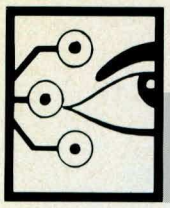

CLINICAL RESEARCH

Comparison of the Distance and Near Vistech Vision Contrast Test Systems (VCTS)

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Abstract

This paper describes the essential principles associated with the clinical use of a contrast sensitivity function (CSF) test to document vision loss or improvement. Some advantages of the CSF over the more conventional visual acuity test are described as well as the type of CSF losses associated with several ocular and neurological conditions. Contrast sensitivity was measured on each of 12 normal subjects ages 21 to 27 years on two separate occasions using both the distance and near versions of the Vistech Vision Contrast Test System charts (VCTS). Analysis of the variance showed that the results obtained using the distance and near chart were not significantly different. The contrast sensitivity scores elicited on the second trial, as compared to the first, were found to be consistently higher at all frequencies. This improvement associated with repeated testing is clinically evident among a high percentage of subjects tested but not statistically significant at the .05 level.

Résumé

Ce document fait état des principes de base de l'emploi clinique du test de sensibilité au contraste (contrast sensitivity function test) pour documenter la perte ou l'amélioration de la vision. Il est question des avantages de cette méthode par rapport aux méthodes classiques d'examen de l'acuité visuelle ainsi que des types de pertes de sensibilité au contraste associés à diverses conditions oculaires et neurologiques. La sensibilité aux contrastes a été déterminée chez douze sujets normaux entre 21 et 27 ans, à deux reprises, à l'aide de la version proche et de la version éloignée de la carte VCTS (Vistech Vision Contrast Test System). L'analyse de la variation montre que les résultats issus de l'emploi de cartes à faible ou à plus grande distance ne varient pas de manière significative. Les cotes de sensibilité obtenues au deuxième essai, par rapport à celles du premier, étaient toujours plus élevées, à toutes les fréquences. Cette amélioration, associée à des essais répétés, est évidente chez un grand nombre de sujets testés, mais ne représente pas un facteur significatif au niveau de .05.

Recent advances in contrast sensitivity testing techniques are making the procedure easier to use clinically. The advantages of the CSF test over the conventional visual acuity test continue to be realized. The purposes of this study are to describe the use of contrast sensitivity testing as a measurement of visual performance and to compare results obtained using distance and near versions of the recently developed Vistech Vision Contrast Test System.[1]

Contrast sensitivity is a measurement of the patient's ability to perceive differences between the lightest and darkest areas of a given target. Usually, a sine wave grating is used. This target has uniformly alternating dark and light bands whose edges do not have sharp luminance discontinuities; rather the target luminance distribution varies as a sine function. Mathematically, contrast is defined as the difference between the highest and lowest luminance of a grating divided by their sum: C = (Lmax -Lmin)/(L max + L min).

The width of each band, or, more specifically, the number of dark and light bars per degree of visual angle determines the spatial frequency of the grating. If one dark band subtends 1 min of arc at the observer's eye, as does each stroke of a 6/6 (20/20) letter, then a cycle would subtend 2 min of visual angle at that distance. Since there are 60 min of arc per degree, 30 cycles that subtended 2 min each at the observer would be contained within 1 degree of visual angle. Therefore this spatial frequency would be specified as 30 cycles per degree (c/d). If each band were widened to 2 minutes by reducing the

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original observation distance for the same grating to half, then each cycle would subtend 4 min of arc and the resulting spatial frequency would be 15 c/d. Similarly, halving the grating band width or doubling the observation distance would double the spatial frequency to 60 c/d.

A sine wave grating is used as a test target because it is the simplest form of visual stimulus and its image when modulated through an optical system retains its sine-wave form. Optical defocus merely has the effect of increasing the image's transition zone size, which causes perception of the high frequency gratings to be impaired first.

Testing is usually done by determining the contrast of a grating of a specific spatial frequency at which the subject is at the threshold of just being able and just not being able to differentiate the sine wave grating from a uniform patch of grey. This contrast level is called the threshold contrast for that observer at that spatial frequency. The inverse of this threshold indicates the contrast sensitivity. By determining contrast sensitivity over a range of spatial frequencies (typically from about 0.5 to 20 c/d) a patient's contrast sensitivity function (CSF) can be mapped. A typical contrast sensitivity function is displayed in Fig 1.

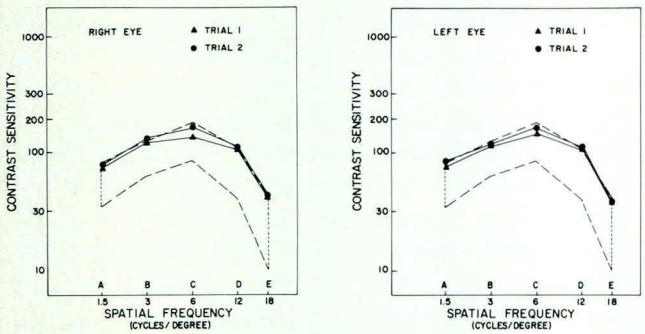

Fig. 1 Comparison of all trial 1 results with all trial 2 results of the right and left eyes respectively. Broken lines indicate the normal range of contrast sensitivity values by VISTECH.

Thus, although both letter charts and contrast sensitivity tests measure thresholds, the former represents an extensity threshold, that is, the minimum size target that can be resolved or recognized[2]. Contrast sensitivity tests measure intensity thresholds; the minimum luminance difference that can be seen. This test usually uses much larger test targets[2].

Snellen acuity can only evaluate the performance of a small part of the visual system, since only the foveal cones have a sufficiently dense mosaic to handle high frequency information. In the retinal periphery, only lower spatial frequency channels are represented[3].

For this reason, disturbances in other parts of the visual system may impair visual function without altering visual acuity. Thus, identical visual acuities may result in substantially different capabilities and conversely, contrast sensitivity function cannot be predicted from visual acuity results alone[4].

However, if CSF data points are extrapolated, the intersection at the abscissa represents the spatial frequency at which a grating can only be seen if its contrast is 100% and any grating of higher spatial frequency is indistinguishable from a uniform patch of grey[3]. This intersection, therefore, corresponds to the cut-off spatial frequency threshold or resolution capability, which is in fact visual acuity measured in cycles per degree.

Experimental research has shown contrast sensitivity to be a more complete description of different types of vision loss. An example of the value of CSF testing is found among contact lens wearers, who may have visual complaints which can be identified by measuring CSF although their visual acuity is normal[5].

Of great diagnostic importance is the fact that characteristic CSF curves are associated with such conditions as multiple sclerosis[4,6], glaucoma[3,7], cataracts[8], amblyopia[9,10], retrobulbar neuritis[10], and other specific pathway disorders[12]. This makes CSF a valuable tool for diagnosis, monitoring and assessment of several primary and secondary ocular conditions as well as evaluating improvement resulting from spectacle, surgical or vision training therapy. Routine use of CSF testing would allow the practitioner to find the first evidence of eye diseases or neurological disorders earlier than with conventional tests or procedures, and occasionally may facilitate differential diagnosis of eye problems[3,13,14].

Contrast sensitivity testing with low spatial frequency gratings has proved to be an efficient screening device for glaucoma and peripheral field losses[3,7]. Refractive blur will cause significant losses in the high spatial frequency range without affecting thresholds for lower spatial frequencies[13]. In neurological conditions such as multiple sclerosis, the mid and low frequency losses are typically as great or greater than the high frequency losses[4,6,13]. Amblyopia, cortical lesions and multiple sclerosis may also result in "notch" losses which selectively affect the intermediate spatial frequencies[13]. Cataracts can produce losses equally across all frequencies, or at high and medium spatial frequencies only[8].

Several testing systems have been utilized including oscilloscope systems, television systems, the Arden Grating Test chart system[15], the Vistest LH-5 chart test system[16] and most recently, the Vistech Vision Contrast Test System (VCTS)[1]. The first two of these are research rather than practitioner employed tools requiring careful calibration and involving test procedures generally unfamiliar to most practitioners and patients.

The Vistech Vision Contrast Test System, recently developed by Ginsburg[1] incorporates new design

features which aim to make CSF testing quick and simple. The VCTS consists of a chart of 5 rows of 9 sinusoidal grating test patches, each row having a different spatial frequency: A = 1.5, B = 3, C = 6, D = 12, and E = 19 c/d. Within each row, the contrast of successive test patches decreases from left to right in steps of approximately 0.1 log unit. The test gratings are randomly arranged in one of three orientations: vertical, 15 degrees right or 15 degrees left. A forced choice technique is used in testing such that the patient must report the orientation of each test grating or report the patch as blank if the grating cannot be perceived. If the patient thinks he sees the grating but is unsure of the orientation, he is encouraged to guess. The low contrast test patch whose orientation the subject can identify correctly is recorded and the results can be compared with a normal curve. Three-chart sets of both the distance version for use at 3.05 m (10 ft) and the near version for use at 45.6 cm (18 in) are commercially available.

The distance chart measures 94 x 67.5 cm. (37 x 27 in) with each test patch subtending 1.63 degrees. The near chart measures 17.4 x 14 cm (6.9 x 5.5 in), with each test patch subtending 1.41 degrees at the eye.

It should be noted that the near chart is used at a distance of 45.7 cm (18 in), thus acting as a stimulus to accommodation of about 2.25 D. Therefore, if a patient's accommodative range is too limited to allow him to see the chart clearly through his add, additional lenses of 2.00 to 2.25 D must be used when administering the test, especially if the patient's normal reading distance is closer than 40 cm.

Method

A total of 24 eyes were tested monocularly using first the distance chart B of the VCTS, then near chart B of the VCTS which had the same arrangement of test patches. In each instance, the right eye was tested before the left. A luminance level of 120 cd/m^2 was maintained on both charts at all times. On the second trial, use of the same chart and testing sequence was repeated. Subjects were all optometry students from the University of Waterloo School of Optometry. Their ages ranged from 21 to 27 years. All were emmetropes or ametropes corrected with spectacles.

Results and Discussion

The results of statistical analysis of the clinical data are summarized in Table 1.

Analysis of variance was applied to determine whether, among normal observers, there is a significant difference between the results obtained with the distance VCTS chart compared to the near chart. The statistical analysis shows that the average results for the two charts are not significantly different. This suggests that either chart may be used interchangeably and results of the two distances could be compared directly for these normal prepresbyopic subjects.

Table 1

Selected statistical indices from results of analysis of variance. (* - Values for P of less than 0.05 indicate that the variable has a significant effect)

	Right Eye		Left Eye	
Source	F	P	F	P
Subject	2.50	0.0076*	3.39	0.0004*
Test Dist	0.80	0.3718	0.00	0.9751
Frequency	187.75	0.0001	171.23	0.0001
Trial	10.96	0.0011*	5.41	0.0210*
Trial*Freq	3.16	0.0152*	0.91	0.4601
Test*Dis*Freq	0.94	0.4422	2.28	0.0627
Trial*Test*Dist	0.00	0.9873	0.89	0.3478
Trial*Dist*Freq	0.95	0.4368	0.37	0.8333

The interaction between test distance and each of the following: trial, frequency and both frequency and trial together were also studied. In each case these interactions were found to be insignificant, further supporting the conclusion that the distance chart and the near chart will give the same CSF findings.

The Student-Newman-Keuls test was also applied to determine whether there was a difference in CSF results with repeated trials. Results for the right and left eyes were analyzed separately. Comparison of the averages of all trial 1 results with all trial 2 results showed the two trials to be significantly different at the .05 level, with the averaged results for all subjects being consistently higher on the second trial than the first at all frequencies for both the right and left eye samples, as shown in Figure 1. This improvement on trial 2 is most likely due to a learning effect which arises on the second trial as the subject becomes more familiar with the test and begins to make judgements more easily about gratings which are near his threshold sensitivity. Analysis of the trial frequency interaction showed that for at least one frequency, a strongly significant increase in CSF was found to occur on the second trial, in addition to the possible learning effect found for the average of the results for all frequencies. The large increase in CSF from 136 to 165 at frequency C is the most likely cause of this additional effect. Other than this, however, analysis of results for each frequency separated did not show the learning effect to be significant. Both the limited number of observations at each frequency as well as the relatively coarse gradations of possible CSF values are likely to have contributed to this finding. It would be interesting to test the significance of the learning effect at each spatial frequency using a larger subject population or a number of repetitions of the same test on the same subjects.

When comparing averaged results for the right and left eye samples, it is noted that the right eyes had slightly higher contrast sensitivity on both trials.

However, the improvement of CSF over the two trials appears to be smaller for the left eye sample. This may be because the subject gained familiarity with the test when his first eye, always the right, was being tested. Consequently, the first test for the left eye would yield a higher contrast sensitivity than if the left eye had been tested first. This would leave less room for improvement on the second trial since it is predicted that this apparent learning effect decreases with successive trials. This would explain why a significant increase was found at frequency C for the right eye but not for the left.

Because the VCTS chart measures contrast sensitivity in discrete steps of 0.1 log unit, any increases in the overall average on the second trial would suggest that a proportional portion of the population tested had a significant increase in CSF. For example, the improvement in contrast sensitivity from 136 to 165 represents close to a 0.1 log unit increase. This would suggest that a large proportion of the sample population had shown a clinically significant increase of one 0.1 log unit step or more at frequency C. Table 2 summarizes the performance at each frequency of all subjects on trial 2 as compared to trial 1. At frequencies A through D, it was found that between 32 and 59% of the subjects had improved CSF scores on the second trial, compared to the 9 - 32% of the subjects whose contrast sensitivity decreased on the second trial at the same four frequencies. Greater variability was found at frequency B, where 37 and 46% of the subjects had increased contrast sensitivity, while the proportion experiencing a decrease was nearly equal to 36 and 41%. This result confirms the expectation that measurements at the highest spatial frequency are subject to the greatest fluctuations, as well as intersubject variability since no steps were taken to improve each subject's more recent spectacle correction.

Table 2

Spatial frequencies: This table summarizes the percentage of the subjects who were found to show increases or decreases in CSF results of one test patch or more on the VCTS charts, as compared to trial 1.

Percentage of subjects showing:	A		B		C		D		E	
	OD	OS	OD	OS	OD	OS	OD	OS	OD	OS
increase	32	41	41	41	59	45	41	55	46	37
decrease	19	14	14	18	9	9	28	32	36	41
no change	50	45	45	41	32	45	32	14	18	23

Analysis of the interaction between chart version (distance or near) and spatial frequency and their combined effect on CSF revealed a consistent, though not statistically significant trend. Among both right and left eye samples, high spatial frequencies were seen slightly more easily with the distance chart.

Higgins et al[17] have shown the "criterion-free" forced choice method of CSF testing to be superior to the method of adjustment when 50 trials at each of 9 spatial frequencies are used, having "excellent long-term stability". The forced choice method was shown to be less subject to fluctuations of criterion over time and is also easier for patients to understand. Although the Vistech chart uses a variation of the forced choice technique, only one trial is made at the "threshold patch" at each spatial frequency, and all possible contrast threshold values are spaced apart in discrete steps of 0.1 log unit. These factors may put limits on the precision of the Vistech system not found with the more thorough technique described by Higgins. The long-term stability of the VCTS results following the possible initial learning effect has yet to be investigated.

Comparison of the typical contrast sensitivity function with the function obtained using the VCTS showed the two to be dissimilar both in terms of the actual contrast threshold values as well as the spatial frequency giving the peak sensitivity. Most test systems show the peak sensitivity to be at approximately 3c/d while the VCTS consistently finds it to be at 6 c/d. This disparity could be due to different luminance levels and different field sizes.

In summary, it was concluded that for normal subjects of the age range tested (21 to 27 years), there is no difference between results obtained with the near chart and those found using the distance chart. It was shown that an improvement in contrast sensitivity associated with repeated trials was found and between 32 and 59% of subjects may be expected to show an increase in contrast sensitivity of 0.1 log unit or more at various spatial frequencies on their second test trial. This improvement, however, was found to be statistically insignificant at the .05 level. It would be interesting to test this "improvement" in contrast sensitivity function by using a larger number of subjects and a number of trials of the same test on the same subjects in a further study on the clinical use of the Vistech system.

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Continued on p. 54

across the inferior retina have been combined to show how extensive this 'grouped' or 'Bear Track' pigmentation is. The largest group lay approximately 10-12 disc diameters inferiorly to the posterior pole. The rest of the exam was unremarkable.

This type of retinal disturbance is a benign pigment epithelial hypertrophy, is well circumscribed, flat and has black uniform pigmentation. These features distinguish it from other types of pigmented areas in the retina (Table 1). Histologically, areas of grouped pigmentation are found to contain unusually large (hypertrophic) RPE cells with many pigment granules.

The disposition for this patient is to describe, sketch and/or photograph the pigment disturbance in enough detail to monitor and assist in differential diagnosis.

Patients of this kind continue to reward and encourage all of us who pick up an ophthalmoscope to explore the peripheral retina.

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Continued from p. 15

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Continued from p. 46

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