Spatial and Temporal Contrast-Sensitivity Functions of the Visual System

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Spatial and Temporal Contrast-Sensitivity Functions of the Visual System

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INDEX HEADING: Vision.

THE dependence of the form of the spatial contrast-sensitivity function for a square-wave test grating upon the duration of exposure of the target has been investigated by Schober and Hilz.[1] Kelly[2] has pointed out an analogous dependence of the form of the temporal contrast (modulation) sensitivity function upon the angular extent of the test target. The reciprocal nature of these spatio-temporal interactions can be particularly clearly appreciated if the threshold contrast is determined for a grating target whose luminance perpendicular to the bars is given by

$$L = L_0(1 + m \cos 2\pi\nu x \cdot \cos 2\pi f t)$$

where m is the contrast, ν the spatial frequency, and f the temporal frequency of the target.

Such a pattern was set up as a display on a cathode-ray oscilloscope and Figs. 1 and 2 show the results of threshold-contrast measurements made by the author (a well-corrected myope). Viewing was binocular at a distance of 2 m. The grating pattern subtended $2.5° \times 2.5°$ in the center of a $10° \times 10°$ screen illuminated to the same mean luminance of 20 cd/m^2.

The general similarity of the two sets of contrast-sensitivity functions is immediately evident but two features are particularly remarkable. First, the form of the fall-off in sensitivity at high spatial frequencies is independent of the temporal frequency and vice versa. Second, a fall-off in sensitivity at low spatial frequencies occurs only when the temporal frequency is also low and vice versa.

The first of these findings implies that the attenuation of high spatial frequencies is provided either entirely by an optical mechanism or partially by an optical mechanism and partially by a process of spatial integration in the nervous system that occurs effectively instantaneously.[1] The second finding is consistent with the suggestion[2,3] that the fall-off in sensitivity at both low spatial and low temporal frequencies is the result of an antagonism between signals from the center and surround regions of receptive fields. Since the surround region of a receptive field has a greater diameter than the center region, signals from the surround are relatively more attenuated at high spatial frequencies than signals from the center. Thus at high spatial frequencies the effect of the surround becomes negligible and the contrast-sensitivity is determined by the temporal characteristics of the center alone. But at high temporal frequencies also the effect of the surround appears to be negligible. Thus it must be assumed that some mechanism causes signals from the surround to be relatively more attenuated at high temporal frequencies than signals from the center.

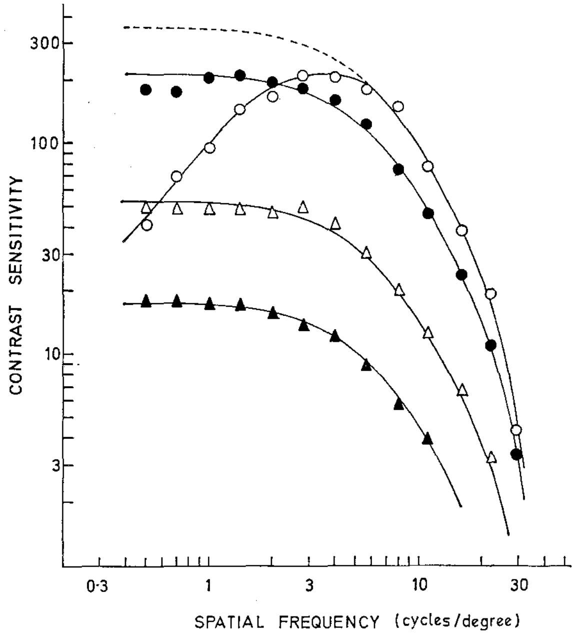

FIG. 1. Spatial contrast-sensitivity (reciprocal of threshold contrast) functions for different temporal frequencies. The points are the means of four measurements and the curves (one with a dashed low-frequency section) differ only in their positions along the contrast-sensitivity scale ○ 1 cycle per second, ● 6, △ 16, ▲ 22 cycles per second.

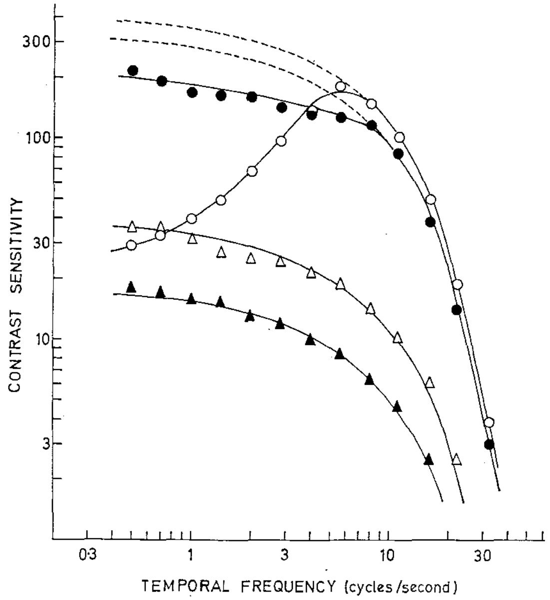

FIG. 2. Temporal contrast-sensitivity (reciprocal of threshold contrast) functions for different spatial frequencies. The points are the means of four measurements and the curves (two with dashed low-frequency sections) differ only in their positions along the contrast-sensitivity scale, ○ 0.5 cycle per degree, ● 4, △ 16, ▲ 22 cycles per degree.

[1] H. A. W. Schober and R. Hilz, J. Opt. Soc. Am. **55**, 1086 (1955).
[2] D. H. Kelly, Doc. Ophthalmol. **18**, 16 (1964).
[3] J. Levinson, Doc. Ophthalmol. **18**, 36 (1964).