THE VISUAL STANDARDS FOR THE SELECTION AND RETENTION OF ASTRONAUTS

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The purpose of this research is to determine the origin and adequacy of the vision standards being used for the selection and retention of astronauts and scientist astronauts. A broad based literature search was carried out to evaluate the adequacy of the present vision test standards which are summarized in Table I.

The scope of the literature search is indicated by the following list of topics covered.

I. Atmospheric Effects
II. Bibliographies of Related Visual Research
III. Color Vision
IV. Contrast Thresholds
V. Dark Adaptation
VI. Depth Perception and Stereopsis
VII. Displays and Visual Simulation
VIII. Effects of Vibration
IX. Flash Blindness, Glare and Radiation Effects
X. Flicker Fusion Frequency
XI. Hardware, Including Ophthalmic Instruments
XII. Illusions and Visual Perception
    i. Aniseikonia
    ii. Autokinesis
    iii. Cyclotorsional Eye Movements

TABLE I

EYE REQUIREMENTS

	DISTANT VISION	NEAR VISION	REFRACTIVE ERROR	MOTILITY	ACCOMMODATION	COLOR VISION	DEPTH PERCEPTION	VISUAL FIELDS	NIGHT VISION	RED LENS TEST
Flying Class I (Pilot) (for flying training)	20/20 each eye	20/20 each eye	Total +1.75 -0.25 Astig. 0.75	Eso. 10 Exo. 5 Hyper 1 Pc 70 or less	At least minimum for age	Must pass VTS CV (10 of 14 plates)	Passing score (Verhoeff) or 30 Seconds (Howard-Dolman) or through "D" on VTA-DP	10° loss in any meridian [illegible] disqualifies	Not required unless indicated by history	No diplopia within 20° of center of [illegible] in cardinal directions [illegible]
Flying Class IA (Observer)	20/70 each eye Correctible to 20/20 each eye	20/20 each eye.	X	Same as Class I	At least mean for age	Same as Class I	Same as Class I	Same as Class I	Same as Class I	Same as Class I
Flying Class II (Training Completed)	Same as Class IA	20/50 each eye. Correctible to 20/20 each eye	X	Eso. 10 Exo. 6 Hyper 1.5 Pc 70 or less	Same as Class I	Must pass VTS CV or minimum score of 50 on VTA-CTT	Same as Class I	10° loss or [illegible] due to active process disqualifies.	Same as Class I.	X
Flying Class III [illegible]	20/400 each eye Correctible to 20/20 and 20/30	Correctible to 20/20 and 20/30	Same as Commission	Same as Commission	X	Same as Class I	X	Same as Class II	Same as Class I	X
Commission (Non-Flying)	20/400 each eye. Correctible to 20/30 and 20/40	Correctible to 20/20 and 20/40	Total 8.00 5.50 Astig 3.00 Aniso. 3.50	Eso 15 Exo 8 Hyper 2 Heterotropia	X	X	X	Defects which interfere significantly with binocular vision disqualify.	Night blindness disqualifies.	X
Enlistment	Correctible to 20/40 and 20/70 or 20/30 and 20/100 or 20/30 and [illegible] or [illegible] to progressive disease.	Correctible to 20/40 in better eye	8.00 8.00	Heterotropia greater than 15° is disqualifying	X	X	X	Same as Commission	Night blindness disqualifies.	X

X - No Standards

iv. Gravitational and Vestibular Effects

v. Night Myopia, Space Myopia and Ganzfeld

vi. Role of Instruction

XIII. Nystagmus

XIV. Ocular Muscle Balance

XV. Physiopathology

XVI. Refractive Error and Refraction

XVII. Space Flight, Including Reconnaissance and Surveillance

XVIII. Visual Acuity-Dynamic

XIX. Visual Acuity-Static

XX. Visual Fields

XXI. Visual Standards

The voluminous literature is indicated by the abstracts included in this report. The coverage of the literature is not exhaustive but it does include the main publications on vision standards for aviators. From the literature it is apparent that many of the vision tests and procedures are inadequate or out dated and that certain physiological aspects of vision that are of importance to aviators and astronauts have been neglected or overlooked. The primary oversight of immediate concern in this report relates to testing for near vision capabilities.

Testing for distance vision function has been the main concern in the past. Yet in modern aviation and in space flight, near vision has risen to high importance while distance vision has become almost unnecessary. The vision tests indicated in Table I could be passed even by a person with a strabismus at the near point, and hence are grossly incapable of identifying those people who have near point heterophorias of significance or accommodative problems at near. Futhermore, to compound

the problem, the maturation of pilots and astronauts ultimately brings them into the age of presbyopia wherein accommodative and related near point heterophoria problems become acute.

The nature of many of the tests in Table I is such that precoaching by fellow cadets or past experience and common sense can allow an otherwise unqualified person to pass the tests. A need exists therefore to make the testing more objective. Alternatively, greater control over subjective techniques is needed to ensure reliable reporting of the vision status of the examinee.

It is recommended that for improvements in standards, further investigation and experimental work be carried out on the need for and methods of testing that might be used in the following areas.

a. Fusional amplitudes at distance and near

b. Fixation disparity at distance and near, a test which might be able to supplant the need for fusion tests

c. Visual functions of dynamic acuity and stereopsis

d. Ocular motility and muscle fields

e. Near point of convergence

f. Dynamic accommodation responsiveness

g. Amplitude of accommodation needed for prolonged efficient visual performance.

While changes in vision testing are indicated, it is perhaps premature to recommend them at this time. The areas most in need of revision and expansion also need more documentation and research which is programmed for the next year. The following section covers the literature abstracted.

I. ATMOSPHERIC EFFECTS

1918 U.S. WAR DEPARTMENT — AIR SERVICE MEDICAL

No Refs. U.S. War Dept., Air Service, Div. of Military Aeronautics, Washington, D.C., Government Printing Office, 1918.

Pilots were classified into one of three altitudes at which they were supposedly safe based on tests to determine their ability to sustain anoxia. These tests included the Dreyer apparatus, Flack bag and rebreathing apparatus, pictures and descriptions are given of each. Low oxygen has a marked effect on any defect of the eyes.

Also see abstract under Depth Perception and Stereopsis.

1944 SCOBEE, R.G. — THE EFFECT OF EXHAUSTION AND MODERATE ANOXIA ON OCULAR MUSCLE BALANCE

No Refs. Army Air Forces Sch. Avia. Med., Randolph Field, Texas. Proj. No. 292, Rep. No. 1, July 1944.

The heterophorias of 14 aviation cadets, all with apparently 1$^{\Delta}$ of hyperphoria, were measured before and after severe physical fatigue and moderately severe anoxia. No significant increase in vertical heterophoria was found. It also appears that the horizontal phorias were insignificantly affected.

1952 CIBIS, P.A. — RETINAL ADAPTATION IN NIGHT FLYING

No Refs. USAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 21-31-014, May 1952.

The temporary loss of the ability to see the horizon on dark nights reported by experienced pilots is enhanced during oxygen deficiency.

Also see abstract under Dark Adaptation.

1953 McFARLAND, ROSS A. — HUMAN FACTORS IN AIR TRANSPORTATION

Extensive Refs. McGraw-Hill Book Co., Inc., New York, 1953.

Page 157: Table of physical characteristics of the standard atmosphere.

Also see abstract under Illusions and Visual Perception: Aniseikonia.

1953 SCHMIDT, I. Ringel, A.G. — EFFECT OF OXYGEN DEFICIENCY AND VARIOUS OTHER FACTORS IN COLOR SATURATION THRESHOLDS

22 Refs. USAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 21-31-002, April 1953.

Using a color saturation threshold meter, the effects of hypoxia, alcohol, and coffee were studied on the saturation thresholds of red, green, and blue. Hypoxia up to an altitude of 18,000 feet had a very small effect on color saturation thresholds, deteriorating recognition of green and blue to a barely significant extent. Alcohol corresponding to 60 ccs. of absolute alcohol impaired recognition of all three colors. Coffee improved the recognition of red and blue.

1958 MILLER, E.F. — EFFECT OF BREATHING 100% OXYGEN AT ATMOSPHERIC PRESSURE UPON THE VISUAL FIELD AND VISUAL ACUITY

4 Refs. U.S. Navy Sch. Avia. Med., U.S. Navy Avia. Med. Center, Pensacola, Florida. Res. Proj. NM 12-01-11, Subtask 11, Rep. No. 1, March 1958.

Effect measured on central and peripheral fields and visual acuity measured using tangent screen, perimeter and Clason Acuity Meter. Results showed no decrements under the conditions stated for a period of over 4 hours.

1959 AERISE, I.J. et. al. — OBSERVATIONS ON MICE EXPOSED TO COSMIC RADIATION IN THE STRATOSPHERE: A LONGEVITY AND PATHOLOGICAL STUDY OF 85 MICE

No Refs. Military Medicine, 24:835-847, 1959.

A study of the biological effects of a 24 hour exposure to primary cosmic radiation was carried out on 85 mice launched in August 1955. The animals were at about 80,000 feet for 23 hours where they were subjected to be hit by 7350 thin-down particles. Control mice on the ground were subjected to the same rigors as the experimental mice; and then both experimental and control mice were allowed to live out their life-span. Results indicate that there apparently was no significant definite evidence that the days exposure to light- and medium-weight primary cosmic particles in the stratosphere had any longterm adverse effect.

1959 SIMONS, D.G. Archibald, E.R. — SELECTION OF A SEALED CABIN ATMOSPHERE

16 Refs. Journal of Avia. Med., 29, 1959.

High altitude balloon capsules give data to design a sealed cabin to operate at space equivalent altitudes. Physiological variables to be considered are outlined. Atmosphere should provide for no

performance decrement rather than for comfort or survival. Discussion of liquid oxygen converters, selection of cabin pressure with relation to "bends", combustibility of atmosphere. The possible use of helium as replacement for nitrogen was proposed.

1961 HART, E.M. — EFFECTS OF OUTER SPACE ENVIRONMENT IMPORTANT TO SIMULATION OF SPACE VEHICLES

No Refs. ASD Tech. Rep. 61-201, AD 269 014, August 1961.

A literature search was carried out to delineate the effects that need to be incorporated into a simulator to adequately simulate the external space environment, and thereby analyze the effects on the crew and vehicle. Recommendations for further studies are given.

1962 MASTERS, R.I. — THE EFFECTS OF ALCOHOL AND ANOXIA ON THE HETEROPHORIAS (THESIS)

66 Refs. Thesis for 1962 Advanced Course in Avia. Med., Brooks AFB, Texas. 1962.

Extensive review of the literature. Summary of effects:
Alcohol—results in esophoria at distance and exophoria at near, with a neutral point in alcohol effect somewhere in between. Various explanations are proposed.
Anoxia—much more disagreement than with alcohol. Most workers note an increase in esophoria at distance with altitude, while the situation at near is more controversial.

1963 LACKEMEYER, J.M. — SPACE CABIN ATMOSPHERE TRACE CONTAMINANTS AND THEIR POSSIBLE INFLUENCE ON VISUAL PARAMETERS

70 Refs. Approx. Human Factors, 5:285-293, 1963.

Ozone can cause marked changes in several visual parameters. It has been shown to be present in the cockpit and passenger cabins of jet airliners in sufficient concentrations to cause visual effects in the laboratory, when flying in the lowest regions of the ionosphere (references given in support). It is also considered that ionized human waste may become highly toxic in gaseous or volatile form. Twenty-eight subjects were exposed for 3 and 6 hours to three different concentrations of ozone, namely 20 pphm, 35 pphm and 50 pphm by volume. From 3424 vision tests it is shown that photopic visual acuity, stereopsis, vertical phoria and color vision were not affected. Heterophorias changed 0-4 1/2° relatively more eso- or exo- however, while prism divergence and convergence also showed marked changes. Perimeter plots showed average increase in field. Scotopic vision was affected in every case. The possibility of contaminent formation in spacecraft and the effects on vision are discussed at length.

1966 KENT, P.R. — OXYGEN BREATHING EFFECTS UPON NIGHT VISION THRESHOLDS

19 Refs. U.S. Naval Sub. Med. Center, Sub. Base, Groton, Conn. Rep. No. 469 MF011. 99-9002.03, February 1966.

Rod and cone night vision thresholds were measured while breathing oxygen at one atmosphere for periods up to 140 minutes and at 2.82 ats. for 20 minutes. One of the five subjects showed elevated thresholds at 1 at. and two of the remaining four at 2.82 ats. Both rod and cone thresholds were lower (more sensitive) after fasting subjects ingested 100 grams of glucose while breathing oxygen at 1 atmosphere. Breathing oxygen at 1 at. enhanced the night vision sensitivity of one fasting subject. Six of eight showed a small decrement in night vision sensitivity while breathing environmental air.

1969 WEITZMAN, D.O.
Kinney, J.S.
Lewis, S.M. — EFFECT ON VISION OF REPEATED EXPOSURE TO CO_2

7 Refs. Sub. Med. Res. Lab., Sub. Base, Groton, Conn. Rep. No. 566, MF 12.524- 004-9015 D.01, February 1969.

Visual effects of repeated exposure to CO_2 at levels commonly regarded as innocuous were investigated. Exposure varied cyclically from 0.03% (air) to 3.00% at one atmospheric pressure every 24 hours for 6 days. A battery of visual tests was administered during this period and in control periods both before and after the exposure to CO_2. Among the various tests, night vision sensitivity and color vision for green were the only ones which repeatedly detected impairment of efficiency during the period of exposure. All other visual functions tested remained normal.

II. BIBLIOGRAPHIES

1939 McFARLAND, ROSS A. — BIBLIOGRAPHY ON THE SELECTION, TRAINING AND PHYSICAL FITNESS OF AVIATION PILOTS

Nat. Res. Council Comm. on Selection and Training of Civilian Pilots and Civil Aeronautic Authority, Washington, D.C., 1939.

Complete bibliography to 1939. Contents include:

I. Phychological studies.
II. Sensory tests.
III. Physiological studies.
IV. Effects of moderate and high altitudes.
V. Medical examinations and tests of physical fitness.
VI. Human factors in airplane accidents.
VII. List of aeronautical journals.

1960 HOPKINS, C.O.
Bernarschmidt, D.K.
Anderson, M.J. — DISPLAY AND CONTROL REQUIREMENTS FOR MANNED SPACE FLIGHT

175 Refs. Aerospace Med. Div., Wright-Patterson AFB, Ohio. WADD Tech. Rep. No. 60-197, April 1960.

Includes a large bibliography.

See abstract under Displays and Visual Simulation.

1961 HEYDACKER, D. — OPTICS AND VISUAL PHYSIOLOGY (ANNUAL REVIEW)

Arch. Ophth. 65:859-902, 1961.

Includes foreign titles.

1962 6570TH AEROSPACE MEDICAL RESEARCH LABORATORIES — INDEX OF AEROSPACE MEDICAL RESEARCH REPORTS PUBLISHED DURING THE PERIOD SEPTEMBER 1959-DECEMBER 1961

6570th Aerospace Med. Res. Labs., Aerospace Med. Div., Wright-Patterson AFB, Ohio. May 1962.

1963 6570TH AEROSPACE MEDICAL RESEARCH LABORATORIES — BIBLIOGRAPHY OF RESEARCH REPORTS AND PUBLICATIONS ISSUED BY THE BIODYNAMICS AND BIONICS DIVISION

6570th Aerospace Med. Res. Labs., Aerospace Med. Div., Wright-Patterson AFB, Ohio. June 1963.

1963 6570TH AEROSPACE MEDICAL RESEARCH LABORATORIES — INDEX OF AEROSPACE MEDICAL RESEARCH REPORTS

6570th Aerospace Med. Res. Labs., Aerospace Med. Div., Wright-Patterson AFB, Ohio. July 1963.

1963 STEARNS, P.E.; Kasparek, C.F. — CATALOG OF SCIENTIFIC PUBILCATIONS 1942-1963

U.S. Nav. Sch. Avia. Med., U.S. Nav. Avia. Med. Center, Pensacola, Florida. December 1963.

Classified into current research, inactive subtasks, terminated projects, joint reports, etc.

1966 AEROSPACE MEDICAL RESEARCH LABORATORIES — INDEX OF AEROSPACE MEDICAL RESEARCH LABORATORIES REPORTS: AMRL-TDR NO. 63-1 THROUGH AMRL-TDR NO. 63-137

Aerospace Med. Res. Labs., Aerospace Med. Div., Wright-Patterson AFB, Ohio. February 1966.

Abstracts of reports by project and task are included.

1966 STEVENSON, S.A.; Trygg, L.E. — A BIBLIOGRAPHY OF REPORTS ISSUED BY THE BEHAVIORAL SCIENCES LABORATORY: APRIL 1946-DECEMBER 1965

Aerospace Med. Res. Labs., Aerospace Med. Div., Wright-Patterson AFB, Ohio. June 1966.

Includes engineering psychology, training psychology, environmental stress, simulation techniques and physical anthropology.

1967 STEVENSON, S.A.; Johnson, R.A. — 1966 SUPPLEMENT TO A BIBLIOGRAPHY OF REPORTS ISSUED BY THE BEHAVIORAL SCIENCES LABORATORY

Aerospace Med. Res. Labs., Aerospace Med. Div., Wright-Patterson AFB, Ohio. April 1967.

1968 KASPAREK, C.F.; Turner, C.E. — ANNOTATED BIBLIOGRAPHY OF REPORTS ISSUED BY THE NAVAL AEROSPACE MEDICAL INSTITUTE, PENSACOLA, FLORIDA: 1 JANUARY 1964-1 JULY 1968

U.S. Nav. Sch. Avia. Med., U.S. Nav. Avia. Med. Center, Pensacola, Florida. June 1968.

1969 KASPAREK, C.F.; Turner, C.E. — ANNOTATED BIBLIOGRAPHY OF REPORTS ISSUED BY THE NAVAL AEROSPACE MEDICAL INSTITUTE, PENSACOLA, FLORIDA: SUPPLEMENT NO. 1, 1 JULY 1968-1 JUNE 1969

U.S. Nav. Sch. Avia. Med., U.S. Nav. Avia. Med. Center, Pensacola, Florida. June 1969.

III. COLOR VISION

1931 COOPER et. al. — DEPARTMENT OF COMMERCE CONFERENCE

No Refs. J. Avia. Med., 2:236-242, 1931.

This paper concerns a group of vision experts discussing the visual requirements for the aviation medical examination. It was suggested that men should not be disqualified merely for missing a couple of Ishihara plates; also several copies of the National Geographic were useful in final testing.

1936 WHITE, M.S. — TESTS FOR COLOR BLINDNESS

48 Refs. J. Avia. Med., 7:134-142, 1936.

Extremely good review of the work and visual tests up to 1936 is presented; color deficiencies are also classified. It appears that no one test was used for color vision testing but, "the ideal method of attacking the problem is to supplement one test with the other." England was using the Edridge-Green lantern.

1942 WHITE, M.S. — A STUDY OF THE VALUE OF THE PSEUDO-ISOCHROMATIC COLOR VISION TEST IN THE SELECTION OF THE MILITARY PILOT

1 Ref. A.A.F. Sch. Avia. Med., Randolph Field, Texas. Proj. No. 12, Rep. No. 1, January 1942.

It was concluded that the tests used in pilot selection for color vision screening were unreliable. The Ishihara test is adequate and should become standard selection procedure.

1951 FARNSWORTH, D. — PROPOSED ARMED FORCES COLOR VISION TEST FOR SCREENING

No Refs. Med. Res. Lab., U.S. Nav. Sub. Base, New London, Conn. Rep. No. 180, 10.146-155. Color Vision Rep. No. 24, August 1951.

Fifteen pseudo-isochromatic plates were selected from the Amer. Opt. Co. selection (14 diagnostic, 1 demonstration). These were 99% effective but the number of plates that failed bears no relation to the degree of deficiency. Specifications given for standard viewing lamp.

1953 SCHMIDT, I.; Bingel, A.C. — EFFECT OF OXYGEN DEFICIENCY AND VARIOUS OTHER FACTORS IN COLOR SATURATION THRESHOLDS

22 Refs. U.S.A.F. Sch. Avia. Med., Randolph Field, Texas. Proj. No. 21-31-002, April 1953.

See abstract under Atmospheric Effects.

1959 SCHMIDT, I. — VISION AND ASTRONAUTICS

14 Refs. Arch. Soc. Amer. Oftal. Optom., II:291-298, 1959.

Visibility of colors depends on the area and luminance of the observed area. Threshold illuminance for correct recognition of colors is about 10 lux; this is equivalent to a distance from the sun of about 3 times the distance of the planet Pluto from the sun. The eyes must be light adapted; if the astronaut scans the sky he becomes dark adapted and a Purkinje shift results.

1962 MILLER, J.W. (Editor) — VISUAL PROBLEMS OF SPACE TRAVEL

Extensive Refs. Nat. Acad. Sciences-Nat. Res. Council, Washington, D.C., 1962.

Pages 3-4: Description of colors seen on launching and in space.

Also see abstract under Space Flight Including Reconnaissance and Surveillance.

1968 WHITCOMB, M.A.; Benson, W. (Eds.) — THE MEASUREMENT OF VISUAL FUNCTION (SYMPOSIUM) PROCEEDINGS OF SPRING MEETING 1965

Extensive Refs. Armed Forces-Nat. Res. Comm. on Vision, Washington, D.C., 1968.

The papers on color vision include a description of the 100 hue test and a short discussion of the laboratory measurement of color vision.

Also see abstracts under Dark Adaptation, Depth Perception and Stereopsis, Ocular Muscle Balance, Refractive Error and Refraction, and Visual Acuity-Static.

1969 WEITZMAN, D.O.; Kinney, J.S.; Luria, S.M. — EFFECT ON VISION OF REPEATED EXPOSURE TO CO_2

7 Refs. Sub. Med. Res. Lab., Sub. Base, Groton, Conn. Rep. No. 556, MR 12.524.004-9015 D.01, February 1969.

Color vision for green showed a repeatedly detectable impairment of

efficiency during a period of exposure to CO_2 at levels commonly regarded as innocuous. The exposure varied cyclically from 0.03% (i.e. air) to 3.0% at one atmospheric pressure every 24 hours for 6 days.

Also see abstract under Atmospheric Effects.

1969 MILLER, H.D. et. al. RESEARCH ON VISUAL PROBLEMS IN SPACE FLIGHT

5 Refs. NASA, Manned Spacecraft Center, Houston, Texas. NASA Contract NAS 9-6865, March 1967-May 1969.

The work covers the investigation of the optical parameters of the Apollo pressure suit helmets and visors and the effect of optical distortions upon visual performance. The primary visual function investigated is binocular depth perception. Results are also included of work done on photokeratitis due to exposure to U-V radiation and the effect of the gold coated lexan visor on color perception.

Also see abstract under Depth Perception and Stereopsis.

IV. CONTRAST THRESHOLDS

1946 BLACKWELL, H.R. CONTRAST THRESHOLDS OF THE HUMAN EYE

9 Refs. J. Opt. Soc. Amer., 36:624-643, 1946.

Experimental data are presented representing approximately 450,000 responses made by trained observers under laboratory conditions (2,000,000 were actually recorded). Contrast thresholds are presented for stimuli brighter and darker than their background, and for 2 values of stimulus exposure. In each case wide variations were studied in the parameters; stimulus contrast, stimulus area and adaptation brightness.

1956 LINFOOT, E.H. TRANSMISSION FACTORS AND OPTICAL DESIGN

J. Opt. Soc. Amer., 46:740-752, 1956.

This paper is concerned with formulating the requirements which must be fulfilled by a realistic theory of optical image evaluation, and with the analytical techniques which enable these requirements to be met to a greater or lesser extent. Some of the short-comings of old and present-day methods of image assessment are enumerated and the above-mentioned requirements are outlined. The Fourier treatment of optical images is extended to cover systems of fairly large aperture and field, working in polychromatic light, and the basic properties of their transmission factors (response functions) are developed. The evaluation of optical images and of optical designs is discussed in terms of these transmission factors.

1956 SCHADE, O.H., SR. OPTICAL AND PHOTOELECTRIC ANALOG OF THE EYE

J. Opt. Soc. Amer., 46:721-739, 1956.

A photoelectric analog of the visual system is constructed in conformance with anatomical data. The analog has the form of a color television camera chain feeding electrical signals to a "computer" (the brain). Evaluation of characteristics is limited to elements preceding the computer, and particularly to the "luminance channel" of the color system. The primary photoelectric transfer characteristics $n_1=f(E_r)$ of the receptors (rods and cones) are computed as a function of retinal illumination (E_r) from threshold signal-to-noise ratios in the effective image area of point sources, disks, and other test objects. The effective image area, which is the convolution of the object area with the sampling area of the visual system, is determined from its Fourier spectrum. The constants of the transfer functions are established from the optical constants of the eye, its storage-time function, and the maximum transfer ratio of statistical units of the rod and cone systems. There is little room for variation of constants, if they are to remain in agreement with observed values. The incomplete dc restoration in the

system (differentiation of edges) is taken into account as a negative image component caused by feedback. System design principles are used as a guide in calculating the signal integration by retinal elements and the relative photoconductor gain characteristics of the receptors which are part of a system of interdependent functions including the primary characteristic, the over-all transfer characteristic to the optic nerve lines, and the four spatial integration characteristics represented by the equivalent passbands of lens and retina for the rod and cone systems. The final solution is perhaps not completely unique for all functions, but does not violate or disagree with fundamental principles or observations as demonstrated by a comparison of the operating characteristic of the analog with the Munsell lightness scale, its noise level with the perception of external noise; and its statistical transfer ratio, relative gain, gamma, and feedback with observed data. The acuity, contrast sensitivity, and threshold visibility of point sources of the analog are, of course, in inherent agreement with corresponding properties of the eye.

1956 VOS, J.J. — VISUAL CONTRAST THRESHOLDS IN PRACTICAL PROBLEMS
Leget, A.
Bouman, M.A.

J. Opt. Soc. Amer., 46:1065-1068, December 1956.

Contrast thresholds—measured with dots and Landolt rings—are given as a function of object size and brightness for 31 observers. The desirability of presenting upper and lower limiting threshold curves is pointed out. Differences with the experiments of Blackwell are discussed. The influence of training is shown to be negligible.

1958 SCHADE, O.H. — ON THE QUALITY OF COLOR-TELEVISION IMAGES AND THE PERCEPTION OF COLOR DETAIL

RCA Review, 495-535, December 1958.

A theoretical and experimental study of the NTSC color system, supported by color photographs, shows that contrast range and color saturation obtained with commercial tricolor kinescopes provide a larger color space than provided by color motion pictures. In fine detail more than 60 per cent of full color information is transmitted and reproduced by the NTSC system because the bandwidth restrictions of the electrical color signals (I,Q) do not affect definition in the vertical dimension and have a smaller effect on the reproduction of horizontal color detail than indicated by earlier evaluations which disregarded the two-dimensional nature of the image. The detail color reproduction appears adequate to the eye because the color errors remaining, although perceptible, are small. This fact is significant because the spatial sine-wave response functions of the color discriminators of the visual system are found to be substantially independent of the color of light and similar to the spatial sine-wave luminance response function of the eye.

1962 KULPALMA, J.J. — SINE-WAVE RESPONSE OF THE VISUAL SYSTEM. II. SINE-WAVE AND SQUARE-WAVE CONTRAST SENSITIVITY
Lowry, E.M.

J. Opt. Soc. Amer., 52:328-335, 1962.

Part I of this series described a method which yielded the sine-wave response of the complete visual system by assuming that the Mach phenomenon is the result of a convolution, in the optical sense, of the object luminance distribution with the effective spread-function of the visual system. This second paper is concerned with measuring the response of the visual system to sine-wave and square-wave spatial distributions using the threshold criterion of contrast sensitivity. Particular emphasis is placed on the low spatial frequencies, a region which is believed to be critically important in the mechanism of visual contrast phenomena. Results strongly imply interaction of two basic mechanisms in the visual system. These mechanisms may be characterized individually as a low-pass filter component (optical) and a high-pass filter component (neural, chemical, electrical, etc.).

1962 KRAUSKOPF, J. — LIGHT DISTRIBUTION IN HUMAN RETINAL IMAGES

J. Opt. Soc. Amer., 52:1046-1050, 1962.

The image-forming properties of the human optical system have been examined with the aid of a photoelectric ophthalmoscope. The light distributions in images of bright vertical lines formed by a double passage through the eye optics were measured. On the assumption that the eye optics are reversible, the light distributions on the retina were computed by means of Fourier transforms. The results are also expressed in terms of the spatial frequency response functions for the eye. The effects of pupil size were examined. The best imagery was obtained with a 5 mm pupil. The results confirmed the earlier measurements on human eyes reported by Flamant. The more recent experiments on animal-material by DeMott do not seem to be relevant to living human eyes.

1962 WOLFE, R.N. — WIDTH OF THE HUMAN VISUAL SPREAD FUNCTION AS DETERMINED PSYCHOMETRICALLY

J. Opt. Soc. Amer., 52:460-469, April 1962.

The response of the human visual system to an optical image is assumed to be linearly related to the logarithm of the spread function of the photographic system projected onto the retina combined with the spread function of the visual system. From psychophysical data derived from viewing (at different distances) a series of pictures generated with different spread functions, an estimate is obtained of the variance of the spread function of the visual system. The square root of this variance ranges from 3μ to 8μ, depending on the techniques used and on the training of the

judges. Although the residual errors in this determination are small, they show systematic trends, indicating that definition depends on other factors than the composite variance.

1962 WESTHEIMER, G. Campbell, F.J. — LIGHT DISTRIBUTION IN THE IMAGE FORMED BY THE LIVING HUMAN EYE

J. Opt. Soc. Amer., 52:1040-1045; September 1962.

By photoelectric scanning, the light distribution was determined in the aerial ophthalmoscopic image of a thin light filament viewed by an observer with an homatropinized eye. Light distributions were obtained for various pupil sizes and degrees of defocusing. Measurements were also obtained with bar and grating objects. To compute the linespread function on the fundus, correction was made for the double passage of the light through the optical system of the eye on the assumption that the spread in angular measure is the same in both directions. The results may be considered to depict distributions which are possibly broader, but certainly not narrower, than the real distributions in the retinal image. The line-spread function on the fundus was determined to have a half-width at half-height of one minute of arc for an eye in best focus with a 3 mm pupil, and this suggests that the point-spread function has half-width 0.66 minute of arc as an upper estimate.

1963 WESTHEIMER, G. — OPTICAL AND MOTOR FACTORS IN THE FORMATION OF THE RETINAL IMAGE

J. Opt. Soc. Amer., 53:86-93, January 1963.

Recent work on eye movement, pupil and accommodation responses is reviewed with emphasis on the relevance of the results to retinal-image formation. Diffraction, chromatic and spherical aberration, and transmission characteristics of the eye, and also new findings concerning the light distribution in the image in the intact human eye are discussed. An introduction is given to the Fourier approach to the analysis of the performance of the eye and visual system.

1964 SCHADE, O.H., SR. — MODERN IMAGE EVALUATION AND TELEVISION (THE INFLUENCE OF ELECTRONIC TELEVISION ON THE METHODS OF IMAGE EVALUATION)

Applied Optics, 3:17-21, 1964.

Introduces image measurement problems brought up by the development of commercial television. The solution to television problems has required growth and cooperation of optical, photographic, and electronic sciences. Present methods of analysis and the importance of the aperture response, sine-wave response, and the noise theory are pointed out. Presents data on the frequency band pass of the eye.

1965 CAMPBELL, F.W. — VISUAL ACUITY VIA LINEAR ANALYSIS

Proceedings of the Symposium on Information Processing in Sight Sensory Systems, 177-193, 1965.

Fourier techniques are applied to the entire human visual system in analyses of the functions of the optics, the retina, and the brain. Prediction of contrast sensitivity using these analyses is satisfactory. Presents contrast sensitivity functions for square and sine-wave functions, and considers binocular vs monocular resolution. Binocular acuity is superior by approximately $\sqrt{2}$. Further testing of this hypothesis awaits the location of a three eyed subject who should show $\sqrt{3}$ improvement over monocular viewing!

1965 CAMPBELL, F.W. Green, D.G. — OPTICAL AND RETINAL FACTORS AFFECTING VISUAL RESOLUTION

J. Physiol., 181:576-593, 1965.

1. With a neon-helium laser as a light source, interference fringes were produced on the retina directly, thus by-passing the effects of the optics of the eye.
2. Threshold contrasts for resolution of these interference fringes were measured. It was found that the contrast sensitivity decreased roughly exponentially with increase in spatial frequency.
3. The contrast sensitivity of the over-all visual system was measured with similar sinusoidal gratings displayed on an oscilloscope. At all spatial frequencies the contrast sensitivity was found to be lower than that obtained with the interference fringes.
4. By finding the ratio between the contrast sensitivities measured by these two techniques, the contrast reduction due to the optics of the eye was calculated. The effects of changes in pupil size and focus on the quality of the retinal image was determined. For an eye with a 2 mm diameter pupil the measured optical attenuation agrees with that predicted for a diffraction-limited system. With increasing pupil size the performance of the optics deviated progressively from a perfect optical system.
5. These results establish that the quality of the optics is substantially better than that determined by recent ophthalmoscopic methods.

1965 FRY, G.A. — PHYSIOLOGICAL IRRADIATION ACROSS THE RETINA

J. Opt. Soc. Amer., 55:108-111, January 1965.

This letter presents a mathematical consideration of absolute threshold data for geometrical targets of various sizes in consideration of photo receptor properties and retinal inhomogeneities.

1965 FRY, G.A. — DISTRIBUTION OF FOCUSED AND STRAY LIGHT ON THE RETINA PRODUCED BY A POINT SOURCE

J. Opt. Soc. Amer., 55:333-335, March 1965.

This latter considers the distribution of light on the retina from a point source. The work extends the findings of other authors by incorporating the Fraunhofer diffraction pattern.

1965 WESTHEIMER, G. — APPLICATION OF FOURIER METHODS TO THE HUMAN VISUAL SYSTEM

Proc. of the Symp. on Info. in Sight Sensory Systems, 157-161, November 1965.

This paper examines the relation between the point spread function of the space domain and the modulation transfer function in the spatial frequency domain to understand the foundation of human spatial visual resolution. The transmission of sinusoidal object distributions into image distributions is discussed, including the demodulation of incoherent imagery depending on wavelength, optical system aperture, aberrations and defocusing. By introduction of fringe patterns on the retina, the effects of spatial frequency limitations are demonstrated for coherent illumination.

1966 CAMPBELL, F.W.
Gubisch, R.W. — OPTICAL QUALITY OF THE HUMAN EYE

J. Physiol., 186:558-578, 1966.

1. Optical quality of the eye was measured at eight pupil sizes between 1.5 and 6.6 mm diameter by recording the faint light emerging from the eye; this light was reflected from the bright image of a thin line on the fundus.
2. The nature of the fundus reflexion was examined; it was found that the fundus acts very much like perfect diffuser while retaining polarization
3. Using the result that the fundus acts like a diffuser, the recorded line images were Fourier analysed to provide modulation transfer functions. These functions indicate an optical quality considerably higher than that found in previous physical studies.
4. Line-spread profiles were then derived from the modulation transfer functions. These profiles are 40% narrower than those of previous physical studies for a 3.0 mm pupil. The narrowest profile occurred with a 2.4 mm pupil.
5. Our results demonstrate that physical and psychophysical studies can yield similar estimates of optical quality. The influence of optical factors not common to both techniques is discussed. Evidence for the existence of neural "image sharpening" mechanisms is revieved.

1966 CAMPBELL, F.W.
Kulikowski — ORIENTATIONAL SELECTIVITY OF THE HUMAN VISUAL SYSTEM

J. Physiol., 187:437-445, 1966.

1. It is known that an object is less detectable when it is viewed against a background containing structures similar to the object. The effect of changing the orientation between the object and background is investigated.
2. Gratings of variable contrast were generated on two oscilloscopes; these were superimposed optically. The angle of orientation between them could be changed. The threshold of one grating, the test grating, was determined in the presence of the other, the masking grating.
3. When the gratings were presented with the same orientation (and locked in phase) the increment threshold of the test grating was found to be proportional to the suprathreshold contrast of the masking grating.
4. As the angle between the test and masking gratings was increased the masking effect fell exponentially.
5. At 12° on either side of a vertical test grating the masking effect was reduced by a factor of two with respect to its maximum value. This angle was independent of the contrast level of masking, the focus, and also the phase coherence of the masking grating.
6. If the test grating was presented obliquely the effect of masking was slightly less.
7. The narrow orientationally tuned channels found psychophysically by this masking technique are compared with the orientationally sensitive cells discovered electrophysiologically in the visual cortex of the cat.

1966 HARRIS, J.L.
Dantley, S.Q. — MECHANISMS OF SPATIAL SUMMATION

Proc. of the Colloq. of Performance of the Eye at Low Luminance, Delft 1965, 39-52, November 1966.

A simple model is postulated, analysed and compared in terms of performance with data from a vision experiment. The purpose of the study was not to attempt to validate the model, but rather to determine whether it is possible to find a model in which the extent of spatial summation exhibited by the visual system can be achieved using only the point spread function associated with retinal imagery and probability summation. The results of the study indicate that the simple model does result in the proper degree of spatial summation, using only the point spread function and probability summation mechanisms. The quantum efficiency calculation does not prove the validity of the model but does show that the model is compatible with quantum statistics.

1966 KRAUSKOPF, J. — SOME EXPERIMENTS WITH A PHOTOELECTRIC OPHTHALMOSCOPE

Proc. of the Colloq. on Performance of the Eye at Low Luminances, Delft 1965, 169-181, November 1966.

Experiments in which the line spread functions of the human eye were determined for white light, monochromatic light, and with various pupil configurations are described. With large pupils the optics of the eye are significantly poorer than a diffraction limited system. The results indicate that neither chromatic nor simple spherical aberration limit the performance of the eye. It is concluded that the irregular variation in dioptric power over the plane of the pupil is the chief limiting factor. Another set of experiments is described in which the changes in fundus reflectivity due to photopigment bleaching were studied. The principal experimental variable was the entry or exit point of the measuring beam in the pupil plane. A direct correspondence between changes in reflectivity and the psychophysical Stiles-Crawford effect was found. These results may be interpreted qualitatively as supporting the wave guide or antenna theory of the Stiles-Crawford effect. However, it is shown that no simple theory of retinal reflectivity can account for the data quantitatively.

1966 MORGAN, R.H. — THE INFLUENCE OF QUANTUM FLUCTUATION AND SINE-WAVE RESPONSE ON VISUAL PERCEPTION

Proc. of the Colloq. on Performance of the Eye at Low Luminances, Delft 1965, 121-128, November 1966.

A new method for the assessment of quantum fluctuation in single photoreceptor systems has been proposed. It follows principles similar to those employed in the evaluation of noise from temperature-limited devices in electronic systems; that is, it postulates that fluctuation in visual systems is a function of (1) the number of available quanta and (2) the frequency response characteristics of the photoreceptor. In this paper, attention has been directed entirely to single photoreceptor systems. However, extension of the methods to systems employing multiple photoreceptors is not difficult.

1966 ROHLER, R.
Hilz, R. — PHYSICAL AND PHYSIOLOGICAL FACTORS IN VISUAL MODULATION TRANSFER

Proc. of Colloq. on Performance of the Eye at Low Luminances, Delft 1965, 105-117, November 1966.

Measurements of the threshold of the human eye for periodical grids and of the modulation transfer function (MTF) of the optical part of the eye have been carried out. The MTF was determined from the light being reflected from the retina. The thresholds for grids as a function of spatial frequency were determined under variation of several parameters such as length and number of grid lines, background luminosity and presentation time. By taking into consideration the MTF, the influence of the optical part of the visual pathway on the threshold could be eliminated. For unrestricted presentation times, the results show strong and nonlinear influences of the neural interactions of the threshold, especially the well known increase of threshold with very small spatial frequencies. For short exposure times, the neural interactions decrease and apparently disappear at presentation times shorter than ca. 10ms. At these exposure times, the threshold data can be explained alone from the MTF of the optical part of the eye.

1966 VAN MES, F.L.
Bouman, M.A. — THE EFFECTS OF WAVELENGTH AND LUMINANCE ON VISUAL MODULATION TRANSFER

Proc. of Colloq. on Performance of the Eye at Low Luminances, Delft 1965, 183-192, November 1966.

The contrast sensitivity of the visual system has been determined with variable-transmittance sinusoidal test objects, by measuring the modulation-threshold as a function of spatial frequency, for monochromatic light of constant average luminance. Data were obtained for wavelenghts of 450, 525, and 650 nm. There is little difference in the modulation threshold curves for red, green and blue at photopic luminances. All three have a minimum at a best-transferred frequency f_m in the photopic luminance range. When the average luminance decreases, f_m decreases for all wavelengths, until, for scotopic luminance levels, contrast sensitivity increases continuously with spatial frequency.

1967 GUBISCH, R.W. — OPTICAL PERFORMANCE OF THE HUMAN EYE

J. Opt. Soc. Amer., 57.407-415, 1967.

The disagreement between physical and psychophysical estimates of human optical performance is discussed. Recent measurements of the eye's modulation transfer functions in white light for several pupil sizes are used to compare the eye with an ideal optical system in terms of normalized modulation transfer functions, point image profiles, and Strehl ratios. Several simple fundal-image profiles are derived from the measured modulation transfer functions, and the importance of these profiles to psychophysical measurements is discussed. Glare is considered as the extension of point spread functions to large angles; experimental measurements are compared with theories for the special case of angular target.

1967 MITCHELL, D.E.
Freeman, R.D.
Westheimer, G. — EFFECT OF ORIENTATION OF THE MODULATION SENSITIVITY FOR INTERFERENCE FRINGES ON THE RETINA

J. Opt. Soc. Amer., 57:246-249, 1967.

It is now well established that, for many test targets, vertical and horizontal orientations yield higher visual acuities than oblique orientations. In order to assess the role of the optics of the eye in this effect, focusing errors of the eye were bypassed by using as the measure of resolving capacity the modulation sensitivity for sinusoidal interference fringes formed on the retina. The modulation sensitivity for vertical and horizontal orientation of the fringes was greater than for oblique orientations for a wide range of spatial frequencies. A similar orientation preference was found for the cut-off spatial frequencies. Measurements of the modulation sensitivity at 15° orientation intervals indicated that maxima in sensitivity were spaced at 90° intervals. Since the effects of the optics of the eye have been eliminated, the origin of meridional variations in acuity must lie in the retina and/or higher visual pathways.

1967 VAN MES, F.L. SPATIAL MODULATION TRANSFER IN THE HUMAN EYE

J. Opt. Soc. Amer., 57:401-406, March 1967.

The contrast sensitivity of the human eye for sinusoidal illuminance changes was measured as a function of spatial frequency, for monochromatic light with wavelengths of 450, 525, and 650 nm. At each wave-length, data were obtained for a number of illuminance levels. All observations were taken at equal accommodation, and corrected for chromatic aberration. If the wavelength-dependent effects of diffraction on the modulation transfer are taken into account, no difference is found between the photopic contrast-sensitivity functions for red, green or blue. For mean retinal illuminances B_o smaller than 300td, threshold modulation M at a given frequency is found to increase in proportion to $B_o^{-1/2}$ (de Vries-Rose law). For B_o greater than 300 td M remains a constant fraction of it (Weber-Fechner law). After separation of the optical modulation transfer of the eye media from the measured neural and a light-diffusion transfer function. The latter can be compared with the analytic transfer function of photographic film.

1968 GREEN, D.G. THE CONTRAST SENSITIVITY OF THE COLOR MECHANISMS OF THE HUMAN EYE

J. Physiol., 196.415-429, 1968.

1. To isolate the color receptive systems of the eye, a sinusoidal grating of one color was superimposed on a bright background of another color and the threshold contrast for resolving the grating was determined.
2. A procedure is described which allows one to estimate the extent by which the bright background reduces the contrast of the test grating of another color. Using this procedure, the measured threshold contrasts of the test grating were replotted in terms of the effective contrast sensitivity for the composite target.
3. The effectivity of a red background in reducing the contrast

of a green grating was found to be determined not by its apparent brightness but rather by the extent to which it excited the green mechanism.
4. The effective contrast sensitivities for a green grating on a green background, for a green grating on a red background, and for a red grating on a green background were found to be not significantly different.
5. Visual acuity for a blue grating on a yellow background was reduced from normal by about a factor of six. This loss in visual acuity was due to both a reduction in contrast sensitivity and a reduction in resolution.

1968 CAMPBELL, F.W. THE HUMAN EYE AS AN OPTICAL FILTER

Proceedings of the IEEE, 56:1009-1014, 1968.

The properties of the image-forming elements of the human eye are compared with the properties of the retina-brain system by considering them as two linear optical filters in cascade. The contrast sensitivity of the complete system is measured at a number of spatial frequency on an oscilloscope. Similar gratings are generated directly on the retina by means of Thomas Young interference, using a neon-helium laser as a coherent light source. In this manner the effect of the eye's dioptrics are bypassed. The quality of the image formed on the retina may then be determined from these two sets of measurements. The effect of pupil size on the quality of the retinal image is described to illustrate an application of the technique.

V. DARK ADAPTATION

1938 HECHT, S. Schlaer, S. — AN ADAPTOMETER FOR MEASURING HUMAN DARK ADAPTATION

24 Refs. J. Opt. Soc. Amer., 28·269-275, 1938.

The original Hecht-Schlaer adaptometer is described. The parameters involved in dark-adaptation are: intensity and duration of preadapting light; the area, retinal location, color and duration of the measuring light. All these are incofporated in the apparatus.

1949 BERRY, W. — REVIEW OF WARTIME STUDIES OF DARK ADAPTATION, NIGHT VISION TESTS AND RELATED TOPICS

Extensive Refs. The Armed Forces Nat. Res. Council Vis. Comm., Vis. Comm. Secretariat, 304 West Med. Building, Univ. of Michigan, Ann Arbor, Michigan. December 1949.

Contains a useful historical account, evaluation and procedure of using night vision selection tests and dark adaptation tests up to August 1946. Abstracts of 106 papers in the field, published between 1941 and 1946 are also included.

1951 CLARK, B. — NIGHT VISION TRAINING: A SUMMARY OF RESEARCH AND PRACTICE

51 Refs. From, "Blackwell, H., Minutes and Procs. of the NRC-Armed Forces Comm. on Vision, 29th Meeting, 1951".

Contents include: basic anatomy and physiology of rod vision, factors involved in the development and maintenance of dark adaptation; limitations of vision at night; recommended techniques for optimum seeing at scotopic intensities; physical factors affecting visibility, special problems in visual perception which occur during scotopic intensities, description and evaluation of near vision training methods.

1951 MUELLER, C.G. — SOME FACTORS IN HUMAN VISUAL DISCRIMINATION

30 Refs. From, "Blackwell, H., Minutes and Procs. of the NRC-Armed Forces Committee on Vision, 29th Meeting, 1951".

Includes comprehensive survey on all the accepted data up to 1951, a description of the Radium Plaque Adaptometer and the use of binoculars in night vision.

1952 CIBIS, P.A. — RETINAL ADAPTATION IN NIGHT FLYING

No Refs. USAF Sch. Avia. Med., Randolph Field, Texas.

Proj. No. 21-31-014, May 1952.

Temporary loss of ability to see the horizon on dark nights has been reported by experienced pilots who regained sight of the horizon when flying in an inverted position. The experimental study shows strong evidence this is due to physiological effects of local retinal adaptation. The effects are enhanced during oxygen deficiency.

1953 CHAMPANIS, A. — AN EVALUATION OF PROBLEMS OF CHART READING UNDER RED ILLUMINATION

28 Refs. Armed Forces Nat. Res. Council Vis. Comm. Secretariat, 3433 Mason Hall, Univ. of Michigan, Ann Arbor, Michigan. January 1953.

Preliminary report into the problem, e.g. depth of dark adaptation required, intensities of red light, etc. Useful bibliography.

1953 FARNSWORTH, D. Hillman, B. — A COMPARISON OF SPECIFICATIONS FOR DARK ADAPTATION RED

17 Refs. Med. Res. Lab., U.S. Navy Sub. Base, New London, Conn. Rep. No. 219, Proj. No. NM 002 014.01.01, February 1953.

Current specifications for red goggles, red compartment lighting fixtures and red panel illumination for dark adaptation purposes are discussed and evaluated.

1953 McLAUGHLIN, S.C. — THE EFFECT OF RED LIGHT ON THE ABSOLUTE VISUAL THRESHOLD

14 Refs. U.S. Navy Sch. Avia. Med., Pensacola, Florida. Proj. No. NM 001 059.28.02, August 1953.

An hypothesis is advanced to account for the appearance or not of red light photosensitization in closely similar experimental situations in terms of the psychophysical method of threshold determination which is employed. This hypothesis explains the appearance in the literature on vision of conflicting data. Results are presented to support the hypothesis and to nullify the "photosensitization phenomenon".

1953 FANG, H.S. Hwang, T.F. — THE INFLUENCE OF PROLONGED STAY IN THE DARK ON FOVEAL DARK ADAPTIVITY

7 Refs. U.S. Navy Sch. Avia. Med., Pensacola, Florida. Proj. No. NM 001 059.30.01, October 1953.

Two subjects were dark adapted for periods from 2 minutes to 10 hours. After 5 to 7 hours, foveal dark adaptivity became two times as high as after one hour. Maximum adaptivity was shown after 8 to 10 hours. The possible mechanism is discussed.

1957 FOOKS, G.
Dimmick, F.L.
Sweeney, E.J.

PILOT STUDIES OF A SCOTOPIC SENSITIVITY TEST

3 Refs. U.S. Navy Med. Res. Lab., Sub. Base, New London, Conn. Rep. No. 285, Proj. No. Nm 23 01 20, Rep. No. 1, Subtask 4, June 1957.

Further experiments with a new test of night vision sensitivity are discussed, which had already indicated: the sensitivity in the visual field must be sampled in two dimensions, size and brightness of the test areas can be used interchangably.

1960 DOMEY, R.G.
McFarland, R.A.
Chadwick, E.

THRESHOLD AND RATE OF DARK ADAPTATION AS FUNCTIONS OF AGE AND TIME

2 Refs. Human Factors, 2:109-119, No. 3, 1960.

Two hundred and forty subjects were used, their age range being 19-89 years. It was concluded that the threshold of dark adaptation as a function of time was lawfully related to chronological age by a curvilinear function. The findings are consistent with the hypothesis that dark adaptation threshold and rate of dark adaptation depend on the basic underlying physiological processes that change with age.

1960 LURIA, S.M.
Schwarts, I.

VISUAL ACUITY UNDER RED VERSUS WHITE ILLUMINATION

8 Refs. U.S. Navy Med. Res. Lab., Sub. Base, New London, Conn. Rep. No. 326, Proj. No. MR 005.14-1001.01.10, January 1960.

The central acuity of 3 subjects was measured at 3 photopic levels (11.2, 1.2, and 0.34 ft.-L) of red and white light using a multiple checkerboard acuity tester. The red light was produced by the Navy standard red filter. The acuity was comparable under both conditions, showing a small, negligible decrease under red light.

1960 McFARLAND, R.A.
Domey, R.G.
Warren, A.B.
Ward, D.C.

DARK ADAPTATION AS A FUNCTION OF AGE I. A STATISTICAL ANALYSIS

24 Refs. J. Geront., 15:149-154, No. 2, 1960.

The range of individual differences in the dark adaptation process as a function of age is considerably greater than has previously been supposed. Two hundred and forty male subjects, ages 16-89 were used. Age and dark adaptation thresholds were highly intercorrelated. The correlation improves as the time in the dark increases. The cone and rod thresholds are highly correlated.

1961 DOMEY, R.G.
McFarland, R.A.

DARK ADAPTATION AS A FUNCTION OF AGE INDIVIDUAL PREDICTION

7 Refs. Amer. J. Ophthal., 51:1262-1268, No. 6, 1961.

Measuring dark adaptation near the asymptote of the function requires 30-40 minutes. When it is required to screen large numbers of people, a test of this length is impracticable. Thus a short test of dark adaptation, predictive of thresholds near the asymptote was developed. The dark adaptation for 241 male subjects, ages 16-89 years was measured. A multiple correlation of 0.91 was obtained between the threshold sensitivity at the 40th minute (the criterion), and age combined with dark adaptation thresholds taken at intervals of 1 minute for the first ten minutes. A correlation of this magnitude allows application of the regression equation to individual performance for the accurate prediction of terminal levels of dark adaptation sensitivity. It was concluded that 3 minutes of preadaptation plus ten minutes of measurement at intervals of one minute under standard laboratory conditions as described permit accurate prediction of terminal levels of dark adaptation sensitivity.

1962 KINNEY, J.S.

A REVIEW OF RECENT LITERATURE ON NIGHT VISION TESTING

15 Refs. Armed Forces-NRC Comm. on Vision, Visual Problems of the Armed Forces, Washington, D.C., Pp. 3-11, 1962.

Only two new tests have appeared since Berry's review (see this section under Berry, 1949), both of which rest on firmer experimental facts than their predecessors. These are the Medical Research Laboratory Test (MRL) and the Army Night Vision Tester. One variable that affects long-term stability is exposure to sunlight, hence seasonal variations are large. The validity of testing is examined from three points of view: is the test measuring what it is supposed to, can night vision testing be used to predict performance in a field situation, and the relationships among a range of night vision tasks from simple to complex.

1962 KISSEN, A.T.

THE EFFECT OF HYPERTHERMIA OF PERIPHERAL DARK ADAPTATION

4 Refs. Aerospace Med. Div., Wright-Patterson AFB, Ohio. Rep. No. AMRL-TDR-62-133, Proj. No. 7222, Task No. 722204, November 1962.

Biochemical regeneration rate of rhodopsin might be altered if retinal blood or tissue temperature are raised by hyperthermia in super- or hypersonic aircraft flight. Peripheral dark adaptation curves were obtained on 5 subjects at comfort (21.0° C) and 65.6° C temperatures alternately, using a modified Hecht-Schlaer adaptometer. In 24 heat experiments, the subjects were exposed to 65.6° C ambient air temperature for 55 minutes after which the heat was shut off The chamber temperature declined, but the subject's remained in

relatively constant hyperthermic conditions during the subsequent 35 minutes of dark adaptation tests. The curves obtained differed from the controls, indicating an increase in dark adaptation rate under the imposed thermal stress conditions.

1966 KENT, P.R. — OXYGEN BREATHING EFFECTS UPON NIGHT VISION THRESHOLDS

19 Refs. U.S. Naval Sub. Med. Center, Sub. Base, Groton, Conn. Rep. No. 469 MF011. 99-9002.03, February 1966.

Rod and cone night vision thresholds were measured while breathing oxygen at 1 at. for periods up to 140 minutes and at 2.82 at. for 20 minutes. The measurements were taken on the Hecht-Schlaer adaptometer. One of the 5 subjects showed elevated thresholds at 1 at. and 2 or the remaining 4 at 2.82 at. Both rod and cone thresholds were lower after fasting subjects ingested 100 grams of glucose while breathing oxygen at 1 at.

Also see abstract under Atmospheric Effects.

1967 ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT — AIRCRAFT INSTRUMENT AND COCKPIT LIGHTING BY RED AND WHITE LIGHT

12 Refs. Agard, Paris, France. Conference Proca. No. 26, Oct. 1967.

It was concluded that scanning an instrument panel using a dim white light causes only a slight loss of dark adaptation compared to that which is possible to achieve after looking at equally legible red lit instruments. There is little difference in the level of adaptation associated with either low temperature white or lunar white lit instruments. At an experimental level it is considered the disadvantages of red integral lighting (loss of color coding, accommodation difficulties) outweigh the advantages (slightly lower threshold). Floodlighting should be easily interchangable from red to white, white being used unless the visual task requires the aviator to detect external objects, when it should be red. If map-reading is required, then only the illumination of the map should be white, the rest being red to maintain dark adaptation on the peripheral retina. Integral and floodlighting systems should be variable in intensity.

1968 WHITCOMB, M.A.; Benson, W. (Eds.) — THE MEASUREMENT OF VISUAL FUNCTION (SYMPOSIUM) PROCEEDINGS OF SPRING MEETING 1965

Extensive Refs. Armed Forces-Nat. Res. Comm. on Vision, Washington, D.C., 1968.

Contains one paper on the clinical measurement of dark adaptation and another on it's correlation with visual sensitivity.

Also see abstracts under Color Vision, Depth Perception and Stereopsis, Ocular Muscle Balance, Refractive Error and Refraction, and Visual Acuity-Static.

1968 KINNEY, J.S.; Lurie, S.M.; Weitzman, D.O. — ANALYSIS OF A VARIETY OF VISUAL PROBLEMS ENCOUNTERED DURING NAVAL OPERATIONS AT NIGHT

Extensive Refs. U.S. Naval Sub. Med. Center, Sub. Base, Groton, Conn. Rep. No. 545, August 1968.

The contents include: a discussion of the background information for naval lighting problems at night; the merits of red or white lighting for naval use; comments on the effects of orange versus red preadaptation.

1968 DOHEN, R.H. — NEAR VISUAL ACUITY UNDER LOW LEVEL RED AND WHITE LIGHT

8 Refs. USAF Sch. Aerospace Med., Brooks AFB, Texas. SAM-TR-68-119, October 1968.

The near visual acuity of 17 subjects ages 35-45 years was measured under white light and red light of 0.1 ft.-L luminance level. Near visual acuity was significantly better under white light for acuity demands of 20/30, 20/40 and 20/50. Visual acuity is equally good under red or white light when the acuity demand is 20/70 or larger and the visual acuity is equally poor under red or white when the acuity demand is 20/20.

1969 WEITZMAN, D.O.; Kinney, J.S.; Lurie, S.M. — EFFECT ON VISION OF REPEATED EXPOSURE TO CO_2

7 Refs. Sub. Med. Res. Lab., Sub. Base, Groton, Conn. Rep. No. 566, MF 12.524.004-9015 D.01, February 1969.

The visual effects of repeated exposure to CO_2 at levels commonly regarded as innocuous were investigated. The exposure varied cyclically from 0.03% (air) to 3.0% at one atmospheric pressure every 24 hours for 6 days. It was found that night vision sensitivity was repeatedly impaired during the period of exposure.

Also see abstract under Atmospheric Effects.

VI. DEPTH PERCEPTION AND STEREOPSIS

1908 JAMES, G.T.B. — ON THE MEASUREMENT OF THE STEREOSCOPIC VISUAL ACUITY

5 Refs. Lancet, 1:1763, 1908.

An apparatus was devised on which the Howard-Dolman apparatus was later based. The principle of the apparatus was to exclude all monocular clues, including relative size. Sticks of different sizes were therefore chosen so that when viewed through an aperture at 20 feet, even though they are at different distances behind the aperture they subtend the same visual angle. Mention is also made of a stereoscope for near based on the same principle.

1918 U.S. WAR DEPARTMENT — AIR SERVICE MEDICAL

No Refs. U.S. War Dept., Air Service, Div. of Military Aeronautics, Washington, D.C., U.S. Government Printing Office, 1918.

The report states repeatedly that plane landing requires perfect stereo vision.

Also see abstract under Atmospheric Effects.

1919 SPEARMAN, C. — DISCUSSION ON VISUAL REQUIREMENTS OF AVIATORS: PART III

No Refs. Trans. Ophthal. Soc. U.K., 39 28-36, 1919.

The landing aviator does not use stereopsis to determine how far off the ground is, but only the shape of the ground and speed of approach Hence stereoscopic vision is only of secondary importance in judging distance; it is useful for judging relative distance but not absolute.

1919 HOWARD, H.J. — A TEST FOR THE JUDGEMENT OF DISTANCE

1 Ref. Amer. J. Ophthal., 2:656-675, 1919.

The development of the apparatus was prompted by the aviation standards (1919) in which a hand stereoscope is used, an instrument allowing no quantitative analysis. The apparatus is based on James' apparatus, (1908-see this section above), as it eliminates all cues except binocular parallax and retinal image size. One hundred and six subjects were employed and tables showing their age, occupation, vision, muscle balance, NP accommodation, NP convergence, pupillary distance, and binocular parallactic angle are given. They show a high correlation between small parallactic angle and high quality visual parameters. The best performers had either ortho- or eso-muscle balances, none had exo-. The limit between "normal" and

"abnormal" standards of distance judgement is thought to be 8.0 seconds of arc. This represents approximately 24 1/2 mm for p.d. equals 57 mm to 19 1/2 mm for 72.5 mm p.d. The test is done with a shutter as most judgements are done instantaneously

1931 BERENS, C.; Smith, H.T. — PRESENT OPHTHALMOLOGICAL STANDARDS FOR COMMERCIAL AVIATION IN THE UNITED STATES

106 Refs. Trans. Amer. Ophth. & Laryn., 36th Annual Meeting, 1931.

The report discusses the visual standards for commercial aviation (1931). Certain parts of the ocular examination are clarified and the military and commercial aviation requirements are compared.

P. 316. "Binocular parallactic displacement plays little part at the great distance at which judgement must be made in flying."

P. 319. Case report given of exercises improving stereopsis.

P. 323. Discussion on whether a man should be disqualified on a failed depth perception test alone.

1932 JARMAN, B.L. — MONOCULAR VISION AND OTHER PECULIAR PHASES OF FLYING AS REGARDS DEPTH PERCEPTION

No Refs. J Avia. Med., 3:194-200, 1932.

Depth perception is very important in taking off and landing a plane, especially the latter. To date there were no accidents in which one-eyed pilots were found at fault. A flyer who learns to fly with one eye and has never experienced binocular vision in flying, always depends on monocular clues for depth perception and doesn't contend with the loss of something he has never had during flying. Monocular pilots are often good pilots in spite of their defects and sometimes perform better than those without handicaps. However, since there is adequate and often excessive pilot meterial available, there is no need to certify any handicapped applicant who must depend on one eye.

1933 TOPMOELLER, W.J. — SUGGESTED MODIFICATION OF THE DEPTH PERCEPTION APPARATUS

No Refs. J. Avia. Med., 3:156-157, 1933.

A device is placed over the depth perception apparatus (e.g., the Howard Dolman Box) like a roof, painted black and containing four 25 watt frosted light-bulbs. A small steel bracket screwed at the four corners of the depth perception apparatus prevents the top from slipping and keeps it stationary. This added device is believed to improve the depth perception apparatus by removing shadows and eliminating glare, and preventing applicant from looking over the top which otherwise aids the higher score with this test. The author offers no statistical evidence of improved performance in

depth perception testing using his modification device; or whether or not it is a common accepted modification.

1940 U.S. ARMY TECHNICAL MANUAL 8-300 — NOTES ON EYE, EAR, NOSE AND THROAT IN AVIATION MEDICINE

U.S. Army Tech. Manual 8-300, Government Printing Office, Washington, D.C., 1940.

The actual manual was not seen. The following is abstracted from "McFarland, Ross A., Human Factors in Air Transportation, McGraw-Hill Book Co. Inc., 1st Ed., 1953." Older pilots have learned to use secondary cues. It has been found that a new candidate making an average error greater than 30mm can improve his score by repeated trails, provided he has no ocular defect.

1942 VERHOEFF, F.H. — SIMPLE QUANTITATIVE TEST FOR ACUITY AND RELIABILITY OF BINOCULAR STEREOPSIS

7 Refs. Arch. Ophth., 28:1000-1019, 1942.

The Verhoeff stereoscopic test is explained. The greatest distance is found for which all 8 presentations are correct; the acuity is then deduced as follows-

$$\text{acuity} = \frac{\text{distance}}{100} \qquad \text{(distance in cms)}$$

It is claimed that this test is far superior to the Howard-Dolman test, one of the advantages being that it reduces guessing to a minimum. The two tests are compared at length. In the discussion following the paper, Ascher comments, "accommodation and convergence . . . are of no help whatever at the distances important for flying."

1942 ROWLAND, W.M. — COMPARISON OF HOWARD-DOLMAN DEPTH PERCEPTION TEST, WULFECK GROUP TEST OF STEREO ACUITY AND KEYSTONE DEPTH PERCEPTION APPARATUS

1 Ref. Sch. Avia. Med., Randolph Field, Texas. Proj. No. 59, Rep. No. 1, July 1942.

Extremely low correlation observed.

1945 SLOANE, A.E. Gallagher, J.R. — EVALUATION OF STEREOPSIS: A COMPARISON OF THE HOWARD-DOLMAN AND THE VERHOEFF TEST

5 Refs. Arch. Ophth., 34.357-359, 1945.

The stereoscopic threshold was determined on both the Howard-Dolman and the Verhoeff tests using 186 subjects. The Verhoeff technique had higher coefficients of self reliability between trials and a

far greater sensitivity; it was therefore thought superior. However, the Howard-Dolman test is also useful in determining stereopsis along with other attributes, as against pure stereoscopic ability.

1946 KIRSCHBERG, L.S.S. — DEPTH PERCEPTION AND FLYING ABILITY

18 Refs. Arch. Ophthal., 36:155-170, 1946.

The paper is a summary of results of studies relating ocular muscle balance to depth perception in the RCAF. An excellent survey of the literature is included. The apparatus employed to evaluate stereopsis is a wooden version of Verhoeff's 1942 model reproduced three times larger than the original. The results of the experiments show:

1. Good visual acuity is an important factor in depth perception.
2. Fusion amplitudes and depth perception are independant.
3. There was no relationship between depth perception and heterophorias in 303 subjects.
4. Orthophoria bears no relationship to flying ability.

1950 NICHOLLS, J.V.V. — THE RELATIONSHIP OF HETEROPHORIA TO DEPTH PERCEPTION IN AVIATION

236 Refs. Amer. J. Ophthal., 33:1479, 1775, 1891 (3 parts), 1950.

Includes a most extensive review of the subject.

Also see abstract under Visual Standards.

1950 RIPPLE, P.H. Wilson, M.E. — ANISEIKONIA IN AIR FORCE CADETS AND ITS RELATIONSHIP TO THE HOWARD-DOLMAN DEPTH PERCEPTION TEST

8 Refs. USAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 21-24-010, August 1950.

No relationship was found.

1951 MUELLER, C.G. — SOME FACTORS IN HUMAN VISUAL DISCRIMINATION

30 Refs. From, "Blackwell, H., Minutes and Procs. NRC-Armed Forces Committee on Vision, 29th Meeting, 1951."

The paper includes a brief survey of the generally accepted data concerned with stereoscopic acuity and the discrimination of real depth.

Also see abstract under Dark Adaptation.

1953 ALTMAN, A. Sloan, L.L. — ANISEIKONIA AND THE HOWARD-DOLMAN TEST

12 Refs. J. Opt. Soc. Amer., 43:473-478, No. 6, 1953.

Experiments with 2 subjects showed that aniseikonia in the horizontal meridian produced a constant error of the same direction and magnitude in the setting of the movable rod as the aniseikonia. The errors in the Howard-Dolman test were only 1/3 to 1/2 of that predicted from binocular disparity. The mean variation about the average position varied from day to day.

1957 GERATHEWOHL, S.J. Cibis, P.A. — SURFACE TEXTURE AND DEPTH PERCEPTION

8 Refs. USAF Sch. Avia. Med., Randolph Field, Texas. Rep. No. 57-24, April 1957.

Experiments on the role of irregular texture for depth perception were made using a plate stereometer to measure true and apparent differences as well as effect of illumination on spatial localization. The results were obtained using two groups of ten subjects and indicated that the accuracy of spatial localization of plane-parallel visual surfaces depends on the perception of separate texture elements, i.e. grain size, grain density, and distribution and distinctness of reference points within the surface pattern. Surfaces with coarse and distinct grain seen at bright illumination provided the greatest accuracy of spatial discrimination, but even micro-structure of surface texture improved depth perception when grit density, grain size and conditions under which it is observed furnished transverse disparity and stereoscopic cues.

1958 MILLER, E.F. — EVALUATION OF CERTAIN VISUAL AND RELATED TESTS: V. RETINAL RIVALRY

10 Refs. Nav. Sch. Avia. Med., Pensacola, Florida. Proj. No. NM 14 01 11, Subtask 6, Rep. No. 5, August 1958.

Retinal rivalry as a possible additional screening device is without value. One hundred and twelve naval aviation cadets were examined and it was found the alternation rates bore no relation to their stereoscopic thresholds.

1967 ADAMS, A.J. Levene, J.R. — STEREOSCOPIC DEPTH ASSOCIATED WITH CYCLOTORSIONAL EYE MOVEMENTS

12 Refs. Brit. J. Physiol. Optics, 24.217-220, No. 3, 1967.

The conditions under which cyclotorsional eye movements occur is outlined. It is shown how they may influence depth perception and produce depth illusions. An explanation is given for the recently reported trafic signal illusion (Bugelski).

1968 WHITCOMB, M.A. Benson, W. (Eds.) — THE MEASUREMENT OF VISUAL FUNCTION (SYMPOSIUM) PROCEEDINGS OF SPRING MEETING 1965

Extensive Refs. Armed Forces-NRC Committee on Vision, Washington, D.C., 1968.

The report includes a section on distance vision including stereopsis. One paper consists of a brief review of the instruments to measure stereopsis, another is concerned with the distinction between perceived depth and distance.

Also see abstract under Color Vision, Dark Adaptation, Ocular Muscle Balance, Refractive Error and Refraction, and Visual Acuity-Static.

1968 LURIA, S.M. Weissman, S. — RELATIONSHIP BETWEEN STATIC AND DYNAMIC STEREOACUITY

9 Refs. J. Exptl. Psych., 76:51-56, No. 1, 1968.

Equidistance settings were obtained from 50 subjects with a Howard-Dolman type apparatus which was either stationary or rotating about the subject at angular speeds of 60-180°/second. Correlations between settings decreased as the disparity of the speeds being compared increased and there was a sharp drop in correlation between the stationary position and any speed. At any given speed of rotation, there was an increase in variability of settings as the viewing time decreased, and a sharp increase below 0.3 seconds. A positive localization error was made by 240 subjects and a negative error by 260. There appears to be a relationship between positive errors and exophoria and negative errors and esophoria.

1968 OHLBAUM, M.K. — THE EFFECTS OF ALTITUDE ON CERTAIN ASPECTS OF VISUAL PERFORMANCE

26 Refs. M.S. Thesis, Division of Optometry, Indiana Univ., June 1968.

Some loss of accommodation, convergence and stereopsis was found at altitudes up to 18,000 feet, and quantified against hypoxia. Wilmer's theory of reduced ciliary tonus was apparently negated inasmuch as a slight increase in tonus was found. No plus acceptance at near was found despite large decrements in accommodation. Thus no justification for the present USAF standards of minimum accommodation was found and an absolute minimum of say 4-5 D is suggested. The author agrees with Scobee in that altitude has no significant effect on the 'phorias.

1969 MILLER, N.D. et. al. — RESEARCH ON VISUAL PROBLEMS OF SPACE FLIGHT

5 Refs. NASA, Manned Spacecraft Center, Houston, Texas. NASA Contract No. NAS 9-6865, March 1967-May 1969.

The work covers the investigation of the optical parameters of the Apollo pressure suit helmets and visors, and the effect of optical distortions upon visual performance. The primary visual function investigated is binocular depth perception. Work was also carried out on photokeratitis due to exposure to U-V radiation and the effect of the visual transmittance of the gold-coated lexan visor on color perception. The apparatus used in the binocular vision depth measurements includes:

1. The Leaf Room
2. Howard-Dolman Peg Test
3. Space Eikonometer
4. Tilting Plane Eikonometer
5. Tilting Lunar Surface Model

1969 LURIA, S.M. Kent, P.R. — THE RELATION OF "DUCTION" TO DYNAMIC STEREOACUITY

4 Refs. Sub. Med. Res. Lab., U.S. Nav. Sub. Med. Center, Groton, Conn. Rep. No. 575, April 1969.

The relation between duction break-recovery (B/R) ratios and localisation error in a test of dynamic stereoacuity was examined in 73 young men. Positive (near) localisation errors, esophoria, high negative spherical correction, high adductive and low abductive B/R ratios were found to be related. Positive errors were associated with high adductive and low abductive B/R-midpoints for esophores but the relationship for exophores was not clear. The difference between the adductive and abductive ratios increased with increasing positive error. Differences between the adductive and abductive B/R midpoints were greater for esophores than exophores and increased with increasing positive errors. The magnitude of the error was related to the magnitude of the spherical correction which the subject wore during the experiment. The direction and magnitude of localization errors was not much more predictable from duction measurements than from 'phorias.

VII. DISPLAYS AND VISUAL SIMULATION

1951 RIPPLE, P.H. Rosd, H.W. — VISUAL PROBLEMS OF PILOT IN PRONE POSITION

9 Refs. USAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 21-24-011, Rep. No. 1, August 1951.

The test persons were subjected to an elevated gaze while in a prone position in bed. A determination was made of the muscle balance and ability to maintain the elevated gaze. Elevation of 15-30° gave all subjects discomfort.

1960 HOPKINS, C.O. Bauerschmidt, D.K. Anderson, M.J. — DISPLAY AND CONTROL REQUIREMENTS FOR MANNED SPACE FLIGHT

175 Refs. Aerospace Med. Div., Wright-Patterson AFB, Ohio. Tech. Rep. No. 60-197, April 1960.

A study was made of the display and control requirements for a manned orbital vehicle of the "space-ferry" type. The mission includes launch, rendezvous, re-entry and landing. Displays, controls and control panels were designed to meet these requirements. Representations of these were constructed and incorporated into full-scale mockups of cockpits for 2 alternate display and control systems.

1961 ADAMS, O.S. Chiles, W.D. — HUMAN PERFORMANCE AS A FUNCTION OF THE WORK-REST RATIO DURING PROLONGED CONFINEMENT

5 Refs. Aerospace Med. Lab., Wright-Patterson AFB, Ohio. ASD Tech. Rep. No. 61-720, November 1961.

Many subjects were confined for up to 15 days while they undertook 5 performance tasks including one to detect warning lights and one pattern discrimination test. It was concluded that with proper control of selection and motivational factors, crews can work effectively for periods of at least two weeks and possibly longer using a 4-on and 2-off work-rest schedule.

1961 BUDDENHAGEN, T.F. Wolpin, M.P. — A STUDY OF VISUAL SIMULATION TECHNIQUES FOR ASTRONAUTICAL FLIGHT TRAINING

No Refs. Tech. Rep. 607756, AD 260 093, March 1961.

A study of the engineering requirements for visual simulation in astronaut flight training, and the present techniques used to accomplish the simulation was carried out. The report includes how and why the techniques were developed to optimize the training value of a simulator.

1962 JONES, E.R.
Hann, W.H.

VISION AND THE MERCURY CAPSULE

12 Refs. Armed Forces-NRC Comm. on Vision, Washington, D.C., 1962.

The paper contains predictions of what might be seen and how through the window of the Mercury capsule. This was written, of course, before the first Mercury mission had taken place. Also contained in the paper are pictures of the instrument panels, the window, and refraction through the latter, etc.

1962 MILLER, J.W. (Ed.)

VISUAL PROBLEMS OF SPACE FLIGHT

Extensive Refs. Nat. Acad. of Sciences-Nat. Res. Council, Washington, D.C., 1962.

Pages 20-24: Discussion of visual displays with consideration for the various novel problems of space flight, e.g. absence of gravity and the presence of various accelerative forces.

Also see abstract under Space Flight, Including Reconnaissance and Surveillance.

1962 McNURLTY, C.F.

SIMULATION TECHNIQUES FOR SPACECREW TRAINING: STATE OF ART. REVIEW

No Refs. MRL Tech. Documentary Rep. 62-32, AD 283 343, April 1962.

Simulation technology is discussed, and the present programs for the development of new techniques for spacecrew training are presented. The requirements are given for visual simulation in a simulator, especially those which demonstrate extravehicular views that would have to be observed by the astronaut.

1963 PFEIFFER, M.G.
Clark, W.C.
Danaher, J.W.

THE PILOTS VISUAL TASK: A STUDY OF VISUAL DISPLAY REQUIREMENTS

33 Refs. U.S.N. Training Device Center, Port Washington, N.Y. Contract No. N61339-783. AD 407440, March 1963.

An analysis was made of the perceptual characteristics of the pilots visual world while performing various flight tasks. These were compared with the perceptual characteristics made available by typical non-programmed visual displays attached to flight trainers. An experiment was then conducted in an F-100 simulator equipped with 151 visual attachments to determine training effects. It was found that even among experienced subjects, the performance was significantly improved, both with regard to the detection of in-flight emergencies and the maintenance of aerodynamic stability. Recommendations are made for improvements in the external visual displays of flight simulators to enhance their training value.

1963 BUDDENHAGEN, T.F.
Johnson, A.E.
Stephan, S.C.
Wolpin, M.P.

DEVELOPMENT OF VISUAL SIMULATION TECHNIQUES FOR ASTRONAUTICAL FLIGHT TRAINING

10 Refs. Behavorial Systems Laboratory, Aerospace Med. Div., Air Force Systems Command, Rep. No. AMRL-TDR-63-54, Vol. 1, June 1963.

This paper considers the uses of high resolution television and an electronic planetarium as visual simulators.

1964 GAINER, C.A.
Obermayer, R.W.

PILOT EYE FIXATIONS WHILE FLYING SELECTED MANEUVERS USING TWO INSTRUMENT PANELS

16 Refs. Human Factors, 6:485-501, 1964.

The first panel configuration had vertically moving tape, the second a round dial. Sixteen subjects were tested in a MB-5 Simulator with flight characteristics of a high performance jet aircraft. Standardized flight profiles were employed. The data collected allows analysis of system performance, eye movements and a correlation of performance and eye movements for each combination of maneuvers and instrument panels. There was no clear-cut distinction between ease of reading vertical or circular instruments, a vertical instrument being preferred for some measurements and a circular for others. It appears that the vertical panels gave more feedback from supporting instruments through peripheral vision.

1968 AUERBACH CORPORATION

VISUAL INFORMATION DISPLAY SYSTEMS-A SURVEY

14 Refs. 96 pp. Chap. VII. Simulation Display Systems (pp.77-84), Office of Technology Utilisation, NASA, Washington, D.C., 1968.

Interesting chapter on computer-simulated space flight, both from the spectator and the astronauts point of view.

1968 VALVERDE, H.H.

FLIGHT SIMULATORS: A REVIEW OF THE RESEARCH AND DEVELOPMENT

Extensive Refs. Aerospace Med. Res. Lab., Aerospace Med. Div., Wright-Patterson AFB, Ohio. July 1968.

General review of flight simulators (research and development) since 1949. The report does not include mathematical models and space flight simulators.

VIII. EFFECTS OF VIBRATION

1966 HOLLAND, C.L. — PERFORMANCE AND PHYSIOLOGICAL EFFECTS OF LONG TERM VIBRATION

14 Refs. Aerospace Med. Res. Labs., Aerospace Med. Div., Air Force Systems Command, Wright-Patterson AFB, Ohio. AMRL-TR-66-145, October 1966.

The investigation was of human performance as a function of selected parameters of simulated, random, vertical vibration environments. Twelve subjects were subjected to 4 different vertical vibration environments for 6 hours at a session. The subjects had to perform 2-dimensional, compensatory tracking and secondary visual and auditory loading tasks. The visual task consisted of reactions to red and green warning lights. It was found that the subjects reacted quicker to lights than control when 2 cps = power peak but slower when 5 cps = power peak.

1968 SHOENBERGER, R.W. — INVESTIGATION OF THE EFFECTS OF VIBRATION ON DIAL READING PERFORMANCE WITH A NASA PROTOTYPE APOLLO HELMET

3 Refs. Aerospace Med. Res. Labs., Aerospace Med. Div., Air Force Systems Command, Wright-Patterson AFB, Ohio. AMRL-TR-67-205, February 1968.

Sinusoidal vibration was used and the force of gravity was passed through the X-axis of the body (subject lying down) with vibration in the X-axis in one experiment, and in the Y-axis in another. Dial-reading ability was assessed at 6, 11, and 15 Hz. with the helmet, with and without a liner. The vibration intensity varied ± 1.2 G in the X-axis experiment, and ± 0.96 G in the Y-axis experiment. The results showed that along the X-axis, dial-reading performance deteriorated most at 11 Hz., less so at 15 Hz. and even less at 6 Hz. Along the Y-axis, the dial-reading performance tends to increase with increasing Hz., but it was better with a liner at 6 Hz. and without a liner at 15 Hz.

1968 RUBENSTEIN, L.
Kaplan, R. — SOME EFFECTS OF X-AXIS VIBRATION ON VISUAL ACUITY

6 Refs. Aerospace Med. Res. Labs., Aerospace Med. Div., Air Force Systems Command, Wright-Patterson AFB, Ohio. AMRL-TR-68-19, June 1968.

Four experiments were conducted to measure vernier visual acuity during sinusoidal vibration of the head in the Y-axis (side-to side). In one half of each experiment, peak acceleration amplitude was held constant at one G, in the other half displacement amplitude was held constant at 0.03 cm. Frequency was the main independant variable.

Experiments I and II examined the effects of vibrating the head at frequencies from 13-78 Hz. These showed in both the constant acceleration and constant displacement conditions acuity is a U-shaped function of frequency and has a minimum in the range of 26-34 Hz.

Experiment III examined effects of vibrating a target. Decrements in acuity due to target vibration were smaller than those due to head vibration under comparable conditions.

Experiment IV also examined effects of vibrating the head as I and II, except orientation of the vernier target with respect to axis of vibration was changed from perpendicular, i.e. vertical, to parallel, i.e. horizontal.

No differences were found between acuity scores produced by the vertically and horizontally orientated targets, for either the constant displacement or the constant acceleration condition.

IX. FLASH BLINDNESS, GLARE AND RADIATION EFFECTS

1923 BRITISH JOURNAL OF OPHTHALMOLOGY — SECTION OF OPHTHALMOLOGY: DISCUSSION ON OPHTHALMOLOGY IN ITS RELATION TO THE NAVY, ARMY AND AIR FORCE

1 Ref. Brit. J. Ophthal., 2:654-658, 1923.

This paper is an example of collective opinion influencing visual standards rather than experimental evidence. For example, "recent experience seems to show that for the pilot the most important effect of glare is to cause lack of convergence and accommodation."

Also see abstract under Ocular Muscle Balance.

1957 HAMILTON, C.E.; Blackwell, H.R. — THE EFFECT OF A HORIZON-LINE LUMINANCE GRADIENT UPON TARGET DETECTABILITY IN ITS VICINITY

3 Refs. Engineering Research Institute, Univ. of Michigan, U.S. Navy Bureau of Ships, Contract No. Nobs-72038, April 1957.

Three series of experiments were reported indicating the magnitude and spatial extent of effects of a horizon-line luminance gradient upon the detectability of nearby targets.
1st series-targets were viewed foveally against non-uniform background fields of photopic luminances.
2nd series-targets were viewed peripherally against non-uniform background fields of scotopic luminances.
3rd series-targets were viewed against uniform backgrounds covering the range from photopic to scotopic luminances (providing a basis for evaluating some of the findings of the first 2 series).
The targets were always presented for 1 second. Results showed a luminance gradient of 2:1 from above to below the horizon-line raises the threshold contrast by only moderate amounts. With the target above the horizon, the target threshold contrast increased less than 14% compared with the uniform field, regardless of the position of the target with respect to the horizon-line. With the target below the horizon, threshold contrast increased by 39% when the target was just adjacent to the horizon. It decreased less than 7% when the target was removed 20 feet from the horizon-line. The horizon-line effect is reduced as the background luminance decreases, being zero for scotopic luminance levels.

1958 METCALF, R.D.; Horn, R.E. — VISUAL RECOVERY TIMES FROM HIGH INTENSITY FLASHES OF LIGHT

9 Refs. Wright Air Dev. Center, Wright-Patterson AFB, Ohio. WADC Tech. Rep. No. 58-232, Astia. Doc. No. AD 205543, October 1958.

Four subjects were exposed to a level of illumination comparable to that likely to be encountered during nuclear operations, and their visual recovery was recorded. Extrapolation of the results to the estimated burn threshold indicates a maximum recovery time of 170 seconds to discriminate a brightness contrast comparable to reading red-lit aircraft instruments.

1959 LEBISH, I.J. et. al. — OBSERVATIONS ON MICE EXPOSED TO COSMIC RADIATION IN THE STRATOSPHERE: A LONGEVITY AND PATHOLOGICAL STUDY OF 85 MICE

No Refs. Military Medicine, 24:835-847, 1959.

See abstract under Atmospheric Effects.

1960 STEUGHOLD, H.; Ritter, O.L. — EYE HAZARDS AND PROTECTION IN SPACE

14 Refs. J. Aerospace Med., 31:670-673, 1960.

The report is concerned exclusively with the sun and retinal burns (includes photographic and subjective reports). The report gives data of solar irradiance near the various planets and explains why the critical time of exposure to the sun to produce retinitis solaris DOES NOT decrease appreciably as the sun is approached.

1961 ALLEN, M.J. — A STUDY OF VISUAL PERFORMANCE USING OPHTHALMIC FILTERS

No Refs. Aerospace Med. Lab., Wright-Patterson AFB, Ohio. ASD Tech. Rep. 61-576, October 1961.

A gradient density filter was found to be superior to naked vision or other filters at about 7,000 ft.-lambers. A Link trainer instrument panel was used and atmospheric conditions were controlled.

1961 SEVERIN, S.L. — RECOVERY OF VISUAL DISCRIMINATION AFTER HIGH INTENSITY FLASHES OF LIGHT

23 Refs. Sch. of Aerospace Med. USAF, Brooks AFB, Texas. 1961.

This study attempts to evaluate the use of a Zeiss Light Coagulator as an experimental source to determine the relationship between exposures of high intensity light and visual recovery. General conclusion: the Zeiss Light Coagulator may be used as a research tool to investigate flash blindness and whether or not it can be measured. "Recovery from dazzle is consistent and repetitive within acceptable units for biologic experimentation." Also, the recovery time increases with increasing intensity of illumination, and the functional loss of vision following a dazzle is decreased by increasing the luminance of the task to be viewed.

1962 SEVERIN, S.L. — A NEW APPROACH TO THE STUDY OF FLASH BLINDNESS
Newton, H.L.
Culver, J.F.

9 Refs. Arch. Ophthal., 67:62-66, 1962.

The study showed that the Meyer-Schwickerath Zeiss light coagulator can be used as a research tool to investigate flash blindness. Results indicated that dazzle recovery is consistent and repetitive within acceptable limits for biological experimentation. All test flashes were of 0.15 sec. duration. Two main trends in the results were found: (1) recovery time increased with increasing intensity of the test flash; (2) time of functional visual loss following dazzle decreased by increasing luminance of the task to be viewed.

1962 SAYLOR, W.P. — SPACE RADIATION GUIDE
Carriker, A.W.
Riwen, C.J.
Winer, D.E.

201 Refs. Aerospace Med. Div., Wright-Patterson AFB, Ohio. Proj. No AMRL-TDR-62-86, August 1962.

The report contains a very comprehensive guide and bibliography. Sections are presented on:

1. Solar Radiation - includes sunspots, solar flares, solar electromagnetic and corpuscular radiation, flare radiation dosage, and proton events.
2. The Van-Allen Belt - includes inner and outer zones, shape, composition, and biological effects.
3. Galactic Cosmic Radiation - includes properties and effects.
4. Biological Effects of Space Radiation - includes absorption, human response, and biological protective measures.
5. Instrumentation
6. Shielding Requirements for Manned Space Flight - includes passage of radiation through matter, and protection against various primary and secondary radiations.

1968 LAPPIN, P.W. — ANALYSIS OF THE FIRST THERMAL NUCLEAR PULSE
Adams, C.F. — AND ASSOCIATED EYE EFFECTS

2 Refs. Aerospace Med. Res. Labs., Aerospace Med. Div., Wright-Patterson AFB, Ohio. Rep. No. AMRL-TR-67-214, December 1968.

The mathematical presentation of the data of the first thermal pulse was obtained in the Dominic Test Series in 1962. An analysis was made of the retinal irradiances form the first thermal pulse energy from weapon yeilds of 1 to 3,000 kilotons. Retinal irradiances were shown to decrease with increasing yield and fall well below the threshold burn levels for yields of 1 kiloton or greater. Since the time to minimum for 1 kiloton detonation is about 2.5 milliseconds and increases with weapon yields, it is concluded that closure of eye

protective devices need only occur after this time for low altitude detonation of 1 kiloton or greater.

1969 PITTS, D.G. — THE EFFECTS OF ULTRAVIOLET RADIATION ON THE EYE

25 Refs. USAF Sch. Avia. Med., Aerospace Med. Div., Brooks AFB, Texas. Proj. No. SAM-TR-69-10, February 1969.

The source used was an argon gas forced transpiration arc. Calibration techniques, monitoring instrumentation, and procedures for studying the effects of ultraviolet on the eye were presented. Rabbit eyes were used, plus some human material. Photophthalmia thresholds were established for various wavelenghts and predictions made for keratitis thresholds for man in outer space. Electron microscopy photographs are included as evidence. Results are presented for lethality in the exposed rabbit cells. It was noted that the critical radiant exposure for photokeratitis in man will be surpassed unless protection is given. Stress is also given to the extreme accuracy required of ultraviolet transmission data of protective devices for it to have useful engineering applications.

X. FLICKER FUSION FREQUENCY

1953 BROZEK, J. — CHANGES IN FLICKER FUSION FREQUENCY UNDER STRESS
Simonson, E.
Taylor, H.L.

7 Refs. USAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 21-32-004, Rep. No. 3, October 1953.

Within a framework of studies on changes of "fitness", the flicker fusion frequency was determined during a control period and under the following conditions:
1. Moderate visual strain
2. Strenuous visual strain
3. Nutritional stresses
4. Miscellaneous severe stresses--hard physical work, work in hot environment and lack of sleep.

The mechanism involved in depression of the fusion level when demonstrated (starvation, strenuous visual work) is not clear and probably varies. The experiment shows the decrease of fusion level cannot serve as an index of degree of involvement of the central nervous system in biologic stresses of the type applied in this study, or that this involvement is minimal.

1962 BEISCHER, D.E. — EXPOSURE OF MAN TO LOW INTENSITY MAGNETIC FIELDS
Miller, E.F.

35 Refs. U.S. Naval Sch. Avia. Med., U.S. Nav. Avia. Med. Center, Pensacola, Florida. July 1962.

Two subjects were exposed for 10 days to a magnetic field of 1/1000 geomagnetic field (50 gamma). The results of a number of physiological and psychological tests were not affected, including space perception. However, decrements were observed in the visual field and especially peripheral critical flicker frequency.

1967 BEISCHER, D.E. — EXPOSURE OF MAN TO LOW INTENSITY MAGNETIC FIELDS IN A COIL SYSTEM
Miller, E.F.
Knepton, J.C.

22 Refs. Nav. Aerospace Med. Inst., NASA NAM1-1018, October 1967.

Travel beyond the earth environment will mean near absence of a magnetic field. This paper is a continuation of the 1962 study by the same authors. It supports the previous study in that the scotopic flicker fusion frequency gradually decreases. This is reversed after exposure. Problems of life in a magnetic field free environment are discussed.

XI. HARDWARE, INCLUDING OPHTHALMIC INSTRUMENTS

1918 U.S. WAR DEPARTMENT — AIR SERVICE MEDICAL

No Refs. U.S.War Dept., Air Service, Div. of Military Aeronautics, Washington, D.C., U.S. Government Printing Office, 1918.

A description and picture of the Dreyer apparatus, the Flack bag and the rebreathing apparatus are given.

Also see abstract under Atmospheric Effects and Depth Perception and Stereopsis.

1933 TOPMOELLER, W.J. — SUGGESTED MODIFICATION OF THE DEPTH PERCEPTION APPARATUS

No Refs. J. Avia. Med., 3:156-157, 1933.

See abstract under Depth Perception and Stereopsis.

1935 GLENN, C.R. — A PRELIMINARY REPORT ON A PERFORMANCE TEST FOR FLYING

No Refs. J. Avia. Med., 6:14-19, 1935.

The paper discusses the modification of the O'Rowke complex coordinator. No visual considerations are made.

1938 HECHT, S. — AN ADAPTOMETER FOR MEASURING HUMAN DARK ADAPTATION
Schlaer, S.

24 Refs. J. Opt. Soc. Amer., 28.269-275, 1938.

See abstract under Dark Adaptation.

1942 VERHOEFF, F.H. — SIMPLE QUANTITATIVE TEST FOR ACUITY AND RELIABILITY OF BINOCULAR STEREOPSIS

7 Refs. Arch. Ophthal., 28:1000-1019, 1942.

See abstract under Depth Perception and Stereopsis.

1944 ADAMS, J.K. — A TEST-RETEST RELIABILITY STUDY OF THE BAUSCH AND LOMB ORTHO-RATER WITH NAVAL PERSONNEL
Beier, D.C.
Imus, H.A.

No Refs. Univ. of Wisconsin, Madison, Wisconsin. OSRD Rep. No. 3969, August 1944.

The occupational vision tests with the Orthorater are sufficient for the present purposes. The far and near point tests appear to be of equivalent reliability.

1945 SLOANE, A.E. Gallagher, J.R. — EVALUATION OF STEREOPSIS: A COMPARISON OF THE HOWARD-DOLMAN AND THE VERHOEFF TEST

5 Refs. Arch. Ophthal., 34:357-359, 1945.

See abstract under Depth Perception and Stereopsis.

1946 KIRSCHBERG, L.S.S. — DEPTH PERCEPTION AND FLYING ABILITY

18 Refs. Arch. Ophthal., 36:155-170, 1946.

No relationship was found between depth perception scores, heterophoria and flying ability for 303 subjects using a modified Verhoeff instrument.

Also see abstract under Depth Perception and Stereopsis.

1947 SCOBEE, R.G. Green, E.L. — TESTS FOR HETEROPHORIA

9 Refs. Amer. J. Ophthal., 30:436-451, 1947.

The paper is concerned with the comparison of red and white Maddox rods in the evaluation of heterophoria.

Also see abstract under Ocular Muscle Balance.

1951 MUELLER, C.G. — SOME FACTORS IN HUMAN VISUAL DISCRIMINATION

30 Refs. From, "Blackwell, H., Minutes and Procs. of the NRC-Armed Forces Comm. on Vision, 29th Meeting, 1951."

Much data on the Radium Plaque Adaptometer is given, together with a discussion of the use of binoculars for night vision.

Also see abstract under Depth Perception and Stereopsis.

1956 GLOVER, H.C. — HIGH ALTITUDE HELMET VISUAL PROBLEMS

1 Ref. Wright Air Dev. Center, Wright-Patterson AFB, Ohio. WADC Tech. Rep. 56-572, ASTIA Doc. No. AD 110543, November 1956.

An analysis is made of the various visual problems in the design and usage of the high altitude suit visors. The visual problems include fields of view, optical distortions, eye relief, antifogging

and antifrosting. The design criteria for helmet visors is outlined.

1959 BIESELE, R.L. — AUTOMATIC TEMPERATURE CONTROLLERS FOR THE MA-1 ALTITUDE HELMET VISOR

No Refs. 4 Appendices on Controller Specifications, Aero. Med. Lab., Wright-Patterson AFB, Ohio. WADC Tech. Rep. 59-232, AF 33(616)-5250, May 1959.

The report covers the technical aspects of a contract for the development of automatic temperature controllers for the MA-1 Altitude Helmet Visor. The controllers were designed to be mounted inside a new high altitude helmet and to maintain the interior surface temperature of the helmet visor by control of the power supplied to an electrical heating coating provided in the visor. The controller is transistorized and may be installed in helmets already provided by the Air Force.

1960 ALLEN, M.J. Carter, J.H. — AN INFRA-RED OPTOMETER TO STUDY THE ACCOMMODATIVE MECHANISM

Amer. J. Optom. & Arch. Amer. Acad. Optom., 37:403-407, 1960.

The apparatus continuously monitors the accommodative state.

1961 ALLEN, M.J. — A STUDY OF VISUAL PERFORMANCE USING OPHTHALMIC FILTERS

No Refs. Aerospace Med. Lab., Wright-Patterson AFB, Ohio. ASD Tech. Rep. 61-576, October 1961.

See abstract under Flash Blindness, Glare and Radiation Effects.

1961 SEVERIN, S.L. — RECOVERY OF VISUAL DISCRIMINATION AFTER HIGH INTENSITY FLASHES OF LIGHT

23 Refs. Sch. of Aero. Med. USAF, Brooks AFB, Texas. 1961.

See abstract under Flash Blindness, Glare and Radiation Effects.

1965 GILLESPIE, K.W. — COMPARITIVE EVALUATION OF USAF STANDARD A/P22S-2 AND IMPROVED A/P22S-2A HIGH ALTITUDE, FULL PRESSURE FLYING OUTFITS

4 Refs. Systems Engineering Group, Res. & Tech. Div., Wright-Patterson AFB, Ohio. Rep. No. SEG-TR-65-9, April 1965.

This report is concerned mostly with the suit itself. However, it

contains several photos of the helmet and the complete optical test data of the helmet for refractive and prismatic power, transmittance and haze.

1966 CARPENTER, J.A. — EVALUATION OF 2% GOLD VISOR
Richey, E.O.

No Refs. USAF Sch. Aerospace Med., Brooks AFB, Texas. Proj. No. SAM-TR-66-71, August 1966.

Results are given of a flight evaluation to determine if the use of a 2% gold visor in daylight degraded the performance of flight duties. Thirteen pilots flew 17 sorties. Slightly diminished vision under cloudy conditions was experienced by some individuals, although missions were all satisfactorily completed. A 2% gold visor is recommended during daylight hours for eye protection from nuclear explosions.

1967 ROCCO, R.M. — RESEARCH AND DEVELOPMENT OF HELMET FACEPIECES FOR SPACE PROTECTIVE ASSEMBLIES

No Refs. Aerospace Med. Res. Lab., Wright-Patterson AFB, Ohio. Rep. No. AMRL-TR-66-193, January 1967.

The tolerances were described within which materials for facepieces should fall. Tests were also described to evaluate the flatness, distortion, radiation transmission, and solar irradiation of the materials.

1968 SHOEMBERGER, R.W. — INVESTIGATION OF THE EFFECTS OF VIBRATION ON DIAL READING PERFORMANCE WITH A NASA PROTOTYPE APOLLO HELMET

3 Refs. Aerospace Med. Res. Lab., Aerospace Med. Div., Air Force Systems Command, Wright-Patterson AFB, Ohio. AMRL-TR-67-205, February 1968.

See abstract under Effects of Vibration.

1968 TREDICI, T.J. — SPECTACLES IN THE COCKPIT
Kislin, B.

12 Refs. Digest XIX, No. VI, Pp. 16-20, 1968.

Twenty-eight per cent of the required medical data for pilot candidates in the USAF is devoted to eye findings. "The visual standards for eligibility for pilot training have changed little since their establishment. As of mid-year 1967 nearly 40% of the Air Force pilots were of the presbyopic zone"—this would seem to mean over 40 years old. As most older aircraft use red cockpit lighting at night, chromatic aberrations exaggerate presbyopia. Flat top bifocals

are the standard issue, but others, e.g. baseball-type, can be supplied.

1968 DECKER, T.A. — RESEARCH LEADING TO NEW VISION TEST TECHNIQUES FOR USE IN THE SPACE ENVIRONMENT
Sperling, H.G.
Paintsmida, T.

90 Refs. NASA/Ames Res. Center, Moffett Field, California. Grant No. NGR 44-012-099, October 1968.

The paper concerns the development of a space borne vision tester for use in the NASA Apollo Applications Program. The report is divided into the selection of visual functions to be measured, the initial phases of new test development and the gathering of baseline data to aid in the evaluation of new vision tests. It reviews the special stressors of the space environment and on this basis selects the visual parameters that should be monitored. These include: a test of binocular coordination; a test of visual fields, a test of retinal sensitivity; a test of intraocular pressure.

1969 CROSLEY, J.K. — AN EVALUATION OF OPHTHALMIC PLASTIC (CR-39) LENSES IN THE U.S. ARMY AVIATION ENVIRONMENT
Bailey, R.W.
Fischer, F.H.

7 Refs. U.S. Army Aeromedical Res. Lab., Fort Rucker, Alabama. USAARL Rep. No. 69-3, February 1969.

Twenty-five army aviators with various refractive errors were selected to test-wear both clear and tinted CR-39 lenses for 6 months. Subjective evaluations were made of the impact resistance, scratch resistance, weight, optical clarity, comfort, cleaning ease, resistance to breakage, and accumulation of foreign material. The user's acceptance was quite good. Lens scratching was not found to be a significant problem. Favorable recommendations are made concerning the general use of ophthalmic lenses for U.S. Army Aviation personnel.

1969 MILLER, N.D. — RESEARCH ON VISUAL PROBLEMS IN SPACE FLIGHT
et. al.

5 Refs. NASA, Manned Spacecraft Center, Houston, Texas. NASA Contract No. NAS 9-6865, March 1967-May 1969.

See abstract under Depth Perception and Stereopsis.

1969 LALIBERTE, A.J. — DESIGN, DEVELOPMENT AND PRODUCTION OF PRESSURE SUIT SPECTACLES

No Refs. NASA Manned Spacecraft Center, R & D Procurement Branch, Contract NAS 9-8090. Submitted by Univis Inc., Omnitech Division,

Route #131, Dudley, Mass. 01550. July 1969.

The author was commissioned by NASA to produce spectacles suitable to be worn in space. As well as correcting any errors, they must also:

1. protect against both infrared and ultra-violet solar radiation.
2. provide the widest possible field of vision.
3. should be able to withstand high gravitational forces without dislodging.

The paper describes the difficulties of under taking such a project and contains transmission curves for the various plastic lenses and sideshields.

1970 DECKER, T.A. Sperling, H.G. — RESEARCH LEADING TO NEW VISION TEST TECHNIQUES FOR USE IN THE SPACE ENVIRONMENT

Univ. of Texas Graduate Sch. of Biomedical Sciences, Texas Medical Center, Houston, Texas. NASA Grant No. NGR-44-012-099, January 1970.

This paper follows that of October 1968 which dealt with the nature of the problem and the initial stages of its investigation. It is concerned with the specific procedures and instruments set out in the previous paper.

XII. ILLUSIONS AND VISUAL PERCEPTION

1. ANISEIKONIA
2. AUTOKINESIS
3. CYCLOTORSIONAL EYE MOVEMENTS
4. GRAVITATIONAL AND VESTIBULAR EFFECTS
5. NIGHT MYOPIA, SPACE MYOPIA AND GANZFELD
6. ROLE OF INSTRUCTION

1. ANISEIKONIA

1942 ELLIOT, A.J. — RELATIONSHIP OF ANISEIKONIA TO FLYING PERFORMANCE IN 175 CRASED TRAINING PILOTS AND 50 EXPERIENCED PILOTS

Canadian National Research Council, Ottawa, Canada. Rep. C-2151, June 1942. Extract from McFarland, R.A., Human Factors in Air Transportation, McGraw-Hill Book Co. Inc., New York. 1953.

Aniseikonic lenses of magnification 1, 2, 3, and 4% at axes 45°, 90°, 135°, and 180° were worn in a series of flights on RCAF aircraft. Most marked effects were noticed when landing on a level grass field some distance from boundaries where no parked aircraft or other monocular clues were present. A similar situation would be smooth water away from a shore or land after a snowfall. In extreme conditions of aniseikonia, pilots tend to fly into the ground as the latter seemed farther away than it was.

1943 DARTMOUTH EYE INSTITUTE — INCIDENCE AND EFFECT OF ANISEIKONIA ON AIRCRAFT PILOTAGE

Dart. Eye Inst., CAA Tech. Rep. 30, Government Printing Office, Washington, D.C., 1943. Extract from McFarland, R.A., Human Factors in Air Transportation, McGraw-Hill Book Co. Inc., New York, 1953.

Two hundred and eighty cadets were given the following tests: (1) Eikonometer Test; (2) Leafroom Test; (3) Frontal Plane Apparatus Test. The amounts of aniseikonia found were very small. No relationship was found between aniseikonia and either (1) pilot success or failure to pass course, (2) difficulty in landing. Nearly all cadets had less than 1% of aniseikonia.

1950 RIPPLE, P.H. Wilson, M.R. — ANISEIKONIA IN AIR FORCE CADETS AND ITS RELATIONSHIP TO THE HOWARD-DOLMAN DEPTH PERCEPTION TEST

8 Refs. USAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 21-24-010, August 1950.

No relationship was found.

1951 CIBIS, P.A. THE EFFECT OF RETINAL ILLUMINATION ON VISUAL PERCEPTION OF SPACE: I. EXPERIMENTAL STUDIES RELATED TO A SPECIAL TYPE OF ANISEIKONIA

62 Refs. USAF Sch. Avia. Med., Brooks AFB, Texas. Rep. No. 1, Proj. No. 21-31-011, March 1951.

Analysis was made of a special type of aniseikonia due to differences in retinal illumination, the state of refraction or in relational threshold of brightness. Spatial distortion and angular disparity between correlated boundaries of real and apparent patterns increase as differences in retinal illumination, refraction, and sensitivity to light increase. Threshold amplitude of depth discrimination remains constant.

1953 ALTMAN, A. Sloan, L.L. ANISEIKONIA AND THE HOWARD-DOLMAN TEST

12 Refs. J. Opt. Soc. Amer., 43:473-478, No. 6, 1953.

See abstract under Depth Perception and Stereopsis.

1953 McFARLAND, R.A. HUMAN FACTORS IN AIR TRANSPORTATION

Extensive Refs. McGraw-Hill Book Co. Inc., New York, 1953.

Page 138. "Present visual selection procedures (of aviation pilots) based on high visual acuity, low refractive errors, and good muscle balance would tend to eliminate subjects with over 1% of image disparity. There seems little justification for including tests for aniseikonia in routine selection, although they may be useful as diagnostic measures in examining borderline cases."

Also see abstract under Atmospheric Effects.

ii. AUTOKINESIS

1962 MILLER, E.F. Graybiel, A. COMPARISON OF AUTOKINETIC MOVEMENT PERCEIVED BY NORMAL PERSONS AND DEAF SUBJECTS WITH BILATERAL LABYRINTHINE DEFECTS

10 Refs. Aerospace Med., 33:1077-1080, 1962.

The main conclusion using 9 normal and 9 bilateral labyrinthine defective subjects was that the sensory organs of the inner ear are not essential for the perception of autokinetic movement.

1967 PITTS, D.G. VISUAL ILLUSIONS AND AIRCRAFT ACCIDENTS

101 Refs. USAF Sch. Avia. Med., Brooks AFB, Texas. SAM-TR-67-28, April 1967.

A complete discussion of spatial disorientation and autokinetic, oculogyral, oculogravic and coriolis illusions is given. Proposed research is outlined and recommendations are given for minimizing the effects of illusions on the pilot. Darkness, inclement weather and emotional stress factors are discussed.

iii. CYCLOTORSIONAL EYE MOVEMENTS

1838 WHEATSTONE, C. CONTRIBUTIONS TO THE PHYSIOLOGY OF VISION

Phil. Trans. R. Soc., 371-394, 1838.

1840 TOURTUAL, J. BERICHT ÜBER DIE HEISTUNGEN IM GEBIETE DER PHYSIOLOGIE DER SINNE, INSBESANDERE DES BESICHTSSINNES

Muller's Arch. Anat. N. Physiol., 56, 1840.

1854 GRAEFE, A. von BEITRAGE ZUR PHYSIOLOGIE UND PATHOLOGIE DER SCHIEFEN AUGENMUSKELN

v. Graefes Arch. Ophthal., 1·28-50, 1854.

1961 AUBERT, H. EINE SCHEINBORE BEDEUTENDE DREHUNG VON OBJEKTEN BEI NEIGUNG DES KOPFES NACH RECHTS ODER LINKS

Virchows Arch., 20.381-393, 1861.

1865 JAVAL, E. DE LA NEUTRALISATION DANS L'ACTE DE LA VISION

Ann. Oculist, Paris, 54:5-16, 1865.

1868 NAGEL, A. ÜBER DIE VORKOMMEN VON WAHREN ROLLUNGEN DES AUGES UM DIE GESICHTSLINIE

Arch. f. Ophthal., 14:228-246, 1868.

1870 AUB, J. / Knapp, F. — FINDEN RODDREHUNGEN DER AUGEN BEI SEITWARTSNEIGUNGEN DES KOPFES STATT

Knapps Arch. Augen-Ohrenheilk, 1:232, 1870.

1870 DONDERS, F.C. — DIE BEWEGUNGEN DES AUGES, VERANSCHAUBLICHT DURCH DAS PHANOPHTHALMOTROP

v. Graefes Arch. Ophthal., 16:154, 1870.

1871 SKREBITZKY, A. — EIN BEITRAG ZUR LEHRE VON DEN AUGENBEIVEGUNGEN

v. Graefes Arch. Ophthal., 17:107, 1871.

1871 WOLKOW, M. — BEITRÄGL ZUR LEHRE VON DEN AUGENBEWEGUNGEN

v. Graefes Arch. Ophthal., 17:233, 1871.

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Wein. Med. Jahrb., 4:72-124, 1874.

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Acad. Proefschrift. Onderzoch. Physiol. Laborat te Utrecht., 3:168ff, 1874.

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Ophthal. Rec., 5:175-178, 1895.

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Z. Physiol. Psychol. Sinnesorg. 12:331-354, 1896.

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Arch. Ophthal. Paris, 17:465-474, 1897.

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Arch. Ophthal., 26:181-203, 1897.

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Arch. ges. Physiol., 80.1-40, 1900.

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Psychol. Rev., 22:354-370, 1915.

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Acta. Oto-laryng (Stockholm), 6:170-174, 1924.

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Amer. J. Physiol. Opt., 7.3-38, 1926.

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Brit. J. Psychol., 19:117-146, 1928.

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Acta Oto-laryng (Stockholm), 12:332-350, 1928.

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v. Graefes Arch. Ophthal., 122:562-571, 1929.

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v. Graefes Arch. Ophthal., 123.476-508, 1930.

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Arch. Ophthal., 30.54-64, 1943.

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Amer. J. Optom., 24, No. 7, 1947.

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Amer. J. Optom., 31:297-307, 1954.

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1962 SCHÖNE, H. ÜBER DEN EINFLUSS DER SCHWERKROFT AUF DIE AUGENROLLUNG UND AUF DIE WAHRNEHMUNG DER LAGE IM RAUM

Z. vergl. Physiol., 46:57-87, 1962.

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Aerospace Medicine, 37.399-403, 1966

1967 ADAMS, A.J. Levene, J.R. — STEREOSCOPIC DEPTH ASSOCIATED WITH CYCLO-TORTIONAL EYE MOVEMENTS

Brit. J. Physiol. Optics, 24 217-220, 1967.

See abstract under Depth Perception and Stereopsis.

1967 ALLEN, M.J. Carter, J.H. — THE TORSION COMPONENT OF THE NEAR REFLEX

Amer. J. Optom., 44 343-349, 1967.

1967 BUGELSKI, B.R. — TRAFFIC SIGNALS AND DEPTH PERCEPTION

Science, 157·1464, 1967.

1968 DIEKER, P. — REGISTRATION OF CIRCULAR EYE MOVEMENTS

Ber Deutsch Ophthal. Ges., 68:477-479, 1968.

1968 FRY, G.A. — NOMOGRAMS FOR TORSION AND DIRECTION OF REGARD

Amer. J. Optom., 45.631-641, 1968.

1968 JANEKE, J.B. — BARBECUE ROTATION IN COMBINATION WITH SINUSOIDAL ROTATION ABOUT A VERTICAL AXIS

Acta Oto-laryng (Stockholm), 65:244-250, 1968.

1968 OKADA, H. — A VERGENCE TEST, ESPECIALLY ON ABNORMAL TORSIONAL EYE MOVEMENTS

Polia. Ophthal. JAP, 19/6, (Pp. 715-723), 1968.

1968 QUÉRÉ, M.A. et. al. — PSEUDO-TORSION OF OBLIQUE MOVEMENTS

Bull. Soc. Ophthal. Franc., 68.945-949, December 1968.

iv. GRAVITATIONAL AND VESTIBULAR EFFECTS

1919 MURPHY, W.E. — OBSERVATIONS DURING EXAMINATIONS OF CANDIDATES FOR THE AVIATION SERVICE

No Refs. Ohio State Med. J., 15:631-636, 1919.

The examination consisted almost entirely of studying the "sense of equilibrium" of the candidates, as this was believed to be the only essential requirement for a pilot. No quantitative visual standards were in force.

1946 GRAYBIEL, A. Clark, B. Hupp, D.I. MacCorquodale, K. — THE ROLE OF VESTIBULAR NYSTAGMUS IN THE VISUAL PERCEPTION OF A MOVING TARGET IN THE DARK

10 Refs. Navy Sch. Avia. Med., Pensacola, Florida. Proj. No. X-148(Av-V4-3), January 1946.

Six subjects reported their visual impressions both during and following rotation while observing a moving target in the dark and

in a lighted room. The target counter-rotates illusorily on rotation of the subject during acceleration and deceleration in the dark. The phenomenon did not occur in the lighted room.

1946 CLARK, B. / Graybiel, A. / MacCorquodale, K. — THE ILLUSORY PERCEPTION OF MOVEMENT CAUSED BY ANGULAR ACCELERATION AND BY CENTRIFUGAL FORCE DURING FLIGHT: II. VISUALLY PERCEIVED MOVEMENT OF A FIXED TARGET DURING TURNS

11 Refs. U.S. Naval Sch. Avia. Med., Pensacola, Florida. Proj. No. X-148(Av-4-3), Rep. No. 8, May 1946.

Results show illusions of motion and displacement may occur during all degrees of bank from 10° to 60°, and always occurred during banks of 40° and above. There is a direct relationship between the degree of bank and amount of motion and displacement observed; the maximum observed displacement of the target from the "true" position was 50°. All displacements were observed in or close to the vertical plane, whereas motion was not only upward and downward, but to the right and left.

1946 CLARK, B. / Graybiel, A. / MacCorquodale, K. — THE ILLUSORY PERCEPTION OF MOVEMENT CAUSED BY ANGULAR ACCELERATION AND BY CENTRIFUGAL FORCE DURING FLIGHT: III. HABITUATION AND TECHNIQUE OF ASSUMING THE TURN AS FACTORS IN ILLUSORY PERCEPTION

9 Refs. U.S. Naval Sch. Avia. Med., Pensacola, Florida. Proj. No. X-148(Av-4-3), Rep. No. 11, July 1946.

No evidence of difference in illusory perceptions was found for different types of banking. Habituation did not occur.

1949 BROWN, R.H. / Niven, J.I. — THE RELATIONSHIP BETWEEN APPARENT DISPLACEMENT AND MOTION IN THE OCULOGYRAL ILLUSION

2 Refs. U.S. Naval Sch. Avia. Med., Tulane Univ. Proj. No. NM 001 037, Joint Rep. No. 1, May 1949.

Twelve subjects were each placed in a Link Trainer at 26 r.p.m. for one minute. The subjects head was maintained at a fixed 15° forward inclination. In general, the target was observed as displaced and always in the direction of apparent movement. There were, however, large individual differences in reports of amount and duration of apparent displacement. For those who experienced apparent displacement of the target, the illusion persisted briefly after the apparent motion had ceased. Correlations of independently observed nystagmus was related to both. The relationship was more significant to motion than displacement.

1949 GRAYBIEL, A. / Brown, R.H. — THE DELAY IN VISUAL ORIENTATION FOLLOWING EXPOSURE TO A CHANGE IN DIRECTION OF RESULTANT FORCE ON A HUMAN CENTRIFUGE

4 Refs. U.S. Naval Sch. Avia. Med., Tulane Univ. Joint Rep. Proj. No. NM 001 037, Joint Rep. No. 3, 1949.

Three subjects were exposed on the human centrifuge to a change in direction of resultant G relative to the body axis. Under the conditions of the experiment, a horizontal line appeared to rotate through an angle corresponding to the change in direction of the resultant force. The subjects task was to keep the line horizontal at all times. A marked discrepancy was noted between the time required to impress the physical force and the period during which he found it necessary to make adjustments in keeping the line horizontal. This is explained as a measure in the delay in the subject's visual reorientation to a change in direction of the resultant G, possibly due to characteristics of the otoliths. This is important in aviation as the full disorienting effects of a change in direction of the resultant G relative to the body axis will not become manifest if the exposure time is short.

1949 MANN, C.W. / Berry, N.H. — THE PERCEPTION OF THE POSTURAL VERTICAL: II. VISUAL FACTORS

14 Refs. U.S. Naval Sch. Avia. Med., Tulane Univ. Proj. No. NR 140-455, NM 001 037, Joint Rep. No. 1, June 1949.

There was no significant difference in the precision of the individuals judgement of the visual vertical and the visual horizontal. The mean errors and variability of judgement are significantly increased when a soft padded seat is substituted for a hard seat. The mean error and variability of judgements of the visual horizontal are significantly greater when the individual is in a position of tilt than when he makes the judgement from a vertical position.

1949 NOBLE, C.E. — THE PERCEPTION OF THE VERTICAL: III. THE VISUAL VERTICAL AS A FUNCTION OF CENTRIFUGAL AND GRAVITATIONAL FORCES

32 Refs. U.S. Naval Sch. Avia. Med., Tulane Univ. NR 140-455, Proj. No. NM 001 037, Joint Rep. No. 7, September 1949.

Three subjects took part in a variety of experiments in a human centrifuge provided with blackout arrangements and electrical devices for recording the angle of resultant force and the subjects determinations of the visual vertical. Results seem to substantiate Mach's hypothesis that subjects adjust the visual vertical as the resultant of the centrifugal and gravitational forces.

1949 PASSEY, G.E. — THE PERCEPTION OF THE VERTICAL VI. ADJUSTMENT TO THE VERTICAL WITH NORMAL AND TILTED VISUAL FRAMES OF REFERENCE

6 Refs. U.S. Naval Sch. Avia. Med., Pensacola, Florida, Tulane Univ. Proj. No. NM 001 037, Joint Rep. No. 10, November 1949.

Five subjects were required to adjust themselves to a vertical position in the presence of a visual frame of reference which was presented in alignment with gravitational vertical, and positions divergent from gravitational vertical. The relationships of findings to the theory of Koffka and others was discussed.

1950 MANN, C.W.; Ambler, R.K.; Passey, G.E. — THE PERCEPTION OF THE VERTICAL: VII. EFFECT OF VARYING INTERVALS OF DELAY IN A TILTED POSITION UPON THE PERCEPTION OF THE POSTURAL VERTICAL

6 Refs. U.S. Naval Sch. Avia. Med., Pensacola, Florida, Tulane Univ. Proj. No. NM 001 063.01.12, Joint Rep. No. 8, January 1950.

After a 60 second exposure to tilt, there was a statistically significant increase in the average error of adjustment to the gravitational vertical. Also, a greater number of errors were made in the direction of the initial tilt. Twelve subjects were subjected to 45° tilts in either quadrant in a lateral plane for 0, 15, 30 and 45 seconds. With increased time of tilt there was an increase in the constant error in the direction of the initial tilt, but there was no increase in the variability of the data for average error, constant error, or number of errors in the direction of the initial tilt.

1950 BROWN, R.H; Guedry, F.E., Jr. — INFLUENCE OF VISUAL STIMULATION ON HABITUATION TO ROTATION

12 Refs. U.S. Naval Sch. Avia. Med., Pensacola Florida, Tulane Univ. Proj. No. NM 001 063.01.11 (formerly NM 001 037), Joint Rep. No. 11, January 1950.

An investigation of habituation to rotation was made under three different conditions of stimulation. (Habituation to rotation = decrement in duration of post-rotational apparent motion of visual objects with repeated rotation.) Three groups of 12 subjects were exposed to identical conditions of rotation and visual stimulation on certain trials in a series of 20 rotational trials. The groups were compared on the basis of these only. Hence the treatment of each group was unique only with respect to trials interpolated between these comparison trials. Intergroup differences in stimulating conditions on these interpolated trials consisted of variations in the amount and nature of visual stimulation present to allow visual fixation of a target light. Whereas one group which had very little opportunity for fixation of the target during the 20 trials did not exhibit habituation, the others, with greater opportunity for visual fixation, did exhibit habituation.

1951 RAY, J.T.; Niven, J.I. — THE PERCEPTION OF THE VERTICAL· XII. THE POINT OF SHIFT FROM VISUAL TO POSTURAL FRAMES OF REFERENCE

5 Refs. U.S. Nav. Sch. Avia. Med., Pensacola, Florida, Tulane Univ. Joint Rep. No. 21, February 1951.

The relative importance of visual and postural factors in the judgement of the vertical is discussed. Four subjects, each making 195 judgements were used. The postural vertical did not differ significantly with the true gravitational vertical under any condition. The judged vertical deviated increasingly from the true gravitational vertical as target displacement from its true position was increased.

1952 GERATHEWOHL, S.J. — PHYSICS AND PSYCHOPHYSICS OF WEIGHTLESSNESS VISUAL PERCEPTION

69 Refs. J. Avia. Med., 23:373-397, 1952.

The paper predicts theoretical conclusions concerning the interaction of proprioceptive and visual senses under conditions of subgravity and zero gravity. It is shown how the predictions seem to have been borne out.

1952 BORING, R.O. — THE EFFECT OF VISUAL STIMULUS VARIABLES UPON THE PERCEPTION OF THE VISUAL VERTICAL

4 Refs. U.S. Naval Sch. Avia. Med., Pensacola, Florida, Tulane Univ. Proj. No. NM 001 063.01, Joint Rep. No. 28, August 1952.

The paper is concerned with a suggestion by J.J. Gibson that when main lines of the visual field are parallel to the direction of the gravitational force, even though the head or body is tilted, there will be a consistancy between visual and proprioceptive cues which yields an invariant resultant. When, however, the visual field is tilted relative to gravitational vertical, judgements of the latter will be less precise and more variable. The experimental results in this paper do not support this theory.

1952 CLARK, B.; Graybiel, A. — ILLUSORY PERCEPTION OF ROTATION FOLLOWING CONSTANT TURNS IN A LINK TRAINER

8 Refs. U.S. Naval Sch. Avia. Med., Pensacola, Florida. Proj. No. NM 001 059.01.31, August 1952.

The illusory perception of rotation was studied in a modified Link Trainer using 31 flight students as subjects. The duration of the illusory effects following rotation increased sharply as the period of constant rotation increased up to 30 seconds and thereafter increased slowly to 2 minutes. The implications of the results are discussed.

1952 GRAYBIEL, A. — OCULOGRAVIC ILLUSION

11 Refs. A.M.A. Archives of Ophthal., 48 605-615, 1952.

A general investigation including some results with after-images and effects of body position. It was found that the important variables determining the appearance of the illusion were:

1. the pattern of centripetal acceleration.
2. the position of the subject.
3. The visual framework.

1954 COCHRAN, L.B.; Gard, P.W.; Northsworthy, M.E. — VARIATION IN HUMAN G TOLERANCE DUE TO POSITIVE ACCELERATION

U.S. Nav. Sch. Avia. Med., Pensacola, Florida. Rep. No. 001 059.02.10, 1954.

The report concerns the determination of G tolerance levels with regards to loss of peripheral vision, blackout and unconsciousness. One thousand subjects, seated in an upright position, were used to establish the following thresholds:

4.1 ± 0.7 G -- loss of peripheral vision
4.7 ± 0.8 G -- visual blackout
5.4 ± 0.9 G -- unconsciousness

Similar visual symptoms do not occur as readily with transverse, i.e. back to chest, G forces until over 12 G. (Ref: Gauer, O. and S. Ruff, Die ertraglichkeitsgrenzen fur flichkrafte in richtung ruckenbrust, Luftfahrtmedizin, 3:225-230, 1939.

1956 WHITE, W.J.; Jorve, W.R. — THE EFFECTS OF GRAVITATIONAL STRESS UPON VISUAL ACUITY

25 Refs. Aero. Med. Lab., Wright-Patterson AFB, Ohio. Rep. No. 56-247, ASTIA Doc. No. AD 110444, November 1956.

A determination of the relationship between increased gravitational force and visual acuity was made when the factor of reduced cerebral circulation is minimized by the use of protective measures known to ameliorate the gross visual symptoms associated with gravitational stress. It was found that gravitational stress has a significant and progressive effect on visual acuity. An hypothesis is advanced to account for this observation.

1958 BROWN, J.L.; Burke, R.E. — EFFECT OF POSITIVE ACCELERATION ON VISUAL REACTION TIME

12 Refs. J. of Avia. Med., 29:48-58, 1958.

The build-up and decay of acceleration followed a sinusoidal function. The reaction time was prolonged by the action of acceleration on the visual system.

1958 WHITE, W.J. — ACCELERATION AND VISION

52 Refs. Aero. Med. Lab., Wright-Patterson AFB, Ohio. WADC Tech. Rep. No. 58-333, ASTIA Doc. No. AD 208147, November 1958.

A review and evaluation of research pertaining to the effects of acceleration on human vision, including an extensive bibliography.

1960 WHITE, W.J. — VARIATIONS IN ABSOLUTE VISUAL THRESHOLDS DURING ACCELERATION STRESS

9 Refs. Wright Air Dev. Div., Wright-Patterson AFB, Ohio. Proj. No. 7222, Task No. 71712, WADD Tech. Rep. No. 60-34, April 1960.

Measurements were made of the absolute threshold of foveal (cone) and peripheral (rod) vision within the range of 1-4 G. Dislocation of the visual function was studied selectively by the use of anti-G suits. It was concluded that:

1. Acceleration levels of 3-4 G approximately double and triple foveal thresholds respectively.
2. Threshold levels in peripheral vision triple at 3 G and quadruple at 4 G.
3. A rise in threshold (decline in sensitivity) was found with repeated exposure to acceleration, the rise being smaller than that associated with the acceleration.
4. The rise in acceleration in peripheral thresholds is, in part, compensated for by anti-G suits.

1961 PIGG, L.D.; Kama, W.N. — THE EFFECT OF TRANSIENT WEIGHTLESSNESS ON VISUAL ACUITY

4 Refs. Aero. Med. Lab., Wright-Patterson AFB, Ohio. WADD Tech. Rep. No. 61-184, Proj. No. 7184, Task. No. 71586, March 1961.

The visual acuity was measured of subjects while exposed to short periods of weightlessness aboard an aircraft flown through "zero-G" trajectories involving transition from 1 G to 2 1/2 G to zero-G. Monocular and binocular acuity of far and near vision were measured on both Snellen and chequerboard targets. Control measurements were made on the ground and in flight a 1 G in a counterbalanced sequence with the zero-G measurements. The results show that the weightless environment produced for this study has a detrimental effect on visual acuity as measured. The decrement is not considered to have a practical significance, the loss of visual acuity of zero-G was 6% in flight. Compared with laboratory tests it was 10%.

1962 MILLER, E.F. — COUNTER-ROLLING OF THE HUMAN EYES PRODUCED BY HEAD TILT WITH RESPECT TO GRAVITY

29 Refs. Acta Oto-laryng., 54:479-501, 1962.

A method is described to measure compensatory torsion to within ± 5.3 minutes of an arc. Torsional eye movements, compensatory to head tilt, were found in all planes except the sagittal. Counter-rolling was always opposite to the lateral component of head tilt, and increased up to a maximum for head inclination of 60-90°, being zero when the head is vertically down. No relationship was found between the amount of counter-rotation and the order in which the measurements were made. A theory is advanced to account for the findings.

1962 HAMMER, L.R. — PERCEPTION OF THE VISUAL VERTICAL UNDER REDUCED GRAVITY

31 Refs. Aero. Med. Res. Lab., Wright-Patterson AFB, Ohio. Proj. No. MRL-TDR-62-55, May 1962.

Judgements of the vertical were made in an unstructured visual field while in flight and under 4 levels of gravity ranging from 1-4 G. Sixteen subjects made 6 judgements in each of 4 G conditions. A 1.8° error at 1 G was found to increase to 3.5° at zero-G. Conditions associated with inflight research were discussed, and suggestions for future research were presented.

1963 WHITE, W.J.; Monty, R.A. — VISION AND UNUSUAL GRAVITATIONAL FORCES

Extensive Refs. Human Factors, 5·239-263, 1963.

The paper gives a review and evaluation of research and observation, the major topics being increased G and null gravity. The operational experience of astronauts is included, and the techniques for minimizing undesirable effects are summarized.

1965 MILLER, E.F.; Fregly, A.R.; Graybiel, A.; van den Brink, G. — VISUAL LOCALIZATION OF THE HORIZONTAL AS A FUNCTION OF BODY TILT UP TO ± 90° FROM GRAVITATIONAL VERTICAL

35 Refs. U.S. Nav. Sch. Avia. Med., NSAM-942, NASA Order No. R-47, August 1965.

The visual horizontal was determined for 3 sophisticated subjects tilted laterally in 10° intervals within ± 90° from the gravitational vertical. The deviation at 10-20° either side of vertical was not significant from that of upright. Inclinations beyond this caused the E-phenomenon to appear and increase bilaterally to maximum about the 40-50° position. (The E-phenomenon is the tendency of the apparent visual horizon to incline in the same direction as the body tilt.) With further inclination the deviation was found to reverse direction and passed through the position of zero deviation (60-80°) to grow as the A-phenomenon. (The latter is the opposite

of the E-phenomenon.) The responses were bilaterally symmetrical.

1966 MILLER, E.F.; Graybiel, A. — MAGNITUDE OF GRAVITOINERTIAL FORCE· AN INDEPENDANT VARIABLE IN EGOCENTRIC LOCALIZATION OF THE HORIZONTAL

25 Refs. J. Exptl. Psych., 71 452-460, 1966.

The direction of gravitoinertial force, i.e. resultant of gravitational and induced centripetal force vectors, was held constant while the magnitude of force varied 1-2 G. The effect of the egocentric localization of the horizontal was measured in 8 normal and 2 labyrinthine defective subjects. The egocentric visual localization of the horizontal deviated from gravitoinertial horizontal as a function of gravitoinertial force; it increased with the amount of body tilt from its alignment with the resultant force. Normal subjects manifested increasing amounts of E-phenomenon; defectives varied from A to E. Roles of otolithic and nonotolithic gravireceptor cues in visual localization in absence of empirical visual cues are discussed.

1967 GRAYBIEL, A. et. al. — VESTIBULAR EXPERIMENTS IN GEMINI FLIGHT V AND VII

33 Refs. Aerospace Med., 38.360-370, 1967.

Astronauts were exposed to weightlessness for 8 days in GT V and 14 days in GT VII. The task was to set a dim line of light in a dark field to an external horizontal reference both pre-, post- and during flight. The most significant finding was the high degree of accuracy in the settings made, suggesting that even without otolith function the central nervous system still maintains accurate visual direction of space. No significant differences between pre- and post-flight responses were found.

1967 PITTS, D.G. — VISUAL ILLUSIONS AND AIRCRAFT ACCIDENTS

101 Refs. USAF Sch. of Avia. Med., Brooks AFB, Texas. SAM-TR-67-28, April 1967.

See abstract under Illusions and Visual Perception: Autokinesis.

v. NIGHT MYOPIA, SPACE MYOPIA AND GANZFELD

1951 KOOMEN, M. Scolnik, R. Tousey, R. — A STUDY OF NIGHT MYOPIA

25 Refs. J. Opt. Soc. Amer., 41:80-90, 1951.

High contrast grating test objects were used. At the lowest luminances, myopia of 1.5-2.0 D was apparent. Night myopia appeared when accommodation was prevented by an optical method and when accommodation was paralysed with homatropine. It was concluded that accommodation is not a significant cause of night myopia. Other tests show that night myopia is primarily a result of uncorrected spherical aberration of the eye. A review of the literature on explanations of night myopia is included under the headings: chromatic aberration, spherical aberration, accommodation, dark adaptation, extra-axial imagery and other theories.

1955 CHIN, N.B. Horn, R.E. — INFRARED SKIASCOPIC MEASUREMENTS OF REFRACTIVE CHANGES IN DIM ILLUMINATION AND IN DARKNESS

7 Refs. Aero. Med. Res. Labs., Wright-Patterson, AFB, Ohio. WADC Tech. Note 55-479, Proj. No. 7157, Task No. 71808, August 1955.

A brief review of the literature on night myopia and empty field myopia and the disagreement over their causes is presented. Measurements of the refractive state of the eye in reduced illumination and darkness were made using an infrared skiascope. Half the subjects showed an increase in the refractive state of the eye as the illumination decreased. The contribution of accommodation to the night myopia measured was generally small. In complete darkness all subjects showed varying degrees of accommodative spasm.

1958 MILLER, J.W. Ludvigh, E. — VISUAL DETECTION IN A UNIFORMLY LUMINOUS FIELD

5 Refs. J. Avia. Med., 29:603-608, 1958.

The apparatus overcomes the difficulties of other methods of investigation of the Ganzfeld, especially those concerned with the extent of the visual field. The targets were moved over a wide range of angular velocities. Target aquisition was investigated as a function of size and location of the target. Targets 10-15 times above threshold disappear. An experiment is given to show that this phenomenon is not associated with accommodation fluctuations.

1960 TEN DOESSCHATE, G. — VISION IN AN EMPTY VISUAL FIELD

Ophthalmologica, 140 322-332, 1960.

A survey of the literature is given and then a summary of the conclusions of a paper in Aeromedica, Vol. VI, 9-68, 1958:

1. Most young people accommodate 0.25-1.75 D in an empty visual field.
2. Some young people showed equal accommodation when the extension of the empty visual field was 20° or over 180°.
3. Some young people showed equal accommodation when illumination of the empty visual field is 1.2 or 500 lux.
4. A window frame or dashboard did not produce any stimulation to accommodation.
5. When colored filters are used to look at an empty visual field, chroma perception diminishes and is often followed by perception of dark grey or even blackness.

1961 BROWN, J.L. — SENSORY AND PERCEPTUAL PROBLEMS IN SPACE FLIGHT

51 Refs. Reprinted from, "Physiological Problems in Space Flight", Charles C. Thomas, 1961.

A general review of the problems of space flight is given. Space myopia should not be a problem as the stars will be an adequate stimulus for accommodation.

Also see abstract under Space Flight, Including Reconnaissance and Surveillance.

1961 LUDVIGH, E. Miller, J.W. — THE PERCEPTION OF MOVEMENT PERSISTANCE IN THE GANZFELD

9 Refs. J. Opt. Soc. Amer., 51:57-60, 1961.

The subjects observed movement of a single, black, spherical stimulus in a Ganzfeld and reported when the movement stopped. Time between real and apparent cessation was called the "time delay". The following formula was proposed:

$$t = r + \frac{1}{av^2}$$

where t = time delay
r = reaction time
a = constant of inverse proportionality
v = velocity

A stimulus traveling at high speed for relatively long periods produces greater perception of velocity than one slower and perceived for a shorter length of time. This is because if the former is suddenly stopped, the contrast is more obvious.

1962 HEATH, G.G. — THE TIME COURSE OF NIGHT AND SPACE MYOPIA

16 Refs. Aero. Med. Div., Aero. Med. Res. Labs., Wright-Patterson AFB, Ohio. Rep. No. AMRL-TDR-62-80, August 1962.

The refractive state of the human eye was measured over periods up to 4 hours in total darkness and in an empty, lighted visual field, using a subjective optometer, an infrared retinoscope, and infrared automatic recording optometer and white light, and infrared photography of the third Purkinje image. Under both viewing conditions, the measurements showed a continuously varying relative myopia produced by accommodative changes, which tended to increase during 3-5 minutes, thereafter with continuous, irregular, rapid fluctuations of as much as 0.75 D, occasional spontaneous changes of the predominant level by as much as 1.00 D and slow drifts of up to 1.50 D over periods of up to 2 minutes. This highly dynamic accommodative activity in an empty visual field contrasts with previous concepts of a passive and relatively fixed "resting state" of accommodation under such conditions. Factors influencing this accommodative activity were also studied.

1962 MILLER, J.W. Hall, R.J. — THE PROBLEMS OF MOTION PERCEPTION AND ORIENTATION IN THE GANZFELD

12 Refs. Armed Forces-NRC Committee on Vision, Visual Problems of the Armed Forces, Washington, D.C., 1962.

The same apparatus is used as Miller and Ludvigh used in 1958. (See this section.) A distinction between the Ganzfeld and absolute darkness is drawn. Results indicate there are marked individual biases whether the perceived center appears to the right or left of the true center. Most subjects reported they fixated on a point in space they thought was center and moved the target to the point. The subjects also resorted to orientation cues from different parts of their bodies as well as any proprioceptive cues from the extraocular muscles. It seems that a subject can detect a 2-3° movement from "something".

1962 TEPAS, D.I. — THE ELECTROPHYSICAL CORRELATES OF VISION IN A UNIFORM VISUAL FIELD

4 Refs. Armed Forces-NRC Committee on Vision, Visual Problems of the Armed Forces, Washington, D.C., 1962.

The hypothesis that high alpha activity is an important indicant of blackout susceptibility is not strongly supported.

vi ROLE OF INSTRUCTION

1952 BORING, R.O. Mann, C.W. — THE ROLE OF INSTRUCTION IN EXPERIMENTAL SPACE PERCEPTION

6 Refs. USN Sch. Avia. Med., Tulane Univ. Proj. No. NM 001 063.01, Joint Rep. No. 30, September 1952.

Two groups of four subjects set a luminescent rod to "vertical" during exposure to visual frameworks which were sometimes tilted and sometimes upright. One group was given careful instructions as to definition of "vertical", and the others were simply told to set to vertical. The constant and average errors by the naive group were consistantly larger than those of the sophisticated group. It was concluded that a number of criteria of verticality are possible in the relatively simple experimental situation and different criteria may be selected by different subjects.

XIII. NYSTAGMUS

1946 GRAYBIEL, A. — THE ROLE OF VESTIBULAR NYSTAGMUS IN THE VISUAL PERCEPTION OF A MOVING TARGET IN THE DARK
Clark, B.
Hupp, D.I.
MacCorquodale, K.

10 Refs. Navy Sch. Avia. Med., Pensacola, Florida. Proj. No. X-148(Av-V4-3), January 1946.

See abstract under Illusions and Visual Perception· Gravitational and Vestibular Effects.

1957 ADES, H.W. — NYSTAGMUS ELICITED BY HIGH INTENSITY SOUND
Graybiel, A.
Morill, S.N.
Torhurst, G.C.
Niven, J.

6 Refs. U.S. Navy Sch. Avia. Med., Pensacola, Florida. Joint Proj. No. NM 130 199, Subtask No. 2, Rep. No. 6, February 1957.

In order to study some of the extra-auditory effects of loud noise, deaf subjects were stimulated by high intensity sound, both pure tone of several frequencies (100-3,000 cycles per sec.) and wide band noise. In those showing positive response to vestibular stimulation in one or more of the standard tests, nystagmus was a regular consequence when the noise was of a sufficiently high intensity. Curves are shown, comprising the thresholds at 6 frequencies of pure tone and for the noise of a jet engine. Dizziness and apparent movement in the visual field were in some cases regular concomitants of nystagmus.

1961 SCHUMANN, W.P. — VISUAL ACUITY AND OPTOKINETIC NYSTAGMUS

10 Refs. Amer. J. Opt. & Arch. Amer. Acad. Opt., 38:646-654, 1961.

The paper gives a good review of the topic. It includes inversion, i.e. reversal of the movements, Goldmann eye pendulum, and the Guenther method. The Goldmann eye pendulum is probably the most accurate objective method.

XIV. OCULAR MUSCLE BALANCE

1919 CAMPBELL, K. — HETEROPHORIA WITH SPECIAL REFERENCE TO FLYING

No Refs. The Medical Press, Pp. 25-27, January 8, 1919.

The article suggests that a certain number of bad landings may be attributed to heterophoria. Tests for heterophoria are discussed, together with prismatic treatment of any deviations.

1919 HOWARD, H.J. — A TEST FOR THE JUDGEMENT OF DISTANCE

1 Ref. Amer. J. Opthal., 2:656-675, 1919.

One hundred and six subjects were used. The best performers with the apparatus had either no muscle imbalance or esophoria, none had exophoria.

Also see abstract under Depth Perception and Stereopsis.

1923 BERENS, C. — THE EYE IN AVIATION: SOME EXPERIENCES IN THE WORK OF THE DEPARTMENT OF OPHTHALMOLOGY, MEDICAL RESEARCH LABORATORY, THIRD AVIATION INSTRUCTION CENTER, A.E.F., FRANCE

Extensive Refs. Mil. Surgeon, 52.35-48, 1923.

The article claims to contain a complete bibliography. The present standards (1923) are given in which, ". . . it seems that the converging power should never be less than double the diverging power at all distances."

Also see abstract under Visual Standards.

1923 LANCET — OPHTHALMOLOGY IN RELATION TO THE NAVY, ARMY AND AIR FORCE

No Refs. Lancet, Pp. 510-518, September 28, 1923.

It is stated in the symposium that in the First World War an exophoria of 2 1/2 degrees or esophoria of 1 1/2 degrees was unsatisfactory. In the discussion, J.F. Carruthers said he could substantiate what Clements had found with respect to orthoptics greatly helping bad landers.

1923 BRITISH JOURNAL OF OPHTHALMOLOGY — SECTION OF OPHTHALMOLOGY. DISCUSSION ON OPHTHALMOLOGY IN ITS RELATION TO THE NAVY, ARMY AND AIR FORCE

1 Ref. Brit. J. Ophthal., 2 654-658, 1923.

It is stated that 1/2° of esophoria or exophoria at distance with the red-green test is "not considered good". The paper is an example of collective opinion rather than experimental results.

Also see abstract under Flash Blindness, Glare and Radiation Effects.

1925 CLEMENTS, E.C. VISUAL PROBLEMS IN REGARD TO FLYING AND INDUSTRIAL FATIGUE FROM A SERVICE STANDPOINT

No Refs. Proc. Roy. Soc. Med., 19:15-23, 1925.

An investigation, "revealed that between 75% and 80% of the flying accidents sent to the hospital from neighboring training schools were the result of unsuccessful attempts at landing". The author delineates the visual requirements as to whether a candidate will be a successful flyer, especially in landing. Flying places the pilot into a world of "altered conditions", those of which are primarily visual in character. Heterophoria contributes to the number of accidents; and it may cause nervousness and fatigue from unconcious strain.

1927 LOY, A.W. DISQUALIFYING EYE MUSCLE IMBALANCES IN AVIATION

No Refs. U.S. Naval Bulletin, 27:335-338, 1927.

The report presents a diagrammatic representation of the disqualifying eye muscle imbalances for USNAP. The standards (1927) were as follows Candidates were disqualified if they had-

1. Prism divergence less than 2Δ.
2. Prism divergence less than 4Δ, associated with esophoria greater than 4Δ.
3. Prism divergence greater than 9Δ, associated with angle of convergence near 40Δ.
4. Prism divergence greater than 15Δ.
5. Exophoria greater than 2Δ at 6 m associated with: (1) angle of convergence near 40Δ (2) diplopia in lateral positions on the tangent curtain.
6. Exophoria greater than 5Δ at 6 m.
7. Exophoria greater than 12Δ at 33 cm.
8. Esophoria greater than 4Δ at 6 m associated with: (1) diplopia in lateral positions of the tangent curtain (2) accommodation of 2 D below or above Duane's table (3) hyperopia near the disqualifying limit (4) prism divergence less than 4Δ.
9. Esophoria greater than 10Δ at 6 m.
10. Hyperphoria greater than 0.75Δ for an applicant.
11. Hyperphoria greater than 1Δ for a qualified pilot.

1930 THORNE, F.H. A REVIEW OF OCULAR MUSCLE IMBALANCE (WITH REPORT OF TWO-HUNDRED AND FORTY-FOUR CASES)

5 Refs. Military Medicine, 66:175-205, 1930.

The qualifying limits concerning ocular muscle imbalance are not rigid. In fact, "an individual may exhibit an imbalance bordering upon a squint before he is disqualified for flying training, provided other pertinent factors are normal". The field of binocular fixation must be maintained 50° from the primary position of gaze, beyond 50° diplopia is of little significance. The existance of a cyclophoria is not investigated as a routine, but only when considered necessary by the examiner. "It is the generally accepted theory that many cases of latent and manifest deviations are accommodative in origin. It is believed, however, that all latent cases exist independent of refractive errors, and that the errors, when fatigue is superimposed, only exaggerate the defect without being the primary cause." Uncorrected refractive error is believed to be the most common cause of increasing the tendency of a latent deviation and production of muscular asthenopia. The accommodative theory of orthophoria, exophoria and esophoria are discussed. Of 244 applicants exhibiting horizontal deviations, 95.9% were associated with refractive errors above 0.25 D, and 72.5% were eliminated. Of a total of 500 applicants examined, 69.7% were relieved from flying because of inability to make proper progress. The Maddox Rod Screen Test is standard for Air Corps measurement of heterophoria, other tests are discussed. A review of the defects which disqualify applicants from flying is given.

1931 ARMY MEDICAL BULLETIN THE SELECTION OF THE AVIATOR

Army Med. Bull., 26·6-25, Chap. II, 1931.

The report describes the methods of measuring the visual parameters in full. Orthophoria is defined (at 20 feet) as being no deviation at all or any deviation less than 2Δ of esophoria, 1Δ of exophoria or 1/2Δ of hyperphoria. It is stated then, "the associated factors are vitally important in determining the significance of heterophoria." Examples of these "associated factors" are, powers of abduction and adduction, associated parallel movements, accommodation, errors in refraction and the power of fusion.

1931 McALESTER, A.W. BALANCE OF THE OCULAR MUSCLES AS RELATED TO FLYING SOME CONSIDERATIONS

No Refs. J. Avia. Med., 2:218-226, 1931.

The article discusses early methods of investigation of ocular muscle balance. A man should not be allowed to enter the service with a hyperphoria of 1°.

Also see abstract under Visual Standards.

1942 GILLESPIE, C.E. AVIATION OPHTHALMOLOGY

No Refs. Indiana Academy of Ophthal. & Otolaryn., 26 26-40, 1942.

The esophoric pilot "will run his nose into the ground", whereas the exophoric pilot may think the ground is nearer than it is.

1943 ABRAHAM, S.V. NEAR HORIZONTAL PHORIA AND DUCTION TESTS

19 Refs. Amer. J. Ophthal., 26:271-279, 1943.

Four thousand subjects were used and typical cases are presented to show how the findings from near horizontal phoria and duction tests fall into 3 characteristic groups. The relation of the base-in reading at 13" to the interpupillary distance is emphasized. The effect of cycloplegia on the findings is shown not to be dependable, even though the tendency for cycloplegia to cause a reduction in the convergence activity is suggested.

1943 KANE, A.L. CORRELATION OF DEFECTIVE VISUAL ACUITY AND POOR OCULAR MUSCLE BALANCE ON ABILITY TO SUCCEED IN FLYING TRAINING

No Refs. Canada, R.C.A.F., Director of Medical Services, Great Britain, O.S.R.D. No. III-1-2233, April 1943.

The report shows no relationship between small 'phorias or convergence and the ability to fly, although the washout rate increases directly with a lowered visual acuity.

1944 SCOBEE, R.G. THE EFFECT OF EXHAUSTION AND MODERATE ANOXIA ON OCULAR MUSCLE BALANCE

No Refs. Army Air Forces Sch. Avia. Med., Randolph Field, Texas. Proj. No 292, Rep. No. 1, July 1944.

See abstract under Atmospheric Effects.

1944 SCOBEE, R.G. AN ANALYSIS OF THE OPHTHALMIC PORTION OF THE "64" EXAMINATION: (1) MUSCLE BALANCE

2 Refs. Army Air Forces Sch. Avia. Med., Randolph Field, Texas. Proj. No. 139, Rep. No. 1, November 1944.

The requirements when the paper was written were heterophoria and prism divergence determinations at 20 feet--the only test at near fixation being the near point of convergence (Pc and PcB). One hundred and fifty subjects were used. The measurement of the near point is considered too inaccurate to be worth measuring; it is recommended that the heterophoria and prism divergence should be measured at near. The study agrees with that of Abraham (6,000 subjects were used) who found that prism divergence, not the absolute value of heterophoria is the factor on which asthenopic symptoms depend. Tables are given comparing Abraham's and this studies hetero-

phoria and prism divergence means at 13 inches. New standards are suggested to which candidates should conform for prism divergance and heterophoria at 13 inches.

1945 ROYAL CANADIAN AIRFORCE VISUAL FACTORS IN AIRCREW SELECTION

4 Refs. Assoc. Comm. on Avia. Med. Res., National Res. Council, Canada. Rep. No. C2791, February 1945.

Ocular muscle balance findings (with the exception of relatively high hyperphoria at 15 inches) and relatively high convergence insufficiency or excess are not related to flying performance.

1945 SCOBEE, R.G. A COMPARISON OF TESTS FOR HETEROPHORIA

1 Ref. AAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 375, Rep. No. 1, April 1945.

Tests compared are:
At distance 20 feet--(1) Maddox rod (2) von Graefe prism (3) subjective and objective cover test.
At distance 13 inches--(1) Maddox rod (2) von Graefe prism (3) Maddox wing (4) Thorington test (5) subjective and objective cover test.
It is recommended that the Maddox rod test at 20 feet is the best when both ease of performance and relative accuracy are concerned. Although it is admitted the subjective and objective cover test are the most accurate, they take too long to perform.

1945 SCOBEE, R.G. A COMPARISON OF TESTS FOR HETEROPHORIA: EFFECT OF LIGHT AND DARK ON THE SCREEN-MADDOX ROD TEST

2 Refs. AAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 375, Rep. No. 3, July 1945.

Using sixty subjects it was found that there is no significant difference in heterophoria measurement when made with the screen-Maddox rod test in a lighted room or a darkened one. This clears up the contraversy of whether heterophorias should be measured with room illumination or in the dark.

1945 SCOBEE, R.G. A COMPARISON OF TESTS FOR HETEROPHORIA RELIABILITY OF THE SCREEN-MADDOX ROD TEST

3 Refs. AAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 375, Rep. No. 2, July 1945.

One hundred and thirty-one subjects were used. Two examiners examined each subject on each of two different days. A reliability coefficient of 0.95 was found for lateral heterophoria measurement. A table is

included of the distribution of horizontal phorias among the subjects, but the subjects were all aviation cadets and not a sample of the general population.

1945 SCOBEE, R.G.
Green, E.L.
Moss, H.L.

A COMPARISON OF TESTS FOR HETEROPHORIA VARIATIONS IN THE SCREEN-MADDOX ROD TEST DUE TO OCULAR DOMINANCE, RED COLOR, AND SCREENING

12 Refs AAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 375, Rep. No. 4, July 1945.

Conclusions:

1. 0.4Δ more esophoria is produced at both 20 feet and 13 inches when screening is used in conjunction with a Maddox rod--no matter whether the rod is red, white or placed before the dominant or non-dominant eye.
2. No significant difference in the results are obtained whether the rod is placed before the dominant or non-dominant eye at either 20 feet or 13 inches. This contradicts results found by P. Dolman whose paper was the basis for placing the rod before the non-dominant eye in the old standards. Hence the test for dominance should be dropped from the standards and the rod placed before the right eye.
3. About 0.25Δ less esophoria is found at 20 feet with a white Maddox rod. There is no significant difference at 13 inches. Hence a white Maddox rod should be used.

1945 SCOBEE, R.G.

AN ANALYSIS OF THE OPHTHALMIC PORTION OF THE "64" EXAMINATION. (2) MUSCLE BALANCE-A SUMMARY OF SUGGESTED CHANGES

7 Refs. Army Air Forces Sch. Avia. Med., Randolph Field, Texas. Proj. No. 139, Rep. No. 2, August 1945.

Additional conclusions to his work in 1944 (see above) are given. Prism divergence should be measured at 13" instead of 20'--the minimum should be 15Δ at 13". Heterophoria should be measured at 13" as well as 20'--with limits of:

1. exophoria less than 15Δ.
2. esophoria less than 10Δ.
3. hyperphoria not more than 1.5Δ.

The Maddox rod (white) should always be placed before the right eye and the test for the dominant eye omitted (these recommendations now apply).

1946 KIRSCHBERG, L.S.S.

DEPTH PERCEPTION AND FLYING ABILITY

18 Refs. Arch. Ophthal., 36 155-170, 1946.

No relationship was found between depth perception scores, hetero-

phoria and flying ability for 303 subjects.

Also see abstract under Depth Perception and Stereopsis.

1947 IMUS, E.A.

EVALUATION OF EYE EXAMINATION

72 Refs. U.S. Navy Sch. Avia. Med., Pensacola, Florida. June 1947.

Two hundred and fifty Naval Aviators who had returned from combat or operational tours of duty were given a complete eye examination, including screening with the Orthorater. No significant relationship was found between lateral phoria at distance and depth perception measured with the Orthorater. The mean distance heterophoria using the Orthorater among the subjects was 0.6Δ exophoria, whereas the corresponding measurement for 1000 enlisted men was 0.75Δ esophoria. Using the Maddox rod and dissociating prisms the average distance heterophoria was 0.36Δ esophoria for the 250 aviators.

Also see abstract under Visual Standards.

1947 SCOBEE, R.G.
Green, E.L.

TESTS FOR HETEROPHORIA

9 Refs. Amer. J. Ophthal., 30.435-451, 1947.

The article contains the comparison of red and white Maddox rods. The human eye is approximately 0.5Δ hyperopic for the color red. (Duke-Elder, Practice of Refraction, Philadelphia, P. Blackiston Son and Co., 1928, p. 66.) Hence an increased convergence tendency should be found with a red Maddox rod, relative to a white Maddox rod. The latter is also usually more optically correct. The average reading with the white Maddox rod was 1.43Δ of esophoria, that of the red Maddox rod was 1.68Δ esophoria. Hence relatively 0.25Δ more exophoria was found with the white Maddox rod.

1947 LIVINGSTON, P.C.

THE ROLE OF HETEROPHORIA IN BINOCULAR DISHARMONY WITH SPECIAL REFERENCE TO AIR PILOTAGE

1 Ref. Brit. Med. J., 2 409-411, 1947.

The author delineates the general etiology of symptom and symptomless heterophoria, and the relationship between heterophorias and flying. A heterophoria may result from prolonged fatigue from concentrated flying. He believes that symptomless heterophoria is best left alone, and prescription in these cases will produce discomfort and in general make the patient worse off.

1951 RIPPLE, P.H. Rose, H.W. — VISUAL PROBLEMS OF PILOT IN PRONE POSITION

9 Refs. USAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 21-24-011, Rep. No. 1, August 1951.

See abstract under Displays and Visual Simulation.

1952 HEBBARD, S.W. — CONSISTANCY OF CLINICAL DATA

1 Ref. Optom. Weekly, June 19, 1952.

A distance 'phoria should be measured while all fusion stimuli are eliminated. Peripheral vision of the refractor aperatures may be present in some cases. The effect may be minimized if the eyes are occluded with only brief uncoverings (either prisms or Maddox rods being used). The Maddox rod was placed in front of the occluded eye. However, in most cases there is no significant difference with the usual technique.

1954 KRIMSKY, E. — AN APPRAISAL OF AVIATION EYE TESTS WITH RECOMMENDATIONS

8 Refs. J. Avia. Med., 25:243-253, 1954.

The usual tests administered are too subjective and the apparatus employed makes observation of the eyes impossible, e.g. phorometer and Orthorater. The latter is of no clinical value. Emphasis is placed on the cover test to detect muscle imbalances (objective) rather than the Maddox rod, (which is too subjective and the conditions are too artificial). Undue emphasis has been placed on the importance of the near point of convergence, and the pencil-to-nose exercises were given too indiscriminately. To determine whether responses are true or false, the examiner should constantly examine the positions of the corneal light reflexes. The red lens test is entirely subjective, subjects may even close one eye to avoid diplopia, or it may elicit heterophoria like the Maddox rod. Measuring 'phorias without ductions is valueless, phorias and ductions should be measured at different distances. Orthoptics may enable a candidate to pass an aviation eye exam but improvements usually are only temporary.

1958 MILLER, E.F. — EVALUATION OF CERTAIN VISUAL AND RELATED TESTS: II. PHORIA

13 Refs. U.S. Naval Sch. Avia. Med., Pensacola, Florida. Res. Proj. No. NM 14 01 11, Subtask 6, Rep. No. 2, April 1958.

Experiments were done to determine whether large near 'phorias exist among pilots who were screened by the required visual tests. The four methods used were:

1. von Graefe prism
2. Maddox rod
3. Keystone DB9 target
4. Renshaw monocular projections

Although the test-retest reliability of most of these tests was found to be satisfactory, the actual values measured by the different tests varied considerably. Graphs are included showing the frequency distributions of the 'phorias both at near and far. The heterophorias at near varied between 16Δ esophoria and 19Δ exophoria.

1962 MASTERS, R.I. — THE EFFECTS OF ALCOHOL AND ANOXIA ON THE HETEROPHORIAS (THESIS)

66 Refs. Thesis for 1962 Advanced Course in Avia. Med., Brooks AFB, Texas. 1962.

See abstract under Atmospheric Effects.

1963 LAGERWERFF, J.M. — SPACE CABIN ATMOSPHERE TRACE CONTAMINANTS AND THEIR POSSIBLE INFLUENCE ON VISUAL PARAMETERS

70 Refs. Approx. Human Factors, 5:285-293, 1963.

Twenty-eight subjects were exposed for 3 to 6 hours to three different concentrations of ozone, namely: 20 pphm, 35 pphm and 50 pphm by volume. Heterophorias changed ± 4 1/2Δ. The possibility of contaminant formation in spacecraft and the effects on vision are discussed at some length.

Also see abstract under Atmospheric Effects.

1968 LURIA, S.M. Weissman, S. — RELATIONSHIP BETWEEN STATIC AND DYNAMIC STEREO ACUITY

9 Refs. J. Exptl. Psych., 76:51-56, No. 1, 1968.

See abstract under Depth Perception and Stereopsis.

1968 WHITCOMB, M.A. Benson, W. (Eds.) — THE MEASUREMENT OF VISUAL FUNCTION (SYMPOSIUM) PROCEEDINGS OF SPRING MEETING 1965

Extensive Refs. Armed Forces-Nat. Res. Comm. on Vision, Washington, D.C., 1968.

Two papers are included, the first discusses the possibility of producing a fully automated screening device to detect both the fusion status and the deviation in the primary and other directions. The second discusses laboratory measurements of ocular muscle balance.

Also see abstracts under Color Vision, Dark Adaptation, Depth Perception and Stereopsis, Refractive Error and Refraction, and Visual Acuity-Static.

1968 OHLBAUM, M.K. THE EFFECTS OF ALTITUDE ON CERTAIN ASPECTS OF VISUAL PERFORMANCE

26 Refs. M.S. Thesis, Division of Optometry, Indiana University, June 1968.

See abstract under Depth Perception and Stereopsis.

1969 LURIA, S.M.
Kent, P.R. THE RELATION OF "DUCTION" TO DYNAMIC STEREO ACUITY

4 Refs. Sub. Med. Res. Lab., U.S. Naval Sub. Med. Center, Groton, Conn. Rep. No. 575, April 1969.

See abstract under Depth Perception and Stereopsis.

XV. PHYSIOPATHOLOGY

1939 ARMSTRONG, H.G. PRINCIPLES AND PRACTICE OF AVIATION MEDICINE

The Williams and Wilkins Co., Baltimore, Md., 1939.

P. 324-5 In considering the effects of atmospheric pressure change on the eye, no objective or subjective change was noted except for injection of the bulbar conjunctiva accompanied by a smarting or burning sensation. This holds presumably up to about 30,000 feet.

Also see abstract under Visual Standards.

1947 LYONS, R.E. ANALYSIS OF THE CAUSES OF DISQUALIFICATION OF 164,687 APPLICANTS REJECTED FOR AVIATION TRAINING

J. Avia. Med., 20:193-200, 1949.

From July 1, 1943 to June 30, 1944 the initial examination on aviation applicants was on WDAGO Form 64 under the provisions of Army Regulation 40-110. From July 31, 1943 to February 17, 1944 applicants were examined under the provisions of AR 40-105, AR 40-110, and relaxed standards in WD circular 176, July 31, 1943. The latter included; V.A. 20/30 correctable to 20/20 O.U., heterophoria within 12$^{\Delta}$ esophoria and 7$^{\Delta}$ exophoria. During the year July 1, 1943 to June 30, 1944, 374,638 applicants were examined of which 164,687 (44%) were disqualified. Of each hundred disqualified, 29.7 did not pass the eye examination, 11.5 had defective V.A., 8.9 defective heterophoria, 7.5 defective color vision and 2.2 had an accommodative defect.

1950 DUGUET, J.
Mercier, A. PHYSIOPATHOLOGY OF THE FLYERS EYE

357 Refs. Translated from French at the USAF Sch Avia. Med., Randolph Field, Texas. 1950.

This book is an extremely good source for the subject up to 1950.
1. Effect of altitude on visual apparatus--circulation of retina, ocular tension, pupillary reactions, V.A., visual fields, stereoscopic vision, accommodation, motility, color sense, and night vision (due both to decompression and anoxemia).
2. Visual troubles due to accelerations.
3. Effects of physical factors--light, cold, wind-blast, and vibration.
4. Vision and orientation in the air--illusions.
5. Wounds and burns.
6. Ocular psychoneurosis in aviation.
7. Intoxications.
8. Protection of the flyer's eyes.

9. Visual problems in aircraft design--field of vision, optical properties of windows, etc., arrangement of instrument panel, illumination of cockpit and instrument panel.

1962 SAYLOR, W.P. SPACE RADIATION GUIDE
Carriker, A.W.
Riven, C.J.
Winer, D.E.

201 Refs. Aerospace Med. Div., Wright-Patterson AFB, Ohio. Rep. No. AMRL-TDR-62-86, August 1962.

See abstract under Flash Blindness, Glare and Radiation Effects.

1968 PEACOCK, G.R. LASER PROPERTIES AND EYE HAZARDS (INTERIM REPORT)
Van Nus, F.

51 Refs. U.S. Army Med. Res. Lab., Fort Knox, Kentucky. Rep. No. 776, DA Proj. No. 3A014501B71P, May 1968.

The relation between laser output properties and eye injury are described. A review of laser eye injury data is included together with certain aspects of laser safety.

1968 MARTIN, B.G. EYE OPACITIES IN FLYING PERSONNEL
Tredici, T.J.
Culver, J.F.

No Refs. USAF Sch. Aerospace Med., Brooks AFB, Texas. Review 9-68, September 1968.

A summary is given of an 11 year period of eye opacities found after referral to the School of Aerospace Medicine, Brooks AFB, Texas. The ophthalmology branch saw 3,067 patients, 134 of whom had opacities. These were subclassified as follows, Lenticular-73, Corneal-49, and Vitreous-12. Details of types of the above opacities and the numbers grounded are given. The aetiology of the opacity is reported, if known.

1968 LAPPIN, P.W. ANALYSIS OF THE FIRST THERMAL NUCLEAR PULSE AND ASSOCIATED EYE EFFECTS
Adams, C.F.

2 Refs. Aerospace Med. Res. Lab., Aerospace Med. Div., Wright-Patterson AFB, Ohio. Rep. No. AMRL-TR-67-214, December 1968.

See abstract under Flash Blindness, Glare and Radiation Effects.

1969 MILLER, N.D. et. al. RESEARCH ON VISUAL PROBLEMS IN SPACE FLIGHT

5 Refs. NASA, Manned Spacecraft Center, Houston, Texas. NASA Contract NAS 9-6865, March 1967-May 1969.

See abstract under Depth Perception and Stereopsis.

XVI. REFRACTIVE ERROR AND REFRACTION

1945 HIRSCH, M.J. — RELATION OF VISUAL ACUITY TO MYOPIA

2 Refs. Arch. Ophthal., 34:418-421, No. 5, 1945.

The visual acuity and degree of myopia was measured for 64 eyes. The myopia was within a range of 0.50-13.50 D; all the subjects were college students. The log of the visual acuity plotted against the myopia gives the coefficient of correltaion of +0.95. The results are important in guarding against over-correction of myopia, malingering, etc.

1966 USAF SCHOOL OF AEROSPACE MEDICINE — LECTURE OUTLINES

Ophthalmology Branch, Aerospace Medicine Primary (OBY 9356), OP Handout #11, USAF Sch. of Aero. Med, Aero. Med. Div. (AFSC), Brooks AFB, Texas. August 1966.

Lectures are included on refraction and refractive errors.

1968 WHITCOMB, M.A.; Benson, W., (Eds.) — THE MEASUREMENT OF VISUAL FUNCTION (SYMPOSIUM) PROCEEDINGS OF SPRING MEETING 1965

Extensive Refs. Armed Forces-NRC Committee on Vision, Washington, D.C., 1968.

A paper is included on the clinical and laboratory measurement of refractive error.

Also see abstracts under Color Vision, Dark Adaptation, Depth Perception and Stereopsis, Ocular Muscle Balance, and Visual Acuity-Static.

1969 DURSKY, I.L.; Levene, J.R. — AN ANALYSIS OF SOME REFRACTIVE ERROR TRENDS IN U.S. AIR FORCE PILOTS AND NAVIGATORS

104 Refs. Indiana Univ., Div. of Optometry and Phys. Optics, Bloomington, Indiana. NASA Contract No. NAS 9-8078, June 1969.

There are no fusional amplitude standards. Hence, it is possible to have qualifying heterophoria yet poor fusional amplitude reserves to maintain single binocular vision and vice versa.

XVII. SPACE FLIGHT INCLUDING RECONNAISSANCE AND SURVEILLANCE

1957 HAMILTON, C.E.; Blackwell, H.R. — THE EFFECT OF A HORIZON-LINE LUMINANCE GRADIENT UPON TARGET DETECTABILITY IN ITS VICINITY

3 Refs. Engineering Research Institute, Univ. of Michigan, U.S. Navy Bureau of Ships, Contract No. Nobs-72038, April 1957.

See abstract under Flash Blindness, Glare and Radiation Effects.

1958 BOYNTON, R.M.; Elworth, C.; Palmer, R.M. — LABORATORY STUDIES PERTAINING TO VISUAL AIR RECONNAISSANCE

14 Refs. Aero. Med. Lab., Wright-Patterson AFB, Ohio. WADC Tech. Rep. 55-304, Pt. III, AD 142274, Contract No. AF 33(616)-2565, April 1958.

The third and final report is presented on a program concerning the investigation of relevant variables involved in visual reconnaissance. A mathematical relationship is worked out which yields the contrast required for 60% recognition as a function of subject-target distance, exposure time, and number of confusion forms (struniforms) among which the critical target may be located. By translating altitude into experimental distance, aircraft velocity into viewing time and conditions of viewing (including meteorological conditions) into contrast, predictions are made about how performance should vary as a function of altitude from 500-30,000 feet. Futher studies are reported of a preliminary attempt to understand individual differences in searching ability as the relate to parafoveal form recognition, visual acuity and eye movements.

1961 BROWN, J.L. — SENSORY AND PERCEPTUAL PROBLEMS IN SPACE FLIGHT

51 Refs. Reprinted as Chap. 7 from Physiological Problems in Space Flight, Charles C. Thomas, 1961.

The paper gives a general review of the problems of space flight. It says space myopia should not be a problem because the stars will be an adequate enough stimulus for accommodation. Also covered in the paper are vision, hearing, vestibular senses, other senses, and other problems including time perception and sensory deprivation.

1962 JONES, E.R.; Hann, W.H. — VISION AND THE MERCURY CAPSULE

12 Refs. Armed Forces-NRC Comm. on Vision, Washington, D.C., 1962.

See abstract under Displays and Visual Simulation.

1962 MILLER, J.W. (Ed.) VISUAL PROBLEMS OF SPACE TRAVEL

Extensive Refs. Nat. Acad. of Science, Nat. Res. Council, Washington, D.C., 1962.

The book is a good reference book although it is all conjecture and simulation. The following are discussed:
P. 3-4: Colors seen on the launching and in space.
P. 14. Discussion of simulated gravity.
P. 20-24 Visual displays with consideration for the various novel problems of space flight e.g. absence of gravity, presence of various accelerative forces.
P. 29-37: Vision at various stages in space flight.

1962 MORRIS, F.M. VISUAL ASPECTS OF SPACE FLIGHT

15 Refs. Amer. J. Optom. & Arch. Amer. Acad. Optom., 39 643-652, 1962.

The paper is an introduction to the visual problems likely to be encountered in space, e.g. glare, retinal burns, weightlessness, space myopia, etc.

1963 NARVA, M.A.
Muckler, F.A. VISUAL SURVEILLANCE AND RECONNAISSANCE FROM SPACE VEHICLES

Extensive Refs. Human Factors, 5:295-315, 1963.

The review includes the variables affecting surveillance. An analysis of the theoretical capabilities of direct, unaided vision and manperiscopic vision are presented.

1963 ZINK, D.L. VISUAL EXPERIENCES OF THE ASTRONAUTS AND COSMONAUTS

21 Refs. Human Factors, 5:187-201, 1963.

A comparison is made between the actual visual capabilities and the predicted capabilities. Requirements for further study are discussed.

1967 TAYLOR, J.H. VISUAL PERFORMANCE ON THE MOON

3 Refs. Scripps Inst. of Oceanography, Visibility Lab., Univ. of California, San Diego, California. Ref. 67-3, 1967.

Man will depend largely on his visual sense when he is on the moon. Many of the usual visual cues will be modified or absent on the moon, e.g. size, distance and color of the lunar features without aerial perspective, reference objects and other cues. There will also be harsh luminance contrasts. Photographs showing the effects on the lunar surface of the illumination and reflection from the

LEM are presented in the report. Physical properties of the lunar visual environment, including luminances, reflectances, and illuminances are also included.

1967 BROWN, J.L. THE VISUAL REALM IN SPACE FLIGHT

55 Refs. Physiological Psychology Branch, Psychological Sciences Div., Office of Naval Res., Kansas State Univ., Contract No. NONR-3634(04), December 1967.

A very useful résumé of visual problems in space is presented in the report. ". . . for his size, mass and energy requirement . . . (man) . . . can handle a broader range of situations more effectively and with more flexibility than any automatic equipment which might be designed." For an object that subtends 1' at the eye, its dimension in feet equals 1 1/2 its distance in miles. Gravity, both higher and lower than one G, is also considered. Effects of hyperoxygenation and a discourse on the visual environment of space are included. The report concludes that the characteristics of the human visual process will probably remain unchanged in spaceflight except at very high acceleration or in a low oxygen atmosphere.

1968 CULVER, J.F. THE HUMAN EYE IN SPACE EXPLORATION

15 Refs. 4th International Symposium from Chap. XVIII in Bioastronics and the Exploration of Space, Roadman, Strughold and Mitchell, 1968.

The various defects which it was prophesied would be produced in the visual system in space have not occurred, e.g. space myopia and illusions. A table is included of the primary parameters of the visual environment of space including 90° solar illumination, surface reflectance and mean atmospheric transmission for the earth, EVA, mars and the moon. Also included is a table showing critical visual tasks on the Apollo mission. ". . . daytime illumination at the moon's surface exceeds that on the earth by about 75% and the nighttime illumination facing the earth is approximately 60 times that of the earth due to the earths reflectance."

1968 DUNTLEY, S.Q.
Austin, R.W.
Harris, J.L.
Taylor, J.H. EXPERIMENTS ON VISUAL ACUITY AND THE VISIBILITY OF MARKINGS ON THE GROUND IN LONG-DURATION EARTH-ORBITAL SPACE FLIGHT

Several Refs. Scripps Inst. of Oceanography, Visibility Lab., Univ. of California, San Diego, California. Contract NAS 9-5095, January 1968.

The visual acuity of four astronauts was measured, before, during and after long duration space flights; their visual acuity did not change. The astronauts observed from orbit a prepared and monitored pattern of small white rectangles on the ground to determine the limiting ability to discriminate orientation. The performance was exactly as previously calculated.

XVIII. VISUAL ACUITY - DYNAMIC

1953 LUDVIGH, E.
Miller, J.W.

A STUDY OF DYNAMIC VISUAL ACUITY

4 Refs. Office of Naval Res., U.S. Naval Sch. Avia. Med., Pensacola, Florida. Proj. No. NR-142-023, NM 001 075 01.01, March 1953.

Visual acuity deteriorates markedly as the angular velocity of the test object, relative to the eye, increases. Dynamic visual acuity is measured when the eye is moving. Individuals with similar static visual acuity may differ widely with their dynamic visual acuities. Measurements were taken for objects moving in a horizontal plane between 10-170° per second.

1953 LUDVIGH, E.
Miller, J.W.

DYNAMIC VISUAL ACUITY WHEN THE REQUIRED PURSUIT MOVEMENT OF THE EYE IS IN A VERTICAL PLANE

8 Refs. Office of Naval Res., U.S. Nav. Sch. Avia. Med., Pensacola, Fla. Proj. No. NM 001 075.01.02, May 1953.

The report shows how the visual acuity deteriorates at the angular velocity of the test object, travelling in a vertical plane, is varied between 20° per second and 140° per second.

1953 LUDVIGH, E.

THE INFLUENCE OF DYNAMIC VISUAL ACUITY ON THE VISIBILITY OF STATIONARY OBJECTS VIEWED FROM AN AIRCRAFT FLYING AT CONSTANT ALTITUDE, VELOCITY AND DIRECTION

6 Refs. Office of Naval Res., U.S. Naval Sch. Avia. Med., Pensacola, Fla. Proj. No. NM 001 075 01.03, August 1953.

An equation is derived expressing the relationship between:
1. Size of critical detail visible from an aircraft.
2. The x and y coordinates of an object on the surface of the earth.
3. Altitude of flight.
4. Orientation of the critical detail relative to the plane of flight.
5. The a and b parameters of the observers dynamic visual acuity.
6. Velocity of flight.

The concept of "ease of seeing", E, is advanced.

1954 LUDVIGH, E.
Miller, J.W.

SOME EFFECTS OF TRAINING ON DYNAMIC VISUAL ACUITY

6 Refs. Office of Naval Res., U.S. Nav. Sch. Avia. Med., Pensacola, Fla. Proj. No. NR-142-023, NM 001 075.01.06, September 1954.

The effects of training the dynamic visual acuity of 200 Naval Aviation Cadets were found to be substantial at high angular velocity of test objects, in absolute or percentage terms. At 110° per second, the amount of improvement and the rate of improvement varied greatly among the subjects.

1955 MILLER, J.W.
Ludvigh, E.

A SHORTENED PROCEDURE FOR THE TESTING OF DYNAMIC VISUAL ACUITY

10 Refs. Office of Naval Res., U.S. Naval Sch. Avia. Med., Pensacola, Fla. Proj. No. NR 142-023, NM 001 110.501.08, May 1955.

The data on 200 Naval Aviation Cadets, who were tested by a procedure lasting 45 minutes, was reanalysed on the basis of a test requiring only 12 minutes. Various aspects of the test were examined, such as the reliability and the predictability, and the relationships among the variables. Th shortened form was declared to be suitable for future testing.

1956 MILLER, J.W.
Ludvigh, E.

THE RESULTS OF TESTING THE DYNAMIC VISUAL ACUITY OF 1000 NAVAL AVIATION CADETS

13 Refs. Office of Naval Res., U.S. Nav. Sch. Avia. Med., Pensacola, Fla. Proj. No. NR-142-023, NM 001 110.501, Rep. No. 10, August 1956.

The results of testing the dynamic visual acuity of 1000 Naval Aviation Cadets is presented and some aspects of the data analysed. It was found that the parameter employed to describe the dynamic visual acuity was not distributed normally. The possible causes for this non-normality are considered. It is demonstrated that it is possible to place individuals into statistically distinguishable categories on the basis of their dynamic visual acuity. The possibilities of this with regard to the future selection of pilots is considered.

1956 MILLER, E.F.

OCULAR PURSUIT OF A TARGET MOVING IN AN APPARENT CIRCULAR PATH

7 Refs. U.S. Naval Sch. Avia. Med., Pensacola, Fla. Res. Proj. NM 001 110.012, Rep. No. 1, September 1956.

Dynamic visual acuity tested with a rotary prism was compared with that measured with a rotation mirror apparatus. The abnormally distributed rotary prism thresholds were relatively higher than, yet correlated significantly with, those of the rotating mirror. The relative increase found with the prism in the rate of deterioration of acuity with an increase in angular velocity was attributed to the exclusive factor of the rate of repeated rotation of the eye.

1958 LUDVIGH, E.
Miller, J.W.

STUDY OF VISUAL ACUITY DURING THE OCULAR PURSUIT OF MOVING TEST OBJECTS: I. INTRODUCTION

13 Refs. J. Opt. Soc. Amer., 48:799-802, No. 11, 1958.

The same apparatus is used as before. The mirror is rotated at angular velocities of 10° per second to 170° per second at the nodal point of the eye to be tested. The visual acuity decreased rapidly and markedly as the angular velocity was established by the following semi-empirical equation:

$Y = a + bx^3$ where: Y = size of critical detail in minutes
a = predicted value of static visual acuity in minutes
b = measure of dynamic acuity
x = angular velocity in degrees per second

1958 MILLER, J.W.

STUDY OF VISUAL ACUITY DURING THE OCULAR PURSUIT OF MOVING TEST OBJECTS· II. EFFECTS OF DIRECTION OF MOVEMENT, RELATIVE MOVEMENT AND ILLUMINATION

9 Refs. J. Opt. Soc. Amer., 48:803-808, No. 11, 1958.

The manner in which visual acuity decreases is similar with angular velocity horizontally, vertically or with rotation in a horizontal plane. The formula $Y = a + bx^3$ describes all three movements. The higher the relative angular velocity, the greater the intensity of illumination must be in order to maintain a given visual acuity threshold.

1961 LUDVIGH, E.
Miller, J.W.

THE PERCEPTION OF MOVEMENT PERSISTANCE IN THE GANZFELD

9 Refs. J. Opt. Soc. Amer., 51:57-60, 1961.

See abstract under Illusions and Visual Perception Night Myopia, Space Myopia and Ganzfeld.

1961 SCHUMANN, W.P.

VISUAL ACUITY AND OPTOKINETIC NYSTAGMUS

10 Refs. Amer. J. Optom. & Arch. Amer. Acad. Optom., 38 646-654, 1961

See abstract under Nystagmus.

1964 BURG, A.

AN INVESTIGATION OF SOME RELATIONSHIPS BETWEEN DYNAMIC VISUAL ACUITY, STATIC VISUAL ACUITY AND DRIVING RECORD

Extensive Refs. Engineering Dept., Univ. of California, Los Angeles, Calif. Rep. 64-18, April 1964.

1966 BURG, A.

VISUAL ACUITY AS MEASURED BY DYNAMIC AND STATIC TESTS: A COMPARATIVE EVALUATION

14 Refs. J. Appl. Psychol., 50:460-466, No. 6, 1966.

The report is an attempt to show a relationship between static and dynamic visual acuity. There were 17,500 subjects used, their ages ranging from 16 to 92 years. A higher correlation was shown than with previous studies, the correlation decreasing with increasing speed of target movement. The Bausch and Lomb Orthorater checkerboard target was used and the subject was told he could move his head. The dynamic visual acuity was measured at 60°, 90°, 120° and some at 150° per second. Other conclusions of the report are as follows:

1. The dynamic visual acuity is worse than the static and more so as the speed of the target increases.
2. Visual acuity becomes worse with increasing age, and more so for dynamic than static.
3. Males have better dynamic and static visual acuity than females.

N.B. see Burg, A. (1964) paper for pictures of the apparatus.

1968 LURIA, S.M.
Weissman, S.

RELATIONSHIP BETWEEN STATIC AND DYNAMIC STEREO-ACUITY

9 Refs. J. Exptl. Psych., 76:51-56, No. 1, 1968.

See abstract under Depth Perception and Stereopsis.

XIX. VISUAL ACUITY - STATIC

1943 KANE, A.L. — CORRELATION OF DEFECTIVE VISUAL ACUITY AND POOR OCULAR MUSCLE BALANCE ON ABILITY TO SUCCEED IN FLYING TRAINING

No Refs. Canada, R.C.A.F., Director of Medical Services, Great Britain, O.S.R.D. No. III-1-2233, April 1943.

See abstract under Ocular Muscle Balance.

1948 DEPARTMENT OF THE ARMY — STUDIES ON VISUAL ACUITY

No Refs. Prepared by Staff, Personnel Research Section of Adjutant General's Office, U.S. Government Printing Office, Washington, D.C., 1948.

The purpose of the studies was to examine various aspects of visual acuity through factor analysis of correlations among tests of visual acuity, and to select the best tests in terms of item difficulty and scoring methods. Present methods of testing visual acuity result in a great inconsistancy in standards for vision that are adopted for the military service. The main object of this study is to determine the aspects and influences present in vision tests. From a study of 14 wall chart tests, results are presented showing the factors in visual acuity (far) tests, from the study of 3 commercial devices and other tests, the factors in far and near acuity, depth perception and phoria tests are given. For the 14 wall chart tests, results are presented showing the test-retest reliability by 7 methods of scoring, the frequency distributions of the test scores, analysis of item difficulty, analysis of testing conditions, correlation of letter tests with A.G.C.T. and examinee options. All the studies purposed to improve the wall chart testing as a measurement of vision based upon how well they operate in their present form.

1956 WHITE, W.J.
Jorve, S.R. — THE EFFECTS OF GRAVITATIONAL STRESS UPON VISUAL ACUITY

26 Refs. Aero. Med. Lab., Wright-Patterson AFB, Ohio. WADC Tech. Rep. No. 56-247, ASTIA Doc. No. AD 110444, November 1956.

See abstract under Illusions and Visual Perception: Gravitational and Vestibular Effects.

1957 HAMILTON, C.E.
Blackwell, H.R. — THE EFFECT OF HORIZON-LINE LUMINANCE GRADI. I UPON TARGET DETECTABILITY IN ITS VICINITY

3 Refs. Engineering Res. Inst., Univ. of Michigan, U.S. Navy Bureau of Ships. Contract No. Nobs-72038, April 1957.

See abstract under Flash Blindness, Glare and Radiation Effects.

1958 WHITE, W.J. — ACCELERATION AND VISION

52 Refs. Aero. Med. Lab., Wright-Patterson AFB, Ohio. WADC Tech. Rep. 58-333, ASTIA Doc. No. AD 208147, Noverber 1958.

See abstract under Illusions anf Visual Perception: Gravitational and Vestibular Effects.

1960 LURIA, S.M.
Schwartz, I. — VISUAL ACUITY UNDER RED VERSUS WHITE ILLUMINATION

8 Refs. U.S. Naval Med. Res. Lab., Sub. Base, New London, Conn. Rep. No. 326, Proj. No. MR 005.14-1001.01.10, January 1960.

See abstract under Dark Adaptation.

1960 WHITE, W.J. — VARIATIONS IN ABSOLUTE VISUAL THRESHOLDS DURING ACCELERATION STRESS

9 Refs. Wright Air Dev. Div., Wright-Patterson AFB, Ohio. Proj. No. 7222, Task No. 71712, WADD Tech. Rep. No. 60-34, April 1960.

See abstract under Illusions and Visual Perception· Gravitational and Vestibular Effects.

1961 PIGG, L.D.
Kama, W.N. — THE EFFECT OF TRANSIENT WEIGHTLESSNESS ON VISUAL ACUITY

4 Refs. Aero. Med. Lab., Wright-Patterson AFB, Ohio. WADD Tech Rep. No. 61-184, Proj. No. 7184, Task No. 71586, March 1961.

See abstract under Illusions and Visual Perception. Gravitational and Vestibular Effect.

1961 VORPIO, HANNU — THE OBJECTIVE MEASUREMENT OF VISUAL ACUITY· BY ARRESTING OPTOKINETIC NYSTAGMUS WITHOUT CHANGE IN ILLUMINATION

No Refs. Acta Ophthal. Sup., 39.7-66, (Supplement 66), 1961.

A definition and delineation of factors effecting visual acuity are given. Visual acuity is affected by inherent and external factors which to a great extent don't significantly influence visual acuity in a clinical examination. The author cites several examples.

(a) Optimum pupil size for visual acuity is 2.8-4.0 mm, however, visual acuity is still accurate with pupil sizes up to 5.6 mm.

(b) The eye, and human being as a whole, are very adaptable to various prevailing conditions.

Good delineations are given of the following objective methods of

examining visual acuity.

(1) Evoking optokinetic nystagmus - dependable results though they didn't consider theoretical treatment of resolutions.
(2) Arresting optokinetic nystagmus - these methods (based on an evaluation of visual acuity by reaction of the eye to changes in illumination) "do not seem to give trustworthy results".
(3) Galvanic skin response - very comparable to a subjective exam.
(4) Evoking oscillatory motion - same as (1).

An investigation was carried out to establish whether visual acuity could be tested by arresting nystagmus using the authors procedure. A mutual relationship between the decisive details of test figures was used in both subjective and objective techniques. A thorough delineation of the apparatus, testing procedure and results was presented. The results showed that the authors method is suitable; mutual interdependence between details.

1963 VANDERPLAS, J.M. — VISUAL CAPABILITIES OF PERFORMING RENDEZVOUS IN SPACE

23 Refs. Human Factors, 5:323-328, 1963.

This paper is a review of the detection, discrimination, recognition, identification, judgement, acquisition, homing and docking of space vehicles, pointing out the inadequacies of existing data (1963).

1963 WHITE, W.J.; Monty, R.A. — VISION AND UNUSUAL GRAVITATIONAL FORCES

Extensive Refs. Human Factors, 5:239-263, 1963.

See abstract under Illusions and Visual Perception Gravitational and Vestibular Effects.

1964 BURG, A. — AN INVESTIGATION OF SOME RELATIONSHIPS BETWEEN DYNAMIC VISUAL ACUITY, STATIC VISUAL ACUITY AND DRIVING RECORD

Extensive Refs. Engineering Dept., Univ. of Calif., Los Angeles, Calif. Rep. 64-18, April 1964.

See abstract under Visual Acuity-Dynamic.

1966 BURG, A. — VISUAL ACUITY AS MEASURED BY DYNAMIC AND STATIC TESTS: A COMPARATIVE EVALUATION

14 Refs. J. of Appl. Psychol., 50:460-466, No. 6, 1966.

See abstract under Visual Acuity-Dynamic.

1966 DUNTLEY, S.Q. et. al. — VISUAL ACUITY MEASURED DURING PROLONGED WEIGHTLESSNESS

J. Opt. Soc. Amer., 56:538(A), March 1966.

Tests of visual acuity were performed in connection with the long duration earth orbital flights of Gemini 5 and 7. A small testing device was used by the crew members on several occasions before, during and soon after the flights. No change in the visual acuity was detected.

1968 WHITCOMB, M.A.; Benson, W. (Eds.) — THE MEASUREMENT OF VISUAL FUNCTION (SYMPOSIUM) PROCEEDINGS OF SPRING MEETING 1965

Extensive Refs. Armed Forces-Nat. Res. Comm. on Vision, Washington, D.C., 1968.

Several papers are included on the clinical and laboratory measurement of visual acuity.

Also see abstracts under Color Vision, Dark Adaptation, Depth Perception and Stereopsis, Ocular Muscle Balance, and Refractive Error and Refraction.

1968 DUNTLEY, S.Q.; Austin, R.W.; Harris, J.L.; Taylor, J.H. — EXPERIMENTS OF VISUAL ACUITY AND THE VISIBILITY OF MARKINGS ON THE GROUND IN LONG-DURATION EARTH-ORBITAL SPACE FLIGHT

Several Refs. Scripps Inst. of Oceanography, Visibility Lab., Univ. of Calif., San Diego, Calif. Contract NAS 9-5095, January 1968.

See abstract under Space Flight, Including Reconnaissance and Surveillance.

1968 RUBENSTEIN, L.; Kaplan, R. — SOME EFFECTS OF X-AXIS VIBRATION OF VISUAL ACUITY

6 Refs. Aero. Med. Res. Lab., Aero. Med. Div., Air Force Systems Command, Wright-Patterson AFB, Ohio. AMRL-TR-68-19, June 1968.

See abstract under Effects of Vibration.

1968 LURIA, S.M.; Weissman, S. — RELATIONSHIP BETWEEN STATIC AND DYNAMIC STEREO-ACUITY

9 Refs. J. of Exptl. Psychol., 76:51-56, No. 1, 1968.

See abstract under Depth Perception and Stereopsis.

XX. VISUAL FIELDS

1954 COCHRAN, L.B. — VARIATION IN HUMAN GRAVITY TOLERANCE DUE TO POSITIVE ACCELERATION
Gard, P.W.
Northsworthy, M.E.

U.S. Nav. Sch. Avia. Med., Pensacola, Fla. Rep. No. 001 059.02.10, 1954.

See abstract under Illusions and Visual Perception: Gravitational and Vestibular Effects.

1957 ADES, H.W. et. al. — NYSTAGMUS ELICITED BY HIGH INTENSITY SOUND

6 Refs. U.S. Naval Sch. Avia. Med., Pensacola, Fla. Joint Proj. No. NM 130 199, Subtask No. 2, Rep. No. 6, February 1957.

See abstract under Nystagmus.

1957 FOOKS, G. — PILOT STUDIES OF SCOTOPIC SENSITIVITY TEST
Dimmick, F.L.
Sweeney, E.J.

3 Refs. U.S. Naval Med. Res. Lab., Sub. Base, New London, Conn. Rep. No. 285, Proj. No. NM 23 01 20, Rep. No. 1, Subtask 4, June 1957.

See abstract under Dark Adaptation.

1958 MILLER, E.F. — EFFECT OF BREATHING 100% OXYGEN AT ATMOSPHERIC PRESSURE UPON THE VISUAL FIELD AND VISUAL ACUITY

4 Refs. U.S. Navy Sch. Avia. Med., U.S. Navy Avia. Med. Center, Pensacola, Fla. Res. Proj. NM 12-01-11, Subtask 11, Rep. No. 1, March 1958.

See abstract under Atmospheric Effects.

1958 BLACKWELL, H.R. — DETECTION THRESHOLDS FOR POINT SOURCES IN THE NEAR PERIPHERY. FINAL REPORT
Moldaver, A.B.

14 Refs. Engineering Res. Inst., Univ. of Michigan. Proj. No. ER1 2455, June 1958.

Two observers obtained visual detection thresholds for the foveal center and for 32 locations in the peripheral retina, within a radius of 12° from the fovea. The locations fell along 8 equally spaced meridians of the visual field, at distances of 1, 2, 6, 8 and 12° from the fixation center. These measurements were made at each

of nine levels of background luminance, ranging from zero to 75 foot lamberts. A total of 368,250 observations were made utilizing the temporal forced-choice variant of the method of constant stimuli. The target was a circle whose diameter subtended 1 minute of an arc; the exposure duration was 0.01 second. The relationship between threshold contrast and background luminance for the foveal and peripheral locations was plotted showing discontinuities in the periphery, these are said to represent the well-known rod-cone "break".

1960 WHITE, W.J. — VARIATIONS IN ABSOLUTE VISUAL THRESHOLDS DURING ACCELERATION STRESS

9 Refs. Wright Air Dev. Div., Wright-Patterson AFB, Ohio. Proj. No. 7222, Task No 71712, WADD Tech. Rep. 60-34, April 1960.

See abstract under Illusions and Visual Perception: Gravitational and Vestibular Effects.

1962 BEISCHER, D.E. — EXPOSURE OF MAN TO LOW INTENSITY MAGNETIC FIELDS
Miller, E.F.

35 Refs. U.S. Naval Sch. Avia. Med., U.S. Nav. Avia. Med. Center, Pensacola, Fla. July 1962.

See abstract under Flicker Fusion Frequency.

XXI. VISUAL STANDARDS

1916 COTTLE, C.P. — NAVAL AVIATION PERSONNEL

Milit. Surgeon, 39:353-360, 1916.

Many people think the aviator must have some peculiar inborn quality of senses by which he is able to fly. The beginning of naval aviation was 1910-1911. Physical requirements are given in the Manual for the Medical Department U.S.N., 1914, Chapter 12, Paragraph 2113. These are:

1. Visual acuity shall be normal without glasses. Any error of refraction is rejected.
2. The candidates ability to estimate distance will be determined (method not given).
3. Color blindness for red, green or violet is a cause for rejection.

1917 CONNOR, C.H. — THE SPECIAL PHYSICAL EXAMINATION OF AVIATORS FOR THE UNITED STATES ARMY

No Refs. Milit. Surgeon, 40:29-32, 1917.

The report says, "the most important part of the inquiry narrows down to the examination of the sense of equilibrium." The importance of the eye in this "sense" is acknowledged. "The question of the eye is easily settled, without perfect vision a candidate is not to be considered." Causes for rejection are:

1. Eye disease, diplopia, scotomata or headache after use of the eyes.
2. The movements of the eyes must be regular and identical.
3. There must be an entire absense of nystagmus when the eyes are at rest, straight ahead or 40° laterally.
4. A phorometer is used to detect muscular dificiency and a cycloplegic used for latent error of refraction and fundus exam.

Several tests are explained to determine the state of equilibrium.

1918 BACHMANN, R.A. — THE EXAMINATION OF AVIATORS

No Refs. U.S. Naval Med. Bull., 12:30-41, 1918.

The report suggests a tentative routine based on the examination for flyers of the Army Signal Corps. Many of the tests are of German and Austrian origin. The very complete eye exam includes:

1. Detailed history
2. Stereoscopic acuity of the Holmes stereoscope
3. Ocular movements--motility test vertical and horizontal
4. Pupillary reaction--direct, indirect and accommodative
5. Intraocular tension--by palpation
6. Nystagmus--should be none looking straight ahead or laterally 40° or less
7. Visual field--confrontation test

8. Color perception--Jennings yarn test cards
9. Muscle balance at 20 feet--phorometer used, must be no more than 1° hyperphoria or 2° exophoria or exophoria
10. Visual acuity--20/25 O.U. distance and J1 O.U. near
11. N.P.C. 11 cm at age 20; 13 cm at age 25, 15 cm at age 30
12. Ophthalmoscopy with euphthalmine.

1918 U.S. WAR DEPARTMENT — AIR SERVICE MEDICAL

No Refs. U.S. War Dept., Air Service, Div. of Military Aeronautics, Washington, D.C., U.S. Government Printing Office, 1918.

Pilots were classified into 1 of 3 altitudes at which they were supposedly safe based on tests to determine their ability to sustain anoxia.

Also see abstracts under Atmospheric Effects, and Depth Perception and Stereopsis.

1918 LANCET — THE EFFICIENT SELECTION AND CARE OF FLYING OFFICERS

No Refs. Lancet, 1:190-191, 1918.

The paper gives a general treatment of the problem only. Useful quote, ". . . it must be remembered that, at present, these (standards) are mainly tentative and theoretical, and evolved for the most part by medical men who have no practical knowledge of aviation . . ."

1918 ANDERSON, H.C. — AVIATION AND MEDICINE, AND THE SELECTION OF CANDIDATES FOR THE AIR SERVICE

No Refs. Trans. Med. Soc., London, XLI, 240-270, 1918.

Transactions of the first meeting of any medical society in Britain having talked medically about aviation are recorded.

1. Excess in smoking could lead to diplopia.
2. P. 251. In the vision exam the candidate must have;
   (a) unaided normal vision O.U.
   (b) normal color vision
   (c) vision of 6/9 with +2 D lens disqualified candidates.
3. Heterophoria may cause bad landings (red and green lens test used to evaluate heterophoria).
4. The night blindness test is given only for night bombing.
5. Stereoscopic vision "need hardly be tested".

The discussion afterwards was recorded:

(a) E. Clark said small errors were infinitely worse than large and obvious errors. Heterophoria should be a cause for rejection, especially exophoria.
(b) J. Galloway said vision tests must be standardized and the candidate must have a full visual field.

1918 FLACK, M. — SCIENTIFIC TESTS FOR THE SELECTION OF PILOTS FOR THE AIR FORCE

No Refs. Nature, 101:225-226, 1918.

This paper seems to be based heavily on H.G. Anderson's paper to the Medical Society of London. It says, ". . . the candidate shall have accurate vision . . . (we) must rule out concealed hypermetropia . . . A good color sense is also necessary." The tests are carried out at the British Aviation Candidates Board.

1919 AUTOMOTIVE INDUSTRIES — INTERNATIONAL MEDICAL REQUIREMENTS FOR AERIAL NAVIGATION

No Refs. Automot. Industr., 41:199-200, 1919.

Medical requirements are given for the examination of pilots drafted by the Aeronautical Commission of the Peace Conference in Paris. The eye examination consisted of:

1. The degree of visual acuity required must be compatible with the efficient performance of his duties.
2. No pilot can have more than 2 D of latent hyperopia.
3. Muscle balance must be good and commensurate with refraction.
4. Each eye must have a good field of vision.
5. Color perception must be normal.

Each state may use its own methods at present. Re-examinations should be every six months. Each state may raise, but not lower these minimum requirements.

1920 U.S. WAR DEPARTMENT — AVIATION MEDICINE IN THE A.E.F.

No Refs. Office of the Adjutant General, Doc. No. 1004, Washington, D.C. U.S. Government Printing Office, February 1920.

The entrance requirement for 'phorias exclude about 1° of hyperphoria or 2° of exophoria at 6 meters. The report contains details of which instruments are used for color vision and stereo vision tests. Page 175 gives the effects of lowered oxygen tension on visual aspects. Page 176 gives graphs of the weakening of ocular muscles with various altitudes. Accommodation requirements are recorded: near point of accommodation at 20 years of age should be less than 110 mm, for 25 years of age less than 130 mm, for 30 years of age less than 150 mm. Quote from page 184, "It seems that the converging power should never be less than double the diverging power at all distances " Equipment used in the Ophthalmology Department is listed. Copies of forms used in the U.S. Army Aviation Medical are shown.

1922 TEFFT, L.E.
Stark, E.K. — SPEED OF ACCOMMODATION AS A PRACTICABLE TEST FOR FLIERS

1 Ref. Amer. J. Opthtal., 5.339-342, 1922.

An experiment was done with a tachistoscope to see whether speed of accommodation should be a test in the standards to fly. Sixty subjects were used and a relationship of results was made with visual acuity, depth perception, accommodation, power of convergence and divergence, and retinal sensitivity measured with Cobb's apparatus. At present the standards allow a leeway above or below the normal for each as determined by Duane.

1923 BERENS, C. — THE EYE IN AVIATION· SOME EXPERIENCES IN THE WORK OF THE DEPARTMENT OF OPHTHALMOLOGY, MEDICAL RESEARCH LABORATORY, THIRD AVIATION INSTRUCTION CENTER, A.E.F., FRANCE

Extensive Refs. Milit. Surgeon, 52:35-48, 1923.

The paper claims to be a complete bibliography; it is extensive anyway. Visual standards (1923) are given:

1. Extrinsic ocular muscles--". . . it seems that the converging power should never be less than double the diverging power at all distances."
2. Accommodation--the near point of accommodation must not be greater than· 110 mm at age 20 (9.09 D); 130 mm at age 25 (7.69 D); 150 mm at age 30 (6.67 D).
3. Near point of convergence--"over 80 mm would seem cause for rejection."
4. Visual acuity--uncorrected 20/20 O.U. with no more than 2 D of latent hyperopia would seem to be all right.

1923 DAVIS, W.R. — THE DEVELOPMENT OF AVIATION MEDICINE

1 Ref. Milit. Surgeon, 53.207-217, 1923.

The paper gives a general account of the early history of aviation. The first medical exams for flying in the U.S. were given in 1912; the first blanks and instructions for how to carry out the exam were issued in July, 1914. The first Flight Surgeon was appointed on September 6, 1917. An interesting quote on page 214, ". . . examining a fliers eyes . . . does not call for a skilled ophthalmologist."

1923 BRITISH JOURNAL OF OPHTHALMOLOGY — SECTION OF OPHTHALMOLOGY· DISCUSSION ON OPHTHALMOLOGY IN ITS RELATION TO THE NAVY, ARMY AND AIR FORCE

1 Ref. Brit. J. Ophthal., 2·654-658, 1923.

See abstract under Ocular Muscle Balance.

1927 LOY, A.W. — DISQUALIFYING EYE MUSCLE IMBALANCES IN AVIATORS

No Refs. U.S. Naval Bulletin, 27:335-338, 1927.

See abstract under Ocular Muscle Balance.

1927 LANCET — MEDICAL REQUIREMENTS FOR FLYING AS LAID DOWN BY THE INTERNATIONAL COMMISSION FOR AIR NAVIGATION

No Refs. Lancet, 2:1361-1362, 1927.

Eye exam requirements for private pilots were 6/9 O.U. with correction if necessary. Ocular poise, visual fields, and color vision should be normal. Eye exam requirements for the crew of aircraft for public transport stated that "the candidate must not be completely deprived of the use of either eye and his pupillary reflexes must be normal " Vision must be compatible with efficient performance of his duties, i.e. 100% visual acuity O.U. with out correction.

1929 ICKSTADT, A. — PHYSICAL QUALIFICATIONS AND AERONAUTICAL ADAPTABILITY

No Refs. U.S. Naval Med. Bull., 27:9-16, 1929.

The study was conducted to determine whether the variation in quality of visual attributes within the standards has any bearing on training failure rate. There was no correlation between depth perception, lateral ocular poise, hyperphoria, degrees of differences of accommodation between the two eyes, anisometropia and the failure rate. Hence, "differences in physical findings considered bear no relation to students success of failure . . . the present standards are not too lax." Some visual parameters measured at this time were:

1. Depth perception: 0-25 mm satisfactory
2. Heterophoria: esophoria and exophoria diotance and near (no quantitative data)
3. Hyperphoria: 0-0.75 Δ satisfactory
4. Accommodation: 0-2 D difference between eyes satisfactory
5. Anisometropia: (criteria for anisometropia not given).

1929 BENJAMIN, J.D. — ANALYSIS OF AVIATION PHYSICAL EXAMINATIONS

No Refs. Milit. Surgeon, 65:693-695, 1929.

An analysis is given of individual causes of rejection for flying in the Navy during the 18 months prior to the report. The report shows that 20.8% of the candidates were rejected for inability to read 20/20. In all, 44% were rejected for eyes alone. Hence, eye defects are the greatest physical cause for rejection.

1929 STITT, E.R. — TRENDS IN MEDICAL AVIATION

No Refs. California and Western Medicine, 15:377-382, 1929.

On the advice of General Wilmer (eminent ophthalmologist) 1/2Δ hyperphoria limit is now raised to 3/4Δ (1929). Quote, "the specialists at Pensacola have failed to note any superiority in student pilots who just pass the various eye tests with those who have little or no defects."

1930 HERTZOG, F.C. — THE EYE EXAMINATION

No Refs. J. Avia. Med., 1, 1930.

Between 1928-1930, 78% of all medical rejections were for eye defects. This paper is really an account of the authors personal eye exam routine with notes pertaining to increasing the reliability of the results.

1930 THORNE, F.H. — A REVIEW OF OCULAR MUSCLE IMBALANCE (WITH REPORT OF TWO-HUNDRED AND FORTY-FOUR CASES)

5 Refs. Military Medicine, 66.175-205, 1930.

See abstract under Ocular Muscle Balance.

1930 COOPER, H.J. — THE RELATIONSHIP BETWEEN PHYSICAL DEFICIENCIES AND DECREASED PERFORMANCE

5 Refs. J. Avia. Med., 1:4-24, 1930.

The British found during World War I that their first method of sending anyone who passed the recruiting examination, or who was "a washout" from other branches of the service, to the air force resulted disastrously. Results in the first year indicated that 60% of the pilots killed met death as a result of physical defects. By a subsequent demand for higher physical standards the initial 60% was reduced to 12% in two years. The Air Commerce Act of 1926 placed standards for civil aeronautics under the administration of the Secretary of Commerce as "Air Commerce Regulations". "Physical Standards for Airplane Pilots" elaborates on physical requirements and methods of procedure for medical examination. Military regulation and standards for flying are much more rigid than civil ones. The International Commission for Air Navigation, formed in 1919, represents 26 foreign countries and its regulations govern international air navigation. Though the U.S. had not ratified the I.C.A.N. convention their civil aeronautic requirements adhered closely to them. Regarding regulations made at this time, a delineation of the visual standards for flying personnel are given. "Bad landings are frequently due to ocular muscle imbalance." Wilmer reports (Aviation Medicine in the A E.F., Document No. 1004, Government Printing Office, Washington, D.C.) that Clements of England found 84% of officers turned down for bad landings were successfully treated by visual training techniques. Trained pilots should have at least 2 D of accommodation. The Department of Commerce considers color vision, field of vision, diplopia, and

muscle tests as part of the routine visual examination. A delineation of ophthalmic dispensing of goggles with and without prescription is made. General conclusion of the article: "Physical departures from the normal correlate well with decreased performance."

1931 ARMY MEDICAL BULLETIN — THE SELECTION OF THE AVIATOR

Army Med. Bull., 26:6-25, Chap. II, 1931.

The report describes the methods of measuring the visual parameters in full.

Also see abstract under Ocular Muscle Balance.

1931 BERENS, C.
Smith, H.T. — PRESENT OPHTHALMOLOGIC STANDARDS FOR COMMERCIAL AVIATION IN THE UNITED STATES

106 Refs. Trans. Amer. Acad. Ophth. & Laryn., 36th Ann. Meeting, 1931.

See abstract under Depth Perception and Stereopsis.

1931 CHASE, J.S. — EYES IN AVIATION

No Refs. Rocky Mountain Med. J., 28.203-207, 1931.

A general introduction to eye examinations for aviation is given. The paper insinuates that W.H. Wilmer had much to do with forming the original standards. The following standards are given:
Department of Commerce, Transport and Limited Commercial License 1926--20/20 O.U. separately without glasses, normal muscle balance, visual fields, color vision, and depth perception.
Student and private pilot--20/50 O.U. corrected to 20/20, providing the depth perception result is not over 30 mm.
Army and Navy additional requirements--the candidate is disqualified if a latent error (spherical or cylindrical) of over 1D with homatropine is found. The angle of convergence and the muscle balance at 30 cm is measured.
One eyed pilots are not accepted because there are so many applicants for each position with 2 eyes.

1931 WURDEMANN, H.V. — PHYSICAL EXAMINATION OF AVIATORS

J. Avia. Med., 2.23-28, 1931.

Useful quotes, "20/20 or 100% sharpness in sight required," and "the ocular muscles must function normally."

1931 McALESTER, A.W. — BALANCE OF THE OCULAR MUSCLES AS RELATED TO FLYING· SOME CONSIDERATIONS

No Refs. J. Avia. Med., 2:218-226, 1931.

The paper contains evidence that the original standards were pooled judgements. Useful quotes, ". . . the circulars of instruction speak well . . . for the farsighted intelligence of those who had, by almost pure reason, to devise them . . ." Early methods of investigation of ocular muscle balance are discussed. A man should not be allowed to enter the service with a hyperphoria of 1°.

1932 BERENS, C. — PRESENT OPHTHALMIC STANDARDS FOR COMMERCIAL AVIATION IN THE UNITED STATES

J. Avia. Med., 3, 1932.

Pages 89-94 Tables are given showing the visual standards for the following airplane pilots,
1. U.S.--Army, Navy, commercial, and private.
2. Foreign--approximately 25 countries.
3. International--service and private pilots.

1933 SIMPSON, R.K. — OCULAR REQUIREMENTS FOR FLYING IN THE U.S. ARMY

No Refs. J. Avia. Med., 4·106-110, 1933.

Fourteen steps, or phases in the eye examination are given.
1. Visual acuity 20/20 at 20 feet
2. Depth perception--Howard--25 mm maximum
3. 'Phorias at 6 meters--Risley rotary prism and Maddox rod used--disqualifying conditions.
   (a) esophoria greater than 4$^{\Delta}$ if associated with diplopia on the tangent screen or greater than 1 D hyperopia (measured by retinoscopy)
   (b) esophoria greater than 10$^{\Delta}$ if no other defects occur
   (c) exophoria greater than 2$^{\Delta}$ if associated with an angle of convergence that is less than 50° or diplopia on the tangent screen
   (d) exophoria greater than 5° if no other defects occur
   (e) hyperphoria greater than 1/2° with no other defects
4. 'Phorias at 33 cm exophoria greater than 12$^{\Delta}$ disqualifies
5. Power of prism divergence: disqualified if greater than 15$^{\Delta}$ or less than 4$^{\Delta}$
6. Red lens test at 75 cm, diplopia within 40° disqualifies--any nystagmus noted
7. External exam
8. Size, shape and reaction of pupils
9. Accommodation with Prince or Thorne's rule, within ± 3 D of Fuch's table
10. Power of convergence: less than 40° disqualifies, less than 50°

disqualifies if associated with greater than 1Δ hyperopia
11. Central color vision with Jennings self recording test
12. Field of vision for form and color with Schweigger hand perimeter
13. Refraction greater than 1 DS with cycloplegic disqualifies, greater than 1/2 DC with cycloplegic disqualifies
14. Ophthalmoscopy.

1935 MASHBURN, N.C. — SOME INTERESTING PSYCHOLOGICAL FACTORS IN THE SELECTION OF MILITARY AVIATORS

8 Refs. J. Avia. Med., 6:113-126, 1935.

Useful quote, "many of these standards are arbitrarily conceived, and they may or may not be scientifically sound and mathematically justified." Basically the paper is concerned with psychologically testing the pilot as there was still a high "wash-out" rate even though the pilots passed the medical standards. No tests are given however. General Lyster and I.H. Jones wrote the original examination physical for pilots (A.G.O., 609, May 1917).

1936 WHITE, M.S. — TESTS FOR COLOR-BLINDNESS

48 Refs. J. Avia. Med., 7:134-142, 1936.

See abstract under Color Vision.

1938 SCHWICHTENBERG, A. — THE EVALUATION OF ORTHOPTIC TRAINING FOR AVIATION

Amer. J. Ophthal., 21.980-990, 1938.

The author suggested that static eye tests in aviation be replaced by dynamic ones. He found that pilots with normal visual apparatus when tested by conventional means sometimes showed gross errors when tested on orthoptic equipment.

1939 ARMSTRONG, H.G. — PRINCIPLES AND PRACTICE OF AVIATION MEDICINE

The Williams and Wilkins Co., Baltimore, Md. 1939.

Useful quote, "physical requirements for flying first instituted in this country in 1912 and records show that the requirements for vision and hearing were obtained from the regulations of the Military and Naval services and that a 'text book of physiology' was used as the principle source of information." In 1916 the exam was revised again and a new form completed in May 1917 (recorded on form 609). A stereoscope was used to test depth perception.

Also see abstract under Physiopathology.

1939 MASHBURN, N.C. — THE SELECTION OF THE TRAINEE FOR MILITARY AVIATION

No Refs. Milit. Surgeon, 84:428-441, 1939.

The first Research Board of Air Service was established October 18, 1917, at Mineola, New York. In 1912 special regulations for physical standards of the Signal Corps were set up. "The medical research workers in this country profited greatly from the pioneer work done in Europe (during World War I)."

1940 U.S. WAR DEPARTMENT — STANDARDS OF PHYSICAL EXAMINATION FOR FLYING

U.S. War Dept., Army Regs. No. 40-110, Para. 16-27, U.S. Government Printing Office, Washington, D.C., April 1940.

The report contained just a copy of the standards; no comments were made. Also included was the maximum near points as determined by a special formula.

1942 MASHBURN, N.C.; Marshall, F.A. — AVIATION MEDICAL STANDARDS: BRITISH R.A.F. VS U.S. ARMY AIR CORPS

No Refs. J. Avia. Med., 13:62-71, 1942.

The eye exam section is apparently the most obvious difference between the two. The paper contains tables of standards (1942) for both USAAC and RAF. The most obvious differences were:
1. No refraction is done in the RAF.
2. More stringent and possibly more reasonable 'phoria tests are done in the RAF.

1942 LILJENCRANTZ, E. — PROBLEMS IN THE SELECTION OF AVIATORS

No Refs. J. Avia. Med., 13:107-120, 1942.

A brief survey is given of all the physical standards. Some people have criticized the visual standards as being too severe, but "one-eyed, color blind and grossly ametropic individuals can be taught to fly airplanes, just as armless individuals can be taught to write or swim."

1942 WHITE, M.S. — A STUDY OF THE VALUE OF THE PSEUDO-ISOCHROMATIC COLOR VISION TEST IN THE SELECTION OF THE MILITARY PILOT

1 Ref. AAF Sch. of Avia. Med., Randolph Field, Texas. Proj. No. 12, Rep. No. 1, January 1942.

See abstract under Color Vision.

1942 BAHN, C.A. — OPHTHALMIC REQUIREMENTS OF THE MILITARY SERVICE

Arch. Ophthal., 27:1202-1213, 1942.

A refraction is carried out with cycloplegic. In the Army each eye must have an error less than +1.5 DS or ±0.50 DC. In the Navy each eye must have an error less than +2.00 or -0.50 DS or ±0.50 DC. No dark adaptation tests are given.

1943 BAHN, C.A. — OPHTHALMIC REQUIREMENTS OF THE MILITARY SERVICES. REVISION FEBRUARY 1, 1943

Arch. Ophthal., 29:831-843, 1943.

A change in requirements from the above paper (1942) are given:
1. Different standard for power of convergence.
2. Power of divergence further defined.
3. Red lens test further defined.

1944 BAHN, C.A. — OPHTHALMIC REQUIREMENTS OF THE MILITARY SERVICES: CHANGES FROM FEBRUARY 1, 1943 TO JANUARY 1, 1944

Arch. Ophthal., 31.160-161, 1944.

The requirements are unchanged from 1943 except for those pertaining to the Army Air Corps (see above paper). Some are slightly relaxed for applicants for air crew training.

1945 BAHN, C.A. — OPHTHALMIC REQUIREMENTS OF THE MILITARY SERVICES. CHANGES FROM JANUARY 1, 1944 TO JANUARY 1, 1945

Arch. Ophthal., 33.245-246, 1945.

The differences in the requirements from 1944 are.
1. Visual acuity is tested at 50 cm.
2. Exophoria does not have to be less than 4Δ when associated with prism divergence less than 4Δ.
3. The power of convergence must not exceed the P.D.
4. The table or required accommodative status is given.
5. The table of required field of view is given.

1945 ROYAL CANADIAN AIRFORCE — VISUAL FACTORS IN AIRCREW SELECTION

4 Refs. Assoc. Comm. of Avia. Med. Res., National Res. Council, Canada. Rep. No. C2791, February 1945.

See abstract under Ocular Muscle Balance.

1945 SCOBEE, R.G.; Green, E.L.; Moss, H.L. — A COMPARISON OF TESTS FOR HETEROPHORIA: VARIATIONS IN THE SCREEN-MADDOX ROD TEST DUE TO OCULAR DOMINANCE, RED COLOR AND SCREENING

12 Refs. AAF Sch. Avia. Med., Randolph Field, Texas. Proj. No. 375, Rep. No. 4, July 1945.

The report shows that esophoria is induced both at near and far with a Maddox rod whether it is white or red. However, a white Maddox rod induces about 0.25Δ less esophoria at 20 feet. It is also shown that no significant difference is found in the results whether the Maddox rod is placed before the dominant or non-dominant eye. He recommended that the standards should be changed to accommodate the above.

Also see abstract under Ocular Muscle Balance.

1945 SCOBEE, R.G. — AN ANALYSIS OF THE OPHTHALMIC PORTION O. "64" EXAMINATION. (2) MUSCLE BALANCE-A SUMMARY OF SUGGESTED CHANGES

7 Refs. Army Air Forces Sch. Avia. Med., Randolph Field, Texas. Proj. No. 139, Rep. No. 2, August 1945.

See abstract under Ocular Muscle Balance.

1946 NRC COMMITTEE ON SELECTION AND TRAINING OF AIRCRAFT PILOTS — A STUDY OF VISUAL AND CARDIO-VASCULAR STANDARDS IN RELATION TO SUCCESS IN FLIGHT TRAINING

CAA Div. Res., Report No. 62, Washington, D.C., May 1946.

No significant relationship was found between visual cardio-vasc[illegible] defects investigated and criterion measures of proficiency in the flight training course. The visual factors included acuity, depth perception and accommodation. Four samples of R.A.F. cadets in training at 4 centers in the U.S. served as the subjects. The R.A.F. standards were lower than those of the U.S. services--hence it appears that the Army and Navy standards are unnecessarily stringent.

1947 LYONS, R.E. — ANALYSIS OF THE CAUSES OF DISQUALIFICATION OF 164,687 APPLICANTS REJECTED FOR AVIATION TRAINING

J. Avia. Med., 20:193-200, 1949.

See abstract under Physiopathology.

1947 IMUS, H.A. EVALUATION OF EYE EXAMINATION

72 Refs. U.S. Navy Sch. Avia. Med., Pensacola, Florida. June 1947.

Two hundred and fifty Naval Aviators who had returned from combat or operational tours of duty were given complete eye exams and other tests. The subjects ages ranged between 20-30. An Orthorater was used in testing. Extensive correlations were made between the tests carried out. No significant relationship between for lateral phoria and depth perception was found when measured with the Orthorater. The four tests of depth perception used had a low degree of correlation between them. The 30 mm limit on the Howard-Dolman test was failed by 12.4% of the subjects. Useful quote, "the visual standards for Naval Aviation had been established some 20 years previously (about 1924) upon an arbitary basis, using the best ophthalmological judgement at the time as to what constituted normal visual performance. Unfortunately for science, too few persons with defective vision are willing to attempt the flight training without wearing glasses which correct their vision to normal." The study supposes that important visual factors would cluster around the same level, whereas others would show a wide distribution, e.g. depth perception has a wide distribution.

Also see abstract under Ocular Muscle Balance.

1947 VITELES, M.S. VISUAL STANDARDS AND FLIGHT PERFORMANCE

16 Refs. J. Avia. Med., 18:528-547, 1947.

Two hundred subjects were divided into 4 groups.
Group A—contained 80 subjects with 20/20 O.U. or better; they had very good stereopsis and low refractive error.
Group B—contained 40 subjects with 20/50 or worse uncorrected with 20/20 corrected, high stereopsis, refractive error under 3.00 DS or 2.00 DC also present.
Group C—contained 40 subjects with 20/100 or worse O.U. uncorrected with 20/50 corrected; stereopsis of 10 cm at 6 meters and refractive error of about 4.00 D also present.
Group D—contained 40 subjects sub-grouped into 3 groups, all basically monocular.
A definite relationship was shown between visual efficiency and flight performance. The failure rate of a 50 hour private flight training course was as follows: A) 15% B) 21% C) 30% and D)49%. However, the study showed that students with defective visual acuity were less motivated to fly than those with unimpaired vision. It seems that those in groups C and D may have been influenced by comments made to them saying they were endangering themselves in undertaking flight training. Page 541: 32% of the subjects in C and 27% in D attained scores above the average in A. No accidents were reported in the whole study of 8,000 hours.

1950 NICHOLLS, J.V.V. THE RELATIONSHIP OF HETEROPHORIA TO DEPTH PERCEPTION IN AVIATION

236 Refs. Amer. J. Ophthal., 33:1479, 1775, 1891 (3 parts), 1950.

A most extensive review of the subject is given. The final conclusion, "on the basis of these findings, it is recommended that no limitations be placed upon ocular muscle balance for pilot duty, providing the candidate has no frank diplopia."

1950 PAGE, H.E. HISTORICAL BACKGROUND AND ORGANIZATION OF THE PILOT SELECTION PROGRAM

USAF Sch. Avia. Med. and USN Sch. Avia. Med. & Res., Joint Proj. Rep. No. 1, March 1950.

The report is concerned with the selection of people suitable to be officers, and various psychological tests, not physical standards.

1951 WOLFAN, B.J. SOME ASPECTS OF PROBLEMS OF VISUAL STANDARDS

3 Refs. From, "Blackwell, H., Minutes and Procs. NRC-Armed Forces Committee on Vision, 29th Meeting, 1951."

A general survey.

1954 KRIMSKY, E. AN APPRAISAL OF AVIATION EYE TESTS WITH RECOMMENDATIONS

8 Refs. J. Avia. Med., 25:243-253, 1954.

See abstract under Ocular Muscle Balance.

1957 BURRELL, R.R. HISTORICAL REVIEW OF AIRCREW SELECTION

25 Refs. Air Univ. Sch. of Avia. Med., Randolph Field, Texas. Review 1-56, September 1957.

The study is concerned with the "psychologic selection of pilots," from the "beginning of powered flight to the present." In 1912 the first physical exam was given for flying. "Visual acuity without glasses should be normal . . . color blindness for red, green, or violet is a cause for rejection . . ." "It appears possible . . . (1957) to develop a battery of tests which can be used to screen out candidates with poor prognosis for adaptability to military flying . . ."

1958 THORNE, F.H. — OPHTHALMOLOGY IN AVIATION

No Refs. Arch. Ophthal., 19:253-277, 1938.

The physical requirements of military and commercial aviation are "rigid and are scrupulously maintained." The purpose of standards is to reduce to a minimum the number of persons who may become incapacitated later. Physical standards for pilots of all types of aircraft and of all types of flying are set by the Armed Forces and Dept. of Commerce, and all pilots must have a physical exam every 6 months. There are four visual elements of concern in the exam

(1) Acuteness of vision
(2) Judging distance
(3) Efficiency of the extraocular muscles
(4) Color discrimination

Near vision and amplitude of accommodation are also considered. The Howard-Dolman apparatus is used for depth perception. The relationship between accommodation and convergence is assumed to be 1:1. Regarding color testing, the military follows an outline by Cooley and Crow (Cooley, E.E., and M.C. Crow, Color Vision, Army Med. Bull., No. 34, 1-31, January 1936) which delineates color vision and defectives based on the Edridge-Green theory. The Ishihara plates and the Holmgren Yarn Test are routinely used, the latter claimed to be the most efficient, and thus subsequently used when doubt arises with the other tests. The visual standards were adopted when flying was in it's infancy, and experience was minimal. Consequently, they are more or less arbitrary. Scientifically, the adopted limits have never been justified. Many standards were derived from statistical means, and people with greater error have never been allowed to demonstrate their ability. However, relaxation of the visual standards is not warranted because, "the basis on which they are founded are sound."

1962 FIELDS, V. (Ed.) — FEASIBILITY OF DESCRIBING VISUAL DEMANDS OF MILITARY JOBS

No Refs. Armed Forces-NRC Comm. on Vision, Rep. of working group 10, Office of Naval Research, Contract No. NONR 2300(05), Oct. 1962.

The report contains an explanation of job analyses being done to enable visual standards to be postulated.

1962 MORRIS, A. — A REVIEW OF THE ARMED FORCES-NRC VISION COMMITTEE'S ACTIVITIES RELATIVE TO VISUAL STANDARDS FOR MILITARY TASKS, 1944-1945

Armed Forces-NRC Comm. on Vision, Visual Problems of the Armed Forces, Washington, D.C., 1962.

A very brief summary is given of the contents of Armed Forces-NRC reports from the 1st-14th (called U.S. Army-Navy OSRD Vision Committee) and 15th-35th (called U.S. Army-Navy NRC Vision Committee).

1963 ZINK, D.L. — VISUAL EXPERIENCES OF THE ASTRONAUTS AND COSMONAUTS

21 Refs. Human Factors, 5:187-201, 1963.

See abstract under Space Flight, Including Reconnaissance and Surveillance.

1964 DEPARTMENT OF THE AIR FORCE — AIR FORCE MANUAL 160-1

Air Force Manual 160:1, Department of the Air Force, Washington, D.C., February 1964.

Visual standards page 131, Attachment 13 This section contains the most recent visual standards except for an amendment of February 1, 1967 when "failure of the red lens test in the absence of other eye defects" would not necessarily disqualify the candidate for flying training.

1964 JAMPOLSKY, A.
Morris, A. — VISUAL REQUIREMENTS FOR FLYING: SOME ASPECTS OF RE-EVALUATION

10 Refs. Armed Forces-NRC Comm. of Vision, Rep. on working group 20, Office of Naval Research, Contract No. NONR 2300(05), June 1964.

Interesting quotes, "inequalities exist in the degree of perfection required in the different visual capabilities as established in the visual standards for flying e.g. 20/20 visual acuity, with as much as 10^{Δ} of esophoria allowed." ". . . visual tests . . . are . . . specified (but) there is a lack of uniformity in carying out the instructions." ". . . vision may not be as important for present day flying as was formally supposed." "Pooled visual judgements . . . appear to have proven satisfactory relative to the selection of personnel for flying tasks." A system using a matrix of visual parameters and ten grade decrements is suggested.

1967 JONES, W.L.
Allen, W.H.
Parker, J.F. — ADVANCED VISION RESEARCH FOR EXTENDED SPACEFLIGHT

9 Refs. Aerospace Med., May 1967.

The paper describes the NASA research program and recent (1967) research.

1968 OHLBAUM, M.K. — THE EFFECTS OF ALTITUDE ON CERTAIN ASPECTS OF VISUAL PERFORMANCE

26 Refs. M.S. Thesis, Div. of Optometry, Indiana Univ., June 1968.

No justification for present USAF standards of minimum accommodation was found and an absolute minimum of 4-5 D is suggested. The author agrees with Scobee in that altitude has no significant effect on the 'phorias.

Also see abstract under Depth Perception and Stereopsis.