50 |
| Number of Sectors Used | 2.68 | (2-3) | 3 |
| # of Sector Transitions (Permutations) | 7.17 | (1-17) | 16 |
| Mean Sector/Transitions/Minute | 21.57 | (5.39-50.55) | 46.83 |
| Time Inside Aircraft (Secs) | .54 | (0-1.32) | 3.12 |
| Time Outside Aircraft (Secs) | 18.73 | (9.17-29.60) | 17.38 |

360° Hover Turn Left. This maneuver began from a stabilized three foot hover and terminated upon the completion of a 360° turn about the mid-point of the helicopter.

As can be seen in Figure 4, the binocular group spent 15.46% of their maneuver time inside the cockpit while the monocular aviator never visually entered the inside. The distribution of time spent in the front windscreen is heavily skewed toward sector 2 for the monocular aviator with 90.4% of his time being spent within this one sector. This very large proportion of time combined with minimal transitions produced a high dwell time value for this sector (4.56 seconds). The mean number of permutations (28) for the binocular group was much larger than the nine recorded for the monocular aviator. Again this is reflected in the mean sector transitions/minute where the binocular group yielded a mean of 56.37 while the monocular individual had only 21.39 transitions/minute. Table 2 indicates that the difference in time to complete the 360° turn was minimal. Therefore, though the monocular aviator's time to complete the maneuver was very close to that exhibited by the binocular group, he was much less active visually. In addition, he spent all his time outside the cockpit and spent most of his time in sector two. It would appear that he derived nearly all the cues he required from this area while the binocular aviators relied heavily on sector 3 as well as sector 2.




Binocular Means

Monocular Values

Figure 4

360° Hover Turn Left

Table 2

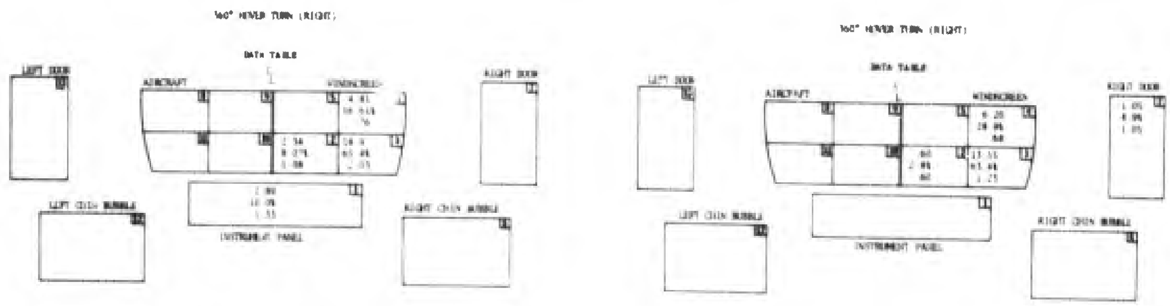
360° Hover Turn Left

| | Binocular Means | Range | Monocular |
|---|---|---|---|
| Total Time (Secs) | 29.88 | (19.06-34.50) | 25.25 |
| Number of Sectors Used | 4 | (3-5) | 3.0 |
| # of Sector Transitions (Permutations) | 28 | (14-48) | 9.0 |
| Mean Sector Transitions/Minute | 56.37 | (24.67-83.48) | 21.39 |
| Time Inside Aircraft (Secs) | 4.62 | (1.19-8.65) | 0 |
| Time Outside Aircraft (Secs) | 25.26 | (10.41-30.3) | 25.25 |

360° Hover Turn Right. This maneuver is essentially the same as the 360° Hover Turn Left with the exception of the direction of turn. It can be seen in Figure 5 that the monocular aviator utilized sector 3 for 63.4 percent of the time. This represents a significant shift from the previous 360° turn where sector 3 was utilized only 1.1 percent of the time. This shift, of course, is understandable when one considers the direction of the turn. It should be noted that the binocular group used sector 3 almost the same percentage of time (65.4%) as the monocular aviator. Also, it is interesting to observe that the monocular aviator utilized about 5% of his time looking out the side window and again he did not visually come into the cockpit during the entire maneuver.

The monocular subject used a total of four visual sectors for this maneuver as compared to the mean of 3.33 for the binocular group. Whereas, there existed a large disparity in the number of sector transitions or permutations, between the groups, for the previous 360° turn, they were nearly equal for this maneuver (20 binocular vs. 22 monocular). However, the range for the binocular group was quite large (2-40), indicating that at least one binocular subject exhibited very little eye movement for this particular maneuver. Again, this activity difference can be seen in the comparison between the number of sector transitions/minute where the binocular group had a mean of 41.83 transitions/minute while the monocular subject had 61.68 transitions/minute. This difference, of course, is influenced by the fact that he completed the maneuver faster than did any of the binocular aviators.

Overall, the monocular pilot appears to be somewhat more active visually than the binocular group during this particular maneuver. The monocular pilot, in general, used the same areas of the windscreen as the binocular group although differences existed in the percentages of time he utilized certain sectors as well as differences in dwell times. Again, the monocular pilot did not visually come inside the cockpit during the maneuver which was not the case for the binocular aviators.



Binocular Means

Monocular Values

Figure 5

360° Hover Turn Right

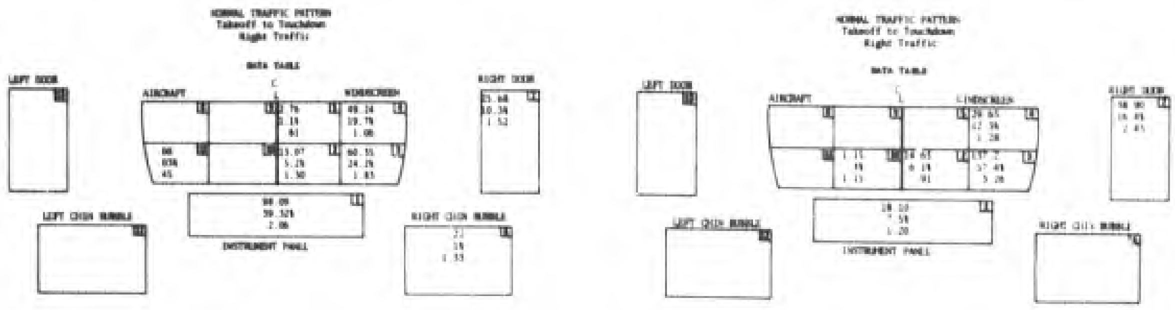
Table 3

360° Hover Turn Right

| | Binocular Means | Range | Monocular |
|---|---|---|---|
| Total Time (Secs) | 28.98 | (26.17-32.23) | 21.40 |
| Number of Sectors Used | 3.33 | (2-4) | 4 |
| # of Sector Transitions (Permutations) | 20 | (2-40) | 22 |
| Mean Sector Transition/Minute | 41.83 | (4.53-91.71) | 61.68 |
| Time Inside Aircraft (Secs) | 2.85 | (.16-5.00) | 0 |
| Time Outside Aircraft (Secs) | 26.13 | (24.79-29.84) | 21.4 |

Normal Takeoff - Right Traffic - Landing. This maneuver started with a normal takeoff from the ground, a right traffic pattern, a normal approach, and ended with a landing to the ground. This maneuver took approximately four minutes for the binocular aviators and the monocular aviator to complete. As can be seen in Figure 6 the binocular group used a total of eight of the thirteen possible sectors as compared to six of the thirteen sectors for the monocular pilot. Sector 2 was utilized the largest percentage of time (57.4% of the total time) for the monocular aviator whereas sector 1, or inside the aircraft was the most visually used sector (39.2%) by the binocular aviators. Table 4 indicates that the monocular aviator used a greater number of sectors than did the binocular group (6 monocular vs. 4.73 binocular). However, the monocular pilot was not nearly as active as the binocular group within the six sectors he utilized. This was indicated by his 110 sector transitions (permutations) as compared to the mean of 158 for the binocular group. The greater activity was again reflected in the 38.08 mean sector transitions/minute for the binocular group as compared to the 27.54 transitions/minute for the monocular subject.

The data from this maneuver indicate that the greatest discrepancy between the monocular and binocular pilots was the percentage of time they spent inside the aircraft. While the binocular group spent 39.32% of their time inside, the monocular pilot spent only 7.59% of his time inside. This difference is of interest because this particular maneuver requires the pilot to perform a pre-takeoff as well as a pre-landing check of his aircraft and engine status gauges. Although the monocular pilot spent only 18.10 seconds inside the aircraft, his dwell time of 1.20 seconds was close to the 2.06 second dwell time exhibited by the binocular group. It seems that the monocular aviator was more selective in his scan of the aircraft and engine instruments during pre-takeoff and landing checks than the binocular aviators.



Binocular Means

Monocular Values

Figure 6

Normal Takeoff and Landing

Table 4

Normal Takeoff and Landing

| | Binocular Means | Range | Monocular |
|---|---|---|---|
| Total Time (Secs) | 249.50 | (198.4-284.7) | 239.65 |
| Number of Sectors Used | 4.73 | (4-5) | 6 |
| # of Sector Transitions (Permutations) | 158.33 | (119-174) | 110 |
| Mean Sector Transitions/Minute | 38.06 | (28.74-55.75) | 27.54 |
| Time Inside Aircraft (Secs) | 98.10 | (50.11-139.06) | 18.10 |
| Time Outside Aircraft (Secs) | 151.41 | (139.45-171.19) | 221.55 |

## SUMMARY

During maneuvers which required turns to the right (360° Hover Turn right and Normal Traffic Pattern-right traffic) the monocular aviator utilized the extreme right sectors of the windscreen and the right side doors (sectors 3,4,7) much more than the binocular aviators. It appears that the monocular aviator has learned to obtain visual information required for proper flight performance during right turn maneuvers; the cues utilized for the successful accomplishment of these maneuvers being obtained from the extreme right side of the cockpit which of course corresponds to the functioning part of his visual system.

For the 360° Hover Turn-Left, the monocular aviator acquired almost all of his visual information from sector 2 of the windscreen. The data indicate that he typically found a visual referent on the ground in the left side of sector 2 and followed the referent through this sector as the helicopter turned and then visually acquired another referent in this sector as the helicopter continued to turn. The binocular aviators on the other hand were much more active visually during this maneuver. They acquired visual information with a rapid scan technique, which entailed a high number of sector transitions and sector transitions/minute.

In conclusion perhaps the most significant results for the maneuvers flown were as follows:

1. Visual areas to the left of the pilot were used infrequently by both the monocular aviator and the binocular group.

2. The upper visual area (sector 5) immediately to the right of the center line was rarely used.

3. The chin bubbles were utilized infrequently by both the monocular aviator and binocular aviators.

4. With the exception of the forward hover the monocular aviator spent less time in the cockpit than did his binocular counterparts. This finding was most pronounced in the Normal Traffic Pattern Maneuver.

5. In general the monocular aviator used the same visual areas as did the binocular aviators with differences arising primarily in the percentage of time they were used and the dwell times.

DISCLAIMER

The findings in this report are not to be construed as an Official Department of the Army position unless so designated by other authorized documents.

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# HELICOPTER FLIGHT PERFORMANCE WITH THE AN/PVS-5, NIGHT VISION GOGGLES

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## SUMMARY

This research entailed rotary wing flight at night in an instrumented UH-1H with aviators utilizing night vision goggles (AN/PVS-5). These devices restrict field of view, provide monochromatic imagery, add weight, and with the exception of bifocals require manual refocus to gain inside visual capability. These second generation image intensification systems were used during low level and nap-of-the-earth (NOE) flight profiles in addition to various maneuver sets. Three intensification systems were compared to the unaided eye over these conditions. These systems included 40° field of view (FOV), 60° FOV and 40° FOV with a 30% bifocal cut. Over twenty aircraft state variables and aviator control inputs were measured and submitted to analysis. In addition to descriptive and univariate techniques, the data were subjected to a multiple discriminant analysis. The subjects (instructor pilots) also responded to questionnaires regarding the preference, training and estimated capabilities of each type of intensification system. This paper summarizes the major findings of both the subjective and objective measures.

## INTRODUCTION

Throughout the ages, man's capability to carry out continuous military operations has been in part limited by his ability to function effectively at night. Current U. S. Army doctrine emphasizes the need to expand aviation operations to a 24 hour capability. Two approaches are being pursued in an attempt to effectively extend aviation operations into the night. One approach concerns the development of techniques to train aviators to fly with the unaided eye while the other approach concerns the utilization of devices which enhance night vision. One such device, the AN/PVS-5 night vision goggles (NVG) amplifies existing ambient light thus intensifying the images presented to the eye.

The AN/PVS-5 goggles were originally developed for ground use but are now considered to be an interim solution to aid the pilot's night vision. Previous research projects utilizing the NVG's in the airborne setting have not directly addressed evaluation of helicopter flight performance with and without the aid of the NVG's.[1,12,13,14] These projects have examined helicopter flight performance with the aid of the NVG's only as an adjunct to other tactical field tests. Therefore, statements concerning the effectiveness of the NVG's in relation to flight performance have been limited, typically, to subjective impressions which often reflect a bias from other experimental treatments involved in the field tests. The findings of these projects have provided, in several cases, contradictory comments about the capabilities produced by the NVG's. Much of the conflict concerning the utility of the NVG's stems from the fact that the effectiveness of the goggles varies greatly according to the: (1) existing ambient light levels, (2) flight maneuvers performed, (3) altitudes (AGL) at which flights are made, (4) aircraft flown, (5) amount of training the pilots have received with the NVG's, and (6) whether or not bright external lights are present, such as flares, which cause temporary problems with the NVG's and degrade the dark adaptation of the unaided eye.

Combat Development Command (CDEC) project 43.7, Phase I found that "the NVG, tested in all tactical modes, appeared to assist the crew in flying with greater safety at low altitudes at a slightly greater airspeed."[12] The objective of the project was not to directly examine helicopter flight performance, but to "establish the state-of-the-art of helicopter anti-tank operations under clear night conditions, to develop aviator training requirements for this type experiment, and to identify problem areas for night operations."[12] The report also pointed out that "NOE flight under a no moonlight condition may be defined as 125 feet above tree level. Night NOE at higher light levels can be flown at near daylight standards (fifty feet above tree or obstacle level)."[12] However, these altitudes would have to be reduced in flat terrain areas to prevent optical and electronic detection. Although a number of problems were noted in connection with the use of the NVG, "their use was most desired during the lowest light level periods."[12] A very definite advantage of the NVG's noted in the CDEC report was their automatic light level regulation capability. Thus, flares and illumination rounds only momentarily disrupt vision with the NVG while sometimes causing a significant degradation of dark adaptation in the unaided eye.

Modern Army Selected Systems Test Evaluation and Review (MASSTER) Test Number 1040 also evaluated the NVG's in an airborne setting.[1,14] This test examined the AN/PVS-5 night vision goggles along with other flight related items of equipment in tactical situations. Again aviator flight performance was not directly examined, but inferences were made about the performance enhancement the NVG's provided. "When flares and other bright light sources such as rocket motor-burn, vehicle headlights, etc., were encountered, the AN/PVS-5 goggles were superior to unaided eyes." "When using the goggles, the crew experienced no loss of night vision and was able to see clearly as soon as the light source was out of the field-of-view. This allowed the pilots who were using the goggles to fly much lower, faster, and safer than the crews who were not using them."[1]

The Military Airlift Command operationally examined the AN/PVS-5 40° field of view NVG and the older SU-50C 60° field of view NVG in order to evaluate their relative potential for Local Base Rescue (LBR) use.[13] The results of the operational test and evaluation indicated "that the AN/PVS-5 NVG's were superior to the 60° field of view goggles and demonstrated excellent potential for the LBR mission."[13]

Several laboratory assessements of the NVG have been made in relation to some of the problems identified concerning their use.[2,3,4,5,6,8,11] Investigators at the U. S. Army Aeromedical Research Laboratory found that:

(1) The afterimages "Brown-Eye Syndrome" sometimes seen following use of AN/PVS-5 NVG's "are a normal physiological phenomenon and need not be of concern."[3]

(2) "Although dark adaptation is not fully degraded by the AN/PVS-5 NVG, there is some reduction and should it be necessary to remove the goggle, it will require about two minutes to reach the fully dark adapted state."[5]

(3) Also noted was that the effect of a light source upon dark adaptation is a function of both the intensity and wavelength of the source. The suggestion was made that future NVG systems employ yellow-orange phosphors instead of the green phosphors used, in order to maximally protect dark adaptation.[5]

(4) "The use of a black background map is a suitable solution to the problem of losing information when the NVG is used."[4] The black background map produced "equally good results when viewed under red illumination with the unaided eye."[4]

(5) Changes should be considered for improvement of the crashworthiness and comfort of the NVG, such as moving "the vertical support straps forward to the c.g. of the goggles," "decreasing the weight of the goggles as much as possible" (perhaps with a plastic lens and magnesium housing), and "strengthening the attachment of the lens to the face mask to improve the pressure distribution for crash loads."[6] Additionally, a suggestion was made "to study, design, and develop an integrated helmet-goggle system."[6]

In order to objectively evaluate the NVG's in the airborne environment, the U. S. Army Aeromedical Research Laboratory was asked to measure aviator performance using several variations of these devices in helicopter flight close to the earth at night. Current aviation tactics emphasize helicopter flight at very low altitudes (terrain flying) to avoid the threat of sophisticated air defense weapons. Terrain flying is composed of Nap-of-the-Earth (NOE), Contour, and Low Level flight levels. These flight levels have been defined as: "NOE - Flight as close to the earth's surface as vegetation or obstacles will permit, while generally following the contours of the earth. Airspeed and altitude are varied as influenced by the terrain, weather and enemy situation. The pilot preplans a broad corridor of operation based on known terrain features which has a longitudinal axis pointing toward his objective. In flight, the pilot uses a weaving and devious route within his preplanned corridor while remaining oriented along his general axis of movement in order to take maximum advantage of the cover and concealment afforded by terrain, vegetation and manmade features. By gaining maximum cover and concealment from enemy detection, observation and fire power, nap-of-the-earth flight exploits surprise and allows for evasive actions. CONTOUR: Flight of low altitude conforming generally, and in close proximity to the contours of the earth. This type of flight takes advantage of available cover and concealment in order to avoid observation or detection of the aircraft and/or its points of departure and landing. It is characterized by a constant airspeed and a varying altitude as vegetation and obstacles dictate. LOW LEVEL: Flight conducted at a selected altitude at which detection or observation of an aircraft is avoided or minimized. The route is preselected and conforms generally to a straight line and a constant airspeed and indicated altitude. This method is best adapted to flights conducted over distances or periods of time."

The purpose of the present investigation was to evaluate the flight performance of aviators during NOE flight (without navigation), Low Level flight and four standard maneuvers while using three configurations of the NVGs and the dark adapted unaided eye.

## METHOD

Subjects: Subjects for this investigation were six rotary wing Army aviators assigned to the Advanced Tactics Division, Department of Flight Training, US Army Aviation School at Ft. Rucker. These pilots had extensive experience in rotary wing flight, having flown an average of 1960 hours in rotary wing aircraft. All were experienced in Nap-of-the-Earth flight and had completed the Army training on this type of flight profile. None of these aviators possessed previous experience with the night vision goggles.

Apparatus: The 40° and 60° field of view (FOV) and 40° FOV bifocals (40°B) night vision goggles were made available by the Night Vision Laboratory. The NVGs are self-contained, battery powered, second generation, passive, binocular devices. The upper 70% of the lense on the 40°B goggles was focused at infinity while the lower 30% was focused at approximately 26 inches. The 40° and 60° FOV goggles were also focused at infinity. The NVGs weigh approximately 1.9 pounds and were mounted on the SPH-4 helmet with snaps and velcro attachments. The test vehicle was a JUH-1H helicopter instrumented to measure and record pilot control inputs and aircraft position, rates and accelerations. This Helicopter Inflight Monitoring System (HIMS) measures aircraft position in six degrees of freedom while simultaneously recording cyclic, collective and pedal inputs and aircraft status values. These data were recorded in real time on an incremental digital recorder. Continuous information from twenty pilot and aircraft monitoring points was recorded for all flights. A list of these parameters is provided in Table 1. This table also lists the derived measures which can be obtained from the recorded parameters.

Table 1

Parameters Measured and Derived Measures

| Parameters Measured | Derived Measured |
|---|---|
| Pitch | Pitch Rate |
| Roll | Roll Rate |
| Heading | Rate of Turn |
| Position x | Constant Error, Average Absolute Error, RMS Error |
| Position y | Ground Speed, Constant Error, Average Absolute Error RMS Error |
| Acceleration x | |
| Acceleration y | |
| Acceleration z | |
| Roll Rate | Roll Acceleration |
| Pitch Rate | Pitch Acceleration |
| Yaw Rate | Yaw Acceleration |
| Radar Altitude | Rate of Climb, Average Absolute Error, Constant Error, RMS Error |
| Barometric Altitude | Rate of Climb |
| Airspeed | |
| Flight Time | |
| Rotor RPM | |
| Throttle | |
| Cyclic Stick (Fore-Aft) | Control Position, Absolute Control Movement Magnitude, Positive Control Movement Magnitude, Negative Control Movement Magnitude, Absolute Average Control Movement Rate, Average Positive Control Movement Rate, Average Negative Control Movement Rate, Control Reversals, Instantaneous Control Reversals, Control Steady State, Control Movement |
| Cyclic Stick (Left-Right) | |
| Collective | |
| Pedals | |

Pilot inputs to controls were treated in the following manner. In considering these measures, it is necessary to define three key terms. First, in obtaining measures on these controls, it was decided that a steady state occurs when a control has not exceeded an empirically defined distance in a specified time. Second, a control reversal occurs any time a control changes direction. Finally, a control movement was defined as any movement starting from a steady state or control reversal and ending with a steady state or control reversal. Using these established criteria, means were computed from all sampled values for magnitude, duration and rate of control movements and mean time for steady states. The totals for number of steady states and control movements were also recorded. Table 2 presents the times and distances which were utilized as criteria delineating movements in these controls.

The distance ranges were established by determining the minimum perceived control movement for the directions of concern which were thought to yield airframe movement independent of time. The times were established by taking one-half the minimum time it took to move the various controls through the distance ranges previously established.

Table 2

Baseline Times and Movement Limits for Controls

| | CYCFA | CYCLR | COLL | THROTTLE | PEDAL |
|---|---|---|---|---|---|
| Time durations in seconds | .25 | .15 | .45 | .50 | .50 |
| Movement limits in inches | .37 | .32 | .35 | .50 | .35 |

A more detailed description of HIMS can be found in USAARL Report No. 72-11.[7] A questionnaire was also constructed to determine the aviators' opinions about the night vision goggles in relation to: (1) flight maneuvers, (2) psychophysiological effects, (3) equipment consideration, and (4) academic/flight training.

## PROCEDURE

Familiarization and Training Phase. Since these aviators had no previous experience with the NVG, all were trained in their use according to the following schedule. Three subjects were provided with NVG simulators and given thirty minutes flight training. During this training they were instructed in how to attach the device to their helmet, shown the various features of the device and allowed to fly different maneuvers while wearing the simulators. An attempt was made to program this period of training so that all subjects would be exposed to similar flight maneuvers as well as allowing them to gain familiarity with the goggles particular to their own needs. In order to accomplish this objective, a standard set of practice maneuvers was performed at least twice by all aviators during the allotted time period. This set of maneuvers is listed in Table 3.

Table 3

Standard Flight Maneuvers

1. Pick up to 3 foot hover
2. Perform a 360° left pedal turn
3. At 3 feet AGL, hover forward (approximately 60 feet) to a predetermined point and set the aircraft down
4. Pick the aircraft up to a 25 foot AGL hover and maintain this hover for 60 seconds
5. Descend to touchdown
6. Pick up to a 5 foot hover
7. Hover rearward to the starting point
8. Set the aircraft down

Three subjects received no simulator training, but were brought into the laboratory, given an introduction to the NVG and allowed to familiarize themselves with them in a darkened room for thirty minutes. These individuals were taught how to attach the goggles to their helmets and to adjust and focus them. They were then allowed to walk around and view different objects in the room.

All subjects received night flight training with the goggles. Order effect was controlled across subjects according to the schedule presented in Table 4. All pilots received 65 minutes of night training and testing. The same programmed set of maneuvers referenced in Table 3 was accomplished with the unaided eye and each type of goggle for all subjects during the night training period.

Table 4

Standard Maneuver
Training and Testing Schedule

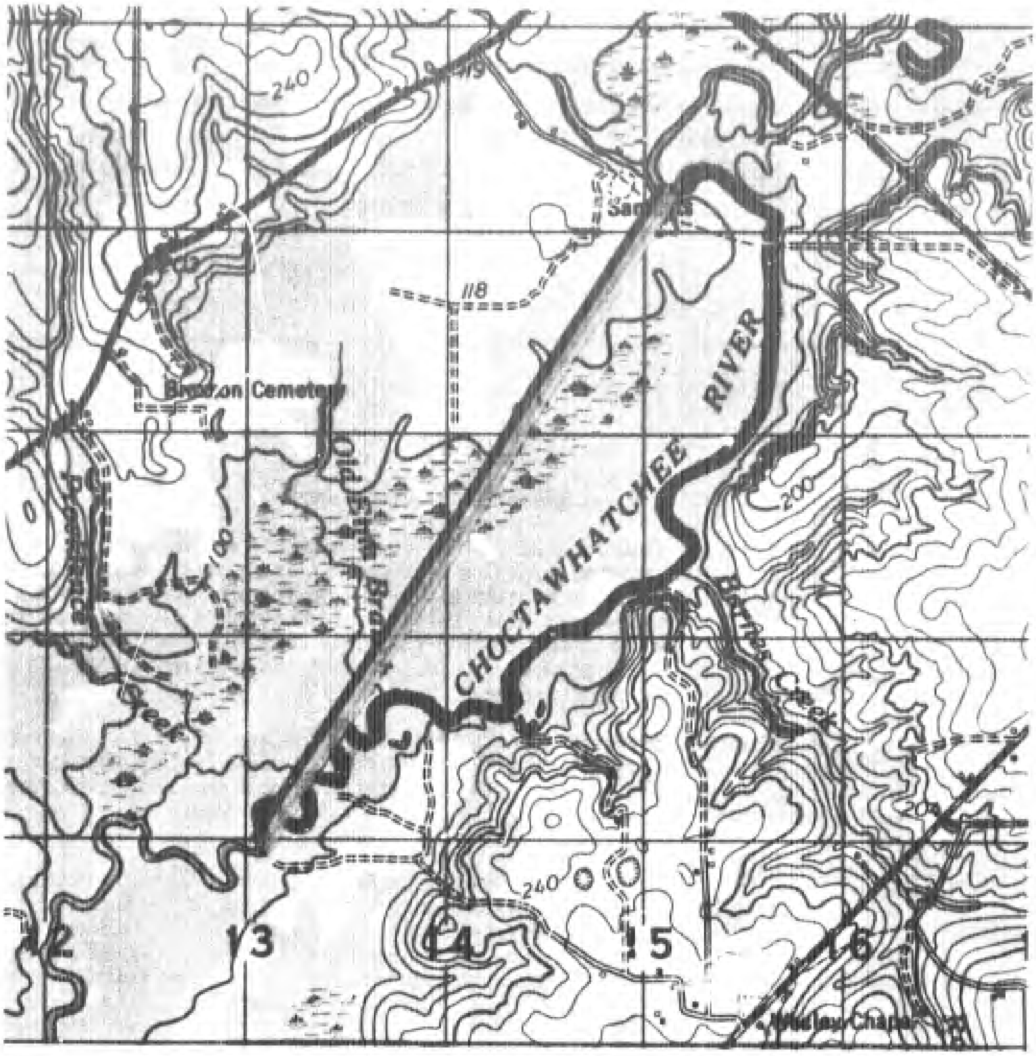
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $S_1$ | Eye-X | 40°-X | 40°-* | 40°-X | 60°-X | 60°-* | 60°-X | 40°B-X | 40°B-* | 40°B-X |
| $S_2$ | Eye-X | 40°B-X | 40°B-* | 40°B-X | 40°-X | 40°-* | 40°-X | 60°-X | 60°-* | 60°-X |
| $S_3$ | Eye-X | 60°-X | 60°-* | 60°-X | 40°B-X | 40°B-* | 40°B-X | 40°-X | 40°-* | 40°-X |
| $S_4$ | Eye-X | 40°-X | 40°-* | 40°-X | 60°-X | 60°-* | 60°-X | 40°B-X | 40°B-* | 40°B-X |
| $S_5$ | Eye-X | 40°B-X | 40°B-* | 40°B-X | 40°-X | 40°-* | 40°-X | 60°-X | 60°-* | 60°-X |
| $S_6$ | Eye-X | 60°-X | 60°-* | 60°-X | 40°B-X | 40°B-* | 40°B-X | 40°-X | 40°-* | 40°-X |

X - Denotes Standard Maneuvers Test (5 minutes)
* - Denotes Practice (10 minutes)

Due to inclement weather and low ambient light levels, the LL-NOE phase of the study had to be postponed for several weeks. Because a considerable period of time elapsed between the time of initial training and the LL-NOE part of the project, the pilots were given refresher training. Each aviator received a twenty minute flight with the goggles during which he was allowed to perform maneuvers which he felt would increase his proficiency.

Low Level - NOE Phase. The LL-NOE phase of this study consisted of both day and night runs. A day orientation flight was first flown by the Safety IP, followed by a familiarization flight by the subject aviator at approximately 200 ft AGL, and then a final LL-NOE flight over the same course at an altitude and airspeed selected by the subject aviators. The aviators were told to choose an altitude and airspeed, for the final day and all night LL-NOE runs, commensurate with safety, but also maintaining maximum masking during the runs. The NOE and Low Level courses are presented in Figure 1. During testing, each pilot mounted and focused the goggles and flew the Low Level course and then entered the riverbed and returned on the NOE section of the mission. The Low Level course terrain was primarily densely wooded areas (trees approximately 60 feet tall) with occasional open fields. The NOE course was a segment of the Choctawhatchee River which was typically wide enough for the helicopter rotor blades to be below the tops of the trees that lined the river. The trees along the NOE course ranged in height from 75 to 95 feet above the river.

All subjects were required to fly the course five times at night according to the schedule referenced in Table 5. One run was made with the unaided eye for familiarization with the course under night conditions followed by four runs, one each with each type of goggle and one dark adapted unaided eye.




**NOE COURSE** ▬▬ **SCALE 1:50,000**

**LOW LEVEL COURSE** ―― **CONTOUR INTERVAL 20 FEET**

**NOE AND LOW LEVEL COURSES USED FOR EVALUATION OF THE NVG**

**FIGURE 1**

Table 5

Night
LL-NOE Flight Schedule

| | | | | | |
|---|---|---|---|---|---|
| $Subject_1$ | Eye | 40° | 60° | 40°B | Eye |
| $Subject_2$ | Eye | 40°B | 40° | 60° | Eye |
| $Subject_3$ | Eye | 60° | 40°B | 40° | Eye |
| $Subject_4$ | Eye | 40° | 60° | 40°B | Eye |
| $Subject_5$ | Eye | 40°B | 40° | 60° | Eye |
| $Subject_6$ | Eye | 60° | 40°B | 40° | Eye |

Illuminance measurements were taken during the time periods of these flights utilizing a Spectra-Pritchard Photometer with Cosine integrator. The time periods for each flight and their respective illuminance levels are presented in Table 6. Also noted are equivalent percentages of moon illumination for the relative illuminance levels presented.

Table 6

Light Levels Measured and Derived

| No. of Ss | Date | Time | Percentage of Moon Illuminated | Mean Illuminance Measured | Moon Equivalent Computed* |
|---|---|---|---|---|---|
| 2 | 31 May | 2100-2430 | .76 | $7.20 \times 10^{-3}$ ft-c | ≈ 3/8 |
| 2 | 1 June | 2100-2445 | .84 | $5.92 \times 10^{-3}$ ft-c | ≈ 2/8 |
| 2 | 2 June | 2110-0130 | .91 | $13.9 \times 10^{-3}$ ft-c | ≈ 5/8 |

*Full Moon = $2 \times 10^{-2}$ ft-c[9,10]
1/2 moon = $1 \times 10^{-2}$ ft-c
1/4 moon = $5 \times 10^{-3}$ ft-c
No moon = $2 - 10^{-4}$ ft-c

Training was conducted in 3/4 to full moon equivalent illuminance levels.

Analysis. Separate analyses were computed for each of the flight segments and maneuvers. Univariate F values were obtained for each of the performance variables examined. A stepwise discriminate analysis program was utilized for initial evaluation of the relationship of the performance measures to visual set group separation. The five or six* most discriminating variables identified in the original stepwise discriminant analysis (based on a set of linear classification functions computed by choosing the predictors in a stepwise manner) were reexamined with the stepwise discriminate analysis program without the lesser discriminating variables thus ensuring df and multivariate F ratio stability.

The output of the stepwise discriminate analysis program included a multivariate F value and a Wilk's Lambda (U-Statistic) associated with the entering of each variable into the classification function. After the last step of the program, a classification matrix was also obtained indicating the proportion of aviators statistically classified into the correct visual condition by the performance scores.

The performance measures found in the stepwise discriminate analyses to be the most discriminating among the four visual sets in each of the six flight segments were then examined in Veldman's (1967) multiple discriminant analysis program.** The program computed univariate F ratios and discriminant weights for the variables, Wilks Lambda to determine the discrimination of the variables or the overall difference among the four group centroids, a chi-square approximation for the discriminant functions or roots to determine the significance of each, and total discriminatory power or estimated omega squared which gives an estimate of the percentage of the total variability in discriminant space that is relevant to group differentiation.

For interpretation purposes, the results and discussion have been divided into univariate data, multivariate data and questionnaire sections. A variable's contribution to the discrimination of a root is determined by the size of the adjusted weights relative to the other variables weights instead of by the univariate F ratio. The univariate F ratio indicates the discrimination a variable has among the groups when examined individually and does not necessarily demonstrate the variable's importance when combined with the other variables in a discriminant root. Primary contributors to a root were considered to be those weights whose absolute values were no less than approximately one half of the largest weight.

Due to space limitations, only the multivariate data for the NOE, 25 foot Hover, and Hover Rearward flight segments will be presented here. The remaining results will be published in a USAARL Report.

## RESULTS AND DISCUSSION

NOE Flight. Table 7 indicates the five most discriminating performance measures in the order they were selected by the stepwise discriminant analysis along with their associated multivariate F values and U-Statistic values. Table 8 indicates the resultant classification of aviators by the five performance variables into their respective groups. With the prior probability of group membership being equal, the performance scores for the NOE flight correctly classified 95% of the aviators into the appropriate visual set.

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*Six performance variables were utilized for examination in relation to the four visual sets during the four standard maneuvers. Data was lost due to a magnetic tape recorder malfunction during one aviator's NOE and low level flight thereby reducing the sample for these two flight segments to five and consequently the number of performance variables utilized to five.

**Since the flight performance for each aviator was examined under all four visual sets or experimental treatments, a technique developed by Schori and Tindall (1972) was implemented in order to insure that the data obtained from this repeated measures design were compatible with assumptions associated with the conventional multiple discriminate analysis programs employed.[15]

Summary data for the multiple discriminate analysis are shown in Table 9. Four of the six performance measures with significant univariate F ratio values were selected by the stepwise discriminant analysis and appear in Table 9. Of these four, only airspeed was a primary contributor to root 1 (which accounted for 74.1% of the variance, $X^2 = 32.3$, df = 7, $p < .0001$).

Examination of Figure 2 indicates that the performance scores produced the greatest separation in root 1 between the unaided eye condition and the three goggle conditions. The total discriminatory power (Table 9) provided by the performance scores was found to be 0.96 or 96% of the variability was relevant to group differentiation. Stated differently, this 96% can be thought of as the total discriminatory power of the predictor battery as a whole.

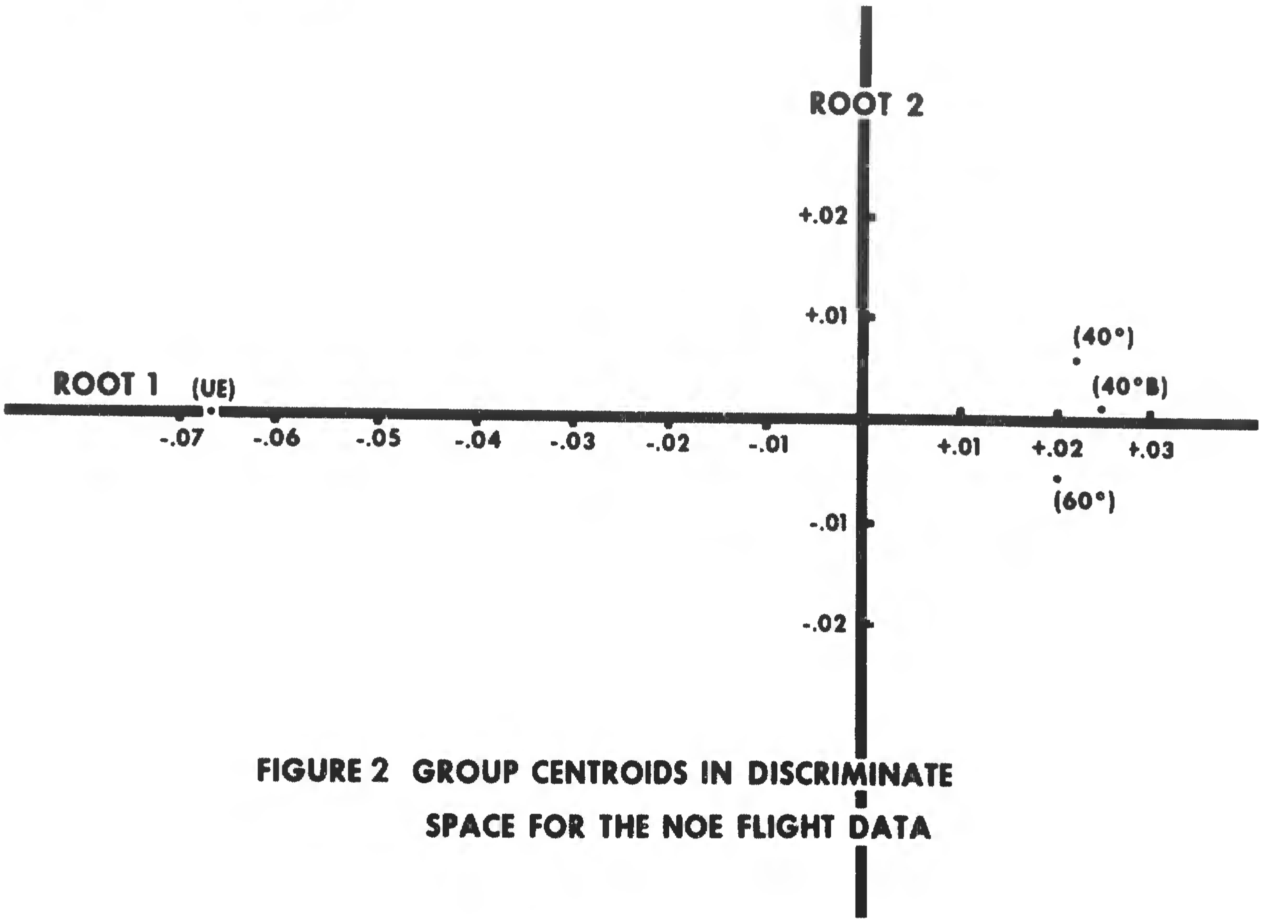


FIGURE 2 GROUP CENTROIDS IN DISCRIMINATE SPACE FOR THE NOE FLIGHT DATA

Inspection of the weights of the performance variables in root 1 (Table 9) indicates that root 1 was primarily defined by the variables Mean Airspeed (in a negative direction) and Cyclic Fore-Aft Absolute Control Movement Magnitude (positive direction). The biggest discriminator in root 1 (Table 9) was mean airspeed and the negative sign associated with this weight indicates that slower airspeeds were associated with the three goggle conditions. Greater magnitude of cyclic fore-aft movements were also associated with the three goggles flight performance.

The altitude at which the NOE course was flown by the aviators under each visual set was a critical factor. The mean radar altitude for the unaided eye group was approximately 62 feet, while the 40°, 40°B and 60° goggle conditions exhibited mean radar altitudes of 51 feet, 52 feet and 54 feet, respectively. Although these altitudes were not statistically different ($p > .05$) the similarity in goggle altitudes exhibited and the 8-11 foot higher mean altitude flown during the unaided eye condition was considered notable. Because the unaided eye group flew slightly higher through the river NOE course, fewer terrain obstacles were encountered, thus requiring fewer cyclic left-right control movements and smaller magnitude cyclic fore-aft control movements. Therefore a slightly higher altitude produced fewer terrain avoidance control movements resulting in a faster mean airspeed for the unaided eye condition relative to the three goggle conditions.

It should be noted again that the height of the trees along the river NOE course ranged from 75-95 feet. The flight data indicate that all four visual sets were effectively masked throughout most of the NOE flight. However, if tactical considerations demanded low altitude NOE flight, the goggles seemed to have provided a slightly lower flight capability. The tradeoff for this lower altitude was: (1) a greater workload due to obstacle avoidance and (2) slower mean airspeeds.

Root 2 in the NOE flight analysis (Table 9) also accounted for a significant percentage of the variance - 24.0%, $X^2 = 18.4$, df = 5, $p < .003$. One can see in Figure 2 (NOE centroids) that root 2 produced the greatest separation between the 40° and 60° goggle conditions. Root 2 is primarily defined by the variables Cyclic Fore-Aft Absolute Control Movement Magnitude (negative direction) and Cyclic Left-Right Control Movement Mean Time (positive direction). The 40° goggle condition reflected

Table 7

Stepwise Discriminate Analysis - NOE Flight Summary Data

| Variable Entered | F Value | df | P | U Statistic |
|---|---|---|---|---|
| Cyclic Left-Right Control Movement Number | 9.72 | 3/16 | < .01 | 0.35 |
| Cyclic Left-Right Absolute Control Movement Magnitude | 1.66 | 3/15 | > .05 | 0.26 |
| Mean Airspeed | 1.72 | 3/14 | > .05 | 0.19 |
| Cyclic Fore-Aft Absolute Control Movement Magnitude | 5.55 | 3/13 | < .05 | 0.08 |
| Cyclic Left-Right Control Movement Mean Time | 6.54 | 3/12 | < .01 | 0.03 |

Table 8

Number of Cases Classified into the Four Visual Sets Using the NOE Flight Data

| | Visual Sets | | | |
|---|---|---|---|---|
| Groups | 40° | 60° | 40°b | Unaided Eye |
| 40° | 5 | 0 | 0 | 0 |
| 60° | 0 | 4 | 1 | 0 |
| 40°b | 0 | 0 | 5 | 0 |
| Unaided Eye | 0 | 0 | 0 | 5 |

Table 9

Multiple Discriminate Analysis - NOE Flight Summary Data

| Variable | 40° Mean | 60° Mean | 40°b Mean | Unaided Eye Mean | F[a] | Adjusted D Weights Root I | Root II |
|---|---|---|---|---|---|---|---|
| Mean Airspeed[1] | 26.55 | 27.48 | 27.20 | 29.83 | 4.33* | -0.106[b] | 0.005 |
| Cyclic Fore-Aft Absolute Control Movement Magnitude[2] | .62 | .66 | .65 | .64 | 1.28 | 0.080[b] | -0.025[b] |
| Cyclic Left-Right Absolute Control Movement Magnitude[2] | .63 | .63 | .64 | .59 | 5.34** | 0.013 | -0.003 |
| Cyclic Left-Right Control Movement Number[3] | 391.8 | 350.4 | 348.4 | 173.8 | 9.72** | 0.031 | -0.010 |
| Cyclic Left-Right Control Movement Mean Time[4] | .16 | .15 | .16 | .15 | 5.88** | 0.020 | 0.023[b] |

Root I - 74.1% of Variance, $X^2 = 32.3$, df = 7, $p < .0001$
Root II - 24.0% of Variance, $X^2 = 18.4$, df = 5, $p < .003$
Total Discriminatory Power (Estimated Omega Squared) = 0.96

[a]Univariate F, df = 3/16
[b]Primary contributor
*p < .05
**p < .01

Units of Measurement
1. Knots
2. Inches
3. Total Number
4. Seconds

shorter fore-aft cyclic movements and longer duration cyclic left-right movements relative to the 60° goggle condition. These two variables indicate that the 40° goggles produced smoother, more gradual control movements than the 60° goggles, which reflects the resolution differences between the two sets of goggles.

Perhaps the most important point to be made about the results of the NOE multivariate analyses is that the flight performance exhibited by the pilots under the unaided eye condition was distinctly different from that occurring under the goggle condition. That is, the three goggles flight performances were, in toto, similar to each other and distinctly separated from the unaided eye groups performance (Figure 2). The classification matrix (Table 8) also supports this in that there was no statistical misclassification between the unaided eye group and the three goggle conditions.

Twenty-five Foot Hover Flight Maneuver. Table 10 lists the six most discriminating performance measures in the 25 Foot Hover flight analysis in the order they were selected by the stepwise discriminant analysis along with their associated multivariate F values and U-Statistic values. Table 11 indicates the resultant classification of aviators into their respective groups by the six performance measures. With the prior probability of group membership being equal, the performance scores correctly classified 92% of the aviators into the appropriate visual condition.

Summary data for the multiple discriminant analysis of the 25 Foot Hover data are shown in Table 12. Three of the four performance measures with significant univariate F ratios ($p < .05$) were utilized, in this case, in the multiple discriminant analysis (Table 12). All three of these variables, Mean Pitch Angle, Cyclic Left-Right Control Movement Number and X Axis Average Absolute Error, were also primary contributors to the first discriminant root.

Table 12 also indicates that root 1 accounted for a significant percentage of the variance - 67.1%, $X^2 = 29.7$, df = 8, $p < .0005$. Examination of the group centroids in Figure 3 indicates that the performance scores produced the greatest amount of separation on root 1 between the 40°B and 60° goggles conditions. On root 2 the greatest amount of separation occurred between the 40°B and unaided eye conditions. The total discriminatory power (Table 12) provided by the performance scores was found to be 0.92 or 92% of the variability was relevant to group differentiation.

The weights of the performance measures in Table 12 indicate that root 1 was primarily defined by Cyclic Fore-Aft Control Movement Number (positive direction) and to a lesser extent by X Axis Average Absolute Error (negative direction), Mean Pitch Angle (negative direction), Pedal Control Steady State Mean Time (positive direction) and Cyclic Left-Right Control Movement Number (negative direction). Therefore, groups with higher centroid values on root 1 (i.e., 60° and 40° goggle groups) have, in general, more control movements with the cyclic in the fore-aft direction, smaller average absolute error in X, smaller mean pitch angle (a more nose-down attitude relative to the other two groups), a greater amount of time in pedal control steady state and fewer control movements with the cyclic in the left-right direction.

Individually, the Average Absolute Error on the X Axis (horizontal displacement) prevails as the dominant performance measure of the 25 Foot Hover maneuver. This variable was not only significant univariately but also was a primary contributor to the first discriminant root. The means for this variable indicate that the 40°B and 40° goggles were better able to maintain their position over the starting point relative to the unaided eye and the 60° goggle condition. Also, all three goggle conditions exhibited superior drift control compared to the unaided eye. The ordering of means along this error variable follows what seems to be a visual resolution continuum with the 40°B and 40° goggles having the highest resolution and the least error, followed by the 60° goggles and the unaided eye which have degraded resolution and correspondingly higher error values. When combined with other performance measures on the 25 Foot Hover data, this resolution/horizontal drift continuum was lost. The 40°B goggle and 40° goggle centroids which had the least horizontal error, were separated in discriminate space through the influence of, primarily, the Cyclic left-right Control Movement Number parameter. On most of the other flight parameters, the 40°B goggle and 40° goggle conditions exhibited similar mean values, however the 40°B goggle condition exhibited more Cyclic left-right control movements than the other conditions. This higher number of cyclic left-right movements seems to be a function of the highly reduced outside field of view associated with the 40°B. The field of view available for outside use was limited to the upper 70% of the lenses on the 40°B. Thus the aviators were forced to scan left and right more to obtain the visual information needed to maintain the high hover, which seems to have also produced the higher number of cyclic left-right movements. However, this scan pattern and/or cyclic left-right activity appears to have resulted in a very low error in the horizontal direction for the 40°B group. The variable X Axis Average Absolute Error was not highly correlated with the other variables utilized, so horizontal drift could not be predicted from the other performance measures of concern in the 25 Foot Hover analysis. Root 2 of the 25 Foot Hover also accounted for a significant percentage of the variance - 23.5%, $X^2 = 16.0$, df = 6, $p < .014$. The two primary contributors on this root indicated that the two groups with high centroid values (40°B and 60°) had more cyclic left-right control movements and longer times between collective control movements relative to the unaided eye and 40° goggle conditions.

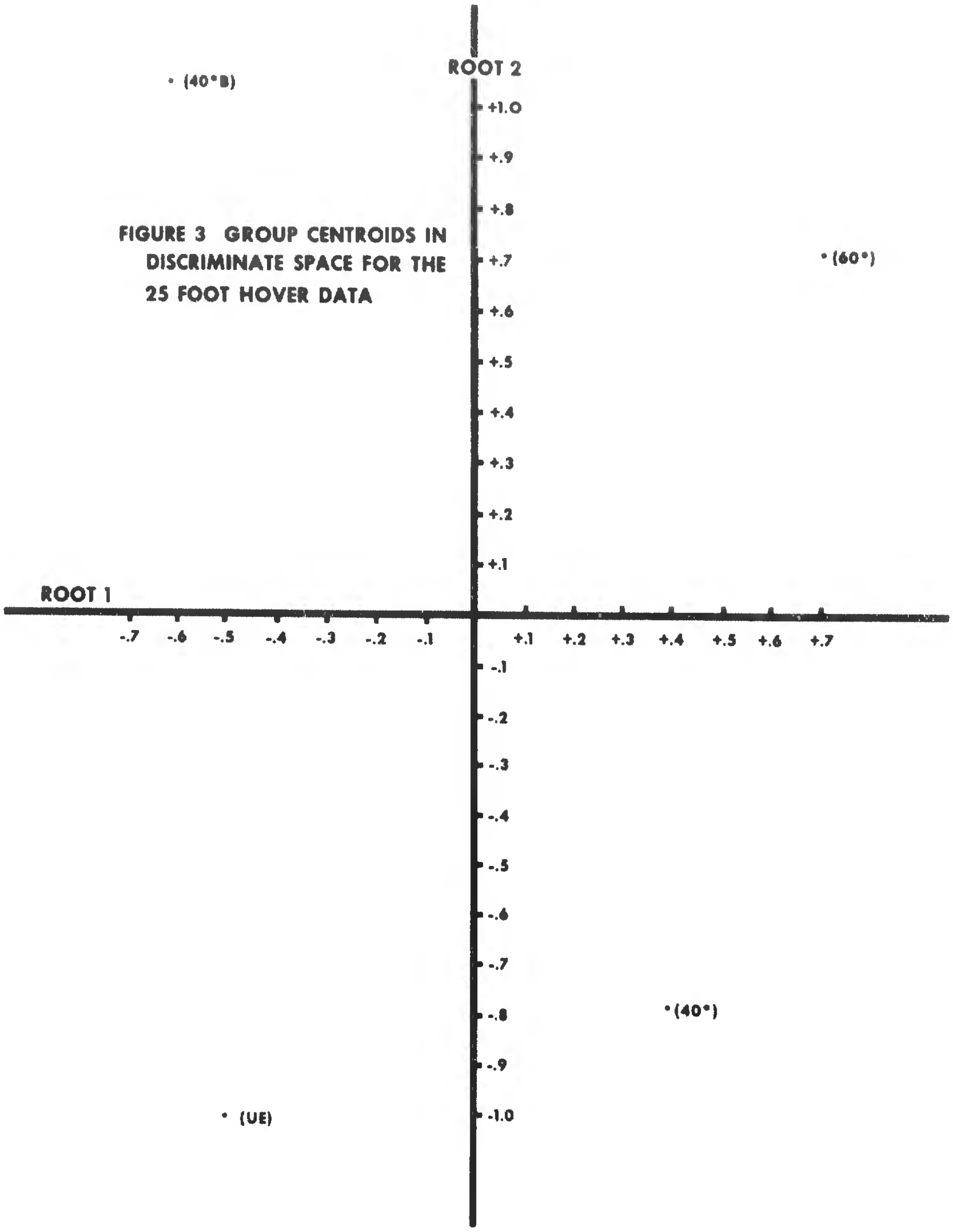


FIGURE 3 GROUP CENTROIDS IN DISCRIMINATE SPACE FOR THE 25 FOOT HOVER DATA

Table 10

Stepwise Discriminate Analysis - 25 Foot Hover Summary Data

| Variable Entered | F Value | df | P | U Statistic |
|---|---|---|---|---|
| Cyclic Left - Right Control Movement Number | 4.97 | 3/20 | < .01 | 0.57 |
| X Axis Average Absolute Error | 3.18 | 3/19 | < .05 | 0.38 |
| Mean Pitch Angle | 3.61 | 3/18 | < .05 | 0.23 |
| Cyclic Fore - Aft Control Movement Number | 2.96 | 3/17 | > .05 | 0.15 |
| Pedal Control Steady State Mean Time | 4.31 | 3/16 | < .05 | 0.09 |
| Collective Control Steady State Mean Time | 2.32 | 3/15 | > .05 | 0.06 |

Table 11

Number of Cases Classified into the Four Visual Sets Using the 25 Foot Hover Data

| | Visual Set | | | |
|---|---|---|---|---|
| Group | 40° | 60° | 40°b | Unaided Eye |
| 40° | 6 | 0 | 0 | 0 |
| 60° | 0 | 6 | 0 | 0 |
| 40°b | 0 | 0 | 5 | 1 |
| Unaided Eye | 0 | 1 | 0 | 5 |

Table 12

Multiple Discriminate Analysis - 25 Foot Hover Summary Data

| Variable | 40° Mean | 60° Mean | 40°b Mean | Unaided Eye Mean | F[a] | Adjusted D Weights Root I | Adjusted D Weights Root II |
|---|---|---|---|---|---|---|---|
| Mean Pitch Angle[1] | 4.49 | 4.26 | 4.47 | 4.94 | 3.67* | -1.65[b] | -1.64 |
| Cyclic Fore-Aft Control Movement Number[2] | 33.3 | 33.3 | 32.8 | 26.0 | 0.98 | 2.13[b] | 0.24 |
| Cyclic Left-Right Control Movement Number[2] | 8.8 | 12.7 | 21.0 | 6.5 | 4.97** | -1.13[b] | 4.04[b] |
| Collective Control Steady State Mean Time[3] | 42.0 | 57.0 | 44.2 | 48.8 | 1.42 | -0.79 | 2.41[b] |
| Pedal Control Steady State Mean Time[3] | 26.6 | 20.3 | 15.8 | 12.5 | 1.39 | 1.53[b] | -0.35 |
| X Axis Average Absolute Error[4] | 9.94 | 11.44 | 7.53 | 15.67 | 4.93** | -1.69[b] | -0.02 |

Root I - 67.1% of variance, $X^2 = 29.7$, df = 8, $p < .0005$
Root II - 23.5% of variance, $X^2 = 16.0$, df = 6, $p < .014$
Total Discriminatory Power (Estimated Omega Squared) = 0.92

[a]Univariate F, df = 3/20
[b]Primary contributor
*p < .05
**p < .01

Units of Measurement
1. Degrees
2. Total Number
3. Seconds
4. Feet

Hover Rearward Flight Maneuver. Table 13 lists the six most discriminating performance measures in the Hover Rearward flight analysis in the order they were selected by the stepwise discriminate analysis along with their associated multivariate F and U-Statistic values. Table 14 indicates the resultant classification of aviators into their respective groups by the six performance variables. With the prior probability of group membership being equal, the performance scores were used to correctly classify 100% of the aviators into the appropriate visual condition.

Summary data for the multiple discriminant analysis of the Hover Rearward flight data are shown in Table 15. Two of the four performance measures with significant univariate F ratios were utilized in this case, in the multiple discriminant analysis (Table 15). These two variables, Pedal Control Movement Number and Radar Attitude Constant Error, were also primary contributors to the first discriminant root.

Table 15 also indicates that root 1 accounted for a significant percentage of the variance - 68.7%, $X^2 = 22.1$, df = 6, $p < .002$. Examination of the group centroids in Figure 4 indicates that the performance scores produced the greatest amount of separation in root 1 between the unaided eye condition and the 60° goggle group. On root 2, the greatest amount of separation occurred between the 60° and 40° goggle conditions. The total discriminatory power (Table 15) provided by the performance measures was found to be 0.97 or 97% of the variability was relevant to group differentiation.

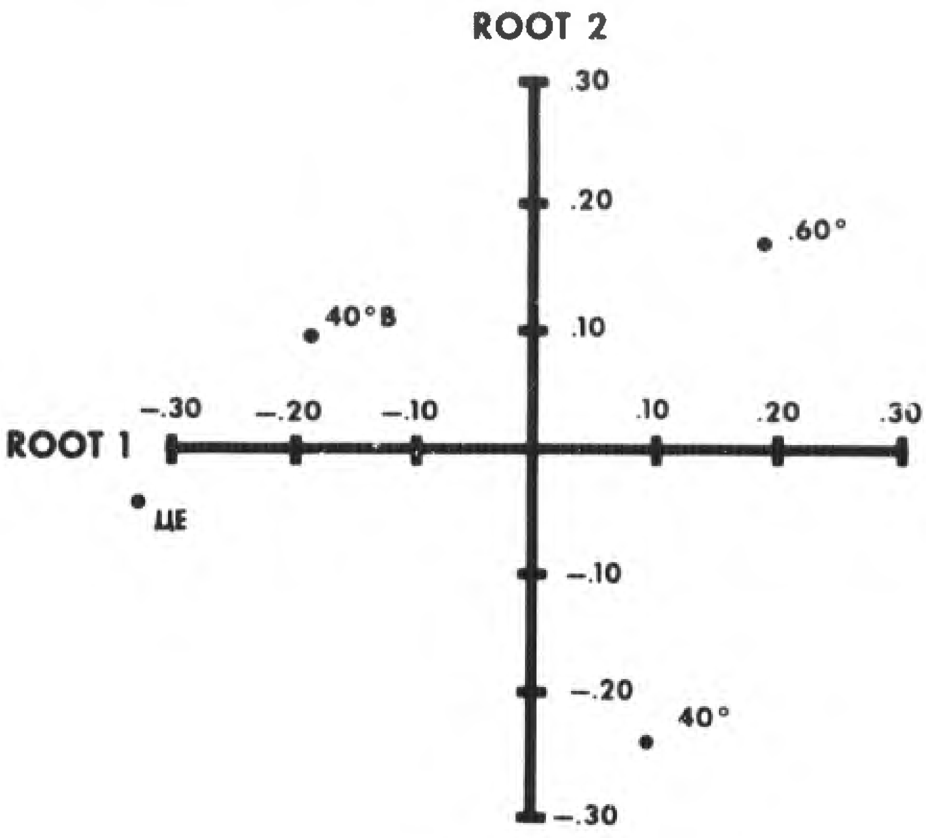


**FIGURE 4**

**GROUPS CENTROIDS IN DISCRIMINATE SPACE FOR THE HOVER REARWARD DATA.**

Inspection of the weights of the performance measures in Table 15 indicates that root 1 was primarily defined by the variable Radar Attitude Constant Error (positive direction) and to a lesser extent by Radar Altitude Absolute Average Error (negative direction), Pedal Control Movement Number (positive direction) and Pedal Control Movement Mean Time (negative direction). Therefore, groups with higher centroid values on root 1 (i.e., 60° and 40° goggles) have, in general, greater constant error in attitude values, less absolute average error in altitude, more pedal control movements, and shorter mean time in pedal control movements. A strict interpretation of the first discriminate function (that is, using the weights and signs of the weights as the guide points) indicates that the 60° and 40° goggle conditions: (1) hovered rearward at higher mean altitudes with less total absolute error in altitude from the five foot command altitude than the 40°B and unaided eye groups and (2) made more and quicker pedal control movements (compared to the 40°B and unaided eye groups).

Table 13

Stepwise Discriminate Analysis - Hover Rearward Flight Summary Data

| Variable Entered | F Value | df | P | U Statistic |
|---|---|---|---|---|
| Pedal Control Movement Number | 12.45 | 3/20 | < .01 | 0.35 |
| Radar Attitude Constant Error | 3.22 | 3/19 | < .05 | 0.23 |
| Radar Attitude Average Absolute Error | 4.31 | 3/18 | < .05 | 0.13 |
| Pedal Control Movement Mean Time | 5.20 | 3/17 | < .01 | 0.07 |
| Cyclic Fore-Aft Control Movement Number | 4.28 | 3/16 | < .05 | 0.04 |
| Cyclic Fore-Aft Control Movement Magnitude | 2.69 | 3/15 | > .05 | 0.02 |

Table 14

Number of Cases Classified into the Four Visual Sets Using the Hover Rearward Flight Data

| | Visual Set | | | |
|---|---|---|---|---|
| Group | 40° | 60° | 40°b | Unaided Eye |
| 40° | 6 | 0 | 0 | 0 |
| 60° | 0 | 6 | 0 | 0 |
| 40°b | 0 | 0 | 6 | 0 |
| Unaided Eye | 0 | 0 | 0 | 6 |

Table 15

Multiple Discriminate Analysis - Hover Rearward Flight Summary Data

| Variable | 40° Mean | 60° Mean | 40°b Mean | Unaided Eye Mean | F[a] | Adjusted D Weights Root I | Adjusted D Weights Root II |
|---|---|---|---|---|---|---|---|
| Cyclic Fore-Aft Absolute Control Movement Magnitude[1] | 0.65 | 0.68 | 0.75 | 0.66 | 2.62 | -0.025 | 0.227[b] |
| Cyclic Fore-Aft Control Movement Number[2] | 20.8 | 34.8 | 33.3 | 27.5 | 2.13 | -0.279 | 0.435[b] |
| Pedal Control Movement Number[2] | 3.8 | 9.3 | 6.0 | 3.8 | 12.46** | 0.449[b] | 0.201 |
| Pedal Control Movement Mean Time[3] | 0.17 | 0.25 | 0.27 | 0.26 | 1.70 | -0.390[b] | 0.256[b] |
| Radar Attitude Constant Error[4] | -0.27 | 4.17 | 1.97 | 2.27 | 3.38* | 0.615[b] | -0.149 |
| Radar Attitude Average Absolute Error[4] | 2.99 | 5.54 | 3.56 | 5.95 | 1.58 | -0.469[b] | -0.205 |

Root I - 68.7% of variance, $X^2 = 37.8$, df = 8, $p < .0001$
Root II - 23.8% of variance, $X^2 = 22.1$, df = 6, $p < .002$
Total Discriminatory Power (Estimated Omega Squared) = 0.97

[a]Univariate F, df = 3/20
[b]Primary contributor
*p < .05
**p < .01

Units of Measurement
1 - Inches
2 - Total Number
3 - Seconds
4 - Feet

A slightly different view of the flight performance of the four groups is provided if the two radar altitude error scores are examined without regard to the control measures. The 40° and 40°B goggle conditions hovered rearward at lower mean altitudes thus they were closer to the command altitude of five feet AGL than the 60° goggle and unaided eye conditions. The 40° and 40°B conditions also exhibited slightly less total absolute error from the command altitude than did the 60° goggle and unaided eye conditions.

Root 2 on the Hover Rearward data also accounted for a significant percentage of the variance - 23.8%, $X^2 = 22.1$, df = 6, $p < .0002$. The largest separation was between the 60° and 40° goggle conditions with three variables primarily contributing to this separation. The weights for these variables indicate that 60° and 40°B goggles had the largest magnitude of cyclic fore-aft absolute control movement and the largest number of cyclic fore-aft control movements as well as the longest time in Pedal Control Movements, relative to the unaided eye and the 40° goggle conditions.

The 100% classification strongly illustrates the degree of difference that the Hover Rearward Maneuver was performed under the four visual conditions. While the control movement variables helped to produce this magnitude of separation across the groups, the radar altitude variables were the primary discriminators.

SUMMARY

For the NOE flight segment, the NVG's were associated with slightly lower flight altitudes. As a function of reduced altitude, mean airspeeds were slower and control activity higher due to a greater obstacle avoidance requirement. The data also indicate that the 40° goggles were associated with smoother, more gradual control movements than were the 60° goggles. It was hypothesized that this may have been a function of the resolution differences between these goggles.

The dominant measure separating the visual conditions of the 25 Foot Hover maneuver was the average absolute error along the longitudinal axis or horizontal displacement. Data on this variable indicate that the 40° and 40°B goggles were associated with better position maintenance over the starting point relative to the 60° goggle and unaided eye. It should also be pointed out that all three goggle conditions exhibited better drift control than the unaided eye condition.

For the Hover Rearward Maneuver the error in altitude scores were the most discriminating among the four visual sets. The data for these two parameters indicate that the 40° and 40°B goggle conditions hovered rearward at lower mean altitudes, thus were closer to the command altitude of five feet AGL than the 60° goggle and unaided eye conditions. The 40° and 40°B conditions also exhibited slightly less total absolute error from the command altitude than did the 60° goggle and unaided eye conditions.

CONCLUSIONS

Based on the above data as well as those not presented because of space limitations and other research efforts, the following conclusions appear to be supported:

1. That illuminance is a critical factor when using NVG's.

2. That given the illuminance is adequate the goggles in general do provide an increased capability over the unaided eye.

3. For enroute work the bifocals which permit inside capability without manual refocus are preferred.

4. The bifocals are not preferred when performing maneuvers close to the terrain. This is probably due to the FOV reduction precipitated by the bifocal.

5. The higher resolution 40° FOV goggles were in general favored over the 60° FOV poorer resolution goggle.

6. Aircraft and cockpit lighting must be made compatible with NVG's.

7. The night vision goggles provide advantages over the unaided eye relative to light flashes. The NVG's don't always provide a real visual advantage over the completely dark adapted unaided eye, but it appears that the NVG's significantly improve the pilot's staying power when operating near temporary bright light sources because of their automatic light level regulation capabilities.

8. An inside capability other than manual refocus is highly desirable and a reduced bifocal cut may be the solution.

9. The mounting of the goggles to shift current weight bearing surfaces and c.g. can and should be modified.

10. Efforts should be directed at reducing their weight.

11. Safety procedures with use of the goggles must be stressed.

12. Further research must be conducted to determine the illuminance levels where the goggles provide increased capability and where they do not.

13. Cognizance must be given to the fact that the goggles are incompatible with certain fire control systems.

DISCLAIMER

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# IN-FLIGHT LINEAR ACCELERATION AS A MEAN OF VESTIBULAR CREW EVALUATION AND HABITUATION

by

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## SUMMARY

Individual differences in susceptibility to motion sickness and in man's ability to habituate to vestibular stimuli demand a specific, individually oriented program of vestibular testing and habituation. Groundbased vestibular evaluation and training must be supplemented by specific in-flight tests and in-flight habituation training for the following reasons:

1) The stimuli which cause vestibular airsickness in high performance aircraft at the shortest latency are rectilinear accelerations (otolithic-stimuli) of amplitudes, jerkloads and frequencies which cannot be simulated on the ground without enormous technical difficulties.

2) The conventional ways of testing for motion sickness on the ground, involving coriolis-effects on rotating chairs, swings, caloric stimulation of the ears and centrifugation, do not simulate closely enough conditions of aircraft flight.

3) Persons who are fairly resistant to motion sickness on the Bårány-chair, on centrifuges or at sea are not necessarily immune to other forms of kinetosis such as flying at hyper- or hypogravity, terrain-following flight or flight during turbulent meteorological conditions.

It is suggested that special vestibular in-flight test and training regimens be used, based on individual traits. The test and habituation flights should include Z-Axis acceleration between -1 and +2 g's, changes of rhythm of such stimulation, and alternation between threshold and sub-threshold maneuvers of opposite direction: Preliminary data obtained in a Lear-jet and in aerobatic light planes have indicated that certain otolithic stimuli are very effective in producing motion sickness, and that habituation can be obtained against such stimuli.

Experience has shown that existing methods of vestibular testing on the ground are of limited use in predicting an individual's susceptibility to airsickness. Moreover, the ability of aircraft crew members to habituate to motion sickness producing stimuli is also individually different and unpredictable. As a result, a percentage of all student pilots must be withdrawn from flight training at a stage when already sizeable costs, effort , time and hope have been invested in them.

The groundbased vestibular evaluation of potential aircrew members is usually based on case history and laboratory methods including electronystagmography, thermal stimulation of the ear canals and Coriolis-stimuli on the Bårány-chair. (10,14,15,17, 18) Such methods mostly concern activities of the semicircular canal system and leave the otolithic system untested. However, research during the last decade has shown that impulses from the otolithic system must be considered as a major, if not the main, contributing factor to airsickness and space sickness.(4,7,9)

That airsickness which can be provoked by head movements during aircraft turns, is, in most textbooks of aerospace medicine, still treated as a semicircular cross--coupling effect (or "Coriolis-stimulation") which depends mainly on otolithic overstimulation. Angular velocity during turns in fast jet aircraft is negligible when compared to the increased Z-Axis g-loads (linear acceleration) during such turns which cause otolith-macular contact forces of quickly changing directions during head movements.(11) In addition, it was found that the astronauts during the skylab missions were virtually immune to "Coriolis-stimulation" on an onboard rotating litter chair, although they became motionsick during such stimulation on the ground.(12) This observation strongly suggests that the motion sickness on the ground or in aircraft caused by head movements during turns, depends on the influence of a changing linear acceleration vector on the otolithic system.

However, under different flight trajectories, it is not the changing direction, but the changing value of the gravitoinertial force which leads to an "overload" of the otolithic system which is followed by motion sickness. In this context it is interesting to note that two kinds of flying maneuvers, maximal duration parabolas and terrain-following flight, can cause airsickness even in some (not all!) experienced test or fighter-pilots. During both maneuvers the gravitoinertial force deviates considerably from 1 g. Parabolic hypogravity leads to increased sensitivity of the otolith system to any additional rectilinear stimulus implied on the basis of 0 g. This hypersensitivity seems to follow the Weber-Fechner-law. When the strong background stimulation of 1 g is absent, any small stimulation (such as caused by acceleration or deceleration of the aircraft or by head movements) has an increased effect. Astronauts, who were already well habituated to long-term weightlessness, could provoke motion sickness by moving quickly through the cabin, or by head intended movements. (7) From fish experiments during parabolic flight and orbital weightlessness in Skylab 3, it can be deduced that hypogravity is a longterm vestibular stimulus of itself, even without additional stimulation.(1,3,4,5)

Since otolithic activity is a major factor of airsickness, it follows that more otolithic tests should be conducted when selecting individuals for a career as airmen. Unfortunately, the repertoire of groundbased otolithic tests is much more limited than that of semicircular canal tests. In any case, testing of the subjective horizontal and subjective vertical during passive tilts (Müller and Auberg phenomena) and the effect of tilting head movements on large human centrifuges (not only on the Bárány--chair) should be included in the battery of tests.

The individual resistance against other otolithic stimuli (e.g. the ones occuring during flight in turbulent meteorological conditions, during terrain following flight, hypogravity flight and flight in helicopters during certain tank fighting missions involving frequent rapid ascent and descent) cannot be tested by any of the conventional groundbased methods. Large human centrifuges can produce radial linear acceleration, but they lack the ability of producing any significant jerk loads ($m/sec^3$) (other than short amplitude buffeting) or oscillating g forces of amlitudes and durations comparable to real aircraft flight. Present-day aircraft simulators, elevators and fall towers either don't provide enough usable amplitude or are not able to accelerate and oscillate sufficiently. Under these circumstances, the most effective and economical method of vestibular evaluation of aircrews is in-flight testing.

For these reasons, we conducted a series of airborn motion sickness tests on human volunteers. All subjects underwent a preceding comprehensive flights physical and vestibular examination on the ground. Most in-flight tests were conducted in an aerobatic single engine aircraft (Fuji 200, 180 hp). In addition, after 60 hours of flight experiments in the NASA Learjet at NASA Ames Research Center, the author observed crewmembers and passengers for symptoms of motion sickness during parabolic flight.

The Z-Axis accelerations were measured by an accelerometer and were recorded on a battery powered directwriting oscillograph, together with the electrocardiogram, respiration and galvanic skin-resistance. Verbal reports concerning motion sickness were recorded on a tape recorder. These studies are still proceding and will be published in detail in a subsequent paper. The following observations appeared significant enough to justify this preliminary publication:

1) Repeated rectilinear Z-Axis acceleration, as caused by continuous sinusoid "roller coaster flight" limited between 0 g and + 2.5 g, was a powerfull stimulus evoking motionsickness.

2) The latency period until the first signs of motion sickness varied in different individuals within large limits (between 90 seconds and 20 minutes).

3) Hypergravity during these maneuvers was subjectively felt to be less disturbing then hypogravity. Maximal duration parabolas of 30-45 seconds weightlessness in the Learjet caused severe vomiting of 3 subjects after only the second parabola and caused after effects of the autonomic system for several hours. Other subjects could stand more then six - 0 g parabolas plus 10 low g parabolas per flight with only minor symptoms.

4) A regular oscillating rhythm was less disturbing then an irregular rhythm. In the case of a regular oscillating rhythm, motion sickness occured suddenly in some individuals with relatively high threshold when the frequency of oscillation was changed, e.g. between 0.1 and 0.2 oscillations per second. Two subjects commented that they could take the maneuvers better if the oscillations were predictable and expected, than if they came irregularly or at a changing rhythm.

5) The objective degree of motionsickness indicated by autonomous symptoms (palor, sweating, yawning, bradycardia, myosis, sick feeling, stomac-awareness, vomiting) was not always paralleled by corresponding subjective sensations. Several subjects felt quite normal until the instant before they become suddenly sick or even vomited; then they felt better again until the next episode of sickness occured. In others, neither real sickness occured nor did other autonomic signs occur for a long time; however the subjects still felt very uncomfortable beginning at an early stage of the " roller coaster flight" and continuing throughout the flight.

6) When the "roller coaster flight" was terminated at the very earliest time of discomfort, the latency period could be gradually "build up" by slightly prolonged subsequent "roller coaster flights". In one low-threshold subject, considerable habituation was already reached during one single flight of five hours total duration in stable air at high altitude when the intervall between the intercalated periods of

of "roller coaster flying" was 20 minutes.

These observations indicate that in-flight vestibular testing in light propeller driven aircraft is a worthwile and comparatively economical tool of vestibular aircrew evaluation, especially concerning otolithic mechanisms leading to motionsickness. Equivalent tests cannot be performed on the ground. Because horizontal speed is not a vestibular stimulus, it is possible to simulate very closely the vestibular effects of jet terrain-following flight in single engine propeller driven light aircraft. The recorded acceleration profiles are then similar to real terrain-following flight over a mountaineous area. In-flight vestibular evaluation of aircrews can be combined with an active vestibular habituation program, which must be based on individual sensitivity of the otolithic system.

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# EFFECT OF INCREASED ATMOSPHERIC ELECTRICITY ON THE BLOOD ELECTROLITES OF AIRPLANE CREW

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## SUMMARY

Airplane pilots during flights sometimes develop disorientation and fly in wrong directions with accidents resulting. Several pilots have observed during group flights that a pilot in the next airplane suddenly stopped radio communication, with his head fallen on his chest, not controlling his aircraft anymore, and was crushed to death. We think that the cause of disorientation or collapse in some of these cases may be the sudden changes in blood electrolites and acidity of the blood produced by increased atmospheric electricity. Experiments we made on airplanes and their crews showed that the atmospheric electricity is higher inside the airplane than outside. Blood samples taken before and after flight showed definite changes of acidity, electrolites and cholesterol. We measured atmospheric electricity daily for 15 months in 1970-71. We observed that following high voltages, there were always increased amounts of traffic and airplane accidents. All these support our views.

Airplane pilots during flight sometimes develop disorientation. Due to disorientation, they sometimes fly in wrong directions, resulting in accidents. We thought that the cause of disorientation in some of these cases might be the changes in blood electrolites and pH (acidity) of blood produced by increased atmospheric electricity. As we know, in many cases of blood acidity changes, such as acidosis or alkalosis, patients become disoriented or collapse, or even lapse into coma, due to abnormal changes in blood pH and electrolites (1).

During our experiments with airplane pilots, three of them related that while flying in groups, each of them on different occasions, had seen an airplane pilot with his head fallen down on his chest. The pilot did not answer the radio communications or any commands coming to his ears. The plane then nosed down and he was crushed to death. In all these three instances, the observers in the next airplanes had thought that the deceased pilot had collapsed during flight (2).

On August 25, 1975, four airplanes, F-104s of the Italian Air Force, crashed into a mountain near Luxemburg. The cause unknown. On May 28, 1971, three airplanes of the South African Air Force crashed in Table Mountain in Africa. The cause unknown again. Why in all these three countries did the pilots lose their alertness suddenly?

During 1970-71 we measured atmospheric electricity daily for 15 months. We observed that whenever there was increased positive atmospheric electricity voltages, following these increases, there were always airplane accidents, traffic accidents and lung bleedings of tuberculous patients in our 1000 bed hospital. This relationship was observed each time when there was a high positive atmospheric electricity voltage (3).

We used a DC voltmeter to measure atmospheric electricity which had filters against artificial electrical fields such as city electricity. This voltmeter was made by Philips Company. Later on we used a portable battery run voltmeter made by Turkish electronic engineers which was similar to the Philips voltmeter.

We measured the voltage differences between an antenna and ground, which means a wire connected to a water pipe. Normal voltage differences were about positive or negative 0.1 mV (millivolt) to 1 mV. The maximum limit of our instrument was positive 45 mV.

In normal days the voltage did not increase more than positive 1-2 mV. But whenever there were negative 1 - 2 - 3 mV voltage and a few minutes later positive 20 - 30 - 45 mV voltages, these were considered high voltages. Following these high voltages, we observed many abnormal changes in several fields of natural life which were published at that time (4). One of these changes was lung bleedings in our 1000 bed hospital. Each time there was high atmospheric electricity continuously for a few days, there was always many new cases of lung bleedings or deaths from bleedings (3).

We observed that, when an electron-charged object is brought near the antenna, which we use for measurement of atmospheric electricity, and that object is pulled away suddenly, there was a positive voltage recording on the voltmeter. We considered that a similar action is taking place in our bodies naturally also when the voltmeter was showing a positive voltage. The possible cause of this voltmeter reaction was the highly energetic photons coming from space which was producing photo-electricity on the antenna and breaking away some electrons from the antenna. We postulated that, the same photons are producing the same effect on the living creatures such as man and thus taking away electrons from cells (7). As we know, removal of an electron from something is called oxidation (8), thus in high atmospheric electricity there is probably very high oxidation in the human body. And in these conditions people probably need more oxygen. While these used electrons were broken away from their natural places, which means cells in man, they were to fall into the blood stream. When they enter the blood, they were to change blood hydrogen ion concentration which means pH, also. Since electrons were negative and hydrogen ions were positive, electrons are going to decrease hydrogen ion concentration. When hydrogen ions are decreased, this means alkalosis of blood which means pH of blood changes in the direction of alkalosis. When there is alkalosis of the blood, the electrolites of calcium and potassium decrease according to the books (7). If this postulate is correct, these changes are to be expected and the counter measures are likely to be useful. With these in mind we measured the blood electrolites of some of the patients in our hospital after bleedings and found definite expected abnormal changes in pH and electrolites. When we put measures to decrease atmospheric electricity on the beds of patients, such as a partial Faraday cage, connected with wire to water pipe, they improve much faster than the controls. This indicated that the increased atmospheric electricity voltage is an important factor in the blood changes and medical condition.

Why The Russian Cosmonauts Died Within A Few Minutes in Soyuz II in 1971: Three Russian cosmonauts in Soyuz II were flying fine in 1971. At that time we were measuring atmospheric electricity daily. During their flight there was very high atmospheric electricity, resulting in lung bleedings in our patients and traffic accidents. When the Russian space craft was entering the atmosphere, they passed through the ionosphere, which must have had much higher electricity than usual, according to our atmospheric electricity measurements. Naturally this has to influence the aircrew members also. Before they entered the ionosphere, they were alive and in fine health. A few minutes later, when they came down, they were dead. As soon as I heard this news on the radio, I thought that the cause of their death was this increased atmospheric electricity. Because increased atmospheric electricity was causing deaths in our patients also (3). Next day I went to the Turkish Air Force Headquarters, explained to them what probably killed the Russians, and told them that the same effect may be the cause of some airplane accidents in the Turkish Air Force. That day, I informed the United States Embassy, Western Germany and Russian embassies about the same possibility. The Turkish Air Force commanders accepted my suggestions for experiments. They gave orders to necessary places and permission for me to make some tests on airplanes and crew members.

On November 9, 1971, we took blood samples from six soldiers before and after one hour of flight. This showed that the pH of blood changed in the direction of alkalosis. Blood electrolites changes: potassium decreased, sodium increased, and cholesterol increased (7). There were no changes in E C Gs taken before and after the flight.

Here are the results of this test:

| Venous Blood pH<br>Normal range:<br>7.27 - 7.43 | Before flight | After flight | Difference in pH |
|---|---|---|---|
| Subject No. 1 | 7.26 | 7.38 | + 0.12 |
| Subject No. 2 | 7.34 | 7.36 | + 0.02 |
| Subject No. 3 | 7.25 | 7.30 | + 0.05 |
| Subject No. 4 | 7.21 | 7.25 | + 0.04 |
| Subject No. 5 | 7.32 | 7.35 | + 0.03 |
| Subject No. 6 | 7.30 | 7.33 | + 0.03 |
| Kalium = K<br>(Potassium)<br>Normal range:<br>4.5 - 5.5 mEq/lt | | | Difference in K |
| Subject No. 1 | 6.15 | 6.96 | + 0.81 |
| Subject No. 2 | 5.63 | 5.37 | - 0.25 |
| Subject No. 3 | 5.88 | 5.63 | - 0.25 |

| Kalium = K (Potassium) | Before flight | After flight | Difference in K |
|---|---|---|---|
| Subject No. 4 | 6.96 | 5.70 | - 1.26 |
| Subject No. 5 | 6.91 | 5.12 | - 1.79 |
| Subject No. 6 | 6.65 | 5.88 | - 0.77 |
| Natrium = Na (Sodium) Normal range: 136 - 148 mEq/1t | | | Difference in Na |
| Subject No. 1 | 143.5 | 147.9 | + 4.4 |
| Subject No. 2 | 139.2 | 152.2 | + 30 |
| Subject No. 3 | 147.9 | 178.3 | + 30.4 |
| Subject No. 4 | 160.9 | 152.2 | - 8.7 |
| Subject No. 5 | 152.2 | 158.4 | + 6.2 |
| Subject No. 6 | 147 | 176 | + 29 |
| Cholesterol Normal range: 150 - 250 mg % | | | Difference in Cholesterol |
| Subject No. 1 | 115 | 120 | + 5 |
| Subject No. 2 | 140 | 150 | + 10 |
| Subject No. 3 | 190 | 195 | + 5 |
| Subject No. 4 | 150 | 160 | + 10 |
| Subject No. 5 | 175 | 175 | ∓ 0 |
| Subject No. 6 | 140 | 150 | + 10 |

pH changed in the direction of alkalosis in all six subjects. K decreased in 5 subjects, increased in 1. Na increased in 5 subjects, decreased in 1. Cholesterol increased in 5, did not change in 1. I think this sudden increase of cholesterol was one of the reasons which produced blood clots in the three Russians who died in Soyuz II.

Our second experiment was performed on January 14, 1972. This time the airplane stayed on the ground with 4 subjects inside.

| Venous blood pH Normal range: 7.27 - 7.43 | Before embarkation | After disembarkation | Difference in pH |
|---|---|---|---|
| Subject No. 1 | 7.29 | 7.27 | - 0.02 |
| Subject No. 2 | 7.32 | 7.30 | - 0.02 |
| Subject No. 3 | 7.27 | 7.28 | + 0.01 |
| Subject No. 4 | 7.30 | 7.30 | ∓ 0 |
| Kalium = K (Potassium) Normal range: 4.5 - 5.5 mEq/1t | | | Difference in K |
| Subject No. 1 | 4.6 | 4.2 | - 0.4 |
| Subject No. 2 | 5.1 | 5.4 | + 0.3 |

| Kalium = K (Potassium) | Before embarkation | After disembarkation | Difference in K |
|---|---|---|---|
| Subject No. 3 | 3.3 | 4.1 | + 0.8 |
| Subject No. 4 | 3.8 | 5. | + 1.2 |
| Natrium = Na (Sodium) Normal range: 136 - 148 mEq/lt | | | |
| Subject No. 1 | 147 | 148 | + 1 |
| Subject No. 2 | 155 | 165 | + 10 |
| Subject No. 3 | 160 | 161 | + 1 |
| Subject No. 4 | 158 | 169 | + 11 |
| Calcium = Ca Normal range: 9 - 11 mg % | | | |
| Subject No. 1 | 9. | 9.1 | + 0.1 |
| Subject No. 2 | 10.2 | 10.2 | ∓ 0 |
| Subject No. 3 | 9.7 | 9.8 | + 0.1 |
| Subject No. 4 | 10.5 | 10.5 | ∓ 0 |
| Cholesterol Normal range: 150 - 250 mg % | | | |
| Subject No. 1 | 110 | 120 | + 10 |
| Subject No. 2 | 165 | 165 | ∓ 0 |
| Subject No. 3 | 160 | 150 | - 10 |
| Subject No. 4 | 150 | 145 | - 5 |

pH differences in this ground experiment were not much nor uniform in any direction. K increased in 3, decreased in 1. Na increased slightly in all 4. Ca did not change much. Cholesterol changes were not uniform.

On November 19, 1971 experiment the atmospheric electricity was measured on the inside and outside of an airplane. The voltage was positive 6 mV at the airfield 2 meters away from the airplane's rear door on the outside. When the antenna was put inside the rear door, the voltage became 12 mV, when the door was closed with antenna inside, the voltage became positive 16 mV. At that time the airplane was on the concrete landing strip. The static electricity wire of airplane was in touch with the ground, but the ground was dry. Therefore there was not much electrical contact. Because of this, the airplane was like an antenna attracting electromagnetic waves, thus increasing the voltage inside. This fact of increased D.C. voltage inside an airplane or a metal box is not known much among electronic engineers nor physicists even though we prove it by showing it to them. Recently we found in books of physics the theoretical information confirming our findings based on experiment and observation. But this is not an easily recognized information among the physicists nor electronic engineers.

Because so far everybody objected to me when I mention this fact by stating that on the inside of a metal box, an electrical charge can not exist, that electrical charges can accumulate only on the outside. This, I know. But while there is no electrical charge on the inside of a metal box, there is a difference of electrical voltage between the inside and the outside of a metal box. And when there is very little electrical charge on the outside, the voltage difference between inside and outside is little. But if there is much electrical charge on the outside then the voltage difference between outside and inside is big. Especially if the metal box is within a strong electromagnetic field, the voltage difference between inside and outside of the metal box must become very big as it was in the case of Soyuz II while passing through the ionosphere. In this condition, when the men inside the metal box touch the inside of metal with bare hands, which connects or transmits electricity, the body electricity is forced to run from the body to the metal and the outside of the metal box, while leaving the man inside without body electricity, thus producing lack of electrical communication inside the human body, which results in death. This was a part of my hypothesis in explaining how the Russians died in

Soyuz II in 1971. But in normal airplane flights, the voltage differences probably are not that extreme and they only produce pH changes, electrolite and cholesterol changes, thus producing collapse or perhaps death during flight.

Part of these tests which were performed in airplanes, and the electrical counter measures we used in our hospital on bleeding lung patients, were shown on Turkish television in 1972. Results of both studies were published later on (3-7).

All these observations and thoughts lead us to believe that when there is increased atmospheric electricity, this may change blood electrolites, cholesterol and pH of blood resulting in disorientation and collapse at times (9-10-11-12-13-14-15).

If pilots are given potassium salts on these days, they may act better during flights. If the training flights are stopped when there is high atmospheric electricity, the airplane accidents may decrease. What I personally do during long flights is that I take calcium, magnesium pills, plus potassium chloride, 2-3 grams, and vitamin C, 1000 mg, by mouth.

Even though the study on the effect of atmospheric electricity began in the 1920s in Soviet Russia with the works of Vasiliev and is still continuing, and a few years later in France and then in the 1930s in Turkey, Professor Aysoy did extensive research in this field; most of the doctors in the world today are not aware how influencial atmospheric electricity can be in our lives. There are many hundred publications in this field written by perhaps about one hundred researchers. The book entitled, "A Survey of Human Biometeorology" includes some of them (published by the World Meteorological Organization of UNESCO).

One reason why an average doctor is not aware or interested in this subject is that, there is no easy way of measuring atmospheric electricity accurately and reliably. But this difficulty is now gone with our newly designed instrument. This instrument was made according to this scheme and the whole thing cost me only a hundred dollars. Any electronic technician can make it in one day.

When you begin to measure atmospheric electricity yourself, you will make the same observations as made by several other researchers and then their results will not look like some kind of fantasy or stretch of the imagination to you anymore. Therefore, please first make some observations with this type of instrument and only then make your objections to our results if you still disagree, which is very unlikely. Because all sciences are based first on observations and experiments and later on theory. We should not begin our objections, which are not based on the measurement of this type of instrument on theoretical grounds.

Since the troublesome part of atmospheric electricity in general is the positive voltage, the negative ion generators were invented years ago. Here I have two of them. One is made in Hungary which can be used in a car or at home. The other one is made in the United States, but has a radioactive element inside. Therefore it is not very good. I use them to decrease pain in rheumatic conditions and asthamatic patients successfully.

I hope, some day soon, some people in my country or your countries shall continue with the blood electrolite and pH measurements on fliers and prevent some of these accidents caused by increased atmospheric electricity.


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Session Organizer's Editorial Note: Dr. Gültekin Caymaz, Ataturk Sanatorium, Ankara, Turkey, has specific information and a schematic diagram relating to the equipment he used.

## GENERAL DISCUSSION

General Perdriel (France):

I took great interest in the two papers by COL Ward and Dr. Dille, as they provide a basis for the policy that we should observe regarding the fitness of flying personnel. First of all, I would like to state that I was most disturbed by the statistical results reported by Dr. Dille concerning the percentage of physically handicapped persons holding civilian licenses in American air transport companies. As a matter of fact, there statistical results reveal that the above mentioned subjects, particularly those suffering from a visual anomaly, are responsible for a higher number of accidents than flying personnel with normal visual functions. The flight tests proposed by COL Ward and his collaborators are indeed interesting for borderline cases of fitness. However, I believe that such flight tests should be associated with various requirements, according to the policy which would be adopted in the French Air Force, should the occasion arise. First of all, I think that all the candidates to flying duties or posts should not necessarily benefit from these complementary tests, as a twenty-year old subject wishing to enroll in the French Air Force must have very satisfactory - if not excellent - visual functions, among other characteristics. However, these flight tests would be quite appropriate for flying personnel with unquestionable experience, as they would enable those to be maintained in their posts should the results be satisfactory. Besides, the tests should be extremely well codified as regards the qualities required from pilots. Two types of tests should be carried out: forced tests, during which the pilot's response to certain events likely to occur in flight would be studied, and spontaneous tests - cases of aircraft incidents or accidents - for determining the reactions of a subject suffering from colour vision anomalies and faced with the necessity of an emergency landing due to engine failure or adverse flight conditions; what terrain would he choose; would he avoid rocks and prefer landing on grassy ground? Visual fatigue, and more particularly chromatic fatigue, affects the pilot in the course of a flight; it has been demonstrated that, after watching the instrument panel for several hours, a subject suffering from dyschromatopsia makes very typical errors in evaluating the data displayed. Therefore, the above-mentioned tests should be of rather long duration, or even repeated, and consequently, would necessitate a considerable infrastructure: as far as the French Air Force is concerned, two, or even three aircraft might be required; they would provide the means of investigating all the borderline cases which we would have to deal with. However, we believe - and this is the basis of our policy - that it is preferable to maintain high standard selection and fitness criteria which, although they are not drastic should ensure flight safety.

Therefore, as a conclusion, while they are interesting, these flight tests should only be carried on exceptionally.

Colonel Ward (USA):

Thank you very much for your critique of Dr. Dille's and my presentations. Which of us would you like to respond first and which specific comments do you wish us to address?

General Perdriel:

Who should be evaluated and what kind of procedures are followed? In the first place, what kind of personnel should the test be addressed at and do they maintain their status in flight school? And the second question is how can this test be carried out?

Colonel Ward:

The U. S. Army evaluates experienced aviators with rare exception. The usual criteria is five hundred hours of flight time as a rated pilot, and this is getting more strict because now we have an abundance of military aviators in our country. The last few people who asked for in-flight evaluations were refused because there was no need to continue them as aviators. The U.S. Army is currently terminating from military service good aviators so an in-flight evaluation of an experienced individual is now exceptional. The usefulness to the U. S. Army for this was during our buildup with the need for aviators in Vietnam. Pilots were having a very short turn around; that is, one year in Vietnam, a year home, a year in Vietnam and a year home, repeatedly. The U. S. Army needed aviators badly at that time and from veterans with injuries it was able to isolate pilots that were very experienced, and utilize them. Due to their age and experience most of them were not used as what we call "Peter Pilot," the individual that flies day after day. They were put in positions where they had to fly, had to know about the flying environment, and had to have the confidence and respect of the people they were working with because of their aviation experience. They were very valuable leaders, examples, and staff officers in these circumstances. An ancillary question to this is, if we get another shortage of aviators in a combat situation what are we going to do with our women? This is a question we have not addressed in this group, and it might be a very interesting one.

To answer the second part of your question, as it concerns just the United States Army, which is separate from our Federal Aviation Agency policy that will be addressed by Dr. Dille. The U.S. Army procedures have become very standardized and we have a protocol. For instance with color vision, and here again it is usually applied only to experienced people as in the case of an allied aviator who had 8 years experience as a fixed wing aviator in his country flying most of the time under light control that our screening test found to be color vision defective. These color vision defective individuals are now given six separate clinical tests that measure with the different degrees of accuracy as discussed in my written paper. They are also given a standardized, as standard as we can make it, in the aircraft observation of the signal lights presented from the control tower, again standardized. You can't order up specific weather conditions, but the distances, the time of day; these can be standardized. They have to pass the signal lights perfectly. They also have to have perfect identification of smoke signals. This is very important for air strikes and identification of units on the ground. Again, there is a specified number of presentations: two of each of the colors that are standardly used in the military are given in random order. Again, they have to do this to perfection. Rather than take someone who can pass these practical tests and has demonstrated flying ability and ground them, they are given a waiver.

With the one allied aviator, I don't know how he got hold of his ambassador so fast, but before I even knew we had a color vision problem we were getting inquiries through diplomatic channels. He was number one or two in his class and had demonstrated his ability. The same quality is true of our other aviators in all these categories. Political pressure is unusual in the United States Army. Dr. Dille is from the U. S. Federal Aviation Agency where they have a different situation and different circumstances. Their civilian aviators have different privileges. Most of us here are military, and we look at the needs of the service; we're training somebody for combat, that's the ultimate objective that we have. If we put somebody back on flying status we feel they have to perform in that environment. We are also in a position where usually we can be somewhat autocratic and say no, and the burden of proof--there is none; the decision has been made. With the U.S. Federal Aviation Agency things are quite different: the burden of proof rests heavily on the FAA and all the civilian airmen have a Congressman, Senators, Lawyers and other pressure. Dr. Dille,

Dr. Dille (USA):

To emphasize, the data that we showed are all civilian pilots and almost all were from a population of 735,000 non-airline pilots. We rely on professional check pilots to make the operational determination and we find they are resistent to doctors telling them how to evaluate the proficiency of pilot. I agree that standardization would be ideal, however, by the sheer numbers involved--approximately 1,000 pilots per week, theoretically checked at 85 different offices. It would be difficult for us plus the wide variation in conditions being evaluated and oftentimes even with combinations of defects in the same individual. Some comments on the area of color--we do look at performance on the VASI, Visual Approach Slope Indicator, which depends on fairly normal red color perception. We are undertaking the study now of the Australian T VASI, which gives a configuration as well as color code. We think because somewhere between 8 and 9.4 percent of males have some color deficiency that we should be a party to exploring further either eliminating the dependence on color or to reduce the discrimination. We find engineers in the United States would like to remove blue taxi way lights which are not a problem and replace them with green. This would create a problem, and we see no reason at all for it. We are held by tradition to red being a danger signal? Why not orange? To further compound it, we have quizzed, queried our flight instructor pilots and found that only 7 percent knew the color signal light gun code. Only 13 percent of student pilots knew the code; twice as many; they were studying for a written examination. So even though someone can see the color, it still gives a false sense of security when no one knows what it all means. Therefore, perhaps we should explore redundancy, flashing red and steadygreen; one means go and one means no-go and whether you are in the pattern or on the ground. I would be interested in comments . . . we frequently as physicians, talk about terrain identification and I can understand this is a military context. I personally do not know of a single accident in civilian aviation in which inability to identify terrain has lead to complications. I would be interested if anyone in the audience has had this experience. We have a number of accidents in which illusions; configurations including landing on flat terrain or in water or with snow or on even a model aircraft runway. I'm aware of illusions with scale and lack of depth, but no personally due strictly to color defect.

Dr. Chevaleraud, (France):

The first question is addressed to you, Colonel Ward. Yes, we talk now of the helicopter. I am surprised after 8 years of confirmed acuity suddenly to discover a dyschromatic. Could it not be that this is acqured dyschromatopsia, which as you know is the thickness of the lens . . . or other factors? My second question I am addressing to you and also to Captain Frezell. It concerns essentially, what you call monocularizing. In actual fact there are two ways of being monocular. You can be monocular after an injury or an eye tumor you have to have an eye removed and then there is another way to be monocular and this is to be a functionally monocular. That is to say you practically have almost no central visual acuity that can be measured, but you have peripheral vision defect which has helped to place an aide using actuate peripheral vision. I was very surprised that you didn't give the duration between the loss of the eye function and the moment in which you saw the possibility of flight. Captain Frezell, if I understood correctly, tested a patient who had an eye removed in 1967 and started flying again in 1972. Having learned once again, and perfectly, to understand the outside world under these new conditions. Notwithstanding this, if I understood his demonstration, the subject has to learn all over again how to pilot under very particular conditions with monocular vision. So I think it is not really very useful to retrain subjects with monocular vision on an individual basis who ought to be trained as handicapped persons and likewise I don't think it is useful to retrain patients like a normal person. I think it is a contagious reason in a way in which we have a very serious danger when we have individuals who are physically handicapped and visually handicapped that want to be pilots. I think from the standpoint of the status of the Nations it is not useful to try to recuperate these monocular patients and in fact I do say we have no monocular pilots that are concerned with tourism flights, and I eliminate commercial flights. We only have two or three pilots that are monocular and none are flying under one of those conditions.

Colonel Ward:

Why after 8 years of flying activity was he discovered to be color difficient? As for the way he was previously tested and what his nation did with this particular aviator, I don't know. He was sent as one of their best to be trained as a rotary wing aviator by the U. S. Army. In other cases, I have ..d personal experience in color vision defects for many years, and incidentally I am a color vision defective myself. Didn't discover this until age 26 when they put a set of plates in front of me before resigning my Infantry commission to go to Medical School. I found after more study, as you probably know, this is not unusual. Color vision is not a "yes" or a "no," you don't throw a switch. It is more like many shades of grey. I found there were certain federal stock numbers; those are the identifiers of the test plates; one set I could pass the other set I couldn't. One aviator that I evaluated wanted to go to flight school so badly that he went out and bought a set of plates. Then he memorized the plates so that no matter how the plates were presented to him he would pass. We eventually identified the individual. And again, we have six different tests that we standardly use now in our evaluation of these people; they are like screens with different pore sizes. Some days one will slip through and pass while the next day he won't--on a marginal basis. This is where judment comes in. You could test them year after year but was not routine in our service to test them annually. Once they passed, they were passed. However, now we test them yearly.

We agree with your two ways of being monocular. This is discussed in the written presentation where uniocularity is defined as having an enucleated eye and monocularity is the loss of central vision in an eye.

We don't have many one-eyed former aviators to evaluate. The one that Captain Frezell discussed had his injury in 1967 and, you're right, in 1972 he was very rusty on his flying. Didn't have many flying hours. I don't know the specific circumstances in detail concerning this but I'm sure there were extenuating circumstances. Also, in Captain Frezell's study he was used for comparison with the normal binocular pilots. One that I identify with was a LT COL test pilot who was injured in 1966 and we evaluated him in 1967. He had 4,370 flight hours at that time and he was very current. With a small number of persons you have to individualize.

W. F. Oosterveld (Netherlands):

I have one question for Professor von Baumgarten. He supports the modern concept in the elicitation of motion sickness that the otoliths are more important than the canal. What are his thoughts about the use of a human centrifuge in the training of aircrew members? This centrifuge must have a device which makes it possible to invert the cabin during the run. With such a centrifuge a rollercoaster type of otolithic stimulation can be given, varying from plus to minus G and in your situation you are giving only 2.5G stimulation. Of course, weightlessness cannot be achieved on the centrifuge. I am interested in your thoughts about using such rather inexpensive training to replace a lot of airbourne training.

Professor von Baumgarten (Germany):

It is true that centrifuges are very useful but the stimulation on centrifuges does not provide the hypogravity states which occur on pushover in driving ambulances or in airplanes which more easily cause motion sickness. Transition from the hypergravity positive to negative G on centrifuges is further contaminated by semicircular canal stimulation. You cannot make a pushover on a centrifuge and the masses of the centrifuge which have to be moved are much too heavy to cause the centrifuge to stop and go or even to change the speeds of the centrifuge or to move the object along the radius quickly enough to stimulate the actual accelerations which happen to occur in flight. However, it is conceivable that a certain limited amount of transfer occurs in subjects undergoing habituation from one kind of vestibular stimulation to another. Therefore, I am not saying centriguges are not useful. They are useful for certain purposes, but in-flight evaluation is much less expensive than building these hugh centrifuges and simulates much closer the conditions of lying.

Dr. Banderet (USA):

I have two questions for Dr. Caymaz. First of all, is there any relationship between atmospheric pressure and the positive and negative charges that you are measuring? And the second question is have you thought about doing any experiments in which you might manipulate the charges and measure blood parameters?

Dr. Caymaz (Turkey):

In a clear sky, the atmospheric electric voltage varies from negative 2 or 3 millivolts up to positive 30 - 45 millivolts within a few seconds. It stays there for several minutes and then comes down again, then up again with no changes in barometric pressure. Nor is it related with humidity changes. But it is related to the sun.

At nights there is normal low voltage of 0.3 - 1. millivolt (positive voltage). We found only at one time high voltage at night. This was during the eclipse of the moon and we expected it anyway according to our theory on the cause of tides. This is a different theory than the accepted theories related with gravity. Our tides theory is based on the electrically charged particles coming from the sun, the moon and other heavenly bodies. This theory had been published in Turkish in 1970, then translated into English and sent to the Newton Gravity Research Foundation in New Haven, U.S.A. in 1971. On the second question, yes, we can change the voltage and see the results on the patient. On the beds of patients with lung bleedings in our hospital we put a partial Faraday cage connected to a water pipe. Then we put on iron mesh wire as big as the bed above the bed in the air permitting the patient to sit underneath. This was connected to the same wire also. This partial Faraday cage decreased the voltage around the patient about in half. Within 24 hours, the patient's pale color turned to normal pink col r. His blood sedimentation rate decreased. His pH and blood electrolyte values changed in the direction of normal values. His appetite increased. This gave similar results on about five patients while the control patients did not show any change in the course of their diseases during this time.

Professor von Baumgarten:

Dr. Caymaz, how can it be explained that in the case you described in an aircraft a few millivolts of static charge can be dangerous to the crew but several hundreds of volts static charges do not impair health when we accumulate these electrical charges when walking on synthetic carpets in dry air?

Dr. Caymaz:

What you say about production of electricity by rubbing on rugs is correct. That it can produce thousands of millivolts of electricity is correct also. But the voltages we read depend on the sensitivity of the instrument we use. For the same atmospheric electricity changes we can read a few millivolts difference or thousands of millivolts depending on the sensitivity of the instrument. Besides, during rubbing electricity accumulates in a short time and is discharged at one time only. But with atmospheric electricity high voltage is sustained for hours, and repeated the following days. Then the body cannot compensate this anymore, resulting in sickness.

When we measure the electricity of the heart we use an ECG. The voltage we read is 1 millivolt. The body naturally works on very low voltage of electricity. In comparison with 1 millivolt, 45 millivolt atmospheric electricity. In comparison with 1 millivolt, 45 millivolt atmospheric electricity is very high. But these are not the same type of instruments with the same degree of sensitivity. Therefore we cannot really compare them. But on the other hand by observations and experiments, we know that the increased atmospheric electricity produces many changes in our bodies as shown by laboratory tests. And we have to depend on experiments and observations which are the basis of all sciences, not on some theoretical objections.

General Fuchs (Germany):

Dr. Caymaz, would you comment on the official statement that the Soviet Astronauts died because of a decompression accident?

Dr. Caymaz.

Correct. They said the cause of their death was the sudden decrease of atmospheric pressure in Soyuz 11. But this could not have been the reason. Because when there is sudden or gradual decrease in atmospheric pressure, people die from bleedings, not from thrombosis as the Russians died from according to the autopsy report. As we know from submarine divings or skin divings, if the diver comes up too quickly, the pressure decreases fast resulting in bleedings. If the decrease is very fast as in cases of jumping out of airplanes in very high altitudes or going up in baloons as was done experimentally with animals and men, then the lungs are expelled through the mouth with additional bleedings in all other organs while the intestines are balooned with gas. Therefore the cause of death of Russians in Soyuz 11, could not have been decreased atmospheric pressure.

The Russians realized this mistake also and changed their first statement and said that, they died from blood clots in their neck vessels. This was the autopsy report, which did not explain what caused the clots. Then they said there was a slight leak in the cabin. They did not like this either. They finally said that they died from exhaustion, disregarding the loss of pressure. Very likely after all their researching they were not able to find any leak at all. Even if there was a small leak, it would have killed them with hemorrhages which was not the case. Because when they opened the cabin the 3 men had a smile on their faces. And the people who saw them thought that they were happy to come down safely. The smile surprised them, when they were found dead. But I knew what made them have that expression on their faces. Because when people die from respiratory arrest, the $CO_2$ increases in the tissues producing this kind of contractions on the lips as in patients who die from emphysema or $CO_2$ poisoning. Due to increased atmospheric electricity, they developed alkalosis which produced respiratory arrest, resulting in accumulation of $CO_2$. Previously increased cholesterol accumulated in some vessels producing thrombosis as shown in the autopsy.

## SUMMARY

The ultimate assessment of fitness is survival in an inhospitable environment. This has tested adaptation and integrated performance since genesis. Proof of competence in a specific activity is probably one of mankind's earliest examinations. The relatively recent advent of the scientific method has lead us to fragment our study into observations which quantify each function, organ, or system separately. Thereby, an examinee may be declared unfit in entirety when static measurements or observations of any component fails to conform to idealized standards. This arbitrary conclusion fails to appraise and recognize the amazing adaptability and ingenuity of the human organism. Thus, a person can be capriciously denied a livelihood in his chosen profession and society is deprived of the benefit of his productivity.

Man's adaptability, physical and psychological, is one of his most remarkable characteristics. This is perhaps best exemplified in the accomplishments of an individual classified as "handicapped" despite serious, potentially disabling privation. Findings have archeologically demonstrated that crippled individuals were able to live for many years after incurring an impairment. It must be presumed they contributed to their community despite their disability. A person may appear incapacitated, and be definitely unqualified for service, if standard regulations are applied in a rigid, narrow manner. However, there have been famous individuals in many fields of endeavor who were able to overcome their anatomical losses and make significant contributions in their chosen career.

The most famous aviation cases are those of Karjua, Wiley Post and Douglas Bader. Bader, an accomplished aerobatic pilot, went on to serve distinguishedly in combat despite his bilateral amputations, one above-the-knee, the other below-the-knee. As a bilateral amputee, he successfully piloted high performance toe-braking fighters under combat conditions.

The US Navy has its outstanding examples in Captain, later Admiral John M. Hoskins and Lieutenant Commander Frank K. Ellis. "Peg-leg" Hoskins lost a foot during the sinking of the USS Princeton in the Battle of Leyte Gulf; he went on to inspire and command carriers launching jet aircraft. As a Lieutenant, Frank K. Ellis sustained bilateral amputations in a low altitude ejection; he returned to flying in Naval Group III (no carriers and with a fully-qualified pilot).

Historically, the concept of in-flight evaluation of an aviator who was seriously injured and seemingly disabled is not new or particularly original. In-flight evaluation of aircrew fitness is a dynamic method of examining totally integrated, functional ability and capacity. It is still a viable, useable procedure as shown by this AGARD Aerospace Medical Panel Specialists' session. The primary questions which must be answered are: "Is the individual a potential hazard to flight safety?"; and "Can he perform his assigned aviation missions effectively and efficiently?"

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**15. Abstract**


The AGARD Aerospace Medical Panel Specialists Meeting, Ankara, Turkey, 24 October 1975, was on the subject of *The Use of In-Flight Evaluation for the Assessment of Aircrew Fitness.* These proceedings reprint the seven papers delivered at this meeting, and include a general discussion and a Technical Evaluation Report. The importance of in-flight assessment cannot be emphasized too greatly inasmuch as in-flight performance and pathophysiological status and events are the ultimate determinants of fitness to perform safely and effectively in the aerial environment. This is particularly true because such evaluations are frequently the last opportunity to preserve experienced aircrew whose contributions would be forfeited by a less comprehensive and finally definitive analysis of integrated ability.

Many aspects of in-flight determinations of physical, psychological, physiological and bio-aeronautical suitability and fitness of aircrew were considered. These included some in-flight and simulation techniques, examination methods, bioinstrumentation and procedures for fitness studies as well as results of assessment of the ability to fly safely with orthopedic injuries, amputations, and visual deficiences, plus a few other physiological and psychological situations. Also included are assessments of paratroopers and non-pilot aircrew in their performance of duty.