Adaptive Optics Imaging for the Study of Retinal Photoreceptors

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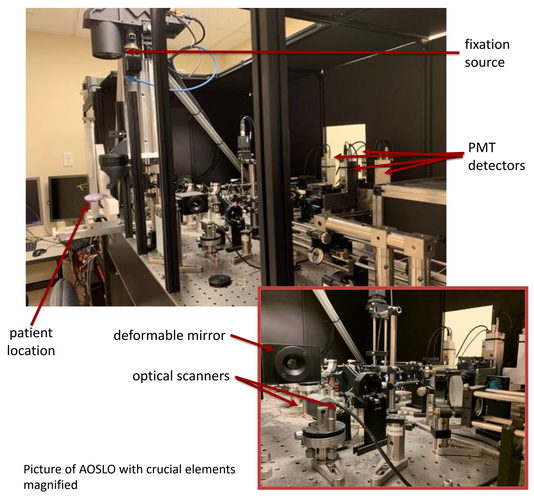
Introduction

Adaptive optics scanning laser ophthalmoscopy (AOSLO) enables visualization of retinal structure with subcellular resolution. Consisting of a wavefront sensor and deformable mirror, AO systems correct the optical aberrations of the eye. Combined with imaging technology, including a light source, optical scanners, and detectors, AOSLO imaging grants us the ability to study properties of individual photoreceptors, such as size and density, in the living eye (Burns *et al.*, 2019). My project will focus on the visualization of AO images in the form of retinal "montages" and compare how the structure of the retina varies between healthy and diseased patients.

Methods

- AOSLO system
  - -> 795 nm super luminescent diode
  - -> 2 optical scanners (horizontal and vertical directions)
  - -> wavefront sensor for measuring optical aberrations
  - -> deformable mirror for correcting optical aberrations
  - -> photo-multiplier tube (PMT) detectors for simultaneous multi-modal imaging

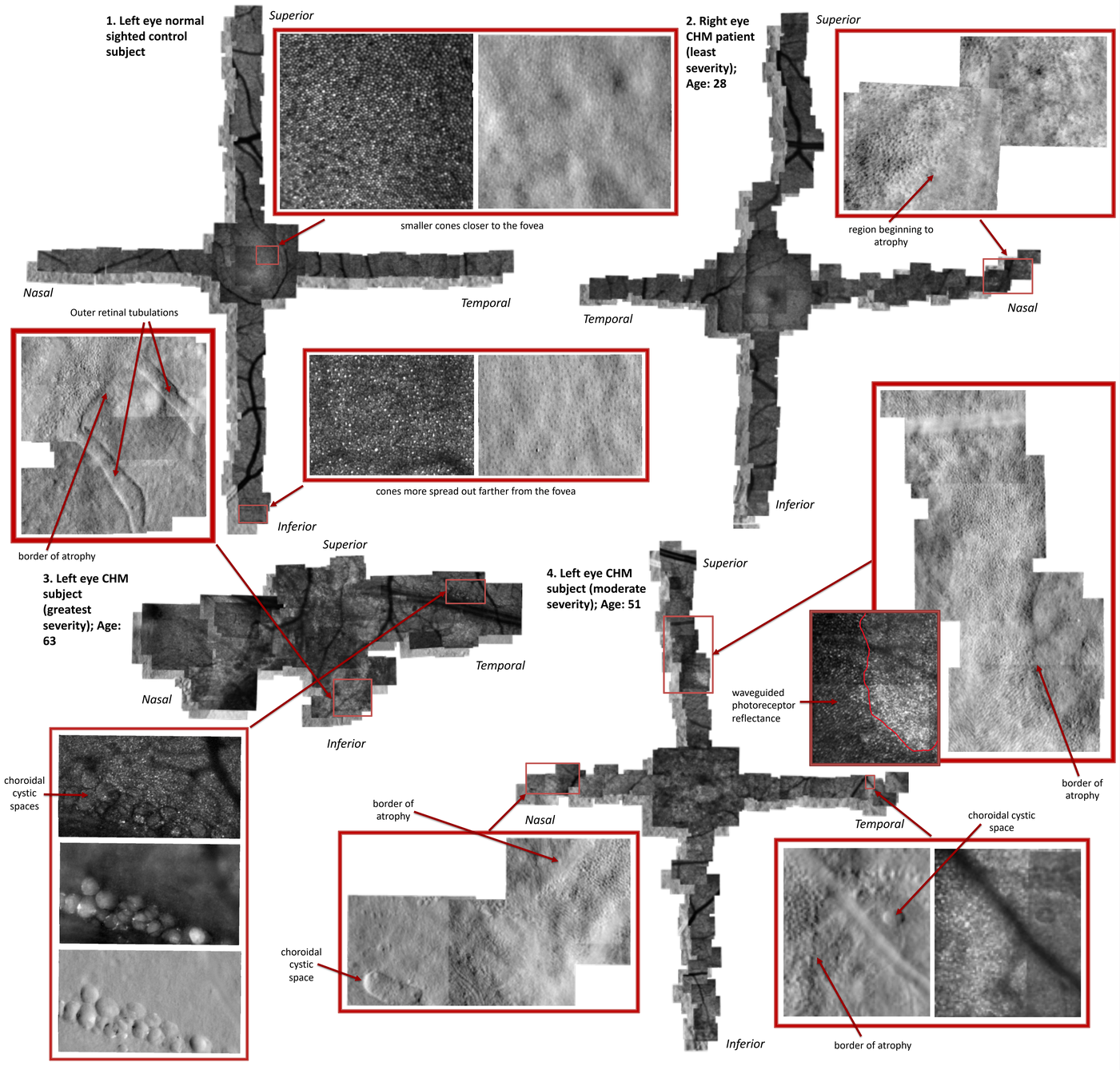


Picture of AOSLO with crucial elements magnified

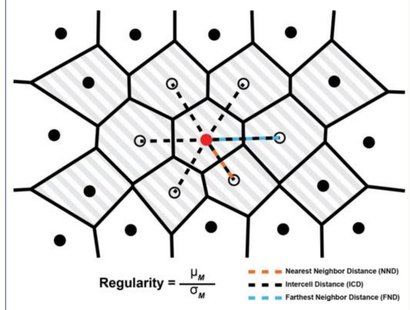
- Image Processing Pipeline: create retinal montages from raw videos obtained by the AOSLO
  - -> desinusoidal matrix: measures and saves the distortion of each pixel along the edges (due to the resonance scanner)
  - -> select reference frame: automatically or manually
  - -> register/align video sequence to reference frame to alleviate eye motion and average frames together for high signal
  - -> distortion removal: remove eye motion artifacts within the reference frame from the registered image
  - -> create the retinal montage: align AO images from adjacent retinal locations with single cone precision

Results

For this project, I compiled montages for 15 control and 3 Choroideremia (CHM) subjects. CHM is an X-linked genetic disorder which results in progressive degeneration of the photoreceptors, retinal pigment epithelium, and choroid. The following images demonstrate what atrophied regions look like in comparison with normal cones, and how the structural effects of CHM advance over time.



Future Directions



Schematic image of hexagonally arranged cone centers with distance measurements labelled from Cooper *et al.*, IOVS 2016.

- Comparing quantitative measurements of cone size and density within healthy and diseased retinal cone mosaics
- Examining the relationship between intercellular distance and number of neighboring cells and disease
- Studying CHM progression over the span of a patient's lifetime

Conclusion

In normal sighted control subjects, retinal cone density is greatest in the fovea and decreases with eccentricity from the retina. Genetic retinal diseases such as CHM affect this normal distribution of cone cells, resulting in atrophied regions where cones are either lost or no longer functioning. These results highlight the ability of AO imaging to capture changes in cellular structure caused by retinal disease. This inspires further examination into the relationship between the structure and function of photoreceptors in health and disease.

Acknowledgements and References

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Burns, Stephen A.; Elsner, Ann E.; Sapoznik, Kaitlyn, A.; Warner, Raymond L.; Gast, Thomas J. *Adaptive Optics Imaging of the Human Retina.* Progress in Retinal and Eye Research. 2019.

Cooper, Robert F.; Wilk, Melissa A.; Tarima, Sergey; Carroll, Joseph. *Evaluating Descriptive Metrics of the Human Cone Mosaic.* IOVS. 2016.