Perceptual Consequences of Elongated Eyes

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Introduction

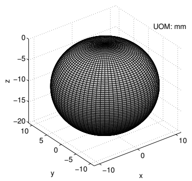
Myopic eyes are elongated compared to the eyes of normally sighted, emmetropic observers. This simple observation gives rise to an empirical question: what are the physiological and perceptual consequences of an elongated retinal surface?

Objective

To develop a framework in which to study the effects of eye shape on visual perception.

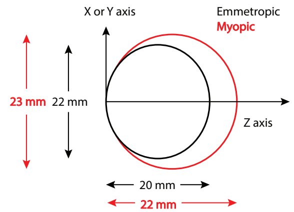
The Eye as an Ellipsoid

We modeled the retinal surface as a non-rotationally symmetrical ellipsoid [1] with equation:



$$\frac{x^2}{R_x^2} + \frac{y^2}{R_y^2} + \frac{(z+R_z)^2}{R_z^2} = 1$$

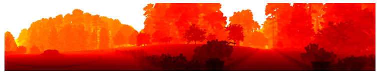
where R_x, R_y and R_z are the semidiameters of the ellipsoid along the x, y, and z axes.



Estimating Retinal Blur Distributions

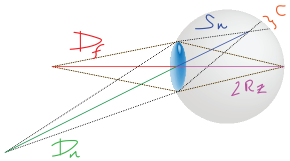
Ray Tracing

We input range image data of natural scenes [2] to the geometric models to estimate the distributions of blur in the visual periphery of myopic and emmetropic eyes.



We employ the thin lens model as an approximation of the eye's lens system. We compute the focal length, f, of the eye with axial length $2R_z$ fixating at distance D_f:

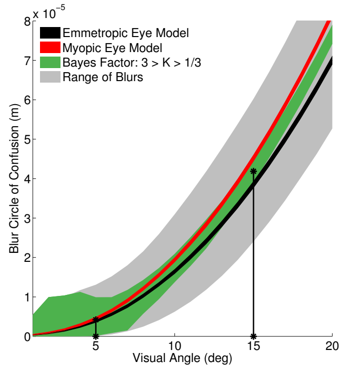
$$\frac{1}{2R_z} + \frac{1}{D_f} = \frac{1}{f}$$



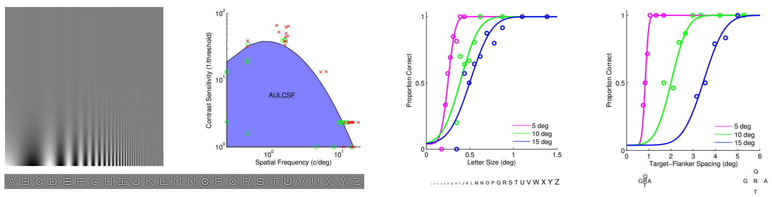
For every point n at distance D_n within the eye's field of view we compute the distance behind the pupil S_n at which the point is in focus. Through ray tracing we estimate the diameter of the blur circle of confusion c

Peripheral Blur Distributions

We estimate the distribution of blur at growing eccentricities away from the fovea of the emmetropic and myopic eyes. We find that myopic eyes are subjected to greater peripheral blur than emmetropic eyes.



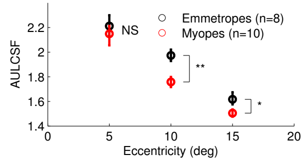
Psychophysical Methods



Psychophysical Results

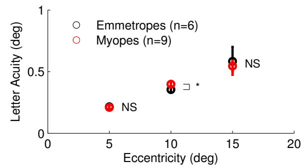
Contrast Sensitivity

The area under the log CSF is not different between best corrected myopic observers and emmetropes at relatively lower eccentricities, but it is at larger eccentricities.



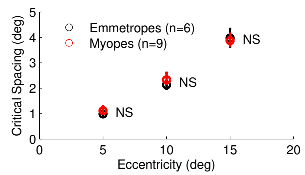
Acuity

Peripheral acuity is similar in myopes and emmetropes.



Crowding

We observed no differences in peripheral crowding zones between myopic and emmetropic observers.



Discussion

We combine MRI measurements of emmetropic and myopic eye shape (from [1]) with range image data of natural scenes (from [2]) to estimate where in the visual periphery perception may be altered due to the different shapes of myopic and emmetropic eyes.

Consistent with our model predictions, the area under the log CSF (estimated using the FAST adaptive testing procedure [3]) decreases in the periphery at a faster rate in best corrected myopic observers than in emmetropes.

A target at a given eccentricity projects onto a larger area of peripheral retinal for myopic than emmetropic eyes. This raises the possibility that crowding zones may differ between eye types. However, we find no significant differences in crowding zones between myopic and emmetropic observers.

Conclusion

We provide a simple geometric eye model to estimate retinal blur distributions in natural environments.

The model highlights differences in retina blur distributions between myopes and emmetropes that have testable perceptual consequences.

No differences in crowding zones between myopic and emmetropic observers suggest that crowding depends on spatial rather than retinal feature separation, which implies differences in the retinocortical transformations in myopes and emmetropes.

References

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