THE MEASUREMENT OF VISUAL EFFICIENCY STANDARDS

FOR PILOTS IN THE UNITED STATES AIR FORCE

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ABSTRACT

Visual standards currently utilized for pilot qualification in the United States Air Force need to be updated as our knowledge of visual science expands. Vergence facility was selected as a test of dynamic visual function. A group of pilots was matched to a group of normal, nonpilot controls. The pilot group did not differ significantly from the control group in the test of vergence facility. This may be an appropriate test for inclusion in the current United States Air Force visual diagnostic battery but other approaches need tobe evaluated.

KEY WORDS

visual standard, flight safety, vergence facility, dynamic vision, visual fatigue, fusion

Military aviation requires a high degree of visual skill and efficiency. The current visual standards for flying status in the United States Air Force employ static tests of visual function. Visual factors utilized in flight are continually changing to meet the demands of the situation. This study evaluates the performance of two carefully matched samples of people on a test of dynamic visual change, i.e., vergence facility. We compared the ability of a sample of military pilots to make rapid fusional movements in a base-in and base-out direction with a group of nonpilots matched for other normal visual characteristics. The number of times each subject could reestablish fusion while viewing an anaglyph target through alternating 16Δ base-out and 4Δ base-in prism lenses was recorded over a one-minute time interval. We found the pilots' ability to initiate and sustain fusional vergence movements to be similar to that of their nonrated military counterparts. Our work does not indicate that this test of visual efficiency would discriminate between the pilots and nonpilots in our sample if it were included in a test battery to identify individuals with exceptional visual proficiency.

INTRODUCTION

The current physical examination for flying status in the United States Air Force includes a detailed visual evaluation.[1] The visual evaluation emphasizes tests of static visual function such as eye alignment and total accommodation. The high technology and responsiveness incorporated in the aircraft used in today's Air Force requires both speed and efficiency for optimum operation. This study evaluates one measure of visual efficiency as a possible indicator for inclusion in the visual analysis section of the Air Force physical examination.

Vergence facility was chosen as one appropriate indicator of visual efficiency. Vergence facility is the speed with which an individual can recover fusion or sustain binocularity in the presence of rapid changes in vergence demand. Tests of vergence facility have been described as important clinical measurements.[2,3] The efficiency with which a patient is able to respond to changes in convergence or divergence demand has been shown to be more of a clinical indicator of patients who will demonstrate visual asthenopia during nearpoint tasks than static functions such

as the vertical or horizontal phoria.[4,5] The efficiency with which a person adjusts to increased convergent and divergent demands seems to improve with increased utilization of the skill.[6] Pilots, in particular, place stringent demands on the vergence system in performing their duties. Constant sightings from horizon, to gauges, to charts, and to approach markers make rapid, accurate vergence shifts necessary in safe aircraft operation. This study examines the ability of pilots to perform these binocular movements in comparison with their nonrelated military counterparts.

METHODS

Fourteen subjects participated in the study. They were selected randomly from an Air National Guard population. The subjects were grouped based on pilot/nonpilot criteria. Several criteria were utilized to ascertain whether both groups were as closely matched on visual characteristics as possible.

Each subject had to pass all the tests of vision required by the Air Force periodic physical examination. The pilots, in addition, had to pass the visual criteria for flying status. Subjects were selected to give an average age that was not statistically different between the two groups and below 45 years of age. This was done to nullify the effect of presbyopia and resultant loss in accommodative convergence which might affect the test of vergence facility.

Any subject who required lenses to correct to 20/20 vision was tested with that correction in place. The subjects were referred to the examiner without knowledge of their age or performance on the periodic physical or visual examination to ensure non-bias in the testing.

The subjects were asked to align a vertical picture (□-X-○) slide made of anaglyph material for monocular presentation under binocular conditions (see Figure 1). They wore anaglyph (red-green) filtered spectacles with the red lens before the right eye. They viewed the "□" with the right eye and the "○" with the left eye. The central "X" was visible to both eyes. The target was set at 40 cm and verified for each subject to ensure constant vergence demand. The appropriate distance vision correction, if needed, was in place.

The target was chosen to provide an adequate accommodative stimulus that could be used by all subjects. The target measured 21 mm in the vertical meridian and 10 mm in the horizontal meridian. The size of the target was selected so that the contours were small enough to produce noticeable diplopia when fusion was broken. A white line 1 mm wide around the target border served as a fusion lock outside the foveal area.[7]

The subjects alternately viewed the target through a 16Δ base-out and 4Δ base-in prism flipper. The subjects were directed to "keep the □-X-○ all in a straight line. You will be viewing them through each side of the glasses for one minute. Let me know when they are in a straight line by saying, 'now'." Each subject was then given a demonstration on the base-in and base-out side to ensure that he or she understood the directions. Each was also asked to report any disappearance of the targets.

The test was continued for one minute. The total number of flips (base-in and base-out sides) was recorded. Each change of lens counted as a single flip.

RESULTS

Table 1 shows the raw data obtained from 14 Air Force personnel examined in this study. Table 2 shows the comparative averages of both pilots and nonpilots for age and the number of completed vergence movements accomplished over a one-minute period. A Bartlett test for homogeneity of group variances was 4.452 (approximate $F = 4.141$; $df = 1, 4.32$; $p = 0.042$). The overall mean was 14.143 5.655 with a pooled within-group standard deviation of 5.813 ($T = 0.552$, $p = 0.591$). There is no statistical significance evident in the test results. The carefully matched samples of flying personnel and nonpilot Air Force personnel are able to initiate shifts in the visual axis with equal facility.

Figure 1. Anaglyph fusion target used to monitor visual alignment and suppression.

DISCUSSION

Visual information processing requires both the ability to accommodate and converge as well as the facility to execute the movements accurately and rapidly. The visual standards utilized for flying duty in the United States Air Force should reflect both facility and ability.

There does not seem to be a difference in this sample of Air Force pilots when tested for vergence facility. The nonrated subjects in this study were able to adapt to large changes in vergence demands as well as the rated subjects. If vergence facility is an important component of vision used in flying, it does not appear to be a discriminating test for assessing dynamic vision based on the results of this study. The size of this sample precludes any definitive statements about the inclusion of the test in a standardized test battery. The importance of carefully matching the sample populations for all visual characteristics other than vergence facility eliminates a large number of tested subjects. The matching criteria is based on the current standards for flight duty in the United States Air Force. Any study evaluating the predictability of a clinical measure must control the other variables that have a direct affect on the test being studied. The sample size used in this study needs to be replicated on a larger sample population maintaining the same stringent matching criteria.

This result does raise a question about the other standards currently used. When we use, for example, phoria and refractive measures which are more stringent than those required for nonpilots, are we really identifying a skill level needed for aircraft

TABLE 1

Identifying data on 14 subjects with the number of flips per minute

	Age	Glasses	Flips/min
Nonpilot			
1	30	0	18
2	31	0	5
3	26	0	12
4	30	1	19
5	40	0	1
6	43	0	17
7	48	0	21
Pilot			
1	41	0	16
2	39	0	15
3	39	1	15
4	42	0	14
5	36	1	18
6	41	0	9
7	46	0	8

0 = no glasses 1 = glasses

TABLE 2

Range, Mean, and Standard Deviation of Observations for All Subjects

	N	Minimum	Maximum	Mean	Standard deviation
Nonpilots					
Age	7	26	48	35.42	8.20
Flips	7	1	21	13.28	7.63
Pilots					
Age	7	36	46	40.58	3.10
Flips	7	8	18	15.00	3.05

control? We need to examine our current standards in light of modern binocular vision theory so that we do not screen out individuals who have a high potential for success as Air Force pilots because of minor deficiencies in noncritical visual skills. The visual portion of the physical examination performed for commission in the United States Air Force defines the minimum visual skills required for duty as an officer. The standards are more demanding for flight physicals, presumably to ensure that officers identified for flight crew duty have the superior visual skills necessary to perform the task. An individual requesting enlisted status or commission in the United States Air Force is required to have a minimum Snellen visual acuity of 20/40 in one eye and 20/70 in the other eye or 20/20 in one eye if the opposite eye is 20/400 or poorer. To qualify for a Class I (Flying Training) visual profile, an individual must have a 20/20 Snellen visual acuity in each eye. These more stringent visual demands required for all flying class levels necessitate an increase in optometry clinic resources, personnel and time demands. This is justifiable on some tests (i.e., red lens, ocular motility), but what do the other tests (i.e., visual acuity, cycloplegic refraction, refractive error) tell us? These tests need to be related to specific factors that differentiate visual skills required for flight performance. Has the research on our visual criteria for flight expanded at the same rate as the technology of flight itself?

The study also indicates that standards used in the active duty force for vision may not necessarily be appropriate when applied to the guard and reserve. This study shows a tendency for the pilot group to be older (mean = 40.57 years) than the nonpilot group (mean = 35.42). Our subjects were drawn from a mixed active duty/Air National Guard population with a higher percentage of Air National Guard personnel represented. Our selected sample of pilots is an accurate reflection of the average age of 37 years for the 3,726 pilots of the Air National Guard as compared with the average age of 32 years for active duty pilots. The combined average age for the Air National Guard and the Air Force Reserve is 38 years. The average of enlisted guard personnel is 33.9 years. Future visual studies need to correlate standards with other Air Force data such as accident rates, rather than age.

CONCLUSION

The purpose of this study was to determine whether a test of vergence facility would be an indicator of superior visual skills. These skills, it was presumed, could be transferred to the accurate vision demands of the military pilot. Fourteen subjects viewed an anaglyph target through a 16-prism diopter (16Δ) base-out prism and a four-prism diopter (4Δ) base-in prism over a one-minute period. There was no difference between a matched sample of pilots and nonpilots.

The current visual standards for flying duty seem to be adequate without the addition of vergence facility testing. The study needs to be expanded both in subjects and scope. The current visual requirements need to be examined to see whether they discriminate individuals with well-developed visual skills. Future investigation also needs to examine whether our current requirements are sensitive to the age differentials evident in today's total Air Force.

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