Is there a single functional channel at the edge of the retina?

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The array of photoreceptors in the fovea is sampled by at least 25 different types of ganglion cell, and the traditional challenge for the psychophysicist is to choose a stimulus, and a regime of adaptation, that isolate a single neural channel. The region of the retina near the ora serrata – a region that corresponds to vision at 90 degrees from the line of sight – offers a tempting study to the psychophysicist, since it can be argued that here there is only a single neural channel, or at least, a small number of channels of a similar type. Polyak observes that near the ora serrata the multiple layers of ganglion cells seen in the fovea are reduced to one. Moreover, ganglion cells occur in small clumps with large spaces between them. What do we know of the corresponding functional channel? Psychophysically, there appear to be four sub-types of motion-sensitive detector, mapping approximately on to the four cardinal directions (To, Regan, Wood and Mollon, 2011, Vision Research, 51, 203). These detectors have their peak sensitivity at a very low spatial frequency and they appear to be insensitive to stationary stimuli. A plausible hypothesis would be that they correspond to four types of ON-OFF directionally-selective ganglion cell: such cells are widely found in the mammalian retina and the four subtypes, corresponding to different cardinal directions, are thought to be genetically pre-specified (for a short review see Morrie and Feller, 2016, Current Opinion in Neurobiology, 40, 45).

Theoretical analysis and practical implications of human photoreceptor densities to the far periphery

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In designing next-generation visual displays and in the management of visual deficits, it is important to have a good understanding of the full capabilities of human visual processing. There is a widespread misconception, even among vision scientists, that the peak cone density in the fovea implies that cone function and color vision is largely restricted to the fovea, and conversely that the high density of peripheral rods implies that they mediate peripheral motion processing and that the periphery a lacks color vision. None of these statements is correct, and a proper understanding of retinal function requires a full specification of photoreceptor density distributions, which I provide in the form of analytic equations incorporating the principles of an inverse cube law of cone resolution, cone density compensation for the effective reduction in retinal luminance with eccentricity, and the secondary occupation of remaining retinal space by rods. The consequences of these principles of photoreceptor population growth dynamics are an appreciable cone density out to the far periphery with undiminished color sensitivity, peripheral temporal resolution up to 100 Hz at high luminance, and photopic motion sensitivity of up to10,000 deg/s. These factors imply a spatiotemporal bandwidth for human vision of about a terabyte/s for full virtual reality and a high sensitivity to brief changes throughout the retina for guiding eye movements to peripheral targets.

Far peripheral vision and pattern recognition

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Peripheral vision has been studied quantitatively for over a century yet relatively little is known about the far periphery. Ironically, many current textbooks give values of the lateral extent that are too small, below 90°, even though correct values of around 110° (due to refraction of the lateral rays) were reported by Hueck in 1840. Eccentricity dependencies for visual performance measures like MAR, letter contrast sensitivity, critical crowding distance etc. vary widely between functions but their study typically stops at the mid periphery, 60° at most. Only studies from the perimetry tradition, like Zigler et al. (1930) or Collier (1931), studied the full visual field for form vision. Yet with the introduction of intraocular lenses the far periphery has regained interest because patients often experience strange shadows at their visual field border, termed negative dysphotopsias. Here I review knowledge on peripheral vision, on peripheral form recognition, and crowding, with an emphasis on large eccentricities.

Mysteries of the blind zone at the extreme periphery of the human retina.

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Proceeding from his psychophysical investigations, A.Yarbus tried to formulate the basic principles of retinal image processing in the visual system. The key idea of A.Yarbus has been to explain the whole variety of color sensations and the phenomena of color constancy taking into account the signals from the so-called blind retina (BR) – the extreme retinal periphery where optical formation of images is supposedly impossible and only diffused light is present. The incomplete perceptual model developed by A.Yarbus has implied that the role of BR is to estimate the ambient light in order to correct the perceived colors of visible objects. Our retrospective analysis of the Yarbus's concept revealed some intrinsic contradictions and restrictions that make it insufficient regarding elaboration of a universal comprehensive model. However, the experimental achievements and general ideas of A.Yarbus are principally interesting and his hypothesis regarding BR deserves more thorough appreciation. In fact, the functions of BR and other parts of the extreme retinal periphery remain unclarified until now though this area has attracted attention of scientists since XIX century. Our aim was to summarize, compare, and analyze all the data accessible that has been obtained by various techniques including natural and diascleral stimulation of BR and adjacent regions, and to verify some predictions in own experiments. As a result, principal conclusions have been gained about the nature of blindness in BR, asymmetry of the nasal and temporal BR and the influence of diascleral stimulation of BR on the visible scenes.

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