ANALYSIS OF HUMAN RECEPTOR DENSITY

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Abstract

Data for densities and sizes of human cones were analyzed as a function of retinal eccentricity. Density of cones followed a decreasing power of about -2/3 over much of the eccentricity range. This decrease, and the subsequent increase in cone density toward the ora serrata, were predictable on the basis of a hypothetical density-control mechanism to equate the integrated luminous flux at the photoreceptors per unit retinal area, together with the empirical rule that cone diameter increases with a power of about 1/3 with eccentricity beyond the foveola. The analysis implies that cones aggregate in inverse proportion to the light impinging on them, and provides an explanation for the pronounced increase to 100% cone density at the ora serrata.

Introduction

Knowledge of the density of receptors as a function of retinal eccentricity is important in studies of spatial resolution, visual sensitivity and the dissection of neural contributions to the visual response. Until recently, the only extensive investigation of overall receptor density in human was by Oesterberg [1], and it has yielded a much-reproduced graph of rod and cone densities as a function of eccentricity. Oesterberg's data, which still cover the widest range of any data available on human retina, are fully validated by studies using more modern techniques [2], but there have been few attempts to characterize the data analytically or determine what principles may be operating to control the receptor distributions.

Cone distribution as a function of eccentricity: Oesterberg's complete data for cone densities in each measured location in the horizontal meridian and four retinal sectors are plotted as a function of eccentricity in double logarithmic coordinates in Fig.1. This type of plot reveals two salient characteristics of the cone distribution. First, the density falls approximately on a straight line with a slope of about -2/3 between 0.2 and 20° eccentricity, most clearly for the horizontal temporal meridian (0°) in Fig. 1 but also supported by the sparse data for the other quad-

V. Lakshminarayanan (ed.), *Basic and Clinical Applications of Vision Science*

rants. Over this range, a regression analysis of the temporal data indicates a density exponent of z=-0.63 with 99% confidence limits of ±0.022 (eq. 1).

$$d_c \propto \theta^z \quad (1)$$

where θ is eccentricity in terms of visual angle from the fovea.

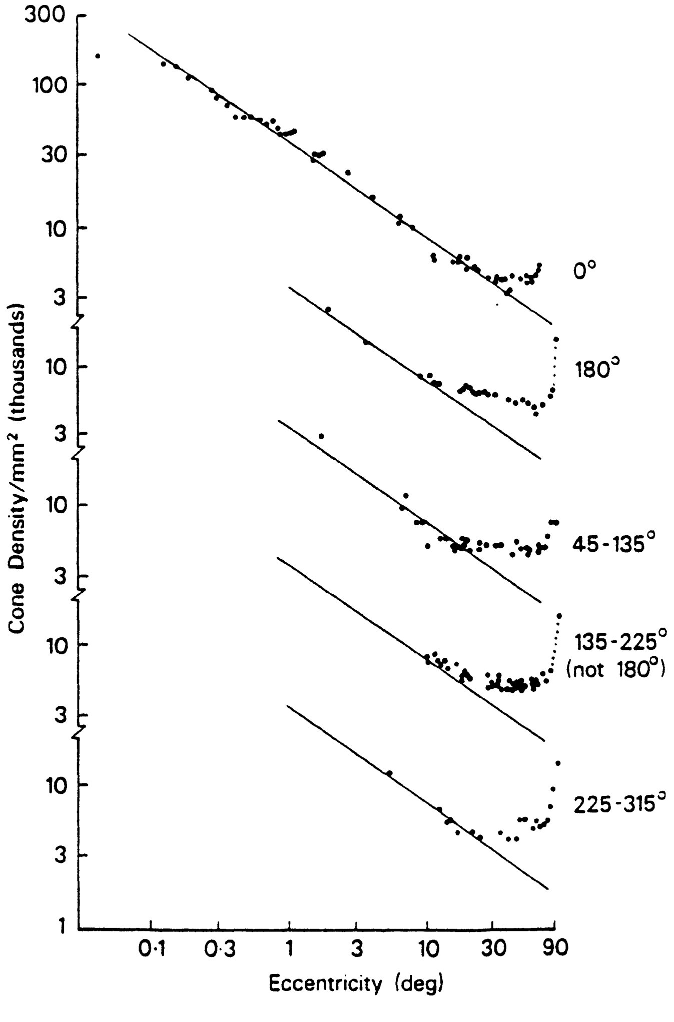

Fig. 1. Log-log plot of cone densities as a function of eccentricity for 5 retinal sectors, with successive plots displaced by 1 log unit, for a narrow sector close to the temporal (0°) meridian and nasal (180°) meridians, and for the upper, temporal and lower quadrants, respectively. Straight lines have slopes of -2/3 for comparison. Note departure of data from these functions beyond about 20° and steep rise in cone density near the ora serrata emphasized by the dotted connecting lines in two cases. From Oesterberg [1].