Character recognition and Riccò's law

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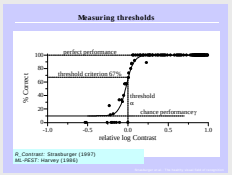
Introduction

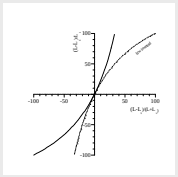
The contrast threshold for the detection of patches of light depends upon stimulus size as described by Riccò's classical law of areal summation; the critical diameter within which Riccò's law holds increases with retinal eccentricity. Here we present an analogon of Riccò's law for the recognition of characters at low contrast, and describe its variation with retinal eccentricity.

Methods

Michelson contrast thresholds for the recognition of singly presented digits were determined in a 10-afc, maximum-likelihood adaptive procedure (ML-Pest + R_Contrast [1,2]), as a function of character size (0.2° – 5°), at 13 retinal eccentricities on the horizontal meridian up to 36°. Thresholds were converted to Weber contrast $C_W = DL/L$ to be comparable to the classical formulations of Riccò's law. Log-log contrast-size functions were analysed with respect to maximum slope and slope of –2.

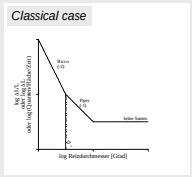


Sample psychometric function



$$C_W = \frac{\Delta L}{L} = \frac{2C_M}{1-C_M}$$

Conversion of Michelson to Weber Contrast



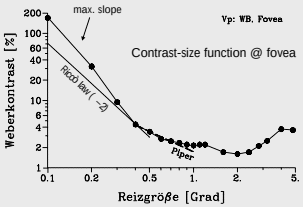
Definition of terms

Sample stimulus

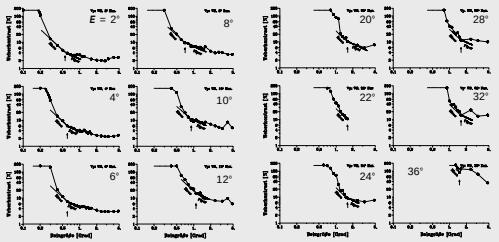
References:
[1] Harvey L.O., Jr. (1986). Efficient estimation of sensory thresholds. Behav Res Meth Instr Comp 18, 623-632.
[2] Strasburger H (1997). *R_Contrast:* Rapid measurement of recognition contrast thresholds. Spatial Vision 10, 495-498.
[3] Fischer, B. and May, H. U. (1970). Invarianzen in der Katzenretina: .... Exp. Brain Res. 11, 448-464.
[4] Oehler, R. (1985). *Spatial interactions ... monkey ... Westheimer paradigm*. Exp Brain Res 59, 217-225.
[5] De Monasterio FM & Gouras P (1975). ... *ganglion cells of the rhesus monkey retina*. *J Physiol 25*1, 167-195.
[6] Spillmann, L. (1964). *Zur Feldorganisation der visuellen Wahrnehmung beim Menschen*..Dissertation, Univ Münster.
[7] Strasburger H (2003). *Indirektes Sehen: Formerkennung im zentralen und peripheren Gesichtsfeld*. Hogrefe.

Results

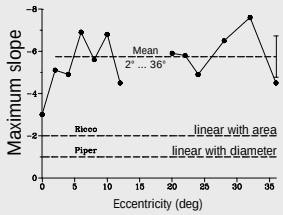
Results: Stimulus size has a more pronounced effect on character recognition than it has on stimulus detection, such that the maximum slope of the (log-log) areal-summation function is much steeper than Riccò's (–2) slope. It ranges from –3 in the fovea to –7.5 at 30° eccentricity. At larger stimulus sizes there is a range at which Weber contrast threshold C_W is proportional to stimulus area S^2 (i.e. slope is –2). I denote this as the Riccò size range, and denote the term $a_R = C_W \cdot S^2$ as effect size. An extended law of areal summation states that within the Riccò range, effect size is a constant multiple of Spillmann's perceptive field size [6, 7], giving rise to a system contant C_0.



- note Weber contrast
- note double log

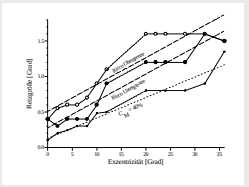


Slope derivation



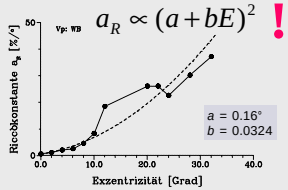
Violation of Riccò's law

- Slope dramatically higher than Riccò's:
- Summation with diameter to the power of 6
- Outside fovea independent of eccentricity



Empirical limits of the Riccò range

$$a_R \propto (a+bE)^2$$!



Riccò effect size $a_R = C_W \cdot S^2$

Extended Riccò law of character recognition (@ intermed. size)

$$a_R = C_W \cdot S^2 = C_0 \cdot D^2$$

$$D = a + bE$$

a = 0.16°
b = 0.0324

a_R: *effect size*
C_W: Weber contrast
S: stimulus size
C_0: 28%, system constant !
D: perceptive field diameter !

C_0 is Weber contrast threshold of a stimulus equal to receptive field size

Fischer & May (1970)

Areal summation:

$$A \cdot \Delta L / L = C_0 \cdot A_R$$

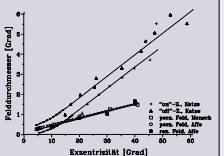
Receptive field size:

$$R = a \cdot (E - E_0)$$

a = 0.052
$E_{0,on\text{-}center}$ = 8.06°
$E_{0,off\text{-}center}$ = 1.61°

A: stimulus area
L: luminance
A_R: receptive field size
C_0: 4.55%, system constant
R: receptive field radius
E: retinal eccentricity
E_0: cutoff parameter
note that it is negative

Note that – unlike in cortical magnif. rules – E_0 is negative! (i.e. E must be sufficiently large, >17°)



Receptive and perceptive field size [3, 4, 5, 6]

Conclusions

(1) Riccò's law holds at intermediate sizes; size range depends on eccentricity

Violation:

(2) At small size, stimulus size is much more important for recognition than it is for detection: sensitivity rises with **third power** of area. (E>4°) (Riccò is 1st order)

(3) Feature detection models, including scale variant and non-linear models, cannot per se predict pattern recognition.

(4) Areal summation at the ganglion cell level does not predict areal summation for character recognition.

Modelling:

(5) Effect size a_R (in the Ricco range) is a purely square function of eccentricity.

(6) Across eccentricity, effect size is a constant multiple of perceptive field size.

(7) The involved system constant C_0 is much larger than that for detection (in cat)