

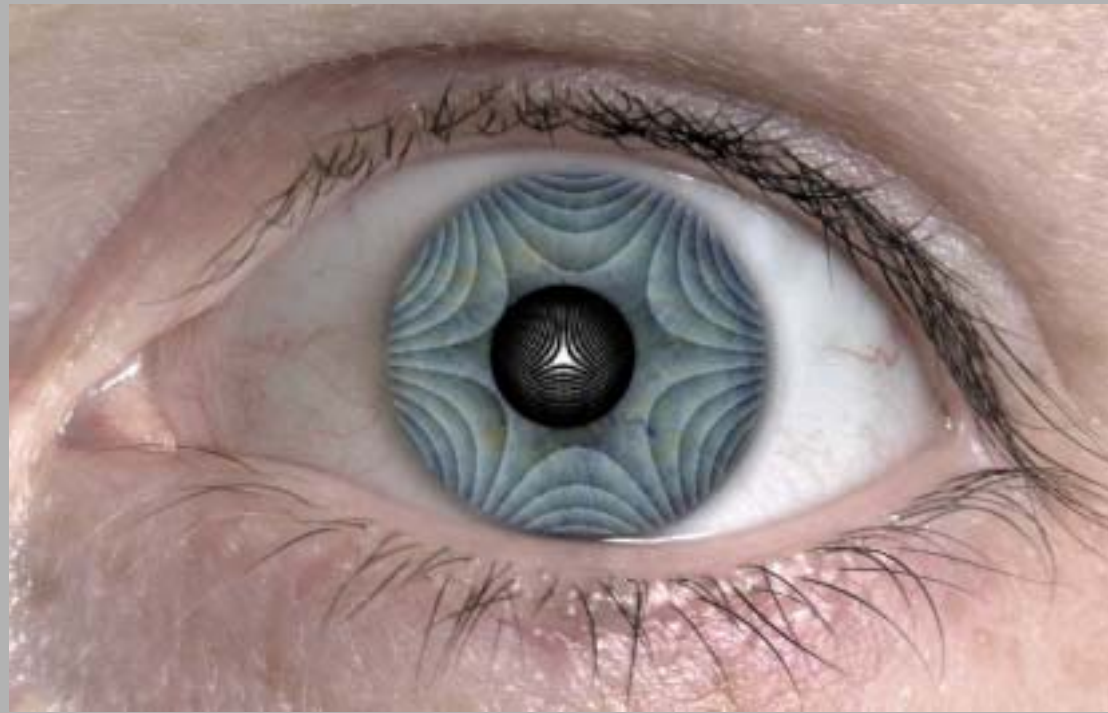
# Image Quality Metrics and Customized Contact Lenses

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## **Collaborators:**

### **Univ of Rochester:**

**Li Chen**

**Nathan Doble**

**Heidi Hofer**

**Scott MacRae**

**Jason Porter**

**Ben Singer**

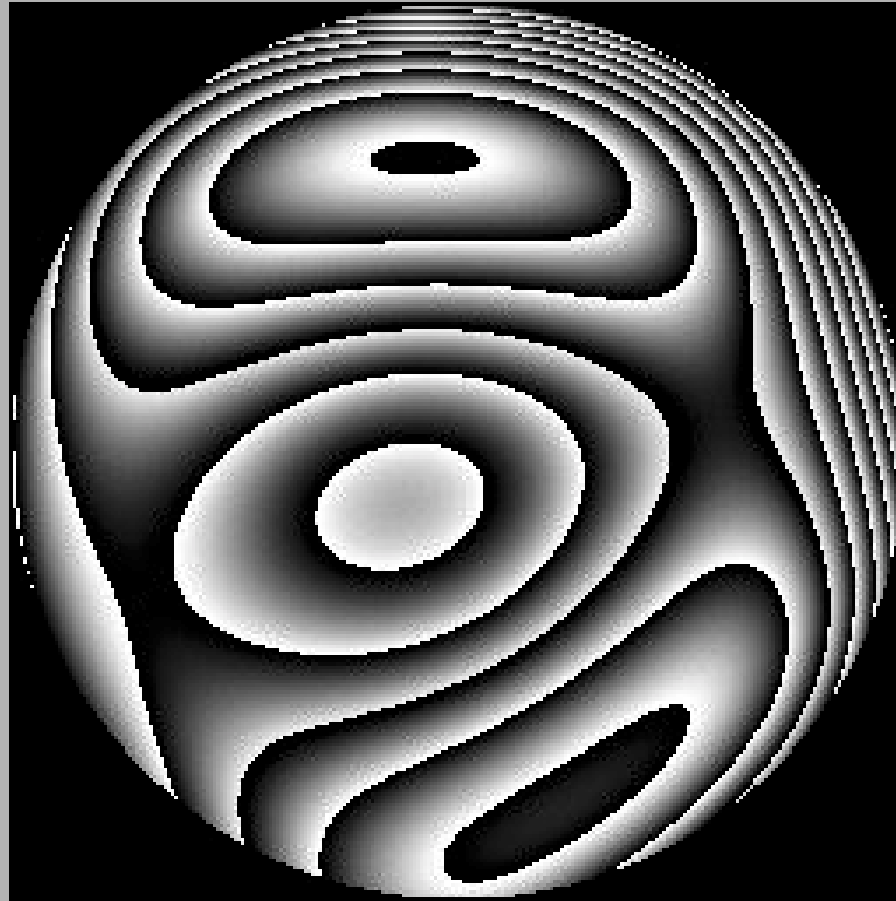
**Remy Tumber**

**Ian Cox, Bausch and Lomb**

**Ray Applegate, University of Houston**

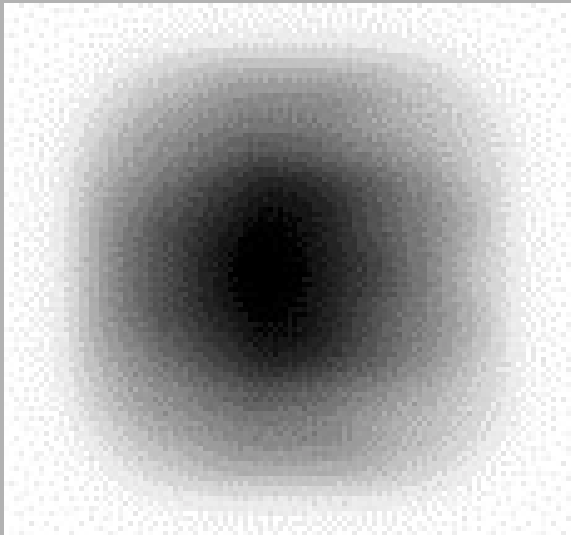
**Larry Thibos, Indiana University**

# How Bad Is This Wave Aberration?

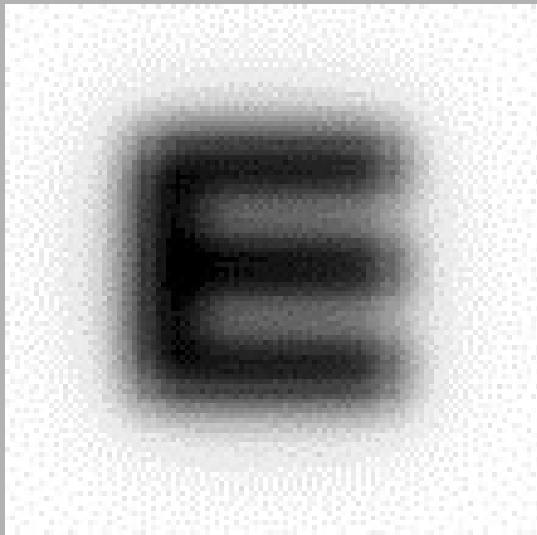


**RMS Wavefront Error = 0.87  $\mu\text{m}$**

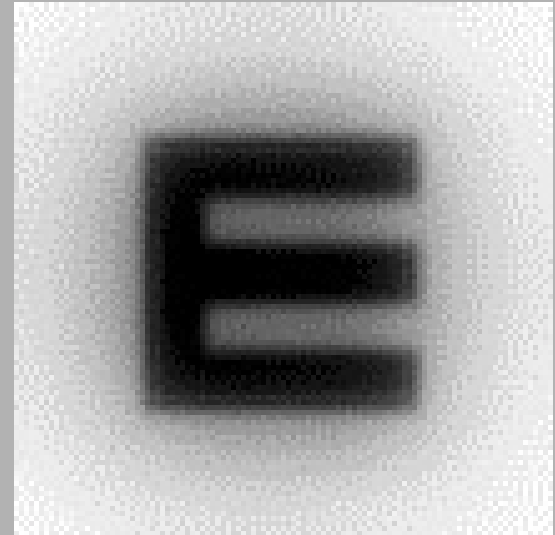
# Some Aberrations Interact Strongly in Image Blur



**Defocus**  
rms = 0.5  $\mu\text{m}$



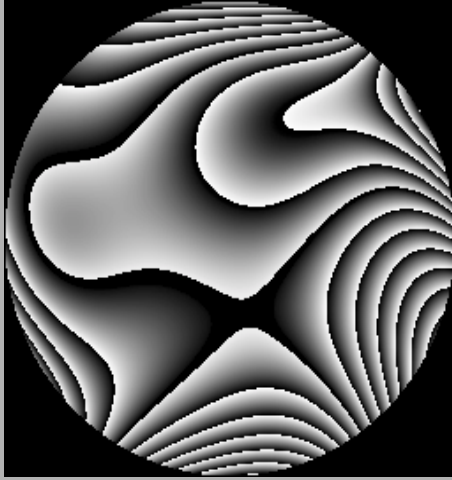
**Spherical  
Aberration**  
rms = 0.16  $\mu\text{m}$



**Defocus and  
Spherical Aberration**  
rms = 0.52  $\mu\text{m}$

# Adaptive Optics Can Create Wave Aberrations

(Subject: ND )



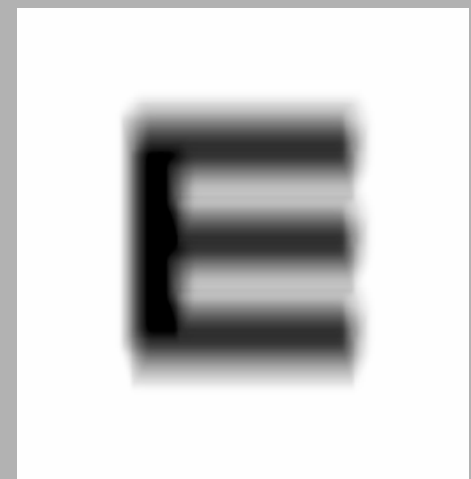
Wave Aberration



After AO correction

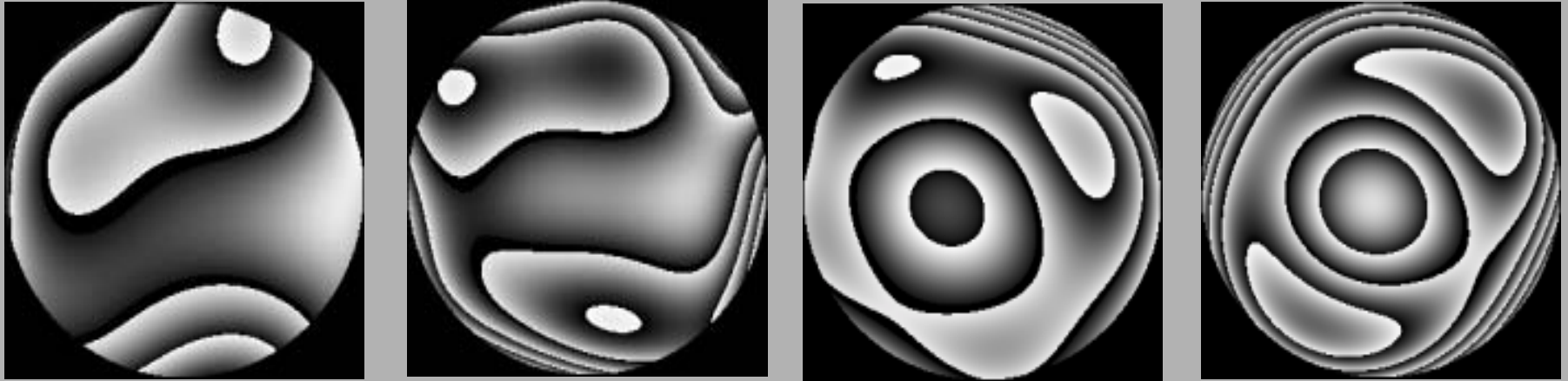


With coma added



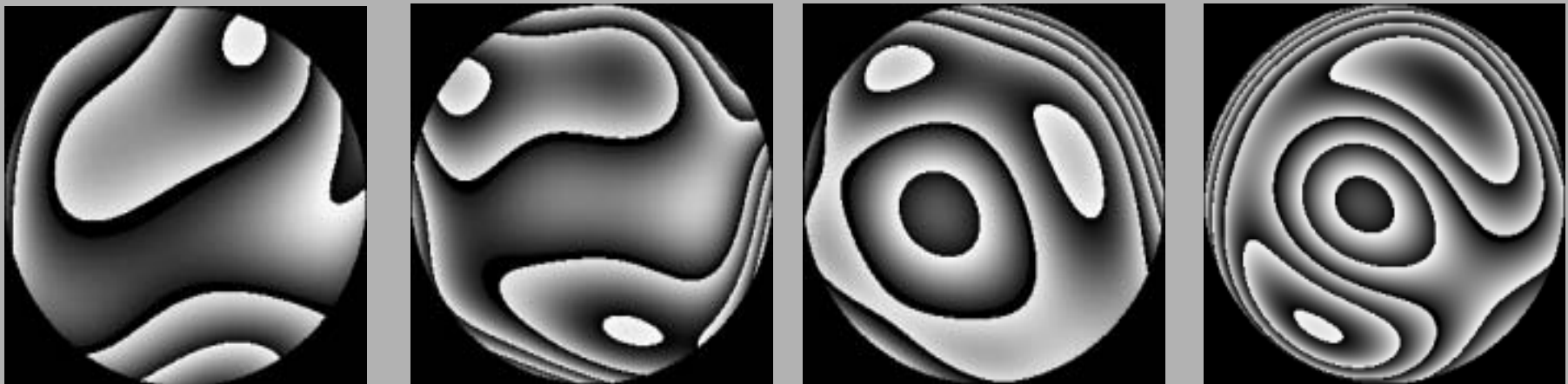
Convolved retinal image

## Wave aberrations from Lasik postOp patient



## Wave aberrations created by adaptive optics

(With real eye, JP)

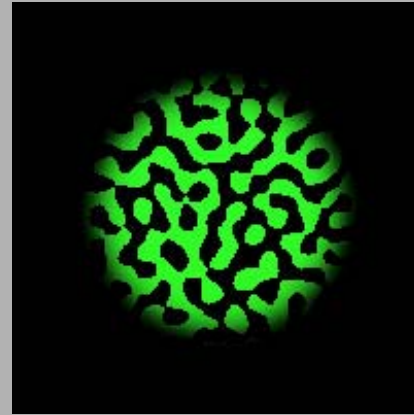


# Blur Matching of Patient Wave Aberrations

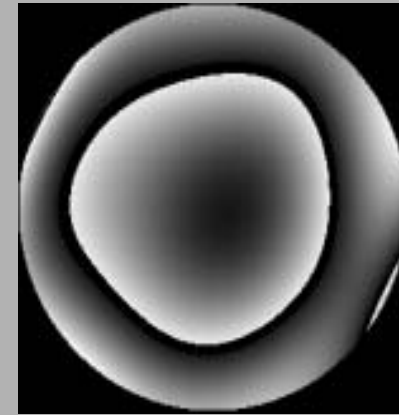
The subject adjusted the amplitude of defocus so that the subjective blur matched that of the patient wave aberration.



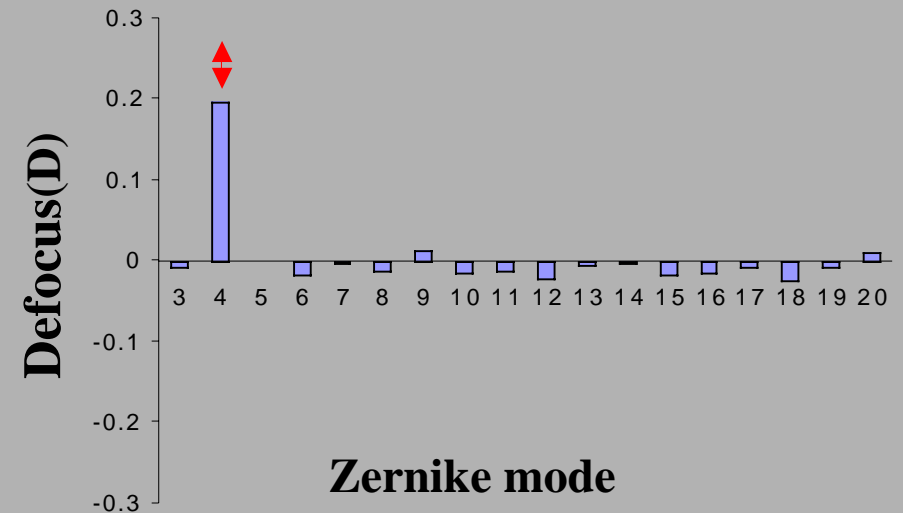
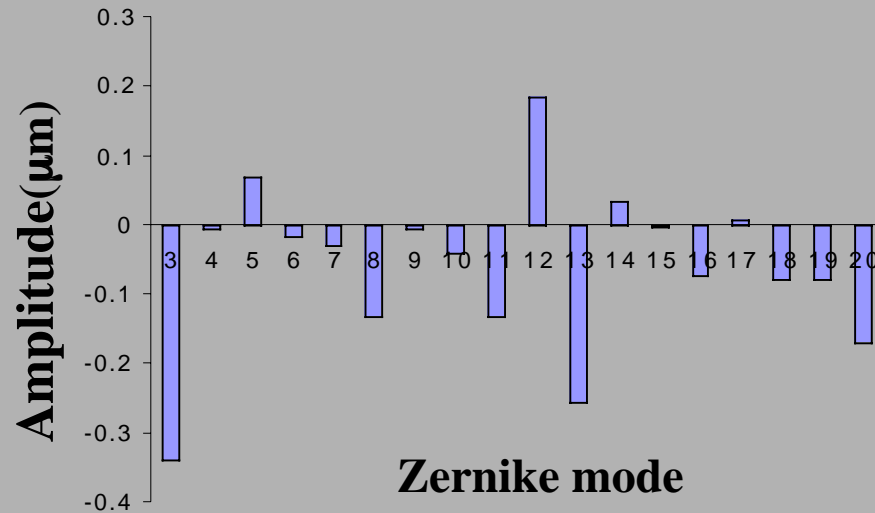
Patient wave aberration



Stimulus



Defocus

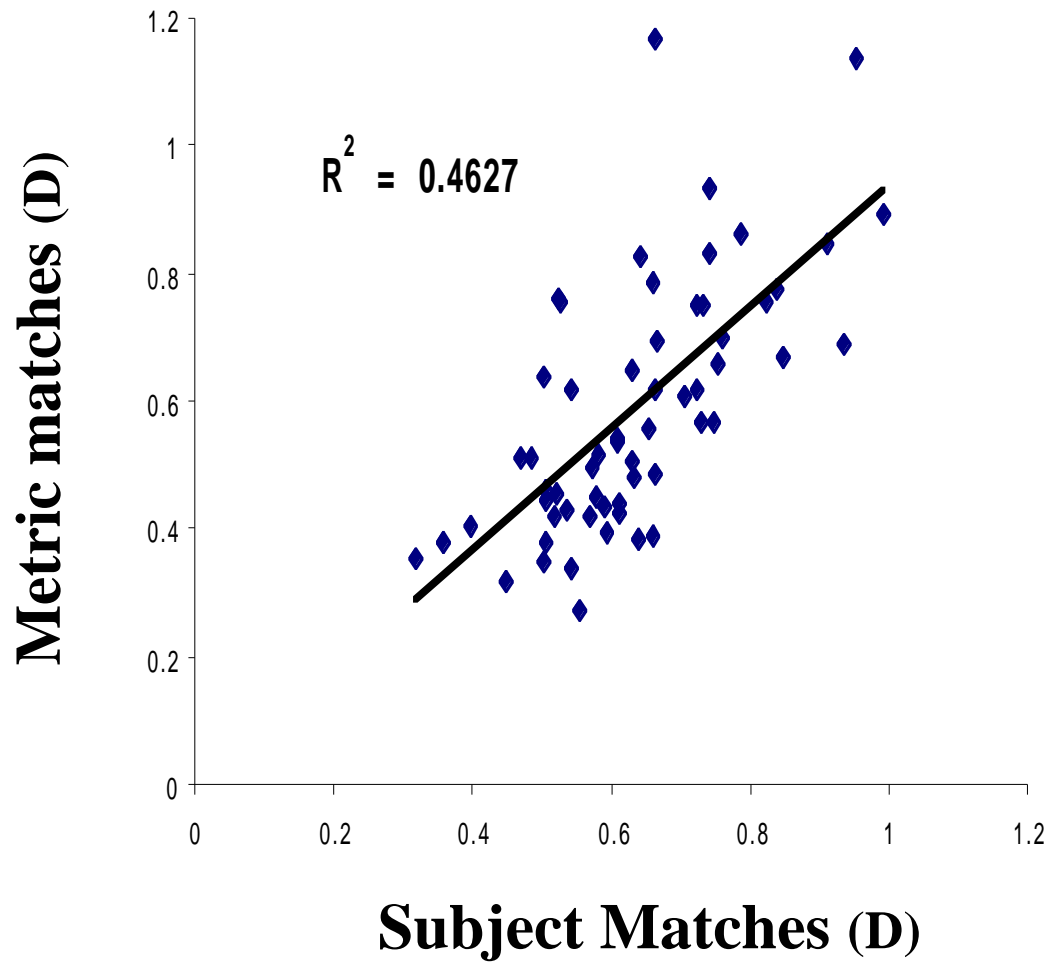


**Blur Matching Controls for  
Neural Differences between  
Patients**

**Compare Subject Matches with Matches  
Made Using T Different Metrics**

**Wavefront RMS  
Neural Sharpness**

# RMS Metric

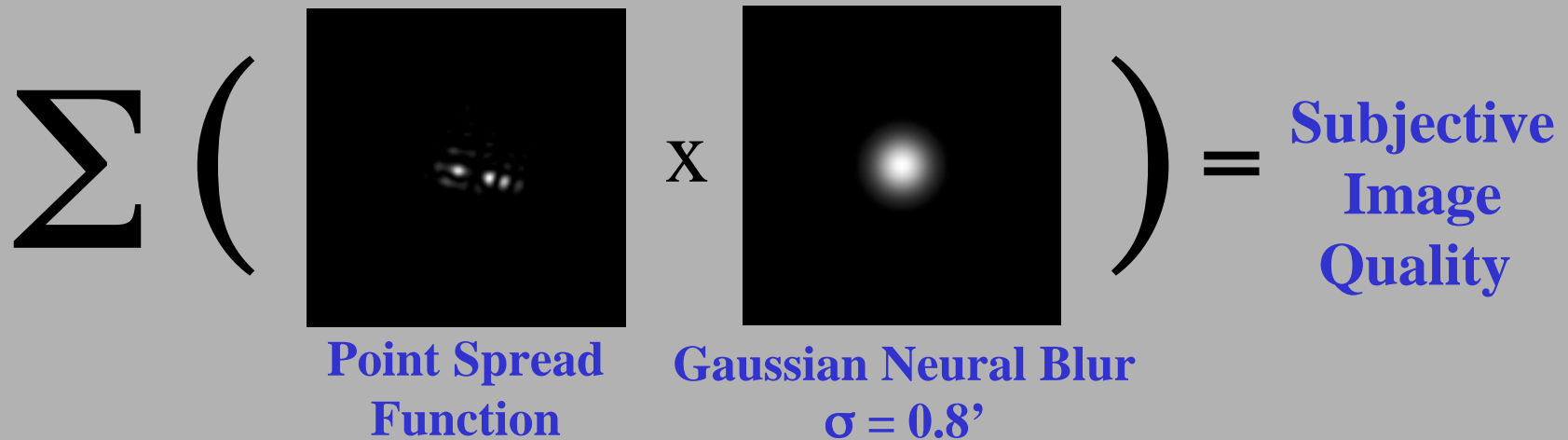


# **Strategy for Metric Development:**

**Algorithm Should Mimic  
the Human Visual System**

- Retinal Image Formation**
- Neural Processing**

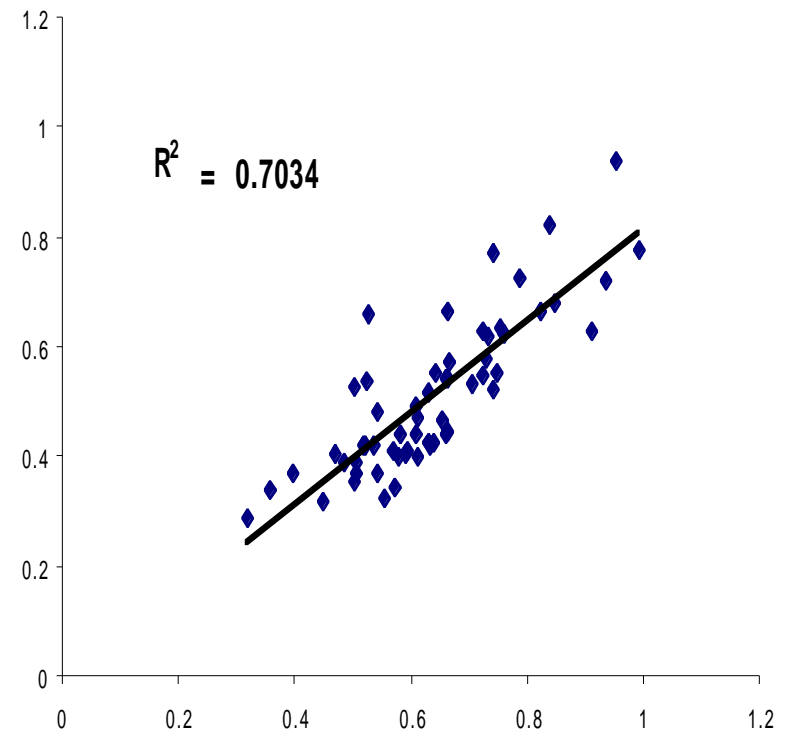
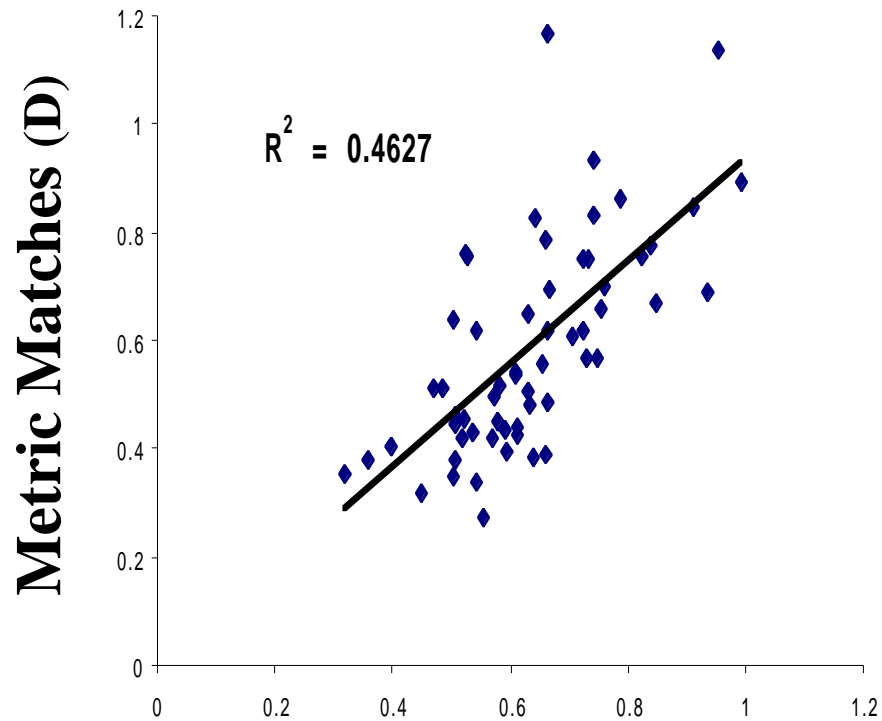
# A Simple, Biologically-Plausible Metric for Subjective Image Quality

$$\Sigma \left( \begin{array}{c} \text{Point Spread} \\ \text{Function} \end{array} \times \begin{array}{c} \text{Gaussian Neural Blur} \\ \sigma = 0.8' \end{array} \right) = \text{Subjective} \\ \text{Image} \\ \text{Quality}$$


The diagram illustrates a metric for subjective image quality. It features a large Greek letter sigma (Σ) on the left, followed by a large opening parenthesis ( ( ). Inside the parentheses, there are two square images. The first image, labeled 'Point Spread Function', shows a blurred, multi-lobed pattern. The second image, labeled 'Gaussian Neural Blur', shows a smooth, circular Gaussian blur. Between these two images is a large 'x' symbol, indicating multiplication. To the right of the closing parenthesis ( ) is an equals sign (=), followed by the text 'Subjective Image Quality' in blue. Below the first image is the text 'Point Spread Function' in blue. Below the second image is the text 'Gaussian Neural Blur' in blue, with 'σ = 0.8'' below it.

## Wavefront RMS

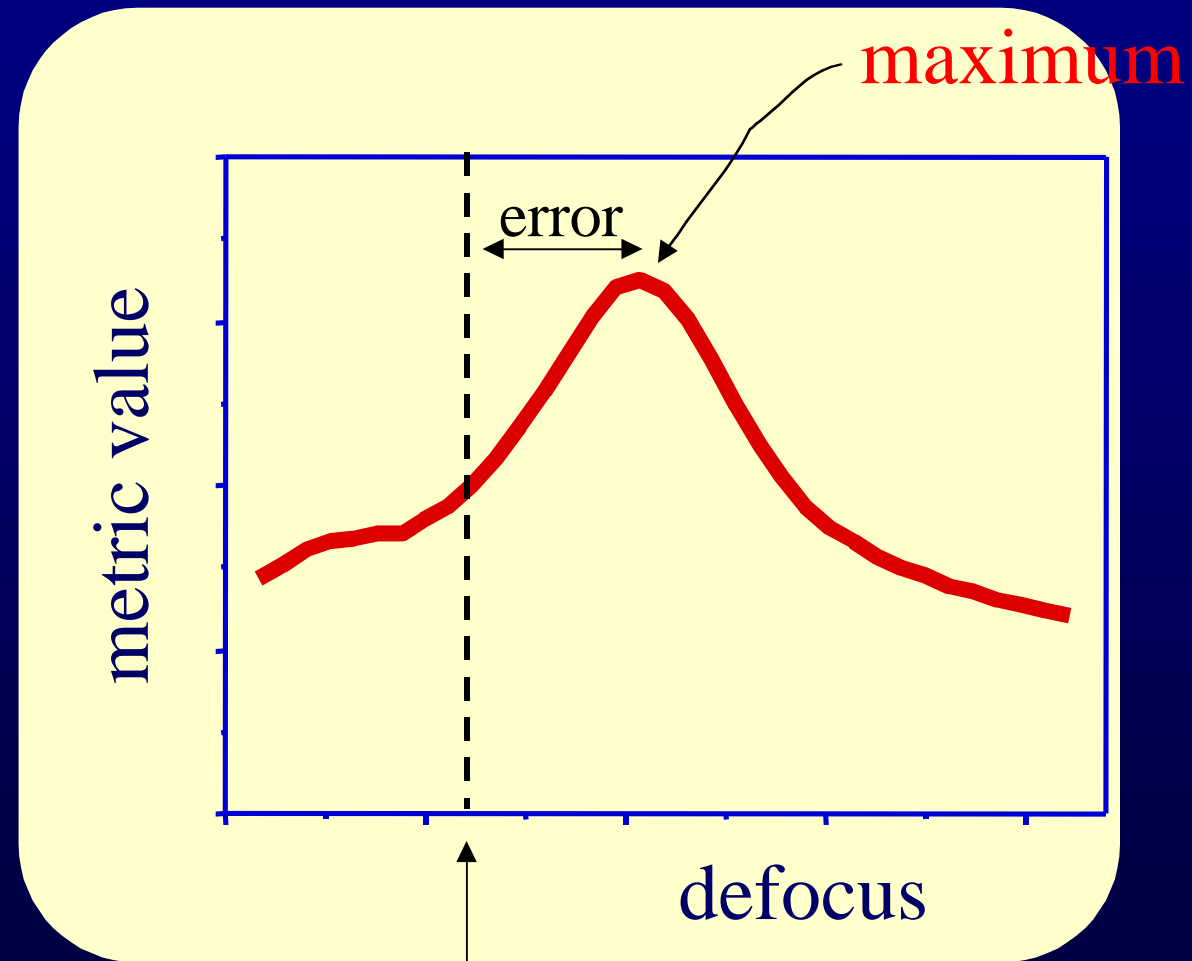
## Neural Sharpness



Subject Matches (D)

# Optimizing refraction with an image quality metric

search in  
3-D space

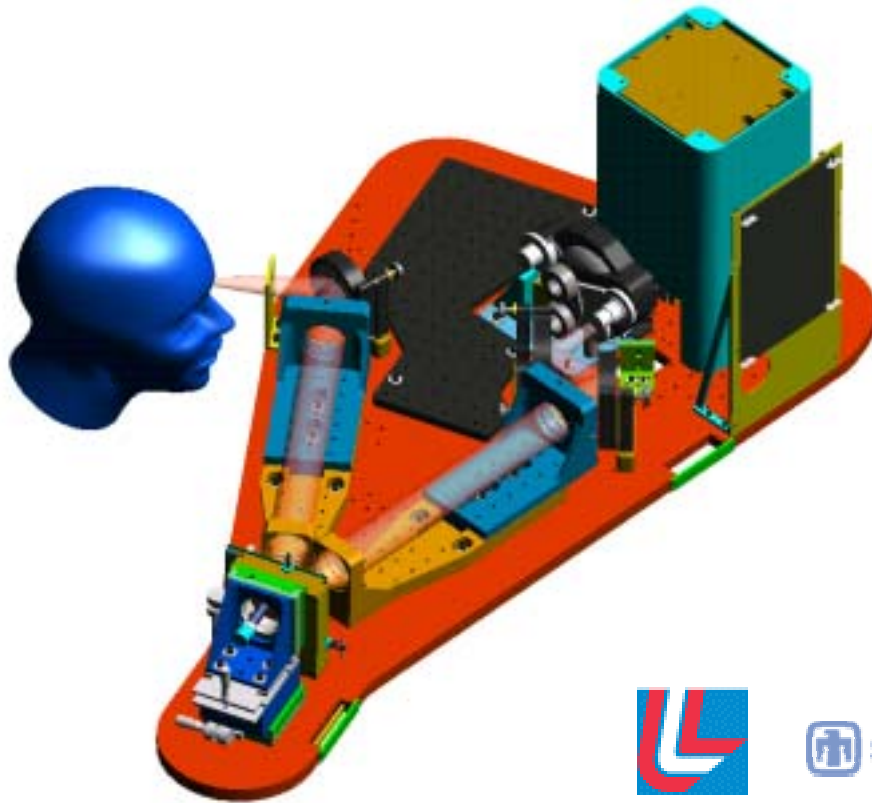


Guirao and Williams (2003)

# **Adaptive Optics Will Replace Phoropters For Prescribing Glasses and Contact Lenses**



# MEMS Adaptive Optics Phoropter



 Sandia National Laboratories

UNIVERSITY OF ROCHESTER



 BOSTON  
MICROMACHINES  
CORPORATION

 BAUSCH  
& LOMB

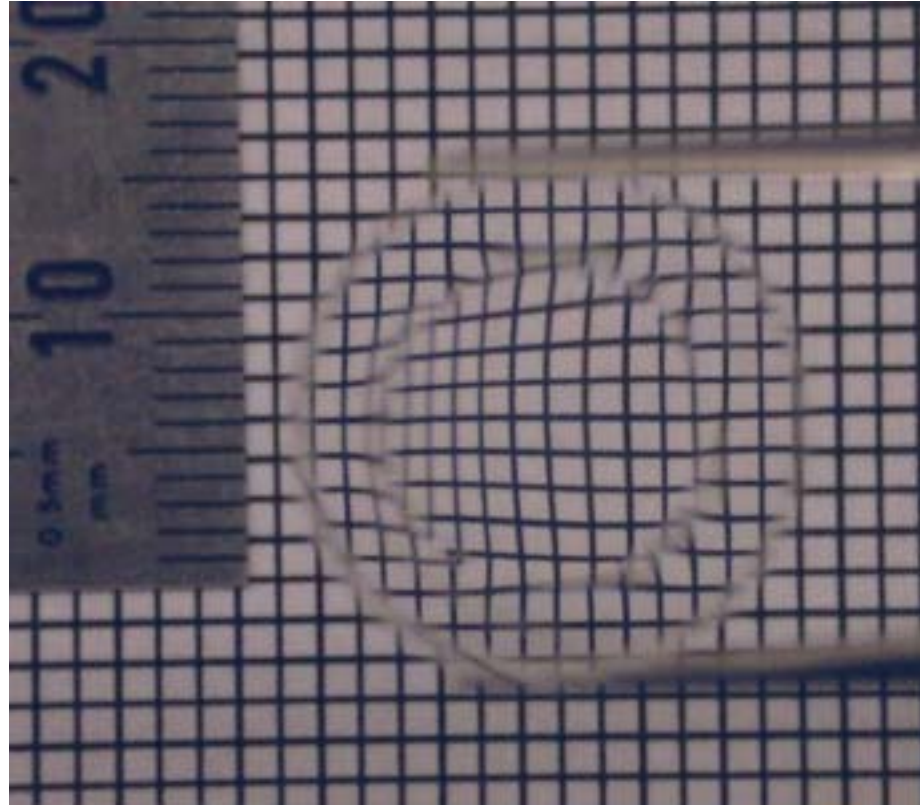
# Customized Contact Lenses



GeunYoung Yoon



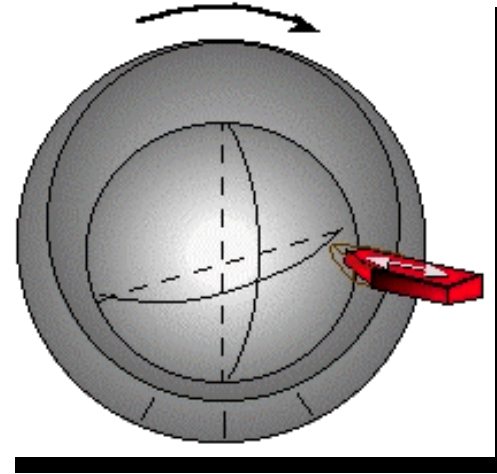
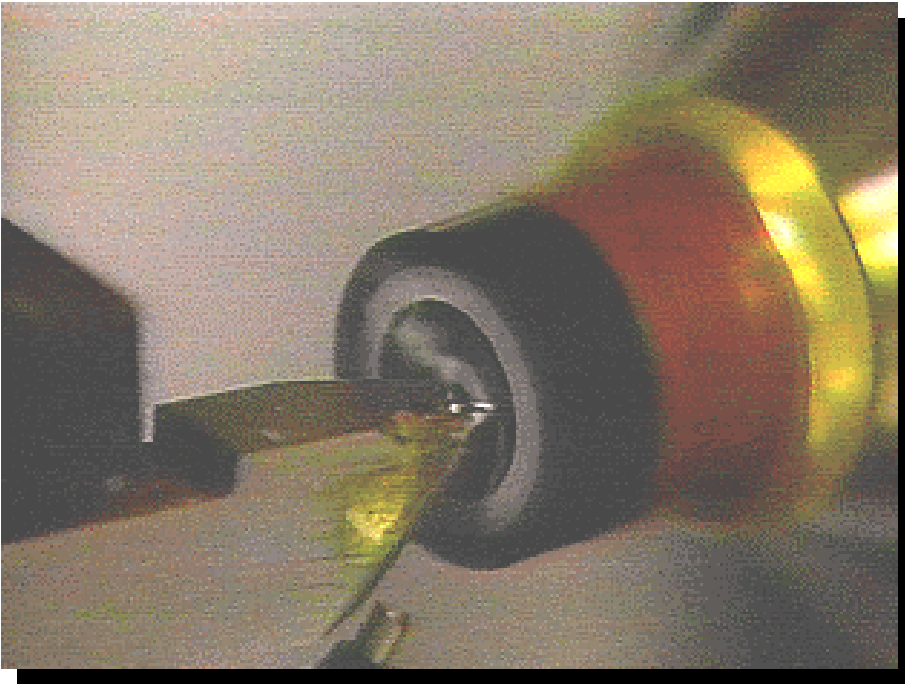
Tae Moon Jeong



Phase Plate

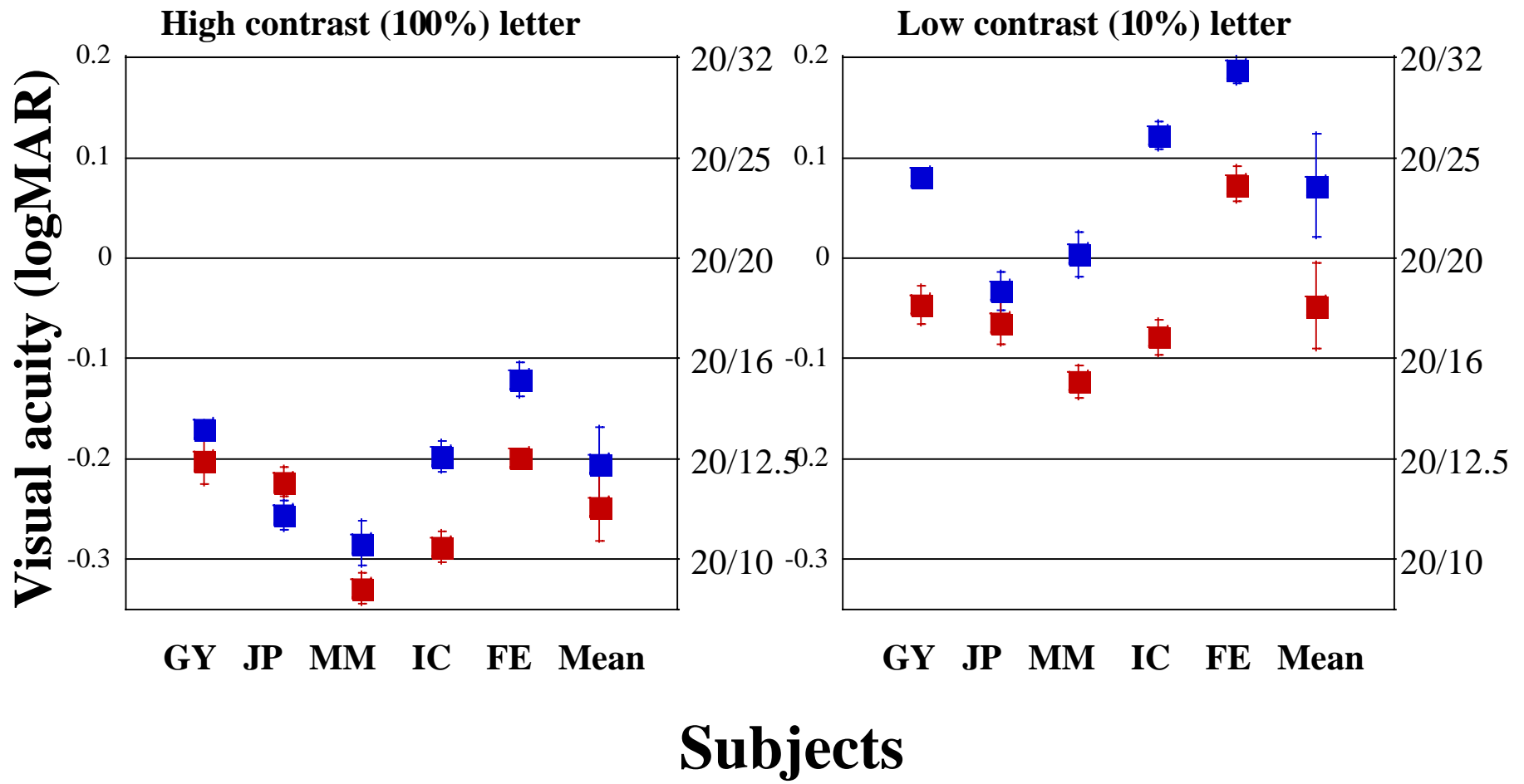
# SOFT TORIC LENS MANUFACTURING

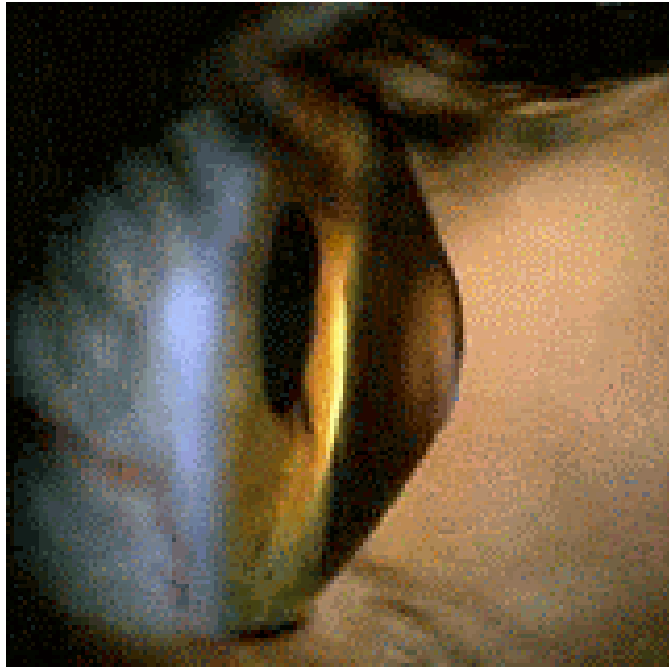
- Lathing (Double or Single Surface)
  - Crimping
  - Fly-Cutting
  - Oscillating Tool Post



# Improvement in visual acuity in normal eyes

- Correcting 2nd order only
- Correcting 2nd + higher order





**Keratoconus**



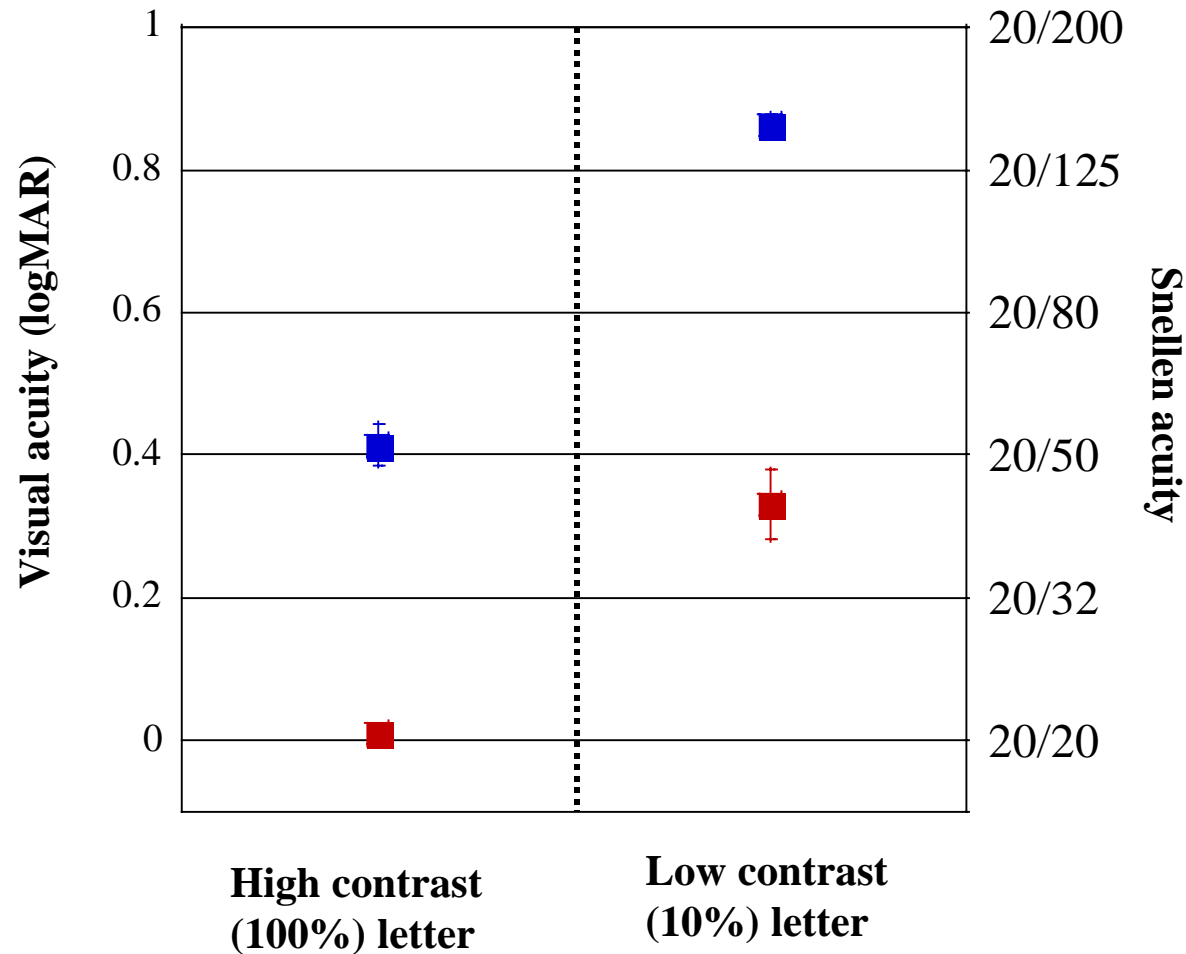
**Corneal Transplant**

[http://www.kcenter.org/news/what\\_is\\_keratoconus.html](http://www.kcenter.org/news/what_is_keratoconus.html)

# Large improvement in visual acuity in a keratoconic eye

■ Correcting 2nd order only

■ Correcting 2nd + higher order



# **Conclusions:**

**We Have a Better Way to Transform  
the Wave Aberration Into Optimized  
Vision Correction**

**Customized Contact Lenses  
Are Coming Soon**