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Small Letter Contrast Sensitivity: An Alternative Measure of Visual Resolution for Aviation Candidates

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By

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Exceptional vision is needed to maintain high levels of aviation performance. Current standards for helicopter pilot training include superior visual acuity with minimal refractive error. Despite these demanding criteria, it is likely that visual ability varies among those who meet the standards for pilot training. A more complete knowledge of visual capabilities in these individuals will allow us to better correlate vision with performance and to develop more criteria for selection. The purpose of this study was to investigate an alternative test of visual resolution for aviation candidates using small letter contrast sensitivity (SLCS). Computer-generated letter charts were used to measure visual acuity (VA) and SLCS in 16 candidates who had satisfied military vision standards for pilot training. The acuity and contrast charts varied, by line, in equal log steps such that the letter recognition task was comparable for the two types of measurement. VA and SLCS were highly correlated in these subjects, indicating that the two tests measure similar aspects of visual resolution. Scores were distributed across two lines on the acuity chart, but across four lines on the contrast chart, suggesting that SLCS offers a more (continued)

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discriminating test of resolution. This assumption was confirmed in that SLCS was more highly correlated with small amounts of refractive error in the candidates tested. SLCS offers a sensitive, adjunctive measure of visual resolution which may be useful for identifying the unique visual abilities required for aviation.

TECHNICAL NOTE

Small Letter Contrast Sensitivity: An Alternative Measure of Visual Resolution for Aviation Candidates

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Exceptional vision is needed to maintain high levels of aviation performance. Current standards for helicopter pilot training include superior visual acuity with minimal refractive error. Despite these demanding criteria, it is likely that visual ability varies among those who meet the standards for pilot training. A more complete knowledge of visual capabilities in these individuals will allow us to better correlate vision with performance and to develop more incisive criteria for selection. The purpose of this study was to investigate an alternative test of visual resolution for aviation candidates using small letter contrast sensitivity (SLCS). Computer-generated letter charts were used to measure visual acuity (VA) and SLCS in 16 candidates who had satisfied military vision standards for pilot training. The acuity and contrast charts varied, by line, in equal log steps such that the letter recognition task was comparable for the two types of measurement. VA and SLCS were highly correlated in these subjects, indicating that the two tests measure similar aspects of visual resolution. Scores were distributed across two lines on the acuity chart, but across four lines on the contrast chart, suggesting that SLCS offers a more discriminating test of resolution. This assumption was confirmed in that SLCS was more highly correlated with small amounts of refractive error in the candidates tested. SLCS offers a sensitive, adjunctive measure of visual resolution which may be useful for identifying the unique visual abilities required for aviation.

THE STRINGENT VISUAL standards for military pilot training underscore the need for exceptional visual abilities. Current standards for helicopter pilot training include minimal refractive error, and superior visual acuity. Even with these demanding criteria, it is likely that variability in visual capabilities exists among those who satisfy these requirements and go on to pilot aircraft. Differences in visual abilities may help explain differences in aviation performance. Therefore, a more comprehensive knowledge of visual abilities in candidates for aviation training may allow us to better predict performance and to develop more exacting criteria for selection.

The requirement for a high level of visual acuity is related to the operational demands of aviation performance. A pilot must identify small, high contrast targets, such as aircraft, approaching from a distance. But is "20/20" good enough? Does variability exist between those who just meet this standard and those who achieve better acuity without correction? Even with very precise measures of visual acuity, the variability between these individuals is likely to be no greater than 1–2 lines on an acuity chart. It would be useful to develop a more exacting measure of visual resolution.

In this study, an alternative measure of visual resolution was evaluated in candidates for aviation training. Research from this laboratory indicated that small letter contrast sensitivity (SLCS) is more sensitive than visual acuity (VA) for revealing subtle amounts of blur. This suggested that SLCS may provide a sensitive index of subtle refractive error and visual ability in candidates for aviation. The preliminary results reported herein support these assumptions.

METHODS

Visual acuity and contrast sensitivity were measured with computer-generated letter charts displayed on a monitor. The luminance of the monitor (37.4 fL) and contrast of individual letters were under software control. The acuity and contrast charts were patterned after the work of Bailey and Lovie (1) and Pelli et al. (4), respectively. Each chart was comprised of rows of letters with five letters per row. The acuity chart consisted of black, high contrast (93%) letters on a white background. The letters were larger on top, and became progressively smaller, by line, in 0.1 log unit steps. The same principles were used to design the letter contrast chart, but letter size was held constant (20/25 Snellen

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equivalent), while contrast decreased, by line, in 0.1 log unit steps (from 93% to 5%). The same letters were used on both charts, but letter sequence was varied by software control from trial to trial to discourage learning effects. Scoring was conducted by letter with a precision of 0.02 log units (2). Acuity and contrast letter recognition thresholds were obtained from 16 subjects (ages 21–26) who recently satisfied all vision standards for helicopter pilot training, including visual acuity, binocular motility, depth perception, and cycloplegic refraction. Subjects were seated 4.8 m from the display in an otherwise dark room, and instructed to start from the top and read each row of the chart as far down as possible. Testing was conducted with each eye on acuity first since subjects were more familiar with this task, followed by contrast sensitivity. Informed consent was obtained from all subjects after protocol approval by our institutional review committee.

RESULTS

Fig. 1 shows log contrast sensitivity (logCS) plotted against visual acuity (log of the minimum angle of resolution; logMAR) for each of 16 subjects. The two measures are correlated highly ($r = 0.85$) suggesting that VA and SLCS reflect comparable aspects of visual function. This assumption is reinforced because small letters are used for each measurement indicating the involvement of common, high spatial frequency mechanisms (3). The diagonal line in Fig. 1 represents the best fit regression of logCS on logMAR. Since the two measures are plotted on scales which span equivalent ranges (0.6 log units), the slope of the function indicates precisely how one measure changes with respect to the other. The steepness of this slope exemplifies that SLCS decreases much more rapidly than VA in these subjects. As indicated on the top and right axes of Fig. 1, visual acuity in these subjects is distributed across two lines on the VA chart, while contrast sensitivity varies across four lines on the SLCS chart. This occurs despite the test design and scoring procedure being essentially equivalent since the same letters are used, and letter size (VA) and contrast (SLCS) vary in equal log steps.

The variability in VA and SLCS across subjects could reflect defocus effects from subtle refractive error which was within military standards for pilot duties. To explore this possibility, logMAR and logCS were evaluated as a function of the spherical equivalent (cycloplegic) refractive error of each subject. Fig. 2 shows logMAR (top) and logCS (bottom) plotted against refractive error ranging from −0.50 to +0.75 sphere. Refractive error accounts for 26% of the variability in VA ($r^2 = 0.26$), but for 40% of the variability in SLCS ($r^2 = 0.40$). Thus, in comparison to visual acuity, small letter contrast sensitivity is correlated more strongly with

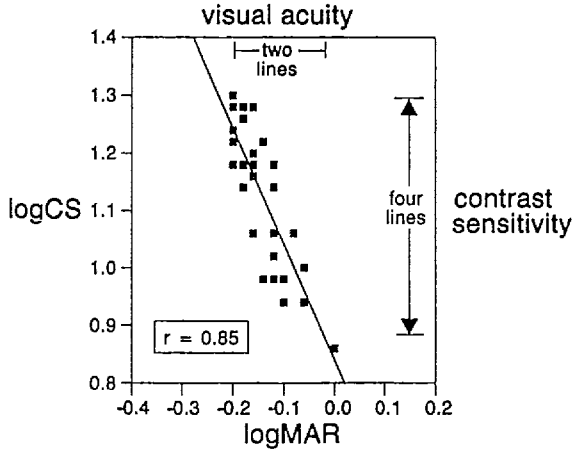

Fig. 1. Log small letter contrast sensitivity (logCS) is plotted against visual acuity expressed as the log of the minimum angle of resolution (logMAR) for 16 candidates for aviation training (32 eyes). The best fit least squares regression line is shown (r = 0.85). The scores were distributed across two lines of visual acuity, but across four lines of small letter contrast sensitivity.

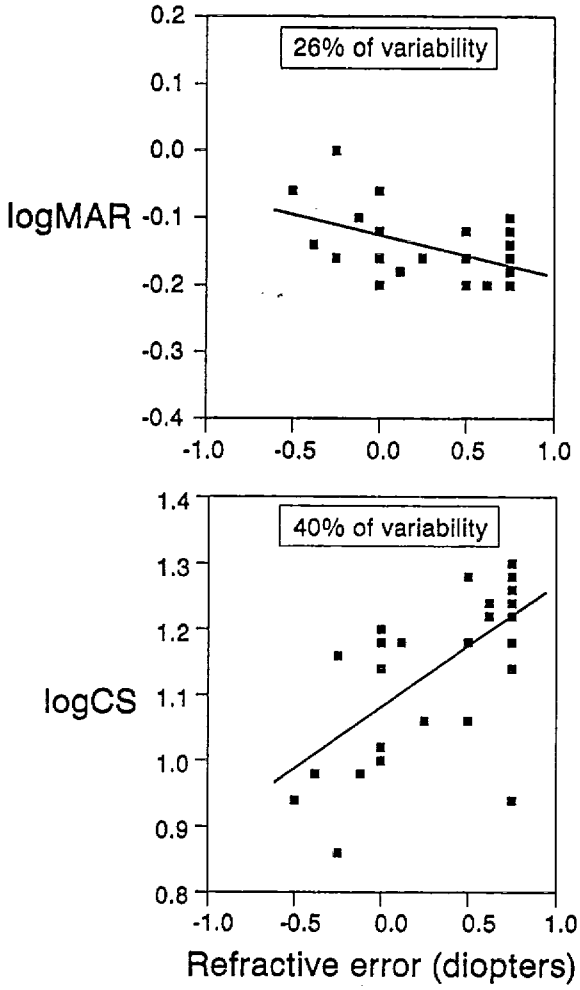

Fig. 2. LogMAR (top) and logCS (bottom) are plotted against the spherical equivalent refractive error for ametropias ranging from −0.50 to +0.75 sphere. The least squares regression line is shown in each plot. Refractive error accounts for 26% of the variability in acuity ($r^2 = 0.26$), and for 40% of the variability in contrast sensitivity ($r^2 = 0.40$).

subtle refractive error in visually eligible pilot candidates.

DISCUSSION

This study demonstrates that contrast sensitivity for recognition of small letters provides an alternative measure of resolution in candidates for aviation. SLCS is correlated highly with visual acuity in candidates who satisfy visual standards for helicopter pilot training. This finding, and because small letter sizes are used in both measurements, indicates that common, high spatial frequency channels are used for VA and SLCS. While this suggests that the two measures are redundant, providing information about the same visual ability, scores were distributed across two lines of VA, but across four lines of SLCS. Since the two tests have a common design and vary, by line, in equal log steps, the greater range of scores for SLCS suggests that it may provide a more discriminating test of resolution. Alternatively, the amount of unexplained variability simply may be greater for SLCS.

One factor which could explain the variability across subjects in VA and SLCS is defocus from refractive error or improper accommodation. Recently, it was demonstrated that SLCS is more sensitive than VA for revealing the effects of small amounts of defocus (5). The present study confirms and extends this empirical finding by demonstrating that subtle refractive error in visually eligible candidates can explain 40% of the variability in SLCS, but only 26% of the variability in VA.

Although SLCS may be more sensitive than VA for revealing subtle refractive error, a considerable amount of variability in VA and SLCS remains unexplained. Part of this probably reflects random error, since the measures were taken only once on each subject, as is commonly done in clinical settings. Also, it is conceivable that an element of the variability reflects real differences in ability which may influence aviation performance. Additional testing with performance-based tasks in operational environments will be necessary to evaluate this possibility.

Interestingly, candidates with mild hyperopia (+0.50 to +0.75 sphere) tended to do slightly better than emmetropes (no correction) on both the acuity and contrast sensitivity tasks. Since refractive error was based on cycloplegic findings, but subjects were tested on VA and SLCS without cycloplegia or correction, these differences could reflect tonic accommodation producing subtle amounts of blur in eyes that are emmetropic by military standards. Such small differences are difficult to discern with standard tests of VA, but are more readily detected by measuring resolution with SLCS.

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