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VISUAL ACUITY AND REACTION TIME IN NAVY FIGHTER PILOTS

A. Morris and P. V. Hamilton

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Volunteer subjects were recruited, evaluated, and employed in accordance with the procedures specified in Department of Defense Directive 3216.2 and Secretary of the Navy Instruction 3900.39 series. These instructions are based upon voluntary informed consent and meet or exceed the provisions of prevailing national and international guidelines.

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The present report is one in a series presenting data collected from U. S. Navy fighter pilots in training at the Air Combat Maneuvering Range, NAS Oceana, VA. The principle objective of the project is to relate visual and biographical parameters to air-to-air target detection and other measures of flying performance. The project has been supported by Naval Air Systems Command and the Naval Medical Research and Development Command.

SUMMARY PAGE

THE PROBLEM

Establishment of performance-based biomedical standards for each aviation community requires acquisition of sufficient data on physiological and psychophysical characteristics, as well as flight performance, to allow determination of how these characteristics influence flying performance. Many piloting tasks depend heavily on vision, so accurate vision data for each aviation community are needed to develop valid performance-based visual standards.

THE FINDINGS

This report summarizes data on selected visual measures for Navy fighter pilots. The vision of 163 pilots was measured using an Automated Vision Test Battery housed in a Mobile Field Laboratory. All pilots were involved in training at the Tactical Air Combat Training System (TACTS) range, NAS Oceana, VA. Data on simple visual reaction time, spot detection ability, and static visual acuity under several conditions are reported, and the influences of age and spectacles on vision are examined. The average high contrast acuity score was 0.40 minutes of visual angle, or 20/8 Snellen; no pilot had worse than 20/15 acuity. These findings, together with other data, suggest that Navy fighter pilots have better vision than non-aviators of the same age, and possibly better vision than student naval aviators. Correlational analyses suggest that acuity threshold, simple visual reaction time, and threshold-stressed reaction time are independent measures of visual functioning. Spectacled pilots had poorer vision than non-spectacled pilots, and older pilots tended to have poorer vision than younger pilots.

RECOMMENDATIONS

1. To evaluate the uniqueness of the vision of this group of fighter pilots, the visual acuity of a comparison group of applicants to the naval aviation training program should be measured quantitatively before screening and/or disqualification on the basis of any aspect of the physical exam.

2. Population samples drawn from other aviation communities should be tested to determine if there are significant differences in visual performance related to critical task requirements.

3. To increase our knowledge of age-related changes in fighter pilots' vision, follow-up retesting of the original group of subjects should be performed where possible.

4. If flying with prescribed glasses is to be permitted, it is essential to determine whether the standard clinical procedure of under correction of myopia is a factor affecting the visual resolution of pilots wearing glasses where optimal acuity is required.

ACKNOWLEDGMENTS

We wish to thank the Commanding Officer and the pilots of FITWING ONE, NAS Oceana, VA, for their willing cooperation with this project. Two former leaders of the vision research effort at NAMRL deserve special recognition: CAPT James Goodson, who was involved from 1972-1982 during the planning and developmental phases of this project, and CDR William Monaco, who was involved from 1982-1985 during the data gathering phase of this project. In addition, Mr. Efrain Molina and Mr. Ed Ricks, both from NAMRL, provided extensive engineering and technical support throughout the project. This report was improved by the critical comments of Drs. Thomas Amerson and Leonard Temme.

INTRODUCTION

The development and implementation of performance-based biomedical standards for selection and retention of military aircrew members is a current Navy requirement. Establishment of such standards requires acquisition of extensive data on physiological, psychophysical, and flight performance measures, as well as determination of which physiological and/or psychophysical measures, individually or in concert, can be used as significant predictors of flying performance.

Critical visual requirements vary somewhat among different flying tasks and aviation communities (Goodson, 1974). A long-term research and development program at the Naval Aerospace Medical Research Laboratory (NAMRL) has been directed toward development of a battery of vision tests and measures, which allows sensitive assessment of many aspects of vision (Morris and Goodson, 1983a; Molina, 1983, 1984). Appropriate tests selected from the overall Vision Test Battery may provide a series of tests tailored to a specific flying task or aviation community. The overall Vision Test Battery was duplicated in a Mobile Field Laboratory (MFL) for the collection of data for operational validation at remote locations.

Navy fighter pilots are faced with the most demanding tasks of any military pilots. In addition to efficiently operating a complex aircraft capable of supersonic speeds, Navy fighter pilots must operate sophisticated avionics and weapons systems; they must perform complex and physiologically-stressful air combat maneuvers (ACM); and they must land safely on moving aircraft carriers at night. A number of critical visual tasks are associated with this job. Accurate measurement of the visual characteristics of Navy fighter pilots will provide a data base for the development of visual standards for this community.

To develop performance-based visual standards for Navy fighter pilots, the overall Vision Test Battery was systematically evaluated, and a series of tests appropriate to that aviation community was selected (Monaco et al., 1985). The MFL was used to administer the selected series of tests to tactical fighter pilots attached to Fighter Wing ONE, NAS Oceana, Virginia. Various measures of performance in ACM training were obtained concurrently for each pilot, as were data on night carrier landing performance, personal history, and flying experience. Preliminary analyses of relationships between visual capabilities and flying performance have been reported (Monaco and Hamilton, 1984, 1985; Morris at al., 1985).

This present report provides a descriptive summary of selected visual capabilities of successful Navy fighter pilots. Statistics on visual reaction time, spot detection ability, and static visual acuity of successful Navy fighter pilots are included. Other measures recorded for the same pilot population include: dynamic visual acuity, contrast sensitivity, dark focus state, lateral movement detection, accommodative flexibility, and effects of helmet visor usage on acuity.

SUBJECTS

One hundred and sixty-three Navy pilots were studied. All were attached to Fighter Wing ONE, NAS Oceana, Virginia. Eighteen of the pilots flew F-4, F-5, or A-4 aircraft and served as the adversary squadron on the Tactical Air Combat Training System (TACTS) range. The remaining 145 pilots flew F-14 aircraft and were drawn from 13 operational squadrons. All of the subjects were male, and all but one were Caucasian. Their ages ranged from 24 to 44 years, with a mean age of 30.? years (SD = 4.1). The age distribution is shown in Figure 1. Twenty of the 163 pilots were wearing prescription spectacles when flying during the day, and these 20 pilots were tested wearing their spectacles.

VISION TESTS AND EXPERIMENTAL PROCEDURES

Vision tests were administered in a Mobile Field Laboratory consisting of two trailers located at NAS Oceana. One trailer housed the Automated Vision Test Battery (AVTB) and contrast sensitivity test device, and the other housed the dynamic visual acuity and dark focus test devices. The optical projectors and other test equipment were controlled by microprocessors. Details of the vision test hardware are presented elsewhere (Morris and Goodson, 1983a; Molina, 1983, 1984).

The complete Vision Test Battery program required over 3 hours for each subject. Selected tests included in this report had the following features in common:

1. Tests involved binocular vision with the subject's eye position fixed through use of a chin/brow rest.

2. The background screen luminance was 343 cd/m^2 (100 ft-L).

3. All tests involved a flat screen at a far distance (5.5 m) and a fixation pattern to locate the centrally presented targets.

4. The test target for all acuity tests was the Landolt-C, with a gap width one-fifth of the letter height. The gap was presented in one of four orientations: up, right, down, or left.

5. Every test began with 10 practice trials.

6. Except for the visual reaction time test, 10 threshold estimates were obtained using the staircase (up-down) psychophysical method, requiring from 40 to 80 test trials.

7. Forced-choice responses were registered with a joystick. The subject's choice of gap orientation and his reaction time were recorded for each trial.

8. Stimulus sizes were specified in minutes of visual angle (mva), and target exposure time was 3 seconds.

Additional details concerning these vision tests are described briefly below. Further test details are available in Morris and Goodson (1983b) and Monaco et al. (1985).

Visual Reaction Time - This test required the subject to press the joystick immediately at the appearance of a suprathreshold spot target (2 mva diameter). Target luminance was 686 cd/m^2, thus giving a target-to-background contrast ratio of +1.0, or 100%. The mean and standard deviation (sec) of the reaction time were computed for 20 test trials. This test was performed only on the last 62 F-14 pilots.

Spot Detection Ability - This test required the subject to indicate detection of a spot target which contrasted 100% with the background, and which was varied in size (and hence angular subtense) between trials to control its visibility. The mean and standard deviation (mva) of the 10 threshold estimates were computed, along with the mean reaction time (sec) for the 10 correct-response trials associated with the 10 threshold estimates. This is referred to as the "threshold-stressed reaction time."

Static Acuity, High Contrast - This test required the subject to indicate the gap orientation of a Landolt-C, which was varied in size between trials, and which contrasted 100% with the background. The mean and standard deviation (mva) of the 10 threshold estimates were computed, along with the mean threshold-stressed reaction time.

Static Acuity, Low Contrast - This test required the subject to indicate the gap orientation of a Landolt-C, which was varied in size between trials. The luminance of the Landolt-C was 377 cd/m^2, thus giving a target-to-background contrast ratio of +0.1, or 10%. The mean and standard deviation (mva) of the 10 threshold estimates were computed, along with the mean threshold-stressed reaction time.

Static Acuity, Low Contrast With Glare - This test required the subject to indicate the gap orientation of a Landolt-C, which was varied in size between trials, and which contrasted 10% with the background. A glare source was positioned between the target screen and the subject, just below his line of sight, and directed toward him (i.e., away from the target screen). This veiling glare source produced a luminance of about 2800 cd/m^2 at the subject's eye position. The target and background luminances and the contrast ratio were not changed. The mean and standard deviation (mva) of the 10 threshold estimates were computed, along with the mean threshold-stressed reaction time. This was the last test administered to each subject, so the glare recovery process did not influence results from other tests.

All data were stored at a mainframe computer facility and manipulated and analyzed using the Statistical Analysis System (SAS). The significance level applied in all statistical tests was 0.05.

RESULTS

The visual reaction time test required subjects to respond by pressing the joystick at the appearance of a supra-threshold spot stimulus. The time required for central processing and interpretation of visual information should have been at a minimum in this test, as only one signal and one choice were involved. Thus, a pilot's simple reaction time value should approximate the minimum time he required to detect the stimulus energy and to accomplish the appropriate motor pattern. The distribution of simple reaction times for 62 pilots is shown in Figure 2. Simple reaction times ranged from 143 to 461 msec, with a mean of 223 msec (SD = 0.055).

In order to assess individual differences in speed of response for the various visual threshold tests, an adjusted variable was derived. The simple reaction time value for <u>each</u> pilot was subtracted from <u>his</u> threshold-stressed reaction times for vision tests involving greater demands of the central and peripheral nervous system. These calculated variables are termed 'adjusted threshold-stressed reaction times.'

Table 1 shows the visual thresholds, threshold-stressed reaction times, and adjusted threshold-stressed reaction times for spot detection ability and visual acuity under different viewing conditions, for the Navy fighter pilots studied. The threshold for the spot detection test was based on the spot diameter, while the thresholds for the acuity tests were based on the size of the gap in the Landolt-C. The threshold mean for the spot detection was significantly different from the threshold mean for the acuity at high contrast (Student's $t = 6.95$, $p < .0001$). Acuity thresholds and reaction times progressively increased with reduced contrast and with the presence of glare. The mean acuity at 100% contrast (0.40 mva, 20/8 Snellen) approximately doubled (0.806 mva, 20/16 Snellen) when contrast was reduced to 10%, and increased approximately one-third again (1.042 mva, 20/20 Snellen) when glare illumination was added. Frequency distributions for acuity threshold means and the two reaction time measures are shown in Figure 3 for the different viewing conditions. The curves in Figure 3 were obtained by rounding off acuity (to 0.05 of log-10 mva) and reaction time (to 0.15 sec) values, by computing the frequency of occurrence for each rounded value, by computing 4th-order polynomials to fit the points described by the frequencies and the rounded values, and by plotting the central peaks of these polynomial functions. None of the 163 pilots had a high contrast acuity score worse than 0.718 mva, which is approximately equivalent to 20/15 Snellen acuity.

Pilot acuity was tested under high contrast, low contrast, and low contrast with glare conditions. Decrements in acuity threshold due to reduced contrast (threshold at high contrast minus threshold at low contrast) and decrements in acuity threshold due to glare (threshold at low contrast minus threshold at low contrast with glare) were computed. Distributions for these acuity decrement variables are shown in Figure 4. The mean decrement in acuity due to reduced contrast was -0.41 mva (range: -0.11 to -1.31), while the mean decrement in acuity due to the presence of glare was -0.24 mva (range: +0.33 to -1.48). In both cases, the mean acuity decrement values were significantly different from 0 (Student's $t > 13.4$, $p < 0.001$). While none of the 163 pilots exhibited improved acuity with reduced contrast, 15 pilots (9%) exhibited improved acuity when glare illumination was added. These 15 pilots did not appear distinguished in any other vision measure, although they averaged 2 years younger than the other pilots.

A correlation matrix of the threshold values from the various vision tests (Table 2) indicates that the thresholds of the four vision tests have significant positive correlations among themselves. A correlation matrix of reaction time values (Table 3) indicates that simple visual reaction time is not significantly correlated with any of the other reaction times, but that the threshold-stressed reaction times of the four vision tests have significant positive correlations among themselves.

The various correlations between pilot age and visual capability are summarized in Table 4. These correlations indicate that, as age increased, simple visual reaction time was significantly slower; spot detection ability, high contrast acuity, and low contrast acuity with glare were significantly poorer; and high contrast acuity thresholds were significantly less consistent. In contrast, reaction times at threshold levels for spot detection and high contrast acuity tests were significantly faster as age increased. In addition to these statistically significant correlations, [illegible] non-significant ($p > 0.05$) positive correlation existed between age a[illegible] reshold for the other vision test (low contrast acuity without glare).

Twenty of the 163 pilots wore authorized prescription spectacles when flying during the day. When compared to spectacled pilots, non-spectacled pilots had significantly better spot detection ability and significantly greater threshold consistency for low contrast acuity without glare (Table 5). In addition to these statistically significant differences, non-spectacled pilots had better acuity under high contrast and low contrast (with and without glare) conditions, than spectacled pilots; however, the differences were not statistically significant. Spectacled pilots were significantly older than non-spectacled pilots (mean ages = 32.5 and 29.9 years, respectively; Student's t = 2.66, $p = 0.0086$).

DISCUSSION

The acuity and reaction time data presented here are for a distinct and highly selected population, Navy fighter pilots. Some of the vision test variables reported in this study are new, and data based on a general subject population are unavailable for comparison. This is not true, however, for simple visual reaction time, some of the acuity measures, and for the spot detection measure.

The mean threshold values for high contrast acuity presented here for Navy fighter pilots are significantly lower (better) than corresponding values reported for the general population. Furthermore, analysis of other vision data on these same pilots indicates that their accommodative status in the dark (dark focus) is significantly less myopic than a population of college students (Temme et al., in review).

Identification of factors responsible for these differences must be done cautiously, as several explanations could apply. The first determination to be made is whether or not the differences are real, or whether they are due to differences in equipment or procedure. If the differences are found to be real, then the second determination to be made is whether or not the visual capabilities of successful fighter pilots are significantly better than those of Student Naval Aviators (SNAs) (i.e., whether or not fighter pilots are visually a non-random sample of all individuals who apply to enter Navy flight training). If fighter pilots are found to possess significantly better vision than the average SNA, then the third determination to be made is whether their better vision is the result of selection (e.g., only those SNAs with unusually good vision may end up being assigned to the fighter pipeline) or experience (e.g., flying cockpit-type aircraft may lead to improved vision).

Examination of available data on acuity at high contrast suggests that Navy fighter pilots may indeed have better acuity than the general population. If one assumes that a frequency distribution for the scores (log scale) from high contrast acuity tests of the general population is normally distributed with a mean of about 20/20 Snellen or 1 mva (Figure 5A), then a frequency distribution for similar values after applying a selection criterion that excluded those with worse than 20/20 acuity should look like the left half of a normal distribution (Figure 5B). The Naval Aerospace Medical Institute (NAMI) applies this 20/20 criterion during entry physical examinations, so if the vision of Navy fighter pilots is not significantly different than that of SNAs who pass NAMI's examination, the frequency distribution of the high contrast acuity scores for the fighter pilots should appear abruptly truncated at 1 mva, like Figure 5B.

Instead, the actual frequency distribution for fighter pilots appears bell-shaped, or normal (see left curve in Figure 3A). The Kolmogorov-Smirnov goodness-of-fit test finds the frequency distribution of high contrast acuity thresholds (log scale) for the fighter pilots not significantly different from normal ($D = 0.099$, $n = 163$). One might speculate that the poorer acuity of older pilots or of spectacled pilots might be responsible for shifting an otherwise abruptly truncated frequency distribution (skewed toward low threshold values) into a seemingly normal distribution. However, the frequency distributions of high contrast acuity scores are not significantly different from normal for younger-than-average pilots ($D = 0.110$, $n = 105$) or for non-spectacled pilots ($D = 0.095$, $n = 143$), according to Kolmogorov-Smirnov goodness-of-fit tests. These comparisons suggest that the high contrast acuity scores of these fighter pilots are not a random sample of the scores of all SNAs who pass NAMI's physical examination (Figure 5C).

A frequency distribution of binocular acuity data obtained using a wall chart for 250 World War II combat and patrol pilots (Imus, 1947) also does not appear abruptly truncated at 20/20 Snellen, but rather tails off toward 20/20 from a mean of about 20/13 Snellen. About 94% of these pilots had 20/15 or better acuity. Also, frequency distributions of acuity data obtained with the Armed Forces Vision Tester (AFVT) for 377 military aircrewmen (Erickson and Burge, 1968, 1969) are abruptly truncated at 20/12 (the best acuity that the AFVT can measure), and tail off toward 20/20. Over 90% of these subjects had 20/15 or better acuity.

This analysis suggests an approach for further research. The same equipment and procedures should be used in a controlled study designed to compare the visual capabilities of Navy fighter pilots, SNAs, and a non-military population. Such a study would determine whether or not the visual differences discussed above are real. Also, if real differences exist, such a study would answer the question of whether differences already exist upon entering flight training, or whether some post-entry process of selection or experience is involved. An alternate approach would be to assume that the differences in vision are real, and that successful fighter pilots are visually distinguished upon entering the Navy. Theoretically, the validity of this assumption could be tested by retrospective analysis of the medical records of successful fighter pilots and their classmates, during the early stages of flight training. In reality, however, the traditional clinical records of acuity are insufficiently detailed to do this.

The results of the proposed research could have a major impact on the operation of the Navy's pilot training program. If successful fighter pilots have better vision than average SNAs, then even greater attention to vision measures would seem appropriate when making recruitment guarantees and pipeline assignments. Also, if successful fighter pilots have better vision than average SNAs, then the details of how they (as a group) end up with distinguished vision need to be understood. If a selection process is involved, it may be possible to accomplish this more quickly and economically than through the current training program. If experience is involved, it may be possible to enhance its effect on vision.

Few of the remaining vision variables can be compared to large-sample published data. Blackwell's (1946) psychophysical data show that, at 100 ft-L background luminance, the threshold size of a spot target having the same contrast as we employed (100% brighter than background) is about 0.45 mva (extrapolated from chart). The threshold mean for the spot detection ability of the Navy fighter pilots is 0.46 mva. The mean simple visual reaction time reported here for Navy fighter pilots (223 msec) is in the range reported in other studies involving visual stimuli (Brebner and Welford, 1980). No direct comparisons are possible between our unadjusted and adjusted threshold-stressed reaction time variables and large sample norms.

The improved acuity demonstrated by 9% of the pilots taking the low contrast acuity test under glare conditions (as compared to non-glare conditions) is unexplained. The high correlation coefficients in Table II indicate that a pilot's rank position in the distribution of the group's scores did not change significantly across acuity tests under high contrast, low contrast, and low contrast-with-glare conditions. The absence of a significant correlation between simple visual reaction time and any of the threshold-stressed reaction times indicates that simple reaction time and threshold-stressed reaction time are independent measures of visual functioning (Table 3).

Although the pilots described here were relatively young (mean age = 30.2 years), and their age range was only 20 years, pilot age was still found to be related to numerous vision measures (Table IV). Older pilots had higher thresholds (poorer vision) than younger pilots for all vision tests, and the correlation between age and threshold was significant in three tests (spot detection ability, high contrast acuity, low contrast acuity with glare). A reduction in acuity with increased age is well known for the general population (e.g., Allen and Vos, 1967). The relationships between reaction time variables and age are less clear. The simple reaction time for the suprathreshold spot target got significantly <u>longer</u> with increased age, which is a frequently documented result (Welford, 1980). It is unclear, however, why the threshold stressed reaction times for several tests became significantly shorter with increased age for these pilots.

After the training phase of their careers, current Navy policy allows pilots whose acuity degrades beyond 20/20 limits to continue flying if vision is correctable to 20/20 by wearing prescription spectacles. Also, due to a change in regulations, some naval flight officers who always needed spectacles for 20/20 acuity have subsequently been trained as pilots. As a group, the 20 pilots in this study who wore prescription spectacles had uniformly poorer vision than the 143 non-spectacled pilots, and for two vision measures, the differences were statistically significant (Table 5). Spectacled pilots were also significantly older than non-spectacled pilots. The difference in visual capabilities between the two groups may be due to the facts that individuals requiring spectacles are often corrected only to 20/20, and spectacles are usually prescribed in 0.25-diopter increments. The vision of most spectacle wearers would be improved with a more precise and optimal correction. If the spectacled pilots in our study had been optimally corrected, their vision might have been as good as non-spectacled pilots. Nevertheless, these results suggest that the spectacle-wearing pilots may perform less well on visually dependent flying tasks than pilots not wearing spectacles. The recently approved admission of SNAs with aviation vision waivers into the pilot community may allow direct testing of this hypothesis.

SUMMARY

In summary, Navy fighter pilots appear to have superior vision. Their visual acuity is better than one would expect either from screening criteria employed upon entrance to aviation training, or from comparison with large sample norms. While certain visual capacities clearly decline with increased age, the question remains open as to whether age-related visual decrement (within the range of values encountered in this study) has a significant influence on performance, since the increase in flying experience with age may at least partially compensate for visual decrement. The poorer visual capacities of spectacled pilots, as compared to non-spectacled pilots, is more disturbing, especially given current proposals to admit spectacled individuals as SNAs. For these individuals, poorer vision from the start could not be compensated for by greater flying experience. Investment of time and funds to optimally correct the refractive errors of spectacled SNAs may well be justified.

RECOMMENDATIONS

1. To evaluate the uniqueness of the vision of this group of fighter pilots, the visual acuity of a comparison group of applicants to the naval aviation training program should be measured quantitatively before screening and/or disqualification on the basis of any aspect of the physical exam.

2. Population samples drawn from other aviation communities should be tested to determine if there are significant differences in visual performance related to critical task requirements.

3. To increase our knowledge of age-related changes in fighter pilots' vision, follow-up retesting of the original group of subjects should be performed where possible.

4. If flying with prescribed glasses is to be permitted, it is essential to determine whether the standard clinical procedure of under correction of myopia is a factor affecting the visual resolution of pilots wearing glasses where optimal acuity is required.

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Table 3. Correlation Matrix for Simple Reaction Time and Threshold Stressed Reaction Times. Data in Each Cell are Arranged as: Pearson Coefficient/Significance Probability/Number of Observations.

Test	Code	A	B	C	D	E
Simple Reaction Time	A	-	-0.0614 0.6355 62	-0.1145 0.3757 62	-0.0314 0.8085 62	-0.1889 0.1416 62
Spot Detection Ability	B		-	0.3075 0.0001 163	0.5005 0.0001 163	0.3721 0.0001 163
Acuity, High Contrast	C			-	0.7279 0.0001 163	0.4229 0.0001 163
Acuity, Low Contrast	D				-	0.5245 0.0001 163
Acuity, Low Contrast w/ Glare	E					-

Table 4. Vision Measures Significantly Correlated with Age.

Vision Measure	Pearson r	Significance Prob.
Simple reaction time, mean	.3961	.0014
Spot detection ability, threshold mean	.2390	.0021
Spot detection ability, threshold-stressed reaction time	-.1600	.0414
Spot detection ability, adjusted threshold-stressed reaction time	-.2487	.0512
High contrast acuity, threshold mean	.1581	.0439
High contrast acuity, threshold consistency (standard deviation)	.1635	.0370
High contrast acuity, threshold-stressed reaction time	-.1760	.0246
Low contrast acuity, with glare, threshold mean	.1647	.0356

Table 5. Vision Measures Having Significantly Different Values Between Pilots Not Wearing Prescription Spectacles (n = 143) and Pilots Wearing Prescription Spectacles (n = 20).

Vision Measure	Mean for Non-spectacled Pilots (mva)	Mean for Spectacled Pilots (mva)	Diff (mva)
Spot detection ability, threshold mean	0.45	0.49	0.04
	<t = 2.07, p = 0.0398>		
Low contrast acuity with glare, threshold consistency (standard deviation)	0.15	0.19	0.04
	<t = 2.11, p = 0.0361>		

t = Student's t.
p = significance probability.

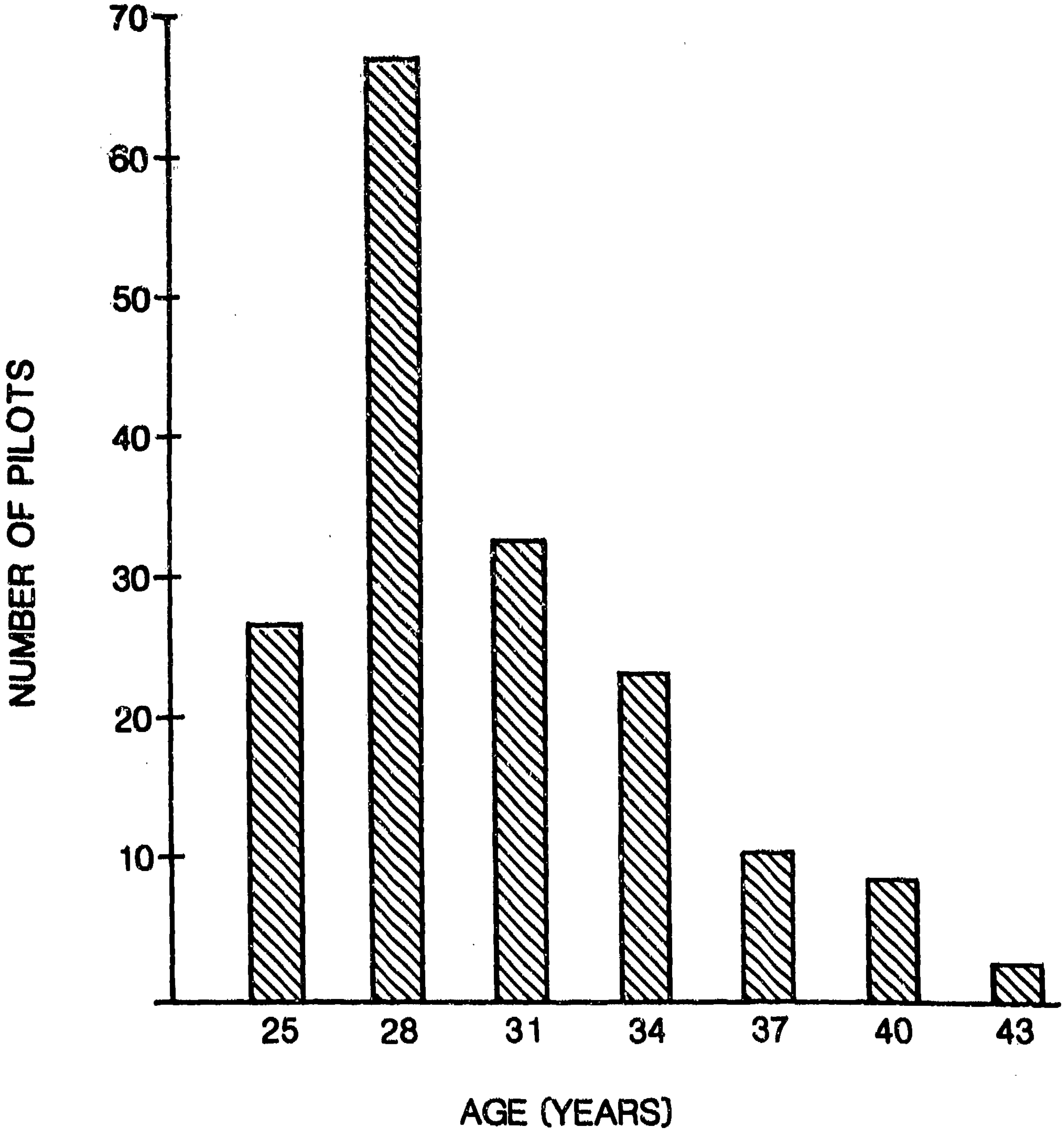

Figure 1. Distribution of ages of the 163 Navy pilots in this study. Midpoints of age class intervals are indicated. The mean age was 30.2 years.

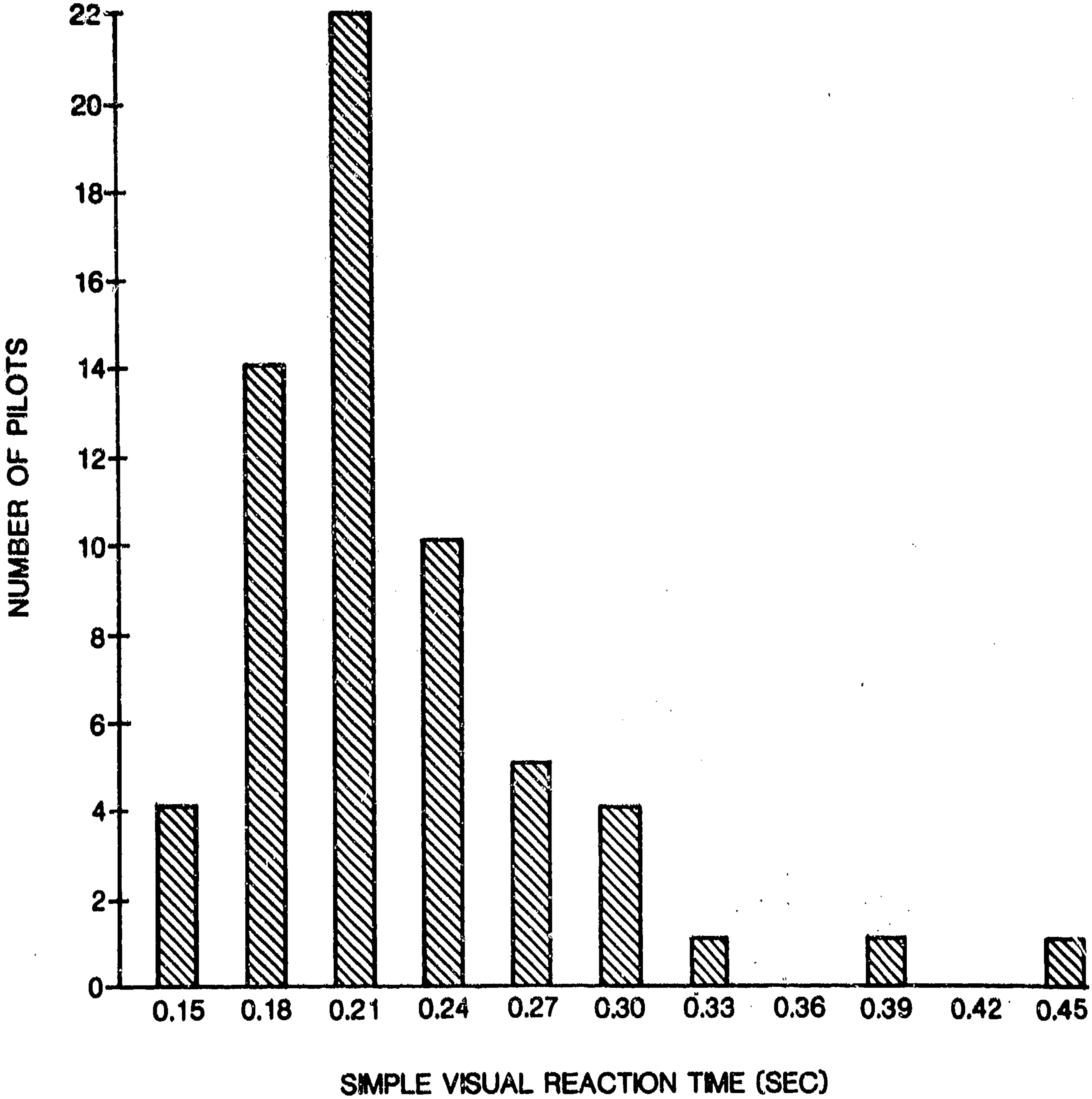

Figure 2. Distribution of simple reaction time means of 62 Navy pilots when tested with a supra-threshold spot target. The group mean reaction time was 223 msec (SD = 0.055).

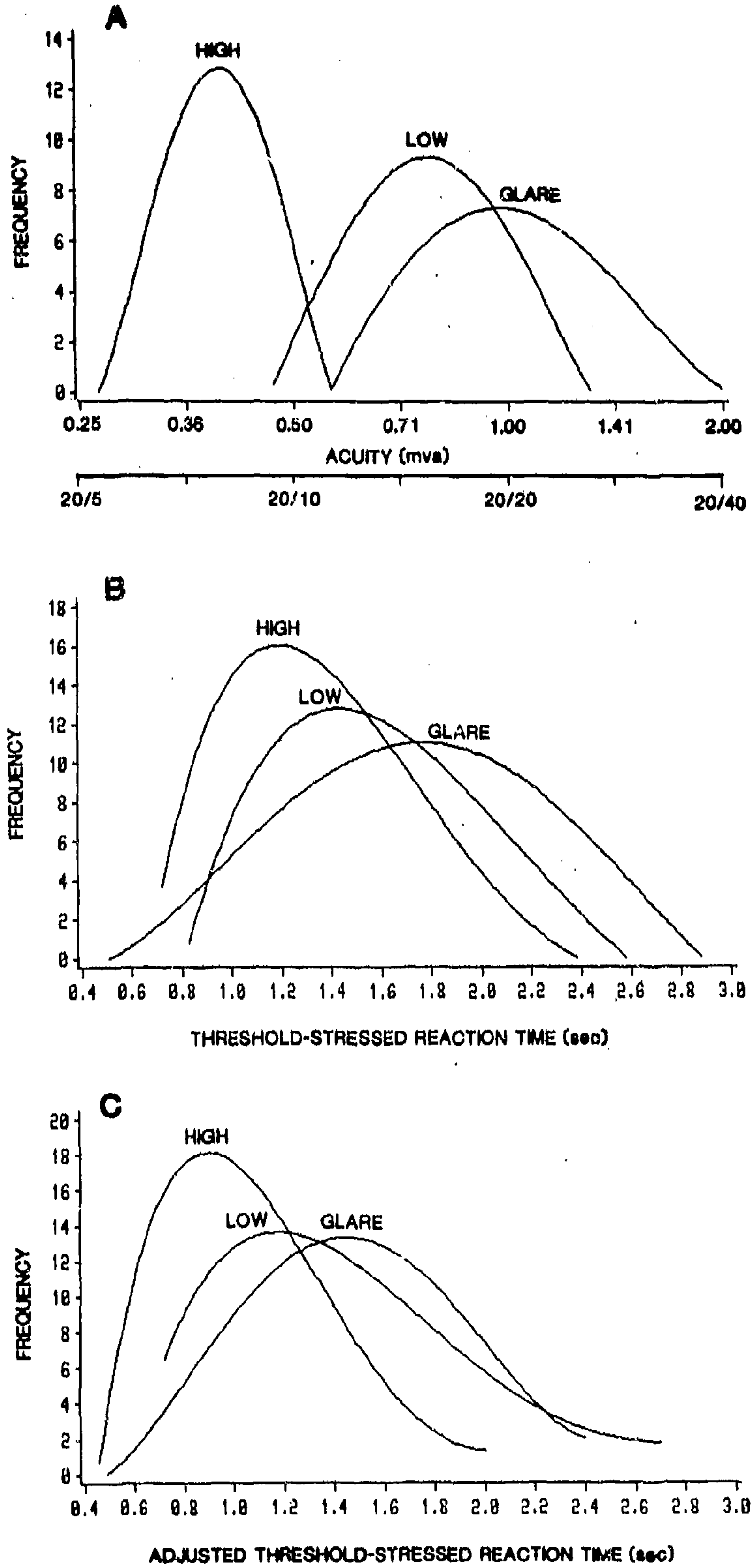

Figure 3. Frequency distributions for static acuity thresholds (A), threshold-stressed reaction times (B), and adjusted threshold-stressed reaction times (C), for high contrast targets (HIGH), low contrast targets (LOW), and low contrast targets with glare (GLARE).

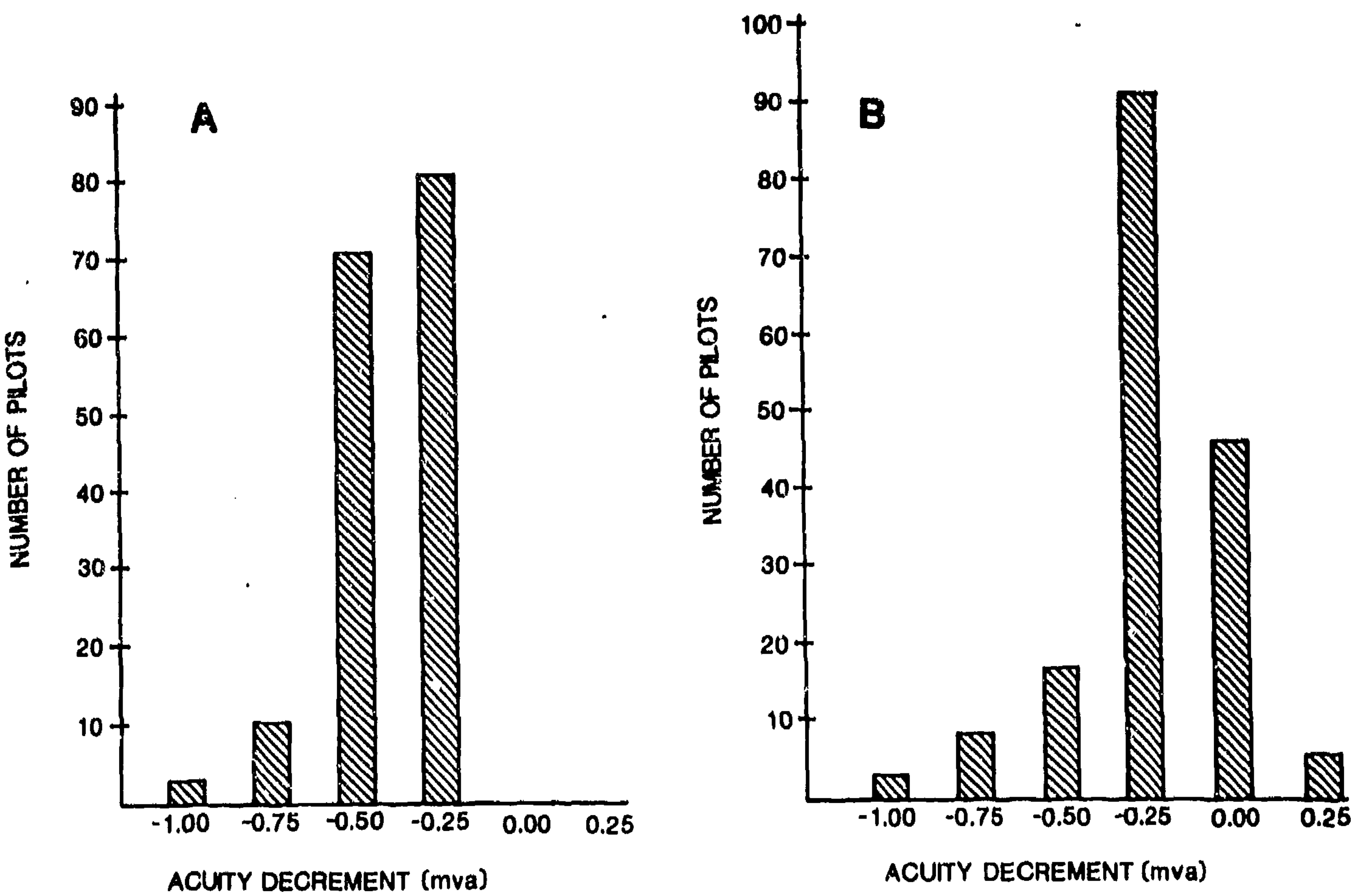

Figure 4. Distributions of decrements in static acuity threshold due to reduced contrast (A) and presence of glare (B).

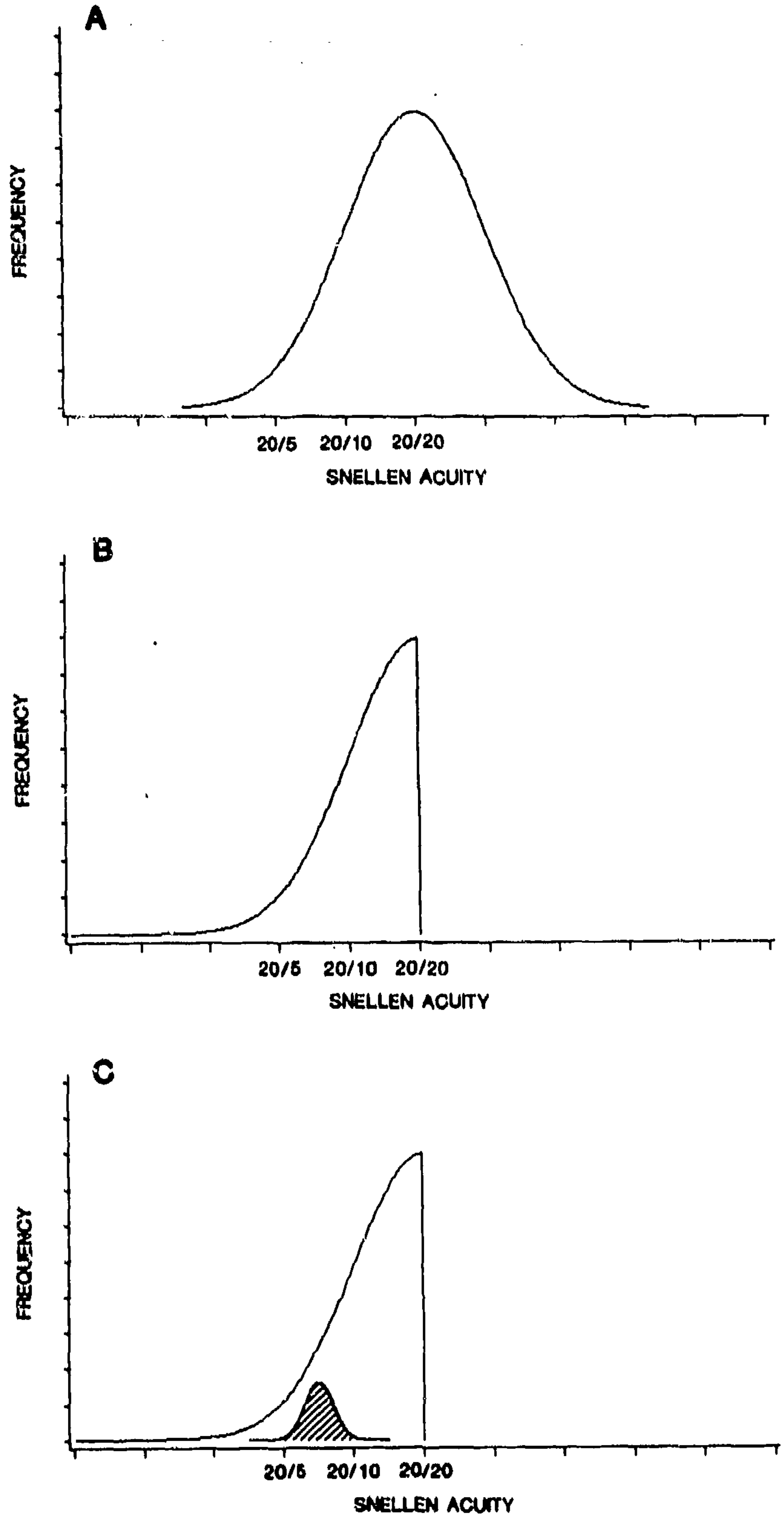

Figure 5. Hypothetical frequency distributions of scores for static acuity tests at high contrast for (A) the general population, (B) that sub-set of the general population having better than 20/20 Snellen acuity, and (C) a non-random sample (shaded area) of that sub-set of the general population having better than 20/20 Snellen acuity.

Other Related NAMRL Publications

Hamilton, P.V. and Morris, A., Effect of the Neutral Density Helmet Visor on the Visual Acuity of Navy Fighter Pilots, NAMRL-1325, Naval Aersopace Medical Research Laboratory, Pensacola, FL, December 1986.

Molina, E.A., "NAMRL Automated Vis[illegible] Testing Devices." In Proceedings of the Tri-service Aeromedical Research Panel Fall Technical Meeting, NAMRL Monograph 33, Naval Aerospace Medical Research Laboratory, Pensacola, FL, November 1984, pp. 198-214. (AD# A168 336)*

Monaco, W.A. and Hamilton, P.V., "Visual Capabilities Related to Fighter Aircrew Performance in the F-14 and Adversary Aircraft," Advisory Group for Aerospace Research and Development Conference Proceedings, No. 396, pp. 38-1 to 39-9, December 1985.

Monaco, W.A., Morris, A., and Hamilton, P.V., Development of Vision Tests for Air-to-air Target Detection, NAMRL-1314, Naval Aerospace Medical Research Laboratory, Pensacola, FL, August 1985. (AD# A168 309)*

Morris, A. and Goodson, J.E., The Development of a Precision Series of Landolt Ring Acuity Slides, NAMRL-1303, Naval Aerospace Medical Research Laboratory, Pensacola, FL, November 1983. (AD# A138 974)*

Morris, A. and Goodson, J.E., "A Description of the Naval Aerospace Medical Research Laboratory Vision Test Battery." (Abstract) Preprints of the Aerospace Medical Association, pp. 40-41, 1983.

Morris, A., Hamilton, P.V., Morey, W.A., and Briggs, R.P., "Vision Test Battery Threshold and Response Time as Predictors of Air-to-air Visual Target Acquisition in F-14 and Adversary Aircraft." Advisory Group for Aerospace Research and Development Conference Proceedings, No. 396, pp. 39-1 to 39-8, December 1985.

Morris, A. and Morrison, T.R., "Development of a Dynamic Visual Acuity Assessment Measure for Prediction of Target Detection in ACM." (Abstract) Scientific Program of the Aerospace Medical Association, p. A12, 1985.

* These publications are available from the Defense Technical Information Center, Cameron Station, Alexandria, VA 22314 (Telephone: commercial 202/274-7633 or AUTOVON 284-7633); or from the National Technical Information Center, 5285 Port Royal Road, Springfield, VA 22161 (Telephone: commercial 703/487-4650; no AUTOVON). Use the AD number when requesting reports. Reports listed without AD numbers may be requested from Code 00A3 at NAMRL.