

# CONTRAST SENSITIVITY IN ONE-EYED PATIENTS



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## 1. Introduction

There is strong psychophysical evidence that spatial visual performance is enhanced under binocular observation. On the other hand, it is widely accepted that monocular deprivation results to improved visual performance in the non-pathological eye. The aim of the study was to investigate the effect of monocular deprivation (i.e. one-eyed patients) on the contrast sensitivity performance of the fellow eye.

## 2. Methods

Twenty monocularly-deprived subjects with an average age of  $29 \pm 10$  years (range 15-45 years) were included in the study. The affected eye of all patients was measured with a visual acuity equal or worse than FC at 1m (3 with FC at  $\leq 1m$ , 3 with FC at  $\leq 20cm$ , 2 with HM at  $\leq 20cm$ , 4 with LP and 8 with NLP). Deprivation time was  $10 \pm 9$  years (range 2 to 29 years). Exclusion criteria for the non-affected eye were any retinal / macular pathology, media opacities (cataract, corneal opacity and vitreous hemorrhage), ocular surgery, glaucoma, major systemic disease and neurological disorders or any other disorders that may compromise successful study participation.

Eighteen more subjects with an average age of  $28 \pm 5$  years (range: 23 to 41 years) served as the control group. Exclusion criteria for the control group were all the above-mentioned exclusion criteria including spectacle-corrected visual acuity worse than 0.00 logMAR, myopia or hyperopia  $> 4.00$  D and anisometropia  $> 0.50$  D. The average spherical equivalent was  $-0.78 \pm 1.54$  D for the one-eyed patients and  $-0.97 \pm 1.65$  D for the control group.

Verbal consent was obtained from all participants after they had received an oral explanation of the nature of the study. The study was conducted in adherence to the tenets of the Declaration of Helsinki and followed a protocol approved by the University of Crete Research Board.

## 3. Experimental Procedure

Contrast sensitivity measurements were performed at 4.0 m distance, monocularly (dominant eye for the control group) and binocularly (only for the control group), with best spectacle sphero-cylindrical correction and natural pupils. Visual acuity was assessed using the UoC European-wide logMAR charts.

Contrast sensitivity was evaluated using vertical ( $90^\circ$ ) sinusoidal gratings (size: 3 deg), modulated at a frequency of 2 Hz in a square-wave reversal mode. Stimuli were displayed on a Sony GDM F-520 CRT monitor, by means of a VSG 2/5 stimulus generator card (Cambridge Research Systems Ltd, Rochester, UK). Seven spatial frequencies (1, 2, 4, 8, 12, 16 and 24 c/deg) were tested. Mean screen luminance was  $30 \text{ cd/m}^2$ . Threshold was determined using a binary-search staircase with a contrast resolution of 1dB (0.05 log units). The average of three thresholds was taken for each spatial frequency. Contrast sensitivity functions were plotted in a log-log scale and were fitted with second-order polynomials.

In order to evaluate any bandwidth-specific loss, the area under the contrast sensitivity function (AUCSF) was calculated (see Applegate et al., 1998) for 3 spatial frequency ranges: the full (0.0 to 1.2 log c/deg), the low (0.0 to 0.5 log c/deg) and the high (0.5 to 1.2 log c/deg) range. Moreover, the spatial frequency cut-off (spatial frequency for CS=0) was calculated from the linear slope of the log-linear CSF plots (for spatial frequencies  $> 2.5$  c/deg).

## 4. Results

**Figure 1** plots average of contrast sensitivity functions under monocular and binocular viewing for the control group. It is evident that sensitivity is increased for all spatial frequencies for binocular compared to monocular vision, with an average difference of 4.2 dB, which corresponds to a 70% improvement in contrast threshold.

High statistical significant differences between the two viewing conditions are found for full-, high- and low- AUCSF areas as well as for the spatial frequency cut-off ( $p < 0.001$  for all indices; paired t-tests).

**Figure 2** shows that average contrast sensitivity is higher at all spatial frequencies in the one-eyed patients than with the dominant eye of the control group. The average difference in contrast sensitivity between the two groups is 5.0 dB, which corresponds to a 83% improvement in contrast threshold.

High statistical significant differences between the two groups are found in full-, high- and low- AUCSF areas as well as in the spatial frequency cut-off ( $p < 0.001$  for all indices; independent samples t-tests). Note that the average contrast sensitivity in monocularly-deprived patients is higher (0.84dB) than the binocular values of the control group. These differences are not statistically significant ( $p > 0.0.5$  in all indices).

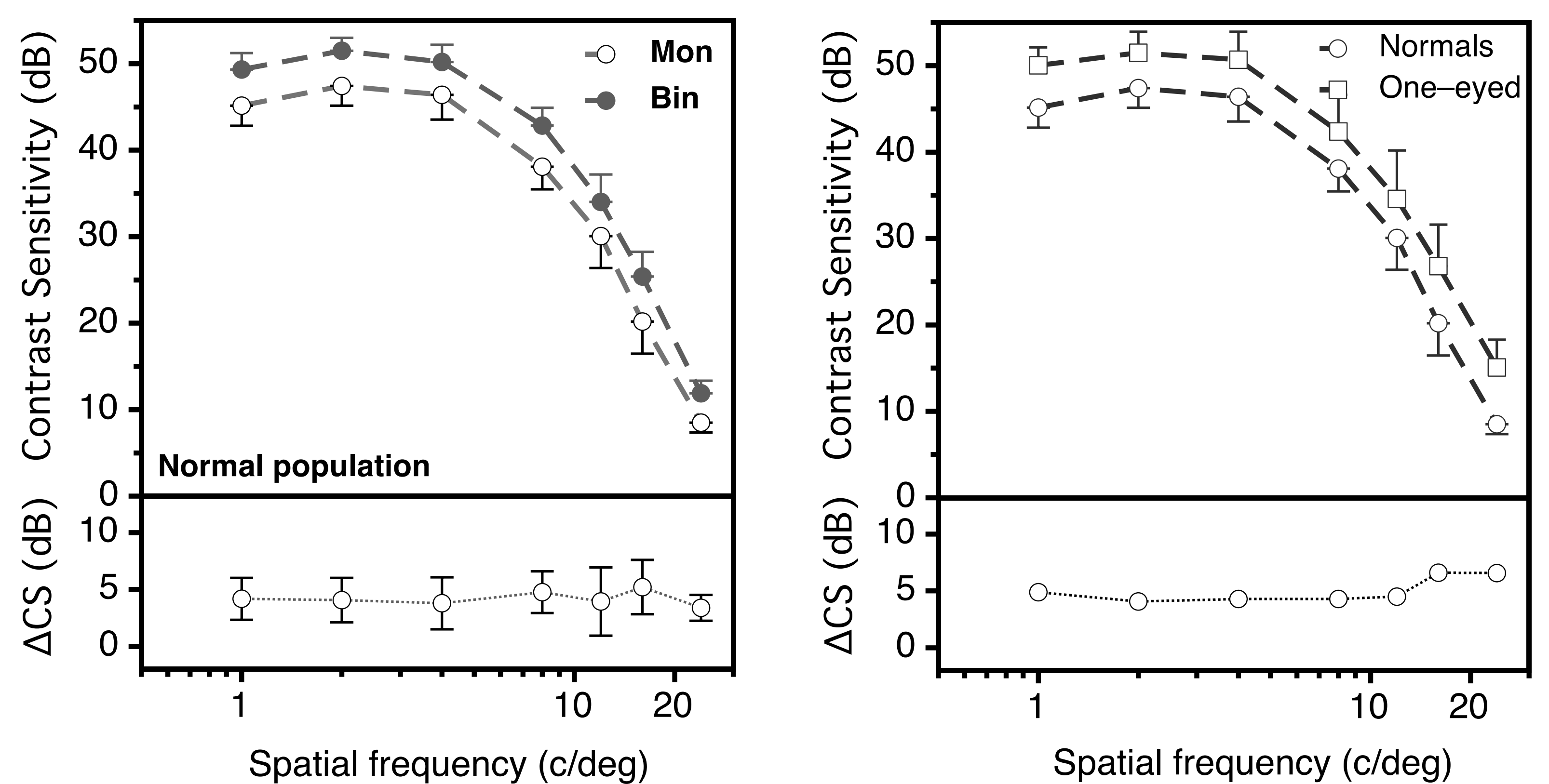


Figure 1: (upper) Average contrast sensitivity functions for the control group (18 participants) under binocular (filled circles) and monocular (open circles) vision; (lower) difference between binocular and monocular contrast sensitivity.

Figure 2: (upper) Average contrast sensitivity functions for the control (18 participants, open circles) and the one-eyed group (20 participants, open squares) under monocular observation; (lower) difference in contrast sensitivity between the two groups (control minus one-eyed).

In both graphs the dashed lines form second order regressions and the bars indicate  $\pm 1$  SD.

## 5. Conclusions

Contrast sensitivity is enhanced by 70% with binocular viewing in normal eyes. One-eyed patients show increases levels of contrast sensitivity compared to monocular values of normal age-matched subjects. The improved performance of the non-pathological eye of patients with monocular deprivation may be the result of neuronal synaptic plasticity of the visual cortex.

## References

1. Tieman SB, Moffett JR, Irtenkauf SM. Effect of eye removal on N-acetylaspartylglutamate immunoreactivity in retinal targets of the cat. Brain Research, 1991; 562:318-322.
2. Nicholas JJ, Heywood CA, Cowey A. Contrast Sensitivity in One-eyed Subjects. Vision Res. 1996;1:175-180.
3. Applegate RA, Howland HC, Sharp RP, Cottingham AJ, Yee RW. Corneal aberrations and visual performance after radial keratotomy. J Refract Surg. 1998;14: 397-407.