Contrast Sensitivity Function in Peripheral Vision

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The study investigated contrast sensitivity in peripheral regions of the retina at three angular eccentricities: 15°, 25°, and 35°. The aim was to determine how contrast perception changes with increasing distance from the fovea, which is responsible for high-resolution central vision. The results demonstrated a gradual decline in contrast sensitivity with greater eccentricity. This effect is associated with reduced cone density and increased rod dominance in peripheral retinal areas. Although peripheral vision is essential for motion detection and spatial orientation, it provides lower sensitivity to fine details and low contrasts. These findings are relevant for visual ergonomics, clinical diagnostics and the design of visual display systems.

Keywords: contrast sensitivity, peripheral vision, detection threshold, sinusoidal grating

INTRODUCTION

Contrast sensitivity is an important parameter of human visual perception and refers to the ability to distinguish differences in luminance between an object and its background. Unlike visual acuity, which describes the ability to perceive fine spatial details, contrast sensitivity better reflects functional visual performance under everyday conditions. The highest contrast sensitivity occurs in the fovea, where cone photoreceptor density is greatest and visual information processing is most efficient. As retinal eccentricity increases, a gradual decline in contrast sensitivity is observed, resulting from anatomical and functional changes within the retina.

Peripheral vision, although less precise, plays a crucial role in motion detection and spatial orientation. Accurate determination of the relationship between viewing angle and contrast sensitivity not only enhances understanding of visual adaptation mechanisms, but also enables optimization of image synthesis by reducing computational demands in regions of lower sensitivity. Furthermore, such analysis may provide insight into the relationship between myopia and peripheral contrast sensitivity [1–3]. The aim of this study is to analyze contrast sensitivity at three retinal eccentricities: 15°, 25°, and 35°, in order to determine the relationship between stimulus location on the retina and the level of contrast sensitivity.

METHODS

The study included 40 healthy participants. Each participant was informed about the experimental procedure prior to testing. During the experiment, participants were instructed to binocular fixate on a black fixation point displayed on the central monitor 85 cm away. On the lateral monitors, sinusoidal gratings with predefined spatial frequencies (1.5, 3, 6, 12 and 18 cpd), variable contrast, and orientations (90° ± 15°) were presented in a randomized order. The gratings were generated using custom software written in Matlab (The MathWorks Inc.).

Participants were required to indicate, using the keyboard, on which monitor (1 or 2) the grating appeared, and subsequently specify its orientation using the arrow keys. If the grating was not visible, participants could press the space bar at any stage of the response.

The studies were carried out in extrafoveal fixation conditions, when the analyzed stimulus was horizontally located at an angle to the visual axis of 15°, 25° and 35°(hereinafter referred to as retinal eccentricities), with each angle tested three times to improve measurement reliability. The order of stimulus presentation was randomized to minimize learning and adaptation effects. The experiment was performed under constant lighting conditions, and the viewing distance was controlled and kept identical for all participants. Subjects were instructed to maintain fixation on the central point throughout the measurement.

After data acquisition, the results were analyzed using Matlab. Contrast sensitivity thresholds were determined for each spatial frequency and retinal eccentricity. A schematic representation of the experimental setup is shown in Figure 1. Figure 2 presents examples of three sinusoidal gratings with different orientations and spatial frequencies.

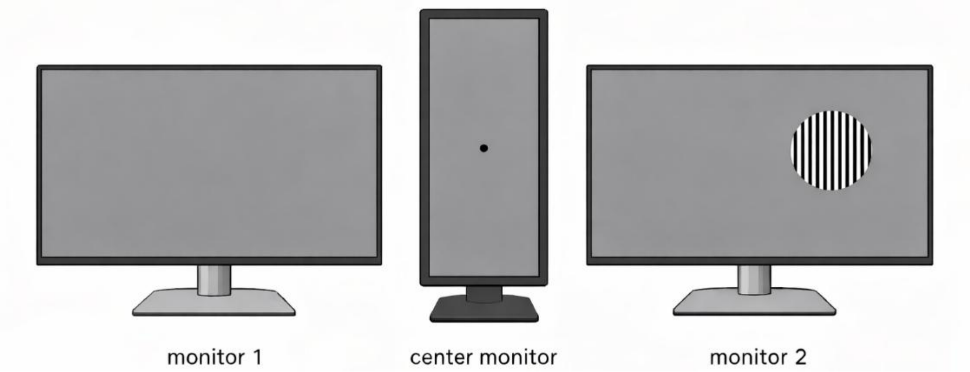

Figure 1. Measurement station used in the study

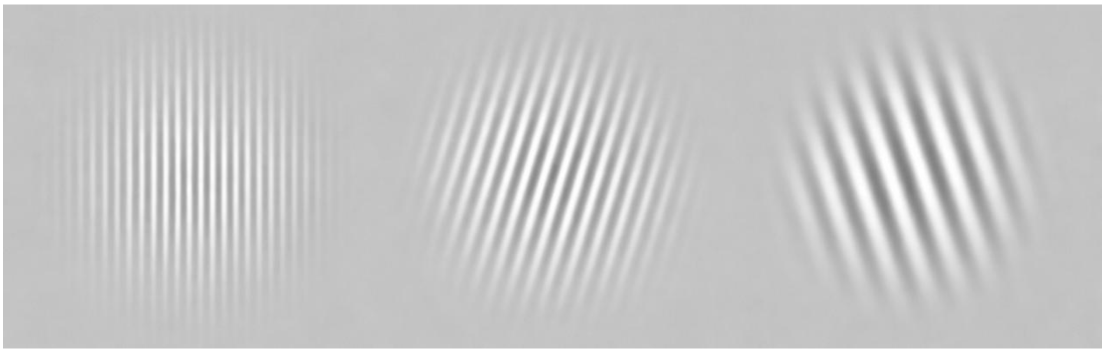

Figure 2. Three sinusoidal gratings with different orientations and spatial frequencies

RESULTS

Contrast sensitivity was defined as the lowest contrast level at which the participant correctly identified the monitor (1 or 2) and accurately reported the orientation of the sinusoidal grating. A response was considered correct only when both criteria were met simultaneously.

Contrast sensitivity thresholds were determined using a custom algorithm implemented in Matlab. For each participant and for each combination of spatial frequency and retinal eccentricity, individual threshold values were calculated and subsequently averaged to obtain group results.

To assess data variability, standard deviations were computed. Statistical analysis was performed to determine the significance of differences between retinal eccentricities and spatial frequencies. During the experiment, it was observed that for certain spatial frequencies, the stimulus could not be perceived even at maximum contrast. The aggregated data together with standard deviations are presented in Figure 3.

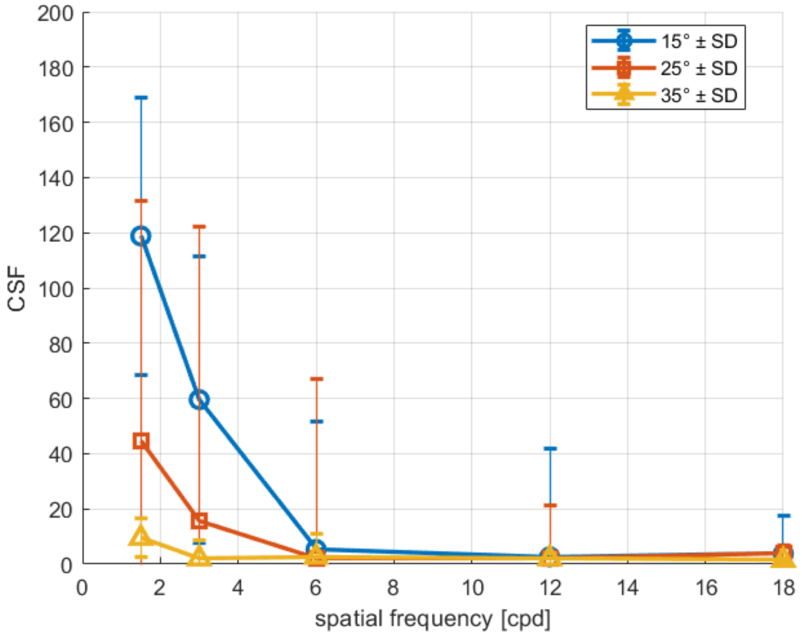

Figure 3 The dependence of contrast sensitivity on retinal eccentricity from the fovea

The graph shows the median contrast sensitivity function (CSF) for three retinal eccentricities (15°, 25°, and 35°) as a function of spatial frequency. For all eccentricities, a clear decrease in CSF was observed with increasing spatial frequency. The highest sensitivity was obtained at 15°, whereas the lowest was observed at 35°.

CONCLUSIONS

In this study, contrast sensitivity was analyzed for three retinal eccentricities: 15°, 25°, and 35°, across different ranges of spatial frequency. The obtained results demonstrated a decrease in contrast sensitivity with increasing retinal eccentricity, confirming the limited ability of peripheral vision to process fine spatial details.

For all analyzed angular distances, a clear reduction in contrast sensitivity was observed with increasing spatial frequency of the stimulus. The highest sensitivity was recorded at 15°, whereas the lowest values occurred at 35°, indicating a strong dependence between stimulus location on the retina and the level of contrast sensitivity.

The obtained results are consistent with observations reported in previous studies [1-3], which also showed a decrease in contrast sensitivity with increasing retinal eccentricity and spatial frequency. The findings emphasize the important role of angular distance in visual perception processes. Moreover, this study may contribute to a better understanding of visual adaptation mechanisms and the relationship between peripheral vision and refractive errors. Future studies should include a larger number of participants and additional retinal eccentricities to further expand the analysis.

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