

# Visual field

*Hans Strasburger and Ernst Pöppel*

The *visual field* refers to the area visible during stable fixation of the eyes, specified in degrees of visual angle. Monocular measurement of the visual field by perimetry shows that the left and the right half of the visual field are not the same size. The temporal visual field, defined as extending from the vertical meridian toward the periphery, is considerably larger than the nasal visual field. Measurements along the horizontal meridian show that targets up to 90 degrees eccentricity can be detected on the temporal side; the limit of light detection is 50 to 60 degrees on the nasal side ([Pöppel and Harvey, 1973](#)). The upper and lower halves of the visual field appear to be equal, with the limits at approximately 50 to 60 degrees eccentricity, although there are large individual differences. If the visual fields of the two eyes are superimposed as in normal vision, the binocular visual field covers up to 180 degrees along the horizontal meridian. The most eccentric part of the temporal visual field that lies beyond the border of the nasal visual field of the other eye is called the monocular crescent. Thus, binocular vision is provided only up to the border of the nasal visual field; the far periphery on the left and right side is seen monocularly.

Visual field measurements are often done using a white test target of high contrast on a highly homogeneous background; the target is moved from the periphery toward the center of the visual field (dynamic perimetry). If, instead, light-difference threshold is measured at various positions of the visual field of one eye using a stationary target (static perimetry), local sensitivity can be determined. Measurement in the perimeter is typically done at 10 cd/m<sup>2</sup> background luminance, that is, under photopic adaptation conditions. Under photopic adaptation conditions, the fovea centralis has the highest sensitivity. The perifoveal region is characterized by a decreasing sensitivity beginning at the fovea and ending approximately at 10 degrees eccentricity. Beyond this there is a plateau of constant sensitivity that extends up to approximately 35 degrees eccentricity on the temporal side and up to 20 degrees eccentricity on the nasal side. Beyond this plateau, sensitivity again decreases until the border of the visual field. The blind spot lies within the plateau region on the temporal side, approximately between 14 and 18 degrees eccentricity along the horizontal meridian ([Figure 1](#)). Under scotopic adaptation, the fovea and perifoveal region are less sensitive than more peripheral regions of the retina because of the shift from cone-dominated to rod-dominated vision. Under these conditions, the most sensitive part of the retina lies at approximately 10 to 20 degrees horizontal eccentricity on the temporal side. If a colored target instead of a white target is used for visual field measurement, subjects are able to detect the target as it is moved from the periphery toward the center of the visual field at greater eccentricities than in tests where they can identify its color.

Sensitivity is always determined after full adaptation to the background luminance has taken place. The dependence of sensitivity on background luminance is governed by Weber's law: The detectable luminance increment  $\Delta L$  (increment threshold) is, over a wide range, a constant fraction of background luminance  $L$ . The Weber fraction, or Weber contrast,  $\Delta L/L$ , is thus a suitable measure of sensitivity. Deviations from Weber's law occur at the ends of the visible range of luminances, that is, at the absolute threshold in dark and in the high photopic range ([Hood and Finkelstein, 1986](#)).

Although sensitivity varies throughout the visual field, apparent brightness remains constant under photopic adaptation; the percept does not get darker toward the periphery of the visual field ([Pöppel and Harvey, 1973](#)). Constancy of brightness throughout the visual field can be demonstrated by using a visual target of constant contrast that is above threshold for all eccentricities tested; it is then scaled with respect to its apparent brightness by the technique of magnitude estimation. Apparent brightness is directly related to the physical energy of the visual stimulus and not to local sensitivity of the retina. Note that this observation disproves Fechner's law as far as accounting for brightness perception throughout the visual field. Under scotopic adaptation, constancy of brightness throughout the visual field is observed only for the periphery; in order for foveal and perifoveal targets to appear equally bright they must have a higher contrast. For constancy of brightness, one has to assume a neuronal mechanism that compensates for the changing sensitivity of the retina as a function of eccentricity. It is still unclear where and how such a mechanism might work, although it has been suggested that it is already implemented at the retinal level.

If the two eyes are properly aligned while fixating an object, each position in binocular visual space at a certain distance (called the horopter) is imaged to corresponding retinal points. In case of a misalignment—that is, if the two visual axes do not cross at the target location—the target is imaged to noncorresponding retinal points. Such a deviation of the visual axes may result in the experience of double images because the visual fields of the two eyes no longer coincide. Proper alignment of the eyes is further necessary for stereoscopic vision; if not corrected in early childhood, misalignment may result in a loss of stereoscopic vision and the reduction of sensitivity in one eye.

Detection of a spot of light at every given position in the visual field is determined by both the spot's luminance and size. The interrelationship of the two variables at the detection threshold is governed by Riccò's law of spatial summation, which states that the product of the luminance increment over the background,  $\Delta L$ , and stimulus area is a constant ( $c$ ) at any given visual field position ([Hood and Finkelstein, 1986](#); [Strasburger, 2002](#)). The diameter of the area around that position within which the law holds (i.e., in which summation occurs) increases as an approximately linear function of eccentricity in the visual field. This area, termed the "perceptive field"

by [Jung and Spillmann \(1970\)](#), seems to correspond to the mean receptive field size. [Fischer and May \(1970\)](#) have generalized Riccò's law to incorporate visual field eccentricity; in their model, Riccò's constant ( $c$ ) increases as a second-order polynomial with eccentricity ([Strasburger, 2002](#)).

Detection of light is slower in the visual periphery than it is in the center, as is evidenced by reaction time in perimetry. Detection time increases as an approximately linear function with eccentricity by 1.8 milliseconds per degree visual angle and up to 30 degrees eccentricity ([Schiefer et al., 2001](#)).

Detection of stimuli is a necessary prerequisite for the performance of more complex visual functions, as form and object recognition. Detection is not a sufficient condition, however, and there is currently no general way of inferring, from detection performance, in which parts of the visual field other visual functions are present. The areas in which such other functions are present are described by subfields of the visual field of detection. The visual field of form recognition extends about  $\pm 40$  degrees horizontally and  $\pm 30$  degrees vertically. With decreasing stimulus contrast, the field of recognition shrinks further in size and covers an increasingly smaller part of the field of detection at same contrast. At the lowest visible contrast, recognition is confined to the foveal and perifoveal field ([Strasburger, 2002](#); [Strasburger and Rentschler, 1996](#)). Contrast sensitivity for the recognition of simple patterns (like digits or characters) can be described within the visual field of form recognition by a product law ([Strasburger, 2002](#))

$$(\log C - \log C_{\text{off}}) (S - S_{\text{off}}) = \text{const.}$$

where  $C$  is the target contrast threshold in Michelson units,  $S$  is the target size, and the limit values  $C_{\text{off}}$  and  $S_{\text{off}}$  at any visual field position vary as approximately linear functions of retinal eccentricity  $E$ :

$$S = a E$$
$$\log C_{\text{off}} = b_0 + b_1 E$$

Most (but not all) visual functions show a decline in performance with increasingly eccentric stimulus position. When sensitivity can be measured by a spatial measure, like spatial resolution for acuity or the size of Panum's area of binocular fusion in stereo vision, that spatial threshold mostly increases as a linear function with retinal eccentricity. [Aubert and Foerster \(1857\)](#) illustrated this for the task of separating two dots (two-point resolution); over the 150 years since, many more functions have been such described. The rate at which performance declines with eccentricity (i.e., the slope of that linear function) is different between the different functions, however. To describe that decline by a single number, the  $E_2$  value has been proposed, defined as the eccentricity at which the foveal value has doubled ([Levi et al., 1985](#)). Note that at larger eccentricities deviations from linearity often occur, such that the  $E_2$  value is most useful at smaller eccentricities. Another class of sensitivity measures, including contrast sensitivity, cannot be expressed in the space domain. For these, their variation across the visual field can be minimized by appropriately scaling the stimulus size, called  $M$  scaling. By  $M$  scaling, the contrast sensitivity function can be made much less dependent on visual field position, with a variation of peak sensitivity across the visual field by about a factor of two remaining ([Koenderink et al., 1978](#); [Rovamo and Virsu, 1979](#)).

The distribution of visual attention plays a most important role in all peripheral visual functions. In the late 19th century, Von Helmholtz reported that targets are better recognized when they are voluntarily attended without shifting visual fixation. The now popular notion of an *attentional spotlight*, pointing at a part of the visual scene which is then better perceived, had already been formulated by Johannes Müller in the early 19th century. Modern research has secured and quantitatively refined the concept ([Eriksen and Eriksen, 1974](#); [Posner et al., 1984](#); see [Gazzaniga, 1999](#) for a review). With respect to the visual field, the size and location of the attentional focus influence the size of the visual field and the performance within, as inherent in the concepts of a "form-resolving field" ([Geiger et al., 1992](#)) or the "useful field of view" ([Ball et al., 1993](#)). Many if not all visual functions depend on attention, including reaction time and contrast sensitivity.

Spatial attention, or its limited precision, also underlies the phenomenon known as *lateral masking* or the *crowding effect*. Both terms describe the fact that patterns in the vicinity of a visual target hinder perception of its form ([He et al., 1996](#); [Strasburger, 2002](#); [Strasburger et al., 1991](#)). The effect is weak in normal, adult foveal vision but is the overriding factor in all of the visual field outside the very center (of 2 degrees diameter). It further plays an important role in foveal form perception of children, and might be the reason why children prefer large print in normal reading. The crowding effect is also important in a kind of disturbed form vision known as amblyopia. Central vision in *amblyopia* seems organized similarly to normal eccentric vision, such that in amblyopic vision a functional fovea is lacking.

How is the visual field represented in the brain? The first observation on visual field representation may have been that of Descartes, who discovered that left and right and top and bottom of an object are reversed on the retina. Thus, the temporal visual field of each eye is represented on the nasal half of the retina, and the nasal visual field on the temporal retina. If one fixates an object and draws a vertical line through the fixation point (this is the vertical meridian), everything that is to the left of this line is represented on the nasal half of the retina

of the left eye, and on the temporal half of the retina of the right eye. Everything to the right of this line is represented on the nasal retina of the right eye, and on the temporal retina of the left eye. Through the optics of the eye, the visual angle of eccentricity in the visual field is translated one-to-one to an angle of retinal eccentricity.

The output of retinal information processing is collected in approximately 1 million ganglion cells, whose axons form the optic nerve. Where the optic nerve leaves the eye at the optic disk corresponds perceptually to the blind spot in the visual field. The optic nerve is split into halves at the optic chiasm. Those axons that carry information from the nasal retina cross over to the other side of the brain and those axons coming from the temporal retina stay on the same side. The fiber bundle beyond the optic chiasm, the optic tract, contains the information that comes from the nasal retina of one eye and the temporal retina of the other. In summary, each visual half field is projected to the contralateral side of the brain and is thus represented on the same side as the corresponding (left of right) hand or other extremity.

Most of the fibers coming from the retina project to the lateral geniculate nucleus (LGN), a subcortical brain structure located in the thalamus, with six layers each innervated by either the right or the left eye. Neurons in adjacent positions in the different layers are innervated by retinal fibers that represent corresponding retinal points of the two eyes. The representation of the retina in the LGN is thus retinotopic: The spatial neighborhood relationships in visual space (its "topology") are preserved through the retina to the LGN, although within the optic nerve and the optic tract such retinotopy appears to be absent.

Interestingly, the two nuclei of the thalamus most closely neighboring the LGN - the medial geniculate nucleus and the ventrolateral posterior nucleus - carry, respectively, the projections of the two other main senses, hearing and touch. Both show topographic organization, tonotopy and somatotopy. A common organizational principle may thus underlie our three main senses.

The LGN projects to the striate cortex via the optic radiation, and the visual field representation in the striate cortex (also called the visual cortex, Area 17, occipital lobe, or V1) retains its retinotopy. At the striate cortex, the separate representations of the visual field in the different layers of the LGN are fused into one visual field representation by way of binocular innervation of cortical neurons. The specific retinotopic representation of the visual field in humans has been mapped with the help of brain-injured patients who had suffered total or partial lesions of the striate cortex ([Teuber et al., 1960](#)). The total loss of striate cortex within one hemisphere results in a complete homonymous hemianopia. A patient with such a condition has no vision in the temporal visual field of one eye and in the nasal visual field of the other. Often such patients show a foveal sparing, which indicates that the fovea of each eye is represented in both hemispheres. Visual field defects can occur for a number of traumatic reasons and can take any form and size in the visual field.

Retinotopy has been studied since the pioneering work of [Inouye \(1909\)](#) and the famous map of [Holmes \(1945\)](#). This map shows the representation of visual space in the primary visual cortex of humans. The vertical meridian is represented along the perimeter of the striate cortex, and the horizontal meridian runs across the base of the calcarine fissure. The macula is at the occipital pole and the periphery is mapped anteriorly up to the junction of the calcarine and parieto-occipital fissure. That junction represents the outer, contralateral visual field border. Most of the striate cortex is buried within the calcarine fissure. A more recent map by [Horton and Hoyt \(1991\)](#) differs from the Holmes map in that the representation of the fovea is much larger. Nowadays, retinotopy can also be studied noninvasively by functional magnetic resonance imaging (fMRI) ([DeYoe et al., 1994](#)). The borders of V1, V2, and V3 can be delineated very well, and work is underway to arrive at more precise scaling within V1.

Although the representation of the visual field at the striate cortex is retinotopic, the cortex does not devote equal neuronal space to equal visual space. The foveal and perifoveal region get much greater emphasis than the periphery, and this fact is expressed by way of the so-called cortical magnification factor  $M$  ([Daniel and Whitteridge, 1961](#); [Talbot and Marshall, 1941](#)). Not only is the density of receptors vastly higher in the central retina but more neuronal machinery is also provided for the same region: Retinal ganglion cells that process information from the central visual field are much more densely packed, and each retinal ganglion cell in turn seems to innervate (via the LGN) a roughly equal area of striate cortex. About an 8-mm linear extent of the cortical area corresponds to 1 degree of visual angle in the central fovea, and this number decreases as an inverse linear function of visual field eccentricity, being halved at about 1.3 to 4.0 degrees eccentricity ([Strasburger, 2002](#)). Note that current estimates of the value of  $M$  in the very center of the fovea vary widely (between 8 and 23 mm/degree) because of methodological difficulties.

There have been numerous attempts to link behavioral, psychophysical data on the inhomogeneity of visual function across the visual field to the anatomical and physiological results ([Strasburger, 2002](#); [Strasburger and Rentschler, 1996](#)). [Covey and Rolls \(1974\)](#) showed that the classic human visual acuity data acquired by [Wertheim \(1887\)](#) matched rather well a psychophysiological measure of the inhomogeneity of V1, namely the distribution of phosphenes (illusory light perception) elicited by electrical brain stimulation with implanted electrodes. [Rovamo and Virsu \(1979\)](#) reported a similarity between the spatial scale of the contrast sensitivity function and the cortical magnification factor  $M$ . However, higher level visual functions, such as form perception and symmetry perception, show a decline in performance with increasing eccentricities unaccounted for by the  $M$  factor ([Drasdo, 1991](#); [Strasburger, 2002](#); [Strasburger et al., 1994](#)). The gradual decrease of spatial visual performance with increasing eccentricity in the visual field can thus be explained partly, but by no means fully, by the properties of the retinocortical pathway.

The striate cortex is surrounded by secondary areas that are also concerned with visual information processing. These extrastriate areas appear to be specialized for the analysis of particular categories of visual information such as depth, movement, or color. The projections to higher areas seem organized into two streams. A ventral stream, leading to the inferotemporal cortex (and ventrolateral prefrontal cortex), seems specialized to object recognition. A dorsal stream, leading to the posterior parietal cortex (and dorsolateral prefrontal cortex), seems specialized to the processing of spatial relationships or positional information ([Ungerleider and Mishkin, 1982](#)). As one moves up this path of projections, the representation of the visual field in each of those higher areas is increasingly less retinotopic and is decreased in visual field extent.

The visual field is also mapped onto subcortical structures like the pulvinar of the thalamus, the reticular nucleus of the thalamus, or the superior colliculus in the midbrain. With an injury in the geniculostriatal pathway, these retinal projections usually remain intact. This is why the retinocollicular or the retinopulvinar pathways are assumed to mediate certain visual functions in blindsight ([Pöppel et al., 1973](#); [Stoerig and Cowey, 1992](#); [Stoerig and Pöppel, 1986](#); [Weiskrantz et al., 1974](#)). The collicular representation of the visual field is probably also essential for the programming of saccadic eye movements. It is conceivable that a visual stimulus from the periphery of the visual field elicits directly a proper saccade on the basis of the collicular representation alone without involving the cortical representation. Thus, the superior colliculus has been considered an important link between the sensory representation of the visual field and the oculomotor system. The reticular nucleus of the thalamus in turn has been suggested to be a part in the implementation of a spatial attentional spotlight ([Crick, 1984](#), based on [Skinner and Yingling, 1977](#)).

## 1. See also

---

[Blindsight, residual vision](#)

[Brightness](#)

[Color vision](#)

[Geniculate bodies, lateral](#)

[Psychophysics](#)

[Retina, vertebrate](#)

[Stereopsis, binocular perception](#)

[Visual adaptation](#)

[Visual motion perception](#)

[Visual perception](#)

[Visual system, organization](#)

**Author's website:**

<http://www.imp-muenchen.de/>

## 2. Further reading

---

Aulhorn E, Harms H (1972): Visual perimetry. In: *Handbook of Sensory Physiology* 7/4, Jameson D, Hurvich LM, eds. Berlin: Springer-Verlag

Boff KR, Kaufman L, Thomas JP, eds. (1986): *Handbook of Perception and Human Performance*. Vol. 1: *Sensory Processes and Perception*. Vol. 2: *Cognitive Processes and Performance*. New York: Wiley

DeYoe EA, Van Essen DC (1988): Concurrent processing streams in monkey visual cortex. *Trends Neurosci* 11:219-226 [[MEDLINE](#)]

Hubel DH, Wiesel TN (1977): Functional architecture of macaque visual cortex. *Proc R Soc Lond B Biol Sci* 198:1-59 [[MEDLINE](#)]

Lachenmayr BJ, Vivell PMO (1992): *Perimetrie*. Stuttgart: Georg Thieme

Polyak S (1957): *The Vertebrate Visual System*. Chicago: University of Chicago Press

Pöppel E, Held R, Dowling JE (1977): Neuronal mechanisms in visual perception. *Neurosci Res Prog Bull* 15: 315-553 [[MEDLINE](#)]

## 3. References

---

- Aubert H, Foerster (1857): Beiträge zur Kenntniss des indirecten Sehens. (I). Untersuchungen über den Raumsinn der Retina. *Arch Ophthalmol* 3:1-37
- Ball K, Owsley C, Sloane ME, Roenker DL, Bruni JR (1993): Visual attention problems as a predictor of vehicle crashes in older drivers. *Invest Ophthalmol Vis Sci* 34:3110-3123 [[MEDLINE](#)]
- Cowey A, Rolls ET (1974): Human cortical magnification factor and its relation to visual acuity. *Exp Brain Res* 21:447-454 [[MEDLINE](#)]
- Crick F (1984): Function of the thalamic reticular complex: the searchlight hypothesis. *Proc Natl Acad Sci USA* 81:4586-4590 [[MEDLINE](#)]
- Daniel PM, Whitteridge D (1961): The representation of the visual field on the cerebral cortex in monkeys. *J Physiol* 159:203-221
- DeYoe EA, Bandettini P, Neitz J, Miller D, Winans P (1994): Functional magnetic resonance imaging (fMRI) of the human brain. *J Neurosci Methods* 54:171-87
- Drasdo N (1991): Neural substrates and threshold gradients of peripheral vision. In: *Limits of Vision*, Kulikowski JJ, Walsh V, Murray IJ, eds. London: Macmillan Press, pp. 250-264
- Eriksen BA, Eriksen CW (1974): Effects of noise letters upon the identification of a target letter in a nonsearch task. *Percept Psychophys* 16:143-149
- Fischer B, May HU (1970): Invarianzen in der Katzenretina: Gesetzmäßige Beziehungen zwischen Empfindlichkeit, Größe und Lage receptorer Felder von Ganglienzellen. *Exp Brain Res* 11:448-464
- Gazzaniga MS, ed. (1999): *The New Cognitive Neurosciences*. Cambridge, MA: Bradford Book, MIT Press
- Geiger G, Lettvin JY, Zegarra-Moran O (1992): Task-determined strategies of visual process. *Cogn Brain Res* 1:39-52
- He S, Cavanagh P, Intriligator J (1996): Attentional resolution and the locus of visual awareness. *Nature* 383:334-337 [[MEDLINE](#)]
- Holmes G (1945): The organization of the visual cortex in man. *Proc R Soc Lond B Biol Sci* 132:348-361

Hood DC, Finkelstein MA (1986): Sensitivity to light. In: *Handbook of Perception and Human Performance*, Boff KR, Kaufman L, Thomas JP, eds. New York: Wiley, pp. 5-1-5-66

Horton JC, Hoyt WF (1991): The representation of the visual field in human striate cortex. A revision of the classic Holmes map. *Arch Ophthalmol* 109:816-824 [[MEDLINE](#)]

Inouye T (1909): *Die Sehstörungen bei Schussverletzungen der kortikalen Sehsphäre*, Leipzig: W. Engelmann

Jung R, Spillmann L (1970): Receptive-field estimation and perceptual integration in human vision. In: *Early Experience and Visual Information Processing in Perceptual and Reading Disorders*, Young FA, Lindsley DB, eds. Washington: National Academy of Sciences, pp. 181-197

Koenderink JJ, Bouman MA, Bueno de Mesquita AE, Slappendel S (1978): Perimetry of contrast detection thresholds of moving spatial sine wave patterns. III. The target extent as a sensitivity controlling parameter. *J Opt Soc Am* 68:854-860 [[MEDLINE](#)]

Levi DM, Klein SA, Aitsebaomo AP (1985): Vernier acuity, crowding and cortical magnification. *Vis Res* 25:963-977 [[MEDLINE](#)]

Pöppel E, Harvey LO Jr (1973): Light-difference threshold and subjective brightness in the periphery of the visual field. *Psychol Forsch* 36:145-161 [[MEDLINE](#)]

Pöppel E, Held R, Frost D (1973): Residual visual function after brain wounds involving the central visual pathways in man. *Nature* 243:295-296 [[MEDLINE](#)]

Posner MI, Walker JA, Friedrich FJ, Rafal RD (1984): Effects of parietal injury on covert orienting of attention. *J Neurosci* 4:1863-1874 [[MEDLINE](#)]

Rovamo J, Virsu V (1979): An estimation and application of the human cortical magnification factor. *Exp Brain Res* 37:495-510 [[MEDLINE](#)]

Schiefer U, Strasburger H, Becker ST, Vonthein R, et al. (2001): Reaction time in automated kinetic perimetry. Effects of stimulus luminance, eccentricity and movement direction. *Vis Res* 41:2157-2164 [[MEDLINE](#)]

Skinner JE, Yingling CD (1977): Central gating mechanisms that regulate event-related potentials and behavior. In: *Progress in Clinical Neurophysiology: Attention, Voluntary Contraction and Event-related Cerebral Potentials*, Vol. 1, Desmedt JE, ed. Basel: Karger, pp. 30-69

Stoerig P, Cowey A (1992): Wavelength discrimination in blindsight. *Brain* 115:425-444 [[MEDLINE](#)]

Stoerig P, Pöppel E (1986): Eccentricity-dependent residual target detection in visual field defects. *Exp Brain Res* 64:469-475 [[MEDLINE](#)]

Strasburger H (2002): *Indirektes Sehen. Formerkennung im zentralen und peripheren Gesichtsfeld*. Göttingen: Hogrefe

Strasburger H, Harvey LO Jr, Rentschler I (1991): Contrast thresholds for identification of numeric characters in direct and eccentric view. *Percept Psychophys* 49:495-508 [[MEDLINE](#)]

Strasburger H, Rentschler I (1996): Contrast-dependent dissociation of visual recognition and detection fields. *Eur J Neurosci* 8:1787-1791 [[MEDLINE](#)]

Strasburger H, Rentschler I, Harvey LO Jr (1994): Cortical magnification theory fails to predict visual recognition. *Eur J Neurosci* 6:1583-1588 [[MEDLINE](#)]

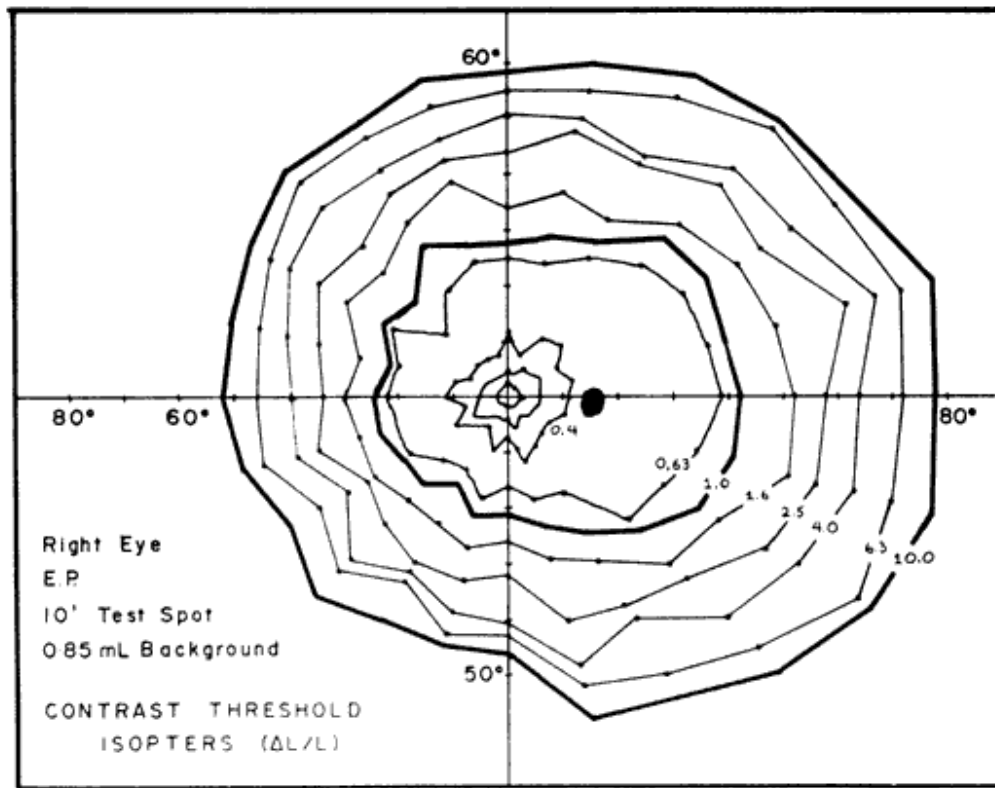
Talbot SA, Marshall WH (1941): Physiological studies on neural mechanisms of visual localization and discrimination. *Am J Ophthalmol* 46:102-113

Teuber H-L, Battersby WS, Bender MB (1960): *Visual Field Defects after Penetrating Missile Wounds of the Brain*. Cambridge, MA: Harvard University Press

Ungerleider LG, Mishkin M (1982): Two cortical visual systems. In: *Analysis of Visual Behavior*, Ingle DJ, Goodale MA, Mansfield RJ, eds. Cambridge, MA: MIT Press

Weiskrantz L, Warrington EK, Sanders MD, Marshall J (1974): Visual capacity in the hemianopic field following a restricted occipital ablation. *Brain* 97:709-728 [[MEDLINE](#)]

Wertheim T (1887): Ueber die Zahl der Seheinheiten im mittleren Theile der Netzhaut. *Albrecht von Graefes Arch Ophthalmol* 33



Copyright © 2004 Elsevier B.V. All rights reserved.

**Figure 1.** Light-difference threshold ( $\Delta L/L$ ,  $L$  = luminance) isopters for the right eye (author E.P.) is determined with a 10-minute arc target. The target was presented for 200 msec on a 0.85 millilambert ( $2.7 \text{ cd/m}^2$ ) background. The visual field is represented in polar coordinates with the fovea at the origin. Horizontal and vertical meridians are marked at  $10^\circ$  intervals; the Weber contrast for the isopters is shown in the right lower quadrant. The contrast for foveal vision under these conditions (for the right eye of E.P.) is 0.1. The isopters are based on measurements along 12 meridians. The measurements along each meridian were obtained in steps of 2 degrees visual angle from the fovea to the limits of the visual field. Note the plateau of constant light-difference threshold surrounding the foveal and perifoveal region with its pronounced extension into the temporal visual field (nasal retina).