

Effects of Optical Correction Media on Contrast Sensitivity

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Abstract

Contrast sensitivity functions (CSFs) were obtained for 257 emmetropic subjects (514 eyes) and 35 contact lens users (64 eyes) in the Republic of Singapore Air Force using the Vistech® Contrast Test System. For the emmetropes, contrast sensitivity tests were carried out with and without plano spectacles (PS). For the myopes, we compared their performances with spectacles, daily-wear soft contact lenses (CLs), and CL plus PS at Snellen visual acuities of 6/6 or better. Paired t-tests showed that there were no significant differences ($P > 0.05$) when CSFs of the emmetropes were measured with and without PS and when that of the CL users were measured with spectacles, CL and CL plus PS. We therefore conclude that myopic optical correction media do not retard CSF significantly based on the Vistech® charts, although they may reduce image size and modify light transmission by being imperfect transparencies. The observed decrease in CSF for myopes even after myopic correction might therefore be related to other factors associated with myopia, such as retinal changes or possibly mild amblyopia.

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Key words: Contrast sensitivity function, Image size, Light transmission, Mild amblyopia, Myopic correction media

Introduction

With the lowering of visual selection criteria in the Republic of Singapore Air Force (RSAF), more aviators are wearing spectacles. It was found that contrast sensitivity function (CSF) is lower among myopes despite spectacles correction to Snellen acuity of 6/6.¹ It was also noted that spectacles reduced the ability of pilots to detect targets² and that decreased CSF is accompanied by a reduction in target detection range." A logical question is whether the reduction of CSF is due to the optical correction media used during these tests, as optical transparencies have been shown to affect light transmission by way of light scatter,^{4,6} reflection, distortion, secondary imagery and birefringence^{7,8} resulting in reduced target contrast. The answer to this question is important operationally as visors, spectacles and contact lenses are increasingly being used by aviators and any of such imperfections may impede target detection and information acquisition during flight.

The aim of this study was to investigate the effect of spectacles, being imperfect optical transparencies, on CSF and to determine the effect of image size reduction from the use of myopic corrective lenses.

Materials and Methods

The CSF was measured for 257 emmetropes by consecutive opportunistic sampling of the Republic of Singapore Air Force (RSAF) personnel who underwent routine annual ophthalmological examination at the Aeromedical Centre, RSAF.

Thirty-five contact lens (CL) users were obtained by random sampling. The emmetropic subjects had 6/6 or better unaided distance Snellen acuity and the CL users were required to have at least 6/6 visual acuity with both spectacles and CL. All had no evidence of any acute or chronic ocular diseases. For the emmetropic subjects it was ensured that their vision remained at 6/6 with plano spectacles (PS). The refractive errors for the emmetropes were determined from automated refractometry and that for the CL users from subjective refraction. Hyperopes of more than +1.00 dioptre of spherical equivalent were excluded.

Contrast sensitivity tests were conducted using the Vistech® Contrast Test System under recommended room lighting of 10 eV at a distance of 3 metres. The charts consist of five rows of achromatic, stationary, sinusoidal gratings which give effective spatial fre-

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quency (spf) of 1.5, 3, 6, 12 and 18 cycles per degree (cpd) at a distance of 3 metres. Each spf has 8 levels of contrast presented in separate 3-inch circular patches with the level of contrast progressively diminishing from left to right. Within each patch, the orientation of the grating may be vertical, tilted to the left or right.

Before the actual test was carried out, subjects were given 5 minutes to adapt to the test field luminance and were then shown binocularly sample gratings of 6 cpd at three possible orientations for 10 seconds so as to minimise errors from uncertainty of orientation pattern which might elevate thresholds.” The test began with the lowest spf.

Subjects were required to record the orientation of the gratings of each patch successively in sequence from left to right along each row. Forced choices were not employed. The lowest contrast patch that was identified correctly was considered the threshold for that row.

Unocular testing was carried out without spectacles and then with PS for the emmetropes. For the CL users, it was done with spectacles, CL and CL plus PS. No glare source was used. The test sequences of no-spectacles and PS for the emmetropes as well as of CL and CL plus PS for the CL users were randomised to avoid possibility of fatigue or improvement due to learning from consistently affecting any particular test category. A different chart was used for each test category with a short rest period in between tests. Only non-multicoated spectacle lenses and soft CLs were allowed. CL users

were told not to wear them for 3 days immediately before the test as they can cause corneal oedema and distortion that may affect post-CL spectacle visual acuity. A complete test will usually take 15 to 20 minutes with no strict time limit imposed.

Contrast scores obtained from the chart for each spf were converted to contrast sensitivity using the conversion table provided by Vistech®. $\log_{10}$ transformation would then be applied, recorded and used for statistical analysis.

Results

There were 35 CL users sampled. One subject was hypermetropic in both eyes ($> +1.00$ D) and 4 others were not correctable to 6/6 with CL in one of their eyes. These eyes were therefore eliminated, giving a total of 64 eyes.

Table I presents the mean CSF (after $\log_{10}$ transformation) of the 257 emmetropic subjects with and without PS. Each spf group was analysed separately and paired t-test was applied for each eye to obtain the 2-tailed probability result.

Note that there was no statistical significance ($P > 0.05$) in CSF in all except for the 12 cpd group. Similarly between CL and CL plus PS, none of the spf showed any statistical significance (Table II). Tables III, IV and V show results between CL and spectacles with breakdown into myopes more than and less than or equal to -5 D. Again no statistical significance was observed except for the 12 cpd group in the ≤ -5 D category.

TABLE I: COMPARISON OF CSF BETWEEN THE NAKED EYES WITH AND WITHOUT PLANO SPECTACLES

Spatial frequency (cpd)	Naked eye			Naked eye + Plano spectacles			t value	2-tailed P
	Mean +2SD	Mean	Mean -2SD	Mean +2SD	Mean	Mean -2SD		
1.5	2.01	1.83	1.65	2.01	1.84	1.66	-1.65	0.10
3.0	2.19	2.04	1.88	2.19	2.04	1.89	-0.96	0.34
6.0	2.33	2.12	1.91	2.33	2.12	1.92	-0.30	0.77
12.0	2.22	1.93	1.64	2.24	1.95	1.65	-3.22	0.001
18.0	1.82	1.46	1.11	1.82	1.47	1.12	-1.82	0.07

No. of eyes = 5 14; CSF: contrast sensitivity function; cpd: cycle per degree; SD: standard deviation

TABLE II: COMPARISON OF CSF BETWEEN CONTACT LENSES WITH AND WITHOUT PLANO SPECTACLES

Spatial frequency (cpd)	Contact lens			Contact lens + Plano spectacles			t value	2-tailed P
	Mean +2SD	Mean	Mean -2SD	Mean +2SD	Mean	Mean -2SD		
1.5	1.95	1.77	1.60	2.00	1.79	1.57	-1.15	0.25
3.0	2.17	1.99	1.81	2.14	2.01	1.87	-1.72	0.09
6.0	2.30	2.05	1.80	2.30	2.07	1.84	-1.27	0.21
12.0	2.19	1.83	1.46	2.21	1.84	1.46	-0.55	0.58
18.0	1.69	1.35	1.01	1.65	1.34	1.03	0.63	0.53

No. of eyes = 64; CSF: contrast sensitivity function; cpd: cycle per degree; SD: standard deviation

TABLE III: COMPARISON OF CSF BETWEEN CONTACT LENSES AND SPECTACLES

Spatial frequency (cpd)	Contact lens			Spectacles			t value	2-tailed <i>P</i>
	Mean +2SD	Mean	Mean -2SD	Mean +2SD	Mean	Mean -2SD		
1.5	1.95	1.77	1.60	1.92	1.77	1.62	-0.01	0.99
3.0	2.17	1.99	1.81	2.13	1.98	1.84	0.27	0.79
6.0	2.30	2.05	1.80	2.27	2.07	1.86	-0.77	0.45
12.0	2.19	1.83	1.46	2.15	1.86	1.58	-1.51	0.14
18.0	1.69	1.35	1.01	1.69	1.36	1.03	-0.39	0.70

No. of eyes = 64; CSF: contrast sensitivity function; cpd: cycle per degree; SD: standard deviation

TABLE IV: COMPARISON OF CSF BETWEEN CONTACT LENSES AND SPECTACLES FOR MYOPES ≤ -5.00 D

Spatial frequency (cpd)	Contact lens			Spectacles			t value	2-tailed <i>P</i>
	Mean +2SD	Mean	Mean -2SD	Mean +2SD	Mean	Mean -2SD		
1.5	1.95	1.78	1.60	1.91	1.77	1.62	0.85	0.40
3.0	2.16	1.99	1.81	2.13	1.99	1.84	0.18	0.86
6.0	2.30	2.04	1.77	2.30	2.07	1.84	-1.36	0.18
12.0	2.22	1.81	1.41	2.12	1.88	1.41	-2.46	0.02
18.0	1.67	1.39	1.10	1.71	1.39	1.07	-0.75	0.46

No. of eyes = 38; CSF: contrast sensitivity function; cpd: cycle per degree; SD: standard deviation

TABLE V: COMPARISON OF CSF BETWEEN CONTACT LENSES AND SPECTACLES FOR MYOPES > -5.00 D

Spatial frequency (cpd)	Contact lens			Spectacles			t value	2-tailed <i>P</i>
	Mean +2SD	Mean	Mean -2SD	Mean +2SD	Mean	Mean -2SD		
1.5	1.95	1.77	1.59	1.94	1.79	1.64	-1.14	0.27
3.0	2.18	1.99	1.80	2.12	1.98	1.85	0.20	0.85
6.0	2.30	2.07	1.85	2.24	2.06	1.88	0.52	0.61
12.0	2.15	1.85	1.54	2.17	1.84	1.50	0.19	0.85
18.0	1.70	1.30	0.90	1.66	1.32	0.98	-0.39	0.70

No. of eyes = 26; CSF: contrast sensitivity function; cpd: cycle per degree; SD: standard deviation

Discussion

The results of this study indicate that the use of corrective lenses does not interfere with CSF significantly even though myopic lenses may reduce image size and affect light transmission in many of the ways mentioned earlier. If image size reduction does affect CSF, then such an effect would become amplified in higher myopia. This however was not observed in the > -5 D group (Table V).

It is indeed possible that CSF may really be retarded by these optical transparencies and that Vistech® charts are simply not sensitive enough to detect them. For example, Hughes and Vingrys¹⁰ have found a reduction in CSF when viewing through aircraft windscreen by using sinusoidal gratings presented on a Tektronic model monitor using the method of Schade.¹¹ Despite this, this present study certainly suggests that the observed decrease in CSF among myopes even after spectacles correction to 6/6¹ is unlikely to be due to optical imperfections and image size reduction by the myopic

lenses, since both studies were done using Vistech® charts.

Therefore, to explain the decrease in CSF one may have to consider other factors such as myopic retinal changes or very mild “amblyopia” (even though refractive errors were not high and Snellen acuities were 6/6) which only manifest itself with contrast sensitivity tests.

Another noteworthy point is that although spectacles and contact lenses may not reduce CSF, it would be erroneous to think that factors such as thickness of the media, type of material, the quality, coatings, cleanliness, angulation and shape would not adversely affect CSF, collectively or separately. This may become significant under operational conditions when the aviator has to look through not only his spectacles but also the visors/goggles and the aircraft windscreen.

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