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THE MEASUREMENT OF CONTRAST SENSITIVITY IN NAVAL PERSONNEL

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THE MEASUREMENT OF CONTRAST SENSITIVITY IN NAVAL PERSONNEL

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ABSTRACT

Some current research suggests that measures of visual contrast sensitivity (CS) may be better predictors of target detection than standard vision tests, such as visual acuity, now used in the Canadian Forces (CF). Traditional methods of acuity testing, such as the Snellen chart, measure the ability to recognize letters of high contrast. However, many tasks performed in operational settings require visual capabilities other than acuity. For example, naval watchkeepers are required to detect and monitor targets that vary widely in shape, size and contrast. The contrast of an object can be reduced by degraded conditions such as low light, fog, snow or rain. For these reasons, CS may be more appropriate than acuity for measuring quality of vision in watchkeepers. The aims of the study were to collect normative CS data on naval personnel, to investigate any changes in CS due to normal watchkeeping tasks, and to evaluate CS as a potential predictor of visual watchkeeping ability. CS measures were taken on 215 CF naval personnel onboard the destroyer HMCS Saguenay, using VISTECH Vision Contrast Test System (VCTS) Model 6500 charts. A subpopulation of 18 bridge and 19 operations room watchkeepers were tested before and after a normal four hour watch period. Finally, supervisors completed questionnaires in order to provide a subjective measure of watchkeepers' performance. No significant changes in CS were found over watch periods. Supervisors' subjective ratings of watchkeeping performance, in terms of speed and efficiency in detecting approaching contacts, were compared to CS scores; no positive relationships were found. However, supervisors' evaluations of watchkeeping performance were positively correlated to subjective evaluations of personality factors such as motivation, confidence, and alertness. CS alone was a poor predictor of watchkeeping performance as assessed by supervisors. The results of this study show no advantage to using CS as a predictive measure of watchkeeping abilities.

INTRODUCTION

Visual target detection is an essential task for watchkeeping on a ship, whether it is performed on the bridge or in the operations room. The bridge watchkeeper's primary task is to spot, and maintain sight of, contacts that may appear on the waters or in the sky surrounding the ship. The operations room watchkeeper's primary task is to spot, and maintain sight of, contacts that appear on radar screens. Both types of watchkeeping tasks emphasize vigilance and target detection. The increased cost of training naval personnel and the need to ensure a high standard of watchkeeping make the assessment of vision an important consideration in the selection of watchkeeping personnel.

Traditional methods for evaluating vision (i.e., visual acuity tests) do not assess all aspects of visual performance. Most acuity tests determine only the ability to see small details that have high contrast. A typical example of an acuity test is the standard Snellen Chart, which tests the individual's ability to identify small black letters on a white background. Acuity measures do not indicate the individual's ability to see the wide range of object sizes at the levels of contrast that are encountered in real life situations.

A more comprehensive measure of vision that is being considered for use by the Canadian Forces (CF) is contrast sensitivity (CS). CS is a measure of an individual's ability to detect luminance differences (contrast) in a visual pattern. The target detection performance of watchkeepers involves visual sensitivity in detecting the contrast difference between a target and its surround. Targets that are detected and monitored at sea (e.g. aircraft, surface vessels and submarine periscopes) vary in size, and contrast can be degraded by low light levels, fog, snow, or rain. Similarly, target contrast on a radar screen can be affected by weather and other conditions. The ability of a bridge watchkeeper to detect and maintain sight of a contact on the horizon, and the ability of an operations room watchkeeper to spot and hold a radar contact, may be more closely related to CS measures than to acuity measures.

CS can be measured by presenting observers with spatial sine-wave patterns which are seen as a sequence of light and dark bands. These patterns can be presented using various types of equipment, including video monitors and photographs. The spatial frequency of the pattern, specified in cycles per degree (cpd) of visual angle, is determined by the width of one cycle of the pattern (one light and one dark band). Subjects are usually tested on several different spatial frequencies ranging from 1 to 24 cpd. Figure 1a shows an example of a chart with photographs of sine-wave pattern used to test CS. Contrast is determined by the difference in luminance between the light and dark bands divided by the sum of the two luminances, and therefore has no units. The minimum contrast at which the pattern can be seen is called threshold contrast, and the reciprocal of the threshold contrast is termed CS (1). CS performance over a range of spatial frequencies yields a contrast sensitivity function (CSF).

As discussed above, an advantage of CS tests is that they may provide measures of visual ability that relate more closely to visual performance under real life conditions than do acuity tests. Objects can be considered to be made up of a number of spatial frequencies, meaning that the ability to detect objects in real life situations depends upon sensitivity to a range of spatial frequencies. Normal acuity tests use high contrast letter charts with spatial frequencies in the range of 18 to 30 cpd. Therefore, acuity is visual performance at a high spatial frequency point on the CSF. Since there is no information about sensitivity to other spatial frequencies in this type of measure, it is not surprising that correlations between measures of acuity and CS are low, except at the high spatial frequencies (1, 2).

In many instances, the most important information about objects is present at the lower spatial frequencies (3). Low spatial frequency information about a scene provides input to complex perceptions such as facial recognition and figure-ground judgements (4). Since the ability to distinguish detail (high spatial frequency information) is often degraded under poor viewing conditions, low spatial frequency information may be vital for detecting and identifying contacts in, for example, naval operations.

Since the CSF provides a more comprehensive description of visual ability than does visual acuity alone, Ginsburg (2; 5, 6) suggested that visual contrast thresholds for sinewave gratings be used to predict target detection in complex displays. This suggestion has been explored in several laboratory and field studies. Ginsburg (7) assessed the ability of 11 pilots to detect an aircraft on a runway during a landing approach in a cockpit simulator. Statistically significant correlations between detection range and CS were found at low and middle spatial frequencies, (frequencies were not reported). In another study, the relationship between CS and the detection of actual approaching aircraft was examined (8). Significant correlations between CS and detection performance were found at 8, 16, and 24 cpd, whereas there were no reliable correlations between the Snellen acuity measure and detection performance. These findings led Ginsburg et al. (8) to conclude that CS is a better predictor of target detection distance than measures of visual acuity.

CS was also found to be a better predictor than Snellen visual acuity for simple road sign detection (9). All subjects had 20/20 visual acuity or better, yet the older group had lower CS than the younger group at 3, 6, and 12 cpd. Discrimination distance of highway signs was significantly correlated to contrast sensitivity at two spatial frequencies, 1.5 and 12 cpd, however, discrimination distances were not related to acuity. In another target detection task, CS at the higher spatial frequencies (12 and 18 cpd) was related to the detection of crash sites in a simulated air to ground search task (10).

The results of these studies suggest that CS tests may be useful as an adjunct to current visual selection standards. CS may have predictive value for operationally relevant visual tasks, and the selection of individuals who score highly on CS tests may increase the probability of success in visual target detection (11).

However, other researchers have found only weak correlations between target detection and CS. In one study, pilots detected approaching aircraft in a telemetry-tracked system with air-to-air combat scenarios (12). There was no significant correlation between aircraft detection distance and either Snellen acuity or sinewave grating CS. In another study that attempted to account for differences in flying performances based on visual differences, the performance of student, instructor and fighter pilots was assessed on simulated flying tasks (13). Again, CS did not correlate with tasks such as formation flight, low-level flight, bombing, and restricted-visibility landing. Even the distance from the runway at which pilots made their first visual flight corrections (a measure expected to relate to CS) was not related to CS. In both studies, CS was measured only at a relatively low spatial frequency (5 cpd), and therefore, was not a complete assessment of CS. Another investigation of CS and aircraft detection tasks found few relationships between CS and detection of actual aircraft (14). In this study, 67 pilots detected approaching aircraft under various weather conditions. Correlations between CS and detection distances were significant in no more than 2 out of 8 groups of pilots at any one spatial frequency. Overall, only 3 of 40 spatial frequency versus detection relationships were significant.

The lack of agreement on the utility of CS for predicting flying performance does not mean that CS is of no use in the CF. CS is a more comprehensive measure of vision than acuity tests currently used. It has been shown to be a useful diagnostic tool for assessing visual health, and may be useful for assessing visual performance under low levels of illumination (15). Several studies have provided normative CS data for aircrew and other groups, (2, 5, 15). However, no CS norms have been established for CF naval personnel, who may differ from the general population or aircrew in terms of experience, health, education, stress, attitudes, and skills. Before CS can be included as a test of vision in the CF, standards must be established. The need for data on CF populations other than aircrew has been recognized by other researchers (16).

If CS measures are to be used to assess visual capability, then factors that might influence CS must be determined. It is not known how time and workload affect CS under watchkeeping conditions. Previous research has demonstrated that CS can be stable for periods of at least six months (5). However, repeated measures of CS can produce practice effects that increase scores (2). There is also some evidence that adaptation to spatial frequencies may be related to visual fatigue. Reliable contrast threshold elevations for low spatial frequencies were found after subjects read text on a VDT for ten minutes (17). It was postulated that a loss of sensitivity to spatial frequencies that are focused on for several hours may account for complaints of visual blurring and fatigue reported by VDT users. Thus, a decrease in CS following a watchkeeping shift might reflect visual fatigue over prolonged viewing. This may be true for watchkeepers in the operations room where adaptation to spatial frequencies at the fundamental frequency of the display may occur (although radar patterns may vary in fundamental frequency according to the scale of the display and the targets being viewed).

Given the conflicting literature on CS, some question is raised as to the usefulness of CS in predicting target detection performance. Although several studies have examined the relationship between CS and task performance in pilots, the validity of using CS scores to predict the performance of naval watchkeepers is unknown. Before CS can be used as a selection criterion for watchkeepers, it must be determined whether CS test results can discriminate among individuals and predict, to some degree, performance on visual watchkeeping tasks.

Data obtained from laboratory studies on CS are limited, in that many of the factors that combine to influence the performance of complex tasks are not easily measured, controlled, or accounted for. There are many potentially important factors that need to be considered when assessing the ability of watchkeepers to detect targets. Environmental factors, such as extreme temperatures, high winds, rough seas and reduced visibility can affect a watchkeeper's motivation, concentration and vigilance, as well as his vision. Success in target detection also involves alertness, which may depend upon shift schedules and other factors; search planning and visual scanning techniques, which are related to training and experience; and personality factors, such as motivation and confidence level when dealing with indistinct or false contacts. One's criterion for deciding whether to respond may be a factor in how soon individuals report that they see sine-wave patterns in CS tests (4). This criterion effect may also apply to how soon individuals tend to report indistinct contacts.

This combination of factors makes it difficult to find a single indicator of performance for a complex task such as watchkeeping. After reviewing the literature on measures of overall flying performance, Sekuler (18) suggested that expert opinion is perhaps the only single measure of overall performance for any complex task involving many variables. One method of providing a measure of actual task performance under operational conditions is to ask supervisors who work with watchkeepers to rate the abilities of individual watchkeepers.

The combined effects of all the above factors and their potential influence on watchkeeper performance support the need to carry out studies on the relationship between CS and performance under operational conditions. If CS proves useful in predicting the performance of watchkeepers under operational conditions, it could be added to current selection tests.

The Present Study

The general purpose of this study was to investigate, under operational conditions, CS as a potential measure of vision in naval personnel. Three specific aims were established in order to investigate some of the questions discussed above. The primary aim was to gather baseline CS and other descriptive data on the ship's company in order to establish norms for CF naval personnel. These norms were contrasted with data collected for aircrew candidates in order to describe population differences. Exploratory research was conducted to investigate two secondary aims: to measure CS before and after a watchkeeping period in order to determine if normal watchkeeping duties have an effect on CS; and to ask supervisors to subjectively evaluate the performance of individual watchkeepers in order to determine whether CS is related to reported watchkeeping abilities.

METHOD

Population

An entire ship's company participated in the study (n = 215, mean age = 28.6, s.d. = 7.0, range = 19 to 52). All participants were healthy males representing a wide range of naval trades and classifications. They included the following three groups.

A. Bridge Watchkeepers (lookouts) (n = 18, mean age = 22.9, s.d. = 1.8)

B. Operations Room Watchkeepers (radar/electronic warfare operators) (n = 19, mean age = 25.0, s.d. = 4.5)

C. Others (remaining ship's company) (n = 178, mean age = 29.6, s.d. = 7.16)

Equipment

The VISTECH Vision Contrast Test System (VCTS) Model 6500 was used to test CS. As shown in Figure 1a, the chart contains a number of circular patches with pictures of sinusoidal gratings that are aligned either -15, 0 or +15 degrees from the vertical. Each patch subtends a visual angle of 1.4 degrees at the viewing distance of 305 cm (10 feet). The five rows of patches test CS at spatial frequencies of 1.5, 3, 6, 12 and 18 cpd (from top to bottom row). Each row contains a high-contrast sample patch at the left, followed by eight test patches, with contrast levels ranging from above to below threshold in approximately 0.1 log unit steps. The observer reads each row from left to right, simply stating the direction in which the bars are oriented, if visible. Thus, possible responses are left, right, up or blank. For subjects tested twice, a different version of the chart was used the second time. The last patch correctly read determines the individual's threshold for that spatial frequency. The threshold for each row or spatial frequency was found using the key shown in Figure 1b and a CSF was obtained for each individual.

Procedure

Testing was carried out in the Sick Bay, with supplementary lighting to provide adequate illumination. The chart was positioned so that glare was minimized and the luminance of the chart was within the 100 to 240 candelas/m^2 (30 to 70 footlamberts) range recommended by the manufacturer. Prior to the test, each participant was given instructions as outlined in the manual (19) and briefed on the differences between CS tests and acuity tests. Subject information and test results were recorded on data forms. Subjects were tested (using corrected vision if glasses were worn) for binocular CS only. Each test took approximately five minutes, including instruction and administration. Following completion of the tests, participants were briefed on their results.

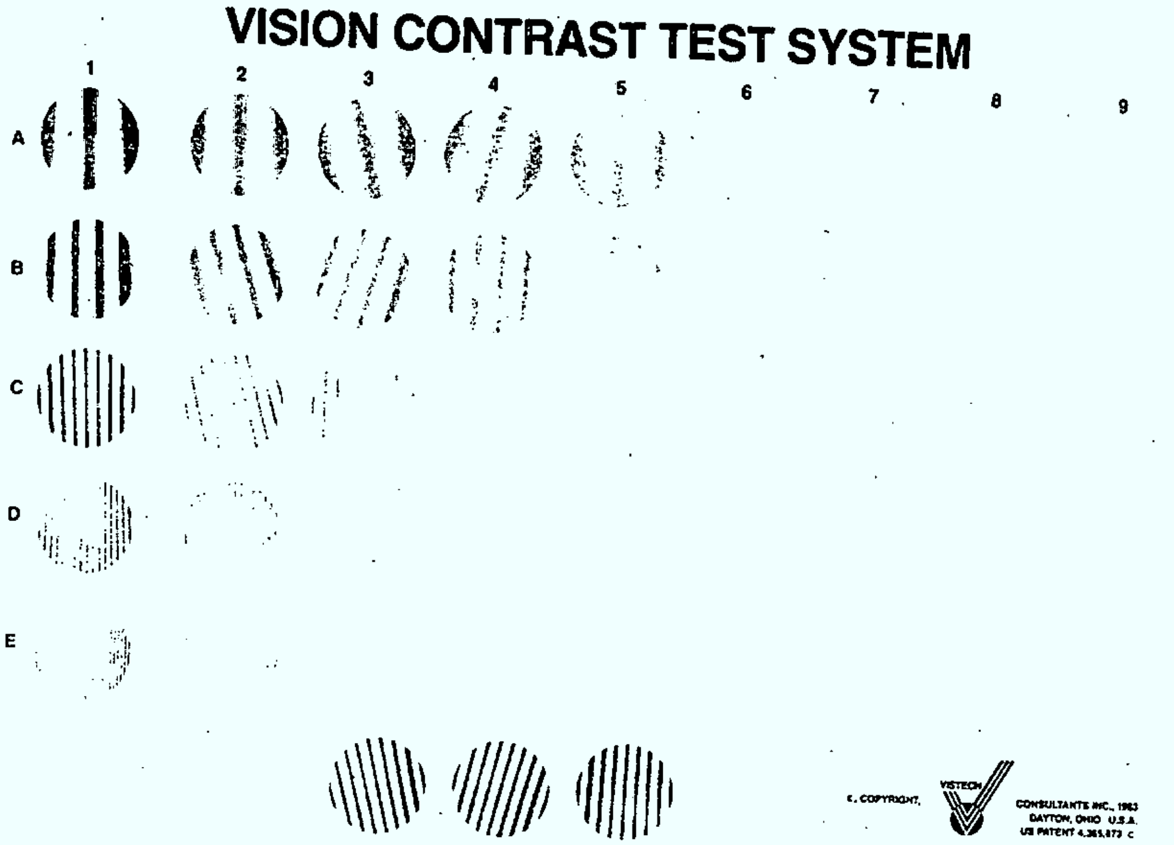


Figure 1a. Example of Vistech VCTS 6500 contrast sensitivity chart.

	1	2	3	4	5	6	7	8	9
A (1.5)	U 4	U 8	L 14	R 28	U 53	L 71	L 95	L 126	B
B (3)	U 4	L 9	R 15	U 30	R 73	L 98	U 130	U 174	B
C (6)	U 6	L 12	U 24	R 58	L 96	R 128	U 171	R 230	B
D (12)	U 13	U 25	U 39	R 52	R 70	L 93	U 125	L 168	B
E (18)	U 8	R 12	U 16	L 22	R 30	U 40	R 53	R 71	B

Figure 1b. Key used to score CS. The letters correspond to the orientation of each grating. The numbers correspond to the CS value for each grating.

Groups A and B were tested twice, once before (1100-1130) and once following (1600-1630) their afternoon watch (1145-1545). Those in Group C were tested only once during the following times: 0800-1030 and 1300-1530. In each group there were three separate watches or sub-groups that were rotated through the time periods described in the test schedule (Appendix 1). It should be noted that during a four hour watch period, personnel normally rotate through various positions, not all of which are visual tasks. The test schedule allowed the entire ship's company to be tested during the six days spent at sea. Testing did not interfere with routine ship operations.

Supervisors completed questionnaires (Appendix 2) on 28 of the 37 watchkeepers. Supervisors did not rate the remaining watchkeepers because of lack of knowledge concerning their watchkeeping abilities. The questionnaires assessed performance on visual and radar contact detection. Questions concerning personality attributes of the watchkeepers were included, since these factors may influence watchkeeping performance or the supervisor's judgement of it. These questions were chosen after discussion with naval personnel about watchkeeping abilities. The questionnaire was not tested for reliability or validity. Finally, supervisors were asked to subjectively rank their watchkeepers' target detection performance with respect to their peers (Appendix 3).

Descriptive statistics were calculated on CS scores for the entire population including groups A and B (both before and after watch), and group C. Between-group comparisons were made using visual observation of graphed results. The relationship between age and CS, and between visual standard and CS, were tested using Pearson Product Moment Correlations. Spearman Rank Correlations were used to test the relationship between CS and questionnaire results.

RESULTS

The objectives of this study were (1) to develop CS norms against which individuals within the navy destroyer population can be compared; (2) to determine the effects of watchkeeping period on CS; and (3) to determine if there is a relationship between CS and supervisors' assessments of watchkeeping performance.

Normative Data

Descriptive statistics for CS at each spatial frequency were calculated for the total population. (For Groups A and B, who had CS measured twice, only the first measurement was used to establish population norms.) Figure 2 shows the mean CSF with standard deviations for the entire crew. Table 1 shows mean values, standard deviations and median values for CS. The data were normally distributed as estimated by measures of skewness.

Table 1. Mean, standard deviations and median CS values for all naval personnel (n=215)

Spatial Freq. (cpd)	Mean	S.D.	Median
1.5	75.7	16.7	71
3	121.9	22.9	130
6	145.0	38.1	128
12	94.5	25.0	93
18	30.6	11.1	30

To test whether there were age related decreases in CS, the population was arbitrarily divided into four age groups and mean CS scores for each spatial frequency were plotted as shown in Figure 3. CS did not decline with age for the naval group, excepting a slight decrease at 18 cpd. No significant correlations were found between CS and age at any spatial frequency.

Individual CF visual standard information was obtained from medical records for comparison with CS scores. CF visual standards classify personnel into six categories, based upon visual acuity measures (Appendix 4). It should be noted that for those observers who wore glasses, CS was tested with corrected vision. Therefore, observers classified as V1, V2 or V3 should have had 6/6 vision. However, many individuals had not had their vision tested recently, and visual standard information was not available for several others. The numbers of participants in each category are shown below.

Visual Standard V1	- 122
Visual Standard V2	- 24
Visual Standard V3	- 30
Visual Standard V4	- 3
Visual Standard unknown	- 36

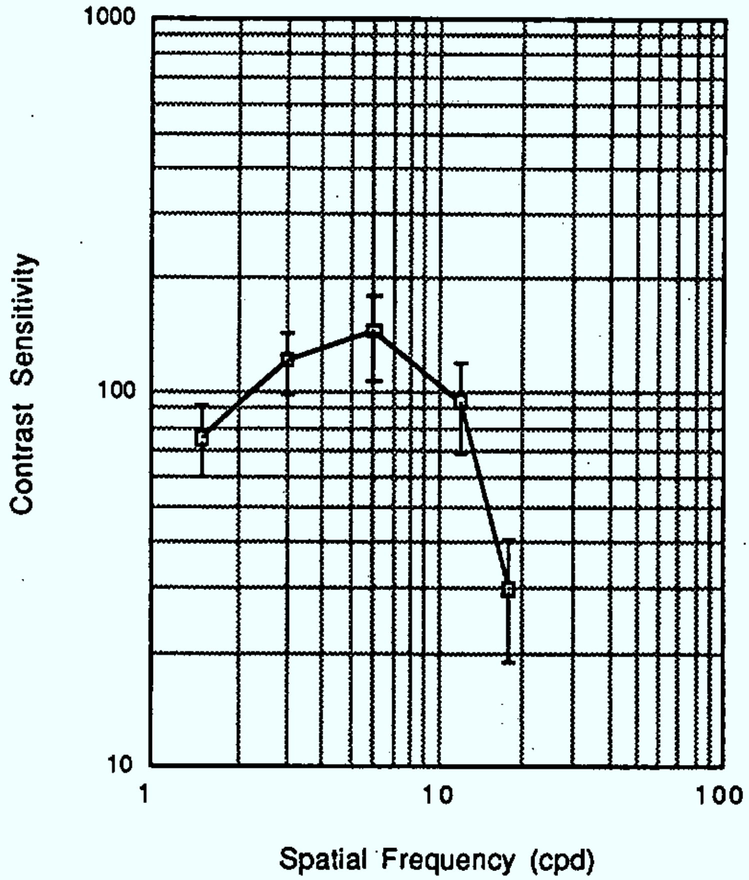
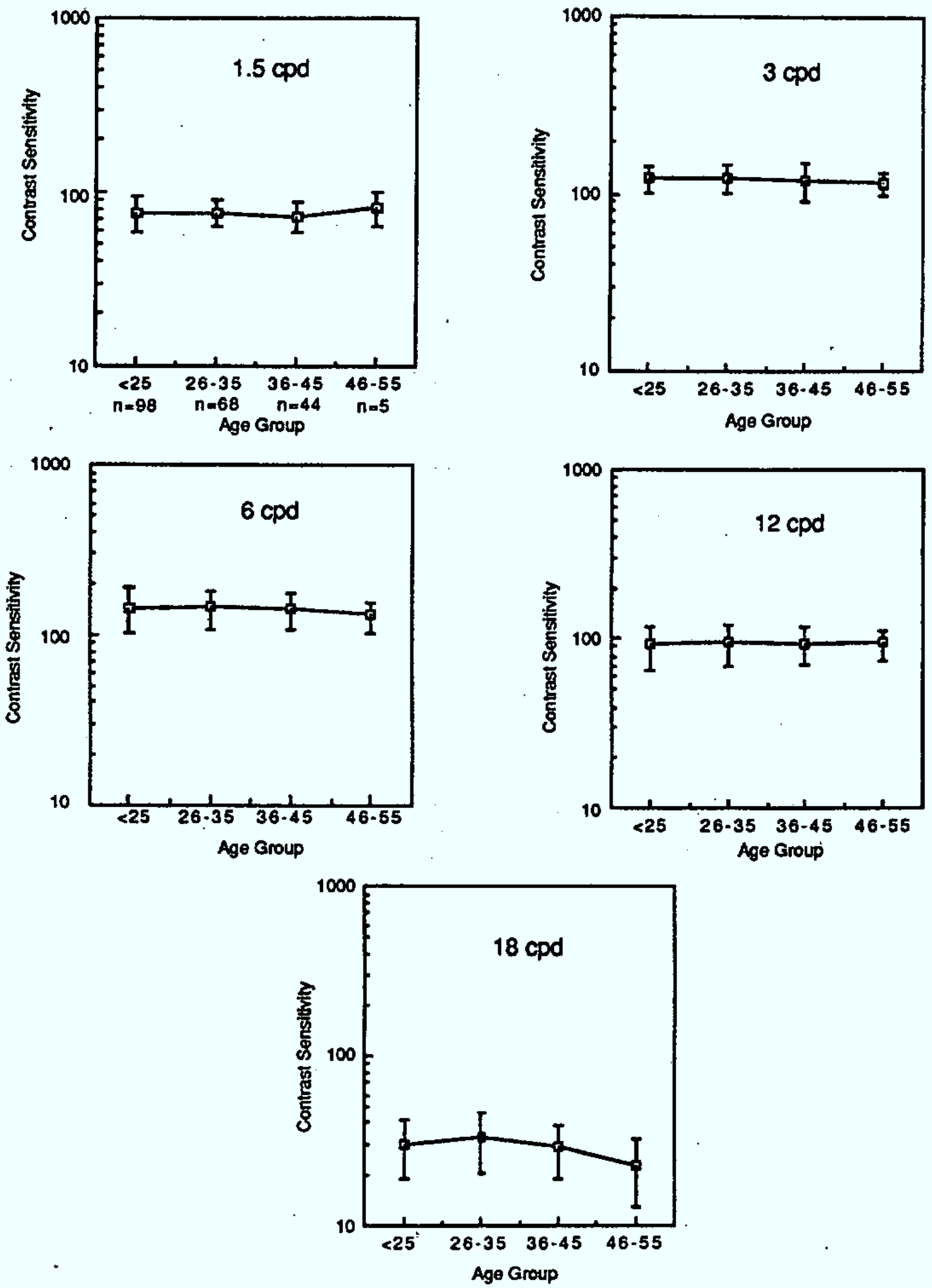


Figure 2. Mean CS scores for 215 naval personnel (Error bars show standard deviations)



<u>Figure 3.</u> The relationship between age and CS at each spatial frequency (Error bars show standard deviations)

Despite the crudeness of the visual standard measurement, it does provide an indication of visual acuity based on the Snellen eye chart. A significant but weak correlation was found between visual standard and CS measured at 18 cpd ($r = .22$, $p < .05$). Correlations at other spatial frequencies were not significant. There was no correlation between rank and CS or experience and CS at any of the spatial frequencies.

Watchkeepers' CS scores were compared to those of the rest of the ship's company (Figure 4). The graph indicates that the mean CSF for watchkeepers does not differ substantially from the mean CSF for the rest of the crew.

The Effect of a Watchkeeping Period

CS measures were taken before and after watchkeeping periods for bridge (Group A) and operations room (Group B) watchkeepers. The means and standard deviations are shown in Figure 5. The graph shows no large differences between CS scores taken before and after watch periods. ANOVA on the logarithm of CS also showed that there were no significant differences between measures taken before and after watch periods for groups A and B at any of the five spatial frequencies. Correlations between before and after CS scores were positive and significant ($p < .05$) at all spatial frequencies, excepting 1.5 cpd. (At 3 cpd, $r = .45$; 6 cpd, $r = .55$; 12 cpd, $r = .43$; 18 cpd, $r = .60$). However, as shown in Table 2, test-retest variability appeared to increase with spatial frequency. For example, at 12 and 18 cpd over half of the observers scored one or more levels above or below their scores on the first CS test.

Table 2. Percentage of Watchkeepers whose second CS scores were the same, above or below their first CS test scores.

Spat. Freq.	CS Categories -3	-2	-1	same	+1	+2	+3
1.5	-	3	27	38	32	-	-
3	-	-	8	68	22	3	-
6	-	3	15	50	24	10	-
12	3	8	24	40	16	8	-
18	5	11	22	22	24	11	5

The Comparison of CS to Watchkeeping Assessments

The use of CS as a predictor of watchkeeping performance was investigated by comparing supervisor's assessments with CS measures at all spatial frequencies. Table 3 presents the means, standard deviations and ranges for the questionnaire data for 28 watchkeepers. For all questions, lower scores indicate better performance. As shown in Appendix 2, Questions A to C relate to visual performance; Questions D to F relate to personality factors.

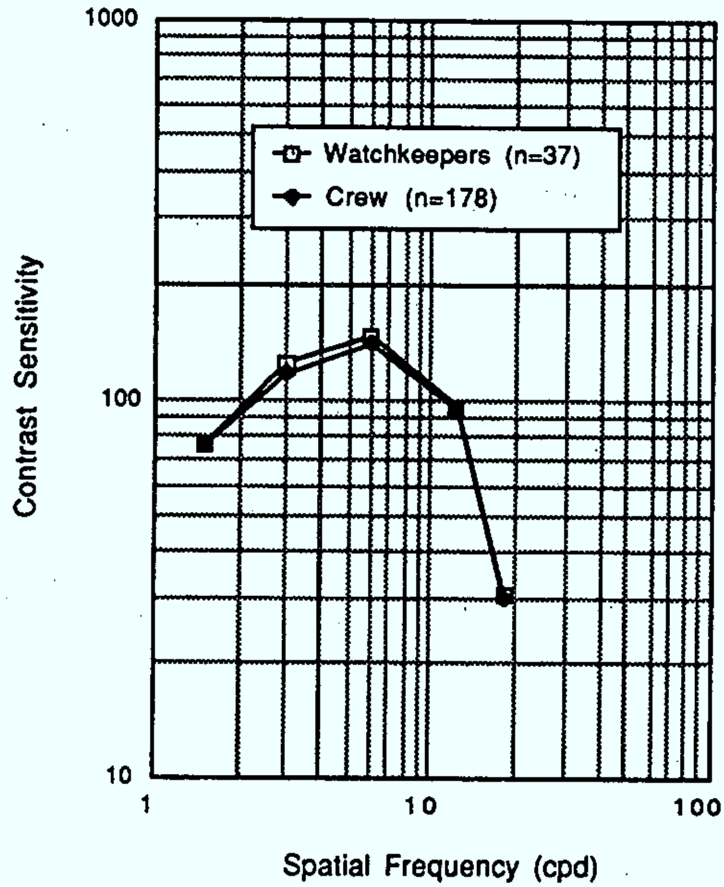


Figure 4. Comparative CS means for Watchkeepers and the rest of the ship's crew

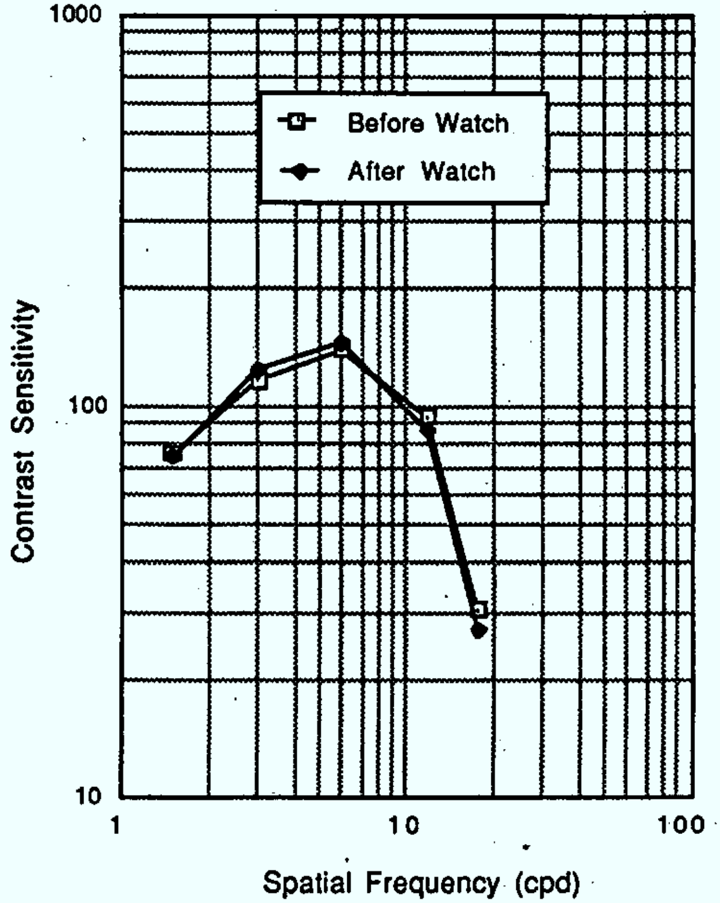


Figure 5. CS means for Watchkeepers before and after watch (n=37)

Spearman's Rank Correlation coefficients were computed between questionnaire results and both sets of CS measures (before and after) to determine if there was a relationship between questionnaire scores and CS. (For this analysis, the signs for negative and positive correlations were reversed; thus, a positive correlation indicates that better performance is related to higher CS). The correlations are shown in Table 4. The results clearly demonstrate that there was no trend toward positive correlations between assessment scores and CS. A few relationships showed significance at the .05 level; however, the comparison of before and after data reveals that these relationships were not consistent.

Table 3. Questionnaire results from supervisor assessments of watchkeepers (n=28)

Question	Mean	S.D.	Range
A-detection	2.66	0.85	1-5
B-identification	2.47	0.87	1-5
C-speed	2.85	0.85	1-5
D-motivation	2.33	1.01	1-5
E-confidence	2.38	1.07	1-5
F-alertness	2.23	0.70	1-4

Table 4. Correlations between questionnaire results and CS scores

Watch	CS Before Watch					CS After Watch				
Assessments	1.5	3	6	12	18	1.5	3	6	12	18
A-detection	.05	-.40	-.03	-.25	-.32	.21	-.15	-.06	-.40	-.13
B-identification	.22	-.53*	-.09	-.13	-.05	-.02	-.24	-.03	-.22	.09
C-speed	.33	-.31	.13	-.19	-.09	.30	.07	.36	-.20	.06
D-motivation	-.18	-.44*	-.36	-.31	-.24	-.32	-.31	-.20	-.48*	-.36
F-confidence	.15	-.29	-.18	-.19	-.34	.06	-.12	.06	-.48*	-.12
E-alertness	-.17	-.53*	-.10	-.10	.01	-.11	-.38	-.11	-.36	.07

*p<.05

Further analysis of the questionnaire data showed that many of the response ratings were related. Inter-correlations between ratings on each of the questions are shown in Table 5. As expected, questions concerning the visual performance of watchkeepers (detection, identification, and speed) were highly correlated. The highest correlation was between Question A, the ability to detect a contact, and Question C, the speed of reporting contacts (r = .77).

Table 5. Correlations between ratings on watchkeeper assessment questionnaire						
	A-detect	B-ident	C-speed	D-motiv	E-confid	F-alert
A-detection	1.00					
B-identification	.73*	1.00				
C-speed	.77*	.56*	1.00			
D-motivation	.63*	.52*	.46*	1.00		
E-confidence	.72*	.67*	.53*	.59*	1.00	
F-alertness	.54*	.56*	.57*	.65*	.36	1.00

*$p < .05$

DISCUSSION

Normative Data

The CS data, as shown in Table 1 and Figure 2, do not adequately describe the distribution of CS scores. A more detailed representation of the variation in CS is shown in Figure 6. This figure shows the percentage of subjects falling into each of the CS values associated with each of the spatial grating patterns on the chart. The dark bars show the percentage of naval personnel that scored at each level of contrast. For comparison, the hatched bars on the graph represent similar data recently collected on CF aircrew candidates (16). The same method of testing CS was used for both groups. The figure shows that most CS scores for both groups lie within 3 categories (0.2 or 0.3 log units) of contrast. Similar variation in CS scores have been reported by other researchers (5).

For the naval population there was greater variation in the high spatial frequency CS measures (12 and 18 cpd) than in the low spatial frequency measures. Variation found in the high spatial frequencies indicates differences in visual acuity. The only relationship found between visual acuity and CS was a weak but significant correlation between visual standard and CS at 18 cpd. These findings are in agreement with correlations found by other researchers (5, 10), who also found that acuity measures were related to CS at the high spatial frequencies. Had actual acuity measures been taken in the present study, rather than relying on Visual Standard information obtained from medical records, higher correlations would have likely been found.

Comparison of naval personnel and aircrew candidates show that mean CS values at spatial frequencies of 12 and 18 cpd were higher for aircrew candidates and that the overall variability in CS scores was greater for the naval population. Better aircrew scores at the high spatial frequencies was most likely due to pre-selection based upon visual acuity.

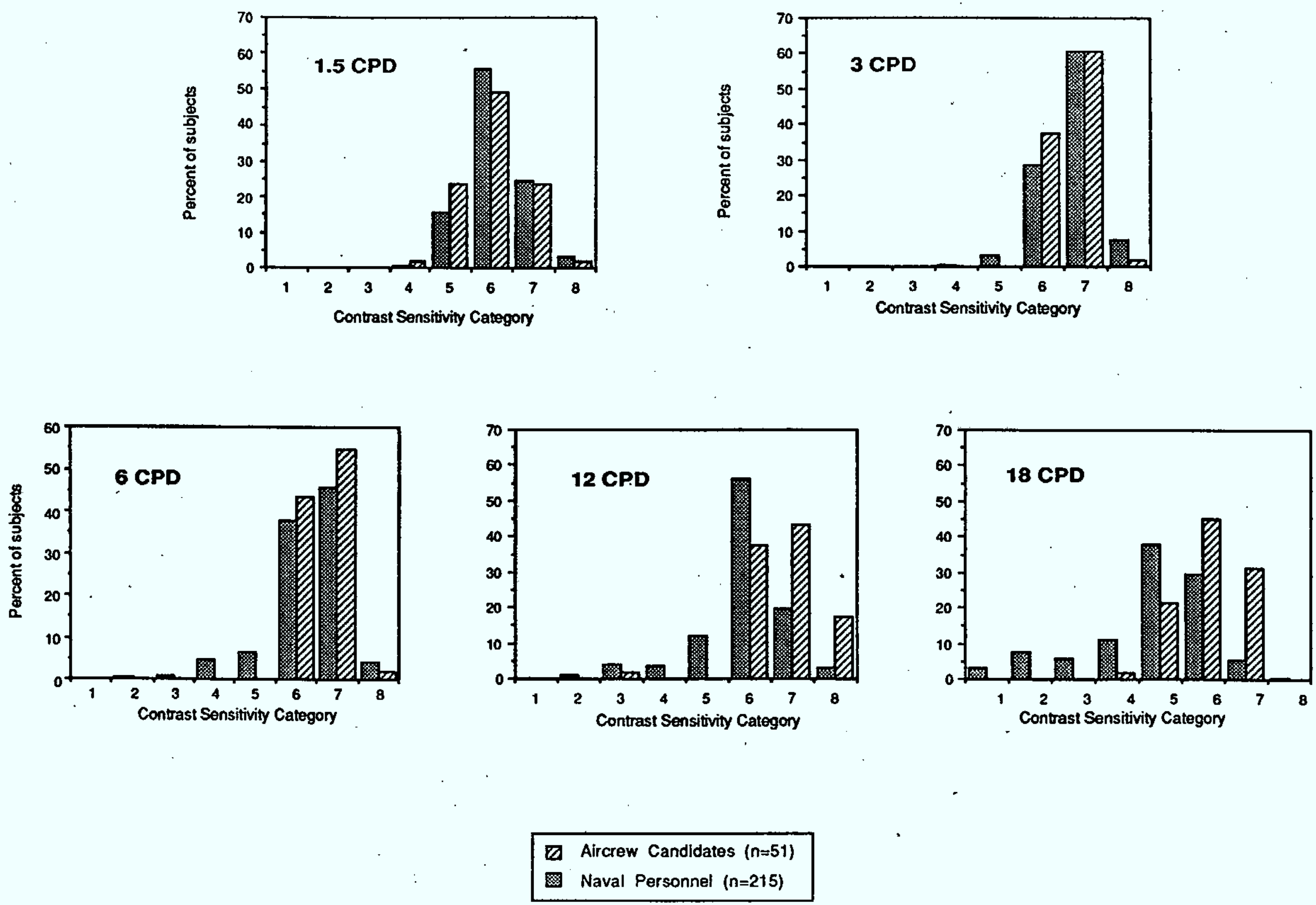


Figure 6. Comparative CS scores for aircrew candidates and naval personnel

(Most aircrew candidates had uncorrected visual acuity of 6/6 or better). However, the naval population demonstrated less variability in CS than did the general population norms that were provided with the test (20). This may be accounted for by the greater heterogeneity of the general population, most notably a greater age range (10 to 70 years).

Although the present study found no difference of age on CS, other researchers have. A review of the effects of aging indicates a general decrease in CS at various spatial frequencies depending on observer selection and methodology (18). The ability to see fine detail declines in adulthood with marked decreases after 50-60 years of age. CS at the lower and middle spatial frequencies was poorer in a comparison of younger (mean = 18.5) and older (mean = 73) groups when screened for high acuity (3). For the naval group, the only age related effect was a slight decrease (non-significant) in CS at 18 cpd (Figure 3). A greater decrease in CS at the high spatial frequencies might have been found if a larger sample of older crew members had been taken.

Watchkeepers were also compared to the rest of the ship's company (Figure 4). Although watchkeepers had slightly lower CS than other crew members, the graph shows that the difference is nonsignificant.

The Effect of a Watchkeeping Period

Measures of CS before and after watch showed no significant change over the four hour watch period for either group of watchkeepers (bridge or operations room). Figure 5 shows that the central tendencies of CS before and after watch are similar. As described in the results, shifts of CS up or down by one or more levels were frequent in the before and after watch scores. Individual subjects were most consistent at the lower spatial frequencies. The before and after watch scores were progressively more varied as spatial frequency increased. The only notable trend was for spatial frequencies of 3 and 6 cpd, where about twice as many subjects scored higher on the second test rather than lower. The results show that CS may be less stable at the higher spatial frequencies, with fairly equal numbers of subjects scoring either much higher or much lower on the second test. Others have reported that CS shifts in test-retest data are quite common (15). Thus, any differences in before and after watch scores may be due to factors such as guessing, intra-subject variability, learning, and test reliability rather than to the effect of the watchkeeping task itself.

Throughout the study, visual workload was low (as assessed by watchkeepers on duty) and visual tasks varied in accordance with routine watch rotations. Further controlled studies under conditions of heavy workload are required to adequately assess the effect of visual fatigue on CS. In addition, a control group of personnel not involved in visual tasks should be tested before and after a four hour shift. Operational and personnel limitations prevented the inclusion of more groups in the present study.

Despite shifts in CS measurements after watch periods, correlations between the two sets of scores were significant for 3, 6, 12, and 18 cpd. Although significant, the correlations were relatively low. The lack of correlation for before and after scores at 1.5 cpd may be due to the narrow range of scores found at that spatial frequency. The data show that despite the reduced between-subject variablity at the low spatial frequency, within-subject variation was still relatively high. CS scores before and after watch were still inconsistent. At the higher spatial frequencies, the between-subject variation was greater than the within subject-variation, resulting in higher correlations between CS measures taken before and after watch. In general, the test-retest results from this study do not provide any evidence that the Vistech charts have high test-retest reliability.

The Comparison of CS to Watchkeeping Assessments

The use of CS as a predictor of watchkeeping performance was investigated by comparing supervisors' assessments with CS measures at all spatial frequencies. The results clearly demonstrate that there was no trend toward positive correlations between questionnaire results and CS (Table 4). Indeed, 75% of the correlation coefficients were negative. It was also found that only 8% of all coefficients were significant. A comparison between CS scores and watchkeeping assessments before and after watch periods shows that these significant relationships were not consistent. It is not clear why negative correlations should be found between CS and supervisors' assessment scores. Examination of individual scores revealed that there were a few individuals who had exceptionally high ratings as watchkeepers (above average on watchkeeping assessments), yet their CS scores were at least one category lower (0.1 log units of contrast below median) than those of their peers. These individuals were considered to have extremely good ability at detecting, identifying and reporting contacts, as well as high levels of motivation, confidence and alertness. In these cases, high CS was not positively related to good watchkeeping performance.

Further analysis of the questionnaire data showed that many of the questions were positively interrelated (Table 5). As expected, questions concerning visual factors (detection, identification, and speed) were highly correlated. High correlations also showed that individuals that were confident would spot and identify contacts first.

The results from the questionnaire should be viewed with caution since it was not validated and there may not have been enough range in CS and watchkeeping scores to adequately assess relationships. Since corrected vision was tested and watchkeepers had already been selected to meet vision standards, the range and distribution of CS scores may have been restricted (most CS scores fell within a range of 0.3 log units of contrast). Also, most watchkeepers were given good performance scores with few individuals scoring poorly (mean on all questions = 2.4, S.D. = 0.8). CS may be predictive of watchkeeping performance for populations that have a wider range and distribution of CS scores and watchkeeping abilities than the population presently sampled.

The results, however, do indicate that overall watchkeeping performance of actual watchkeepers cannot be predicted using only CS measures. In reality, watchkeeping is a complex task that can be affected by many variables, of which the visual component is only one. If supervisors' assessments of watchkeeping performance are considered valid, then the findings from the questionnaire provide no evidence that differences in CS are related to overall watchkeeping ability. Thus, there would be no advantage to adding CS to a visual test battery for selecting better watchkeepers.

CONCLUSIONS

A population norm for the CS of naval personnel was established by testing 215 personnel onboard HMCS Saguenay. Observations indicate that this norm differs from those established previously for CF aircrew candidates and the general population. CS for the naval population is less variable than for the general population and more variable than for the CF aircrew candidates. Naval personnel scored lower than aircrew on the high spatial frequencies. Because of these population differences, the current data set should be used when assessing the CS of naval personnel.

There does not appear to be any systematic effect of watchkeeping period on CS. Since visual workload was low throughout the study, the effects of visual fatigue on CS could not be adequately evaluated. In the present study, CS scores before and after watch periods showed reasonable test-retest reliability.

CS scores of watchkeepers were not positively related to watchkeeping ability as assessed by supervisors. Numerous factors influence overall watchkeeping ability; therefore, measures of visual acuity and CS alone should not be used to select watchkeepers. Most watchkeepers appear to have average or above average CS compared to general population norms; thus, any differences in watchkeeping performance can be attributed to factors other than CS. Likewise, watchkeeping assessments by supervisors were high and had a small range. An adequate assessment of the predictive power of CS for watchkeeping ability requires a population with a wide range of CS and watchkeeping abilities.

RECOMMENDATION

The results of this study show no advantage in using CS as a predictive measure of watchkeeping abilities. Therefore, it is not recommended that CS be added to a visual test battery for selecting watchkeepers.

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Appendix 1

Test Schedule

DAY	TIME	GROUP	WATCH
1	0800-1030	C	-
	1100-1130	A	Red
	1300-1530	C	-
	1600-1630	A	Red
2	0800-1030	C	-
	1100-1130	A	White
	1300-1530	C	-
	1600-1630	A	White
3	0800-1030	C	-
	1100-1130	A	Blue
	1300-1530	C	-
	1600-1630	A	Blue
4	0800-1030	C	-
	1100-1130	B	Red
	1300-1530	C	-
	1600-1630	B	Red
5	0800-1030	C	-
	1100-1130	B	White
	1300-1530	C	-
	1600-1630	B	White
6	0800-1030	C	-
	1100-1130	B	Blue
	1300-1530	C	-
	1600-1630	B	Blue

Appendix 2

INTRODUCTION TO WATCHKEEPER QUESTIONNAIRE

The purpose of this questionnaire is to obtain information from you regarding the watchkeepers visual tasks. Your answers will help in assessing contrast sensitivitiy as a measure of visual ability, and will assist in improving the quality of watchkeeping in the Navy. Your honest opinions are, therefore, essential.

The data collected are to be used for research purposes only. When identifers (name and rank) are requested they are to be used for administrative and statistical control purposes only. Full confidentiality will be maintained in the processing of these data.

WATCHKEEPING ASSESSMENT BY SUPERVISOR

Supervisor: ____

(name)	(rank)	(trade)	(supervisor for how long?)

Watchkeeper: ____

(name)	(rank)	(position)	(group)	(watch)

Each question should be answered by crossing the number which best describes your feelings about the individual. Consider each of the following dimensions independently.

a. The ability of the watchkeeper to detect a contact is:

1	2	3	4	5
extremely good	good	so so	poor	extremely poor

b. The ability of the watchkeeper to correctly identify a contact once it has been detected is:

1	2	3	4	5
extremely good	good	so so	poor	extremely poor

c. Does the watchkeeper report contacts before others.

1	2	3	4	5
almost always	frequently	occasionally	seldom	rarely

d. How would you rate the watchkeeper's level of motivation.

1	2	3	4	5
extremely good	good	so so	poor	extremely poor

e. How would you rate the watchkeeper's level of confidence in his watchkeeping abilities.

1	2	3	4	5
extremely good	good	so so	poor	extremely poor

f. How would you rate the watchkeeper's level of alertness during his watch.

1	2	3	4	5
extremely good	good	so so	poor	extremely poor

Are there any additional comments on the performance of the watchkeeper?

Appendix 3

PEER RATINGS OF WATCHKEEPER'S VISUAL ABILITY

Group: ______________ Watch: ______________ Supervisor: ______________

Subjects (name, rank):	Ranking (highest to lowest):	
______________	______________	highest
______________	______________	
______________	______________	
______________	______________	
______________	______________	
______________	______________	
______________	______________	
______________	______________	
______________	______________	
______________	______________	lowest

Highest Rating: The watchkeeper who receives the highest rating is the most competent visual watchkeeper. He consistently spots contacts and reports them before other watchkeepers. His reports are consistently ahead of all other reports.

Lowest Rating: The watchkeeper who receives the lowest rating is the least effective visual watchkeeper. He rarely spots contacts before others. There are very few reports from this watchkeeper.

Appendix 4

TABLE OF VISUAL STANDARDS

Grading	Uncorrected Vision				Corrected Vision			
	Better Eye		Other Eye		Better Eye		Other Eye	
	Distance	Near*	Distance	Near*	Distance	Near*	Distance	Near*
V1	6/6	N5 & N14	6/9	N6 & N18	N/A	N/A	N/A	N/A
V2	6/18 OR 6/12	N10 & N24 N8 & N16	6/18 6/30	N10 & N24 N12 & N36	6/6	N5 & N14	6/9	N6 & N18
V3	6/120	N/A	6/120	N/A	6/6	N5 & N14	6/9	N6 & N18
V4	N/A	N/A	N/A	N/A	6/9	N6 & N18	6/120	N36
	As long as the refractive error does not exceed plus or minus 7.00 diopters spherical equivalent.							
V5	The category is reserved for serving personnel whose visual category is less than V4 but who, in the opinion of a consultant ophthalmologist, have sufficient visual acuity to perform their duties satisfactorily in their present trade or employment and for whom continued service employment will have no adverse effect. When there are career implications or a satisfactory remustering cannot be done, then a release under QR&O 15.01(3)(b) should be considered.							
V6	This category is assigned to candidates whose visual acuity is less than V4 standards. In the case of serving members, it will be assigned only by an ophthalmologist to those who cannot qualify for a higher grading.							

* Near vision is determined using "TIMES ROMAN" type and is assessed at reading distance (30 to 50 cm) and at 100 cm. The 100 cm distance is important in the aircraft cockpit and similar environments and for users of CRT displays. When two values are shown, such as N5 & N14, the first value refers to the reading distance and the second value to the 100 cm distance.

Approximate equivalents of the "TIMES ROMAN" N type, the Jaeger type and the meterprint size are as follows:

N5 = J2 = 0.5m	N6 = J3 = 0.6m	N8 = J5 = 1.0m	N10 = J7 = 1.4m	N12 = J8 = 1.6m
N14 = J10 = 2.0m	N16 = J11 = 2.2m	N18 = J12 = 2.5m	N24 = J20 = 4.0m	N36 = J30 = 6.0m