Peripheral Refraction and Aberrations for Different Wavelengths: Off-axis Chromatic Aberration

#1556

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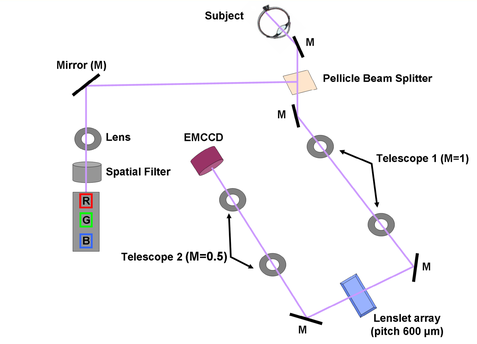
PURPOSE

The interest in the peripheral optical quality of the eye is increasing, mainly because animal studies have shown that off-axis refractive errors may influence the progression of myopia. Off-axis image quality has been often assessed monochromatically using infrared light. To validate previous data obtained with this procedure, it is important to compare off-axis refraction and aberrations for different wavelengths. This may reveal possible systematic measurement errors and potential wavelength dependence of retinal reflections in the periphery. The off-axis chromatic aberrations measured in both emmetropes and myopes could also offer some insights on the issue of the relationship between aberrations and myopia progression.

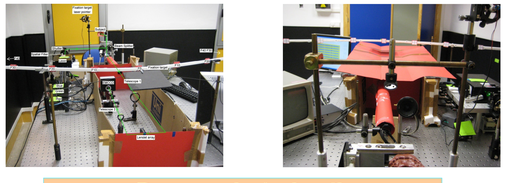
METHODS

Experimental system: off-axis polychromatic Hartmann-Shack (HS) wavefront sensor



- RGB Laser: wavelengths 473 / 532 / 671 nm
- Recording of HS images using a high sensitivity EMCCD camera
- Range of eccentricity measured: -40˚ (N) to 30 (T) in steps of 10˚
- One measurement is the mean of 3 consecutive measurements of 200 ms
- At each color and eccentricity 3 measurements were taken
- Light exposure intensity varied between 0.5 and 1.0 µW/cm².

Pictures of the instrument



Data analysis details

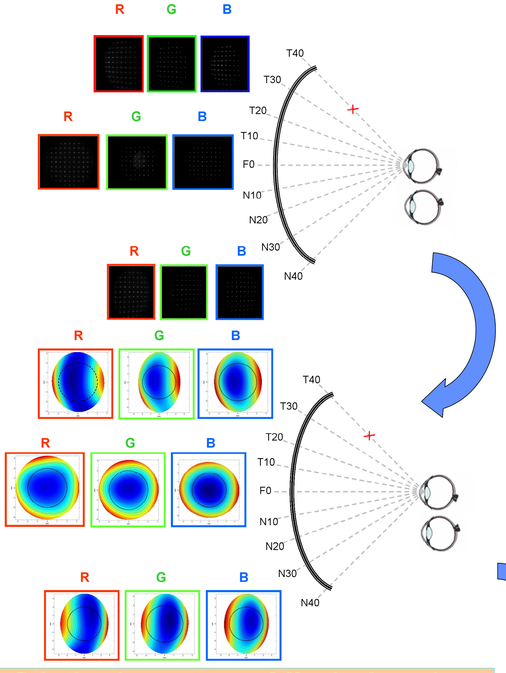
- For each measurement the spot pattern was unwrapped using a b-spline unwrapping algorithm
- 4th order Zernike least squares fit over the whole elliptic pupil
- Zernike coefficients were re-scaled to a 4 mm circular sub-pupil within the original pupil
- Refraction was calculated from low order (defocus & astigmatism) Zernike coefficients
- Astigmatism was decomposed for analysis, further horizontal and vertical coma was examined and spherical aberration
- Higher order RMS was calculated from the 3rd and 4th order terms
- Statistical significance was examined using a multi-variable ANOVA test

Measurement procedure

Subjects participating in the study

	#	Refraction	Age
Emmetropes	5	-0.4 ± 0.3 D	27-33
Myopes	4	-2.1 ± 0.8 D	28-36

Off-axis RGB-HS images & WA's



Calculated parameters: Off-axis aberrations and wavelength dependence

Each Zernike coefficient ($Z(\lambda, \theta, RG)$) was averaged for every color (λ), eccentricity (θ) and state of refraction (RG):

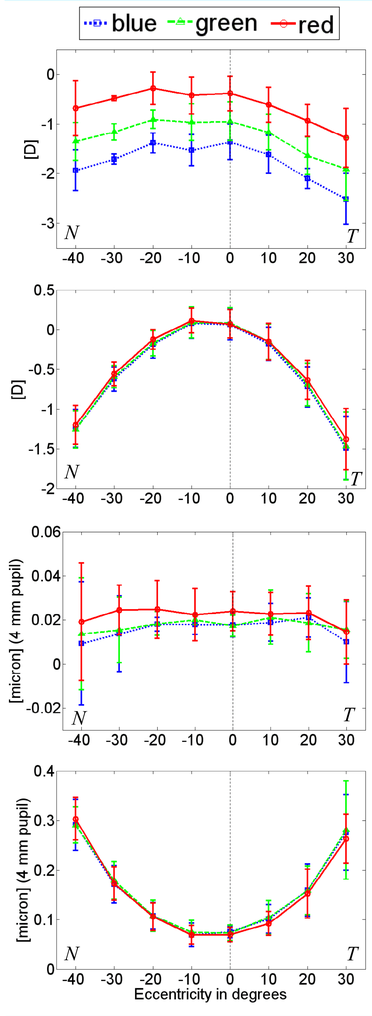
$$Z(\lambda, \theta, RG) = mean_{subjects}(mean_{meas}(Zernike))$$

Chromatic difference of coefficient ($\Delta Z(\theta, RG)$):

$$\Delta Z(\theta, RG) = Z(\lambda_2, \theta, RG) - Z(\lambda_1, \theta, RG)$$

RESULTS

Mean of off-axis chromatic aberrations in emmetropes



Multi-variable ANOVA p-values and comparison

Mean defocus

	Mean Sphere
Color	p<0,01
Refraction	p<0,01
Eccentricity	p<0,01
Color*refr	p=0,9652
Color*ecc	p=0,9983
refr*ecc	p<0,01

Δλ	671-473
Mypopes	1,03 ± 0,14
Emmetropes	0,97 ± 0,11
All	1,00 ± 0,12
Water	0,95
Indiana red. eye	1,06

Horizontal cross-cylinder (J0)

	J0
Color	p<0,01
Refraction	p<0,01
Eccentricity	p<0,01
Color*refr	p=0,6633
Color*ecc	p=0,9723
refr*ecc	p<0,01

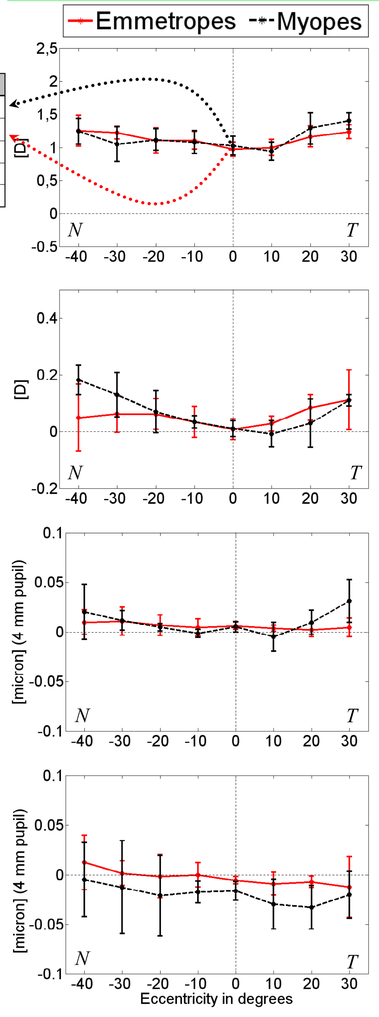
Spherical Aberration

	Sph_Ab
Color	p<0,01
Refraction	p<0,01
Eccentricity	p<0,01
Color*refr	p=0,4519
Color*ecc	p=0,1724
refr*ecc	p=0,4495

Higher Order RMS

	High_RMS
Color	p=0,0801
Refraction	p=0,0373
Eccentricity	p<0,01
Color*refr	p=0,1286
Color*ecc	p=0,9994
refr*ecc	p<0,01

Off-axis chromatic differences (RED-BLUE) in refractive groups



CONCLUSIONS

- *We designed and built an instrument to successfully measure refraction and aberrations in the periphery for wavelengths over the range of the visible spectrum in two refractive groups.*
- *Longitudinal chromatic aberration (LCA) was nearly constant with retinal eccentricity. The chromatic difference of astigmatism and higher order RMS was also found not to vary significantly with eccentricity.*
- *There was no statistical variation found in chromatic aberrations between emmetropes and (mild) myopes.*
- *The use monochromatic light for measurements of peripheral optics may provide an accurate representation of the visible image quality as long as the chromatic shift is taken into account.*

This work received funding from the European Commission's Sixth Framework Program through the Marie Curie Research Training Network 'MY EUROPIA' (MRTN-CT-2006-034021), Ministerio de Educación y Ciencia, Spain (grant nº FIS2007-64765), and Fundación Séneca, Murcia, Spain (grant04524/GERM/06).