On the cortical mapping function

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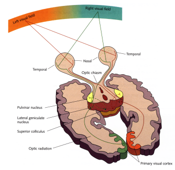
Motivation

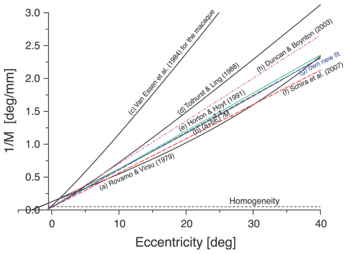
Provide an **explicit quantitative link** between the linear eccentricity function in the visual field and its logarithmic (or exponential) cortical counterpart – for counterchecking mapping results and estimates of the cortical magnification factor

Introduction

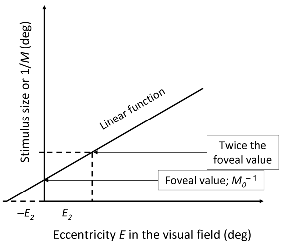
The retino-cortical visual pathway is organized retinotopically: Retinal neighborhood relationships are preserved in the mapping to the cortex. Size relationships in that mapping are also highly regular: The size of a patch in the visual field that maps onto a cortical patch of fixed size follows (along any radian and in a wide range) simply a linear function with retinal eccentricity. This is referred to as M-scaling. As a consequence the mapping of retinal to cortical location follows a logarithmic function along a radian (Schwartz, 1980).



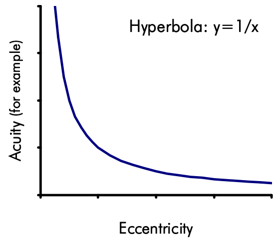
The linear eccentricity function: $M^{-1}/M_0^{-1} = 1 + E/E_2$ & $S/S_0 = 1 + E/E_2$



Several empirical eccentricity functions



Levi's E_2 concept



The inverse follows ~ a hyperbola

Linear –
Works for many visual function in the visual field:

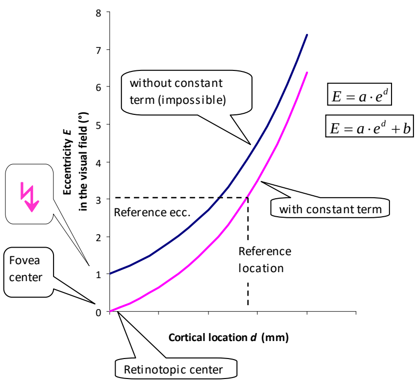
- 1/Acuity
- Grating contrast sensitivity

and also

- 1/Cortical magnification factor: M

The cortical function

Schwartz (1980) has shown that visual field eccentricity and its location in the retinotopic map are linked by a log (or exp) function. He included a simplified form with the constant term omitted. This function, though often used, is physically impossible in the fovea, however!



The link function

eccentricity

Distance from ref.

$$E = E_2 \left(e^{\beta \frac{\hat{d} + d_{ref}}{d_{ref}}} - 1 \right)$$

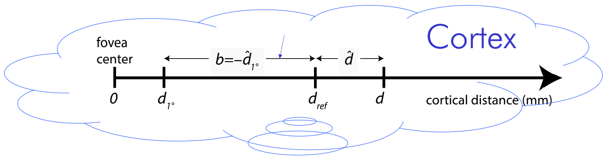
constant term

$$\beta = \ln\left(\frac{E_{ref}}{E_2} + 1\right)$$

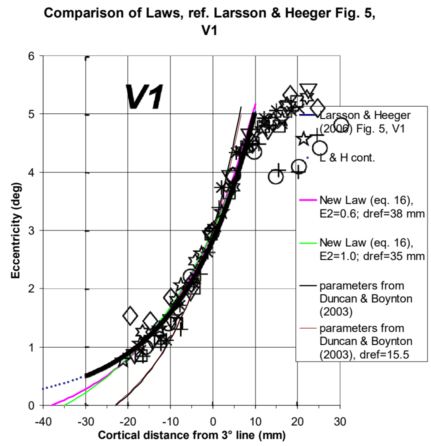
with $\hat{d} + d_{ref} \geq 0$

$$M_0 = \frac{d_{ref}}{\beta \cdot E_2}$$

Foveal cortical magnification factor



Applied to data



Data from Larsson & Heeger (2006). The black curve is the original, impossible function (since the fovea is not at 0 deg). Red is the new law.

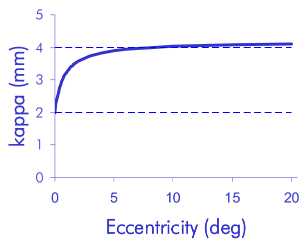
A further application:

Bouma's Law in the cortex (Cortical critical crowding distance)

Pelli (2008) has shown that Bouma's Law, mapped onto the cortex, predicts constant critical distance in the cortical map.

That is only the case for Schwartz' simplified law, however. With the realistic mapping law presented here, cortical critical crowding distance varies according to the function on the right.

(It is only constant when crowding's $\hat{E}_2$ is the same as normal E_2.)



$$\kappa = \frac{d_2}{\ln 2} \ln\left(1 + \frac{\delta_0}{E_2} \frac{(1 + E/\hat{E}_2)}{(1 + E/E_2)} \right)$$

References

- Schwartz, E. L. (1980). Computational anatomy and functional architecture of striate cortex: A spatial mapping approach to perceptual coding. Vision Research, 20, 645-669.
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- Larsson , J., & Heeger, D. J. (2006). Two retinotopic visual areas in human lateral occipital cortex. The Journal of Neuroscience, 26(51), 13128-13142.
- Pelli, D. G. (2008). Crowding: a cortical constraint on object recognition. Current Opinion in Neurobiology, 18, 445–451.