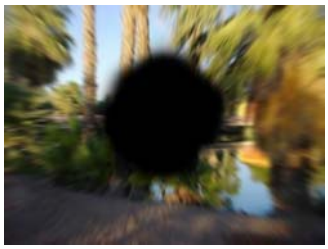
Importance of Fixation Stability in Eccentric Viewing

Karthikeyan Baskaran, Ph.D.
Department of Medicine and Optometry
Faculty of Health and Life Sciences
Linnaeus University, Kalmar

Linnaeus University

Introduction

Low vision is defined as visual acuity less than 0.3 in the better eye with best correction.



Many pathological eye conditions can cause visual impairment and low vision.

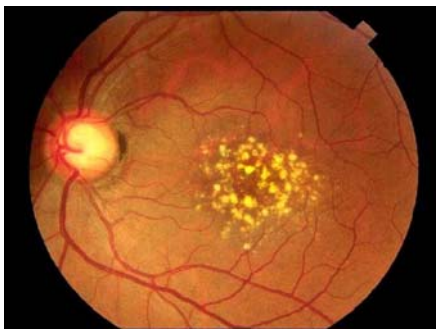
In this talk we focus on low vision subjects with central visual field loss.

Linnaeus University

Central field loss (CFL)

Common cause of central field loss or absolute central scotoma is end-stage macular diseases.

- AMD
- Stargardt's Diseases
- Diabetic Retinopathy
- Hereditary macular disorders
- Other macular diseases

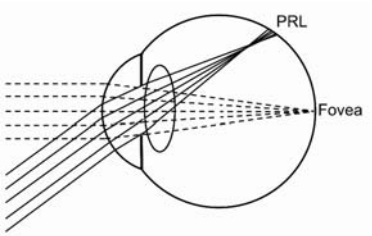


Background

People with absolute central scotoma must rely on their remaining peripheral vision for all vision related tasks.

Most CFL patients adopt eccentric viewing strategy to realign the object of interest on an area of the peripheral retina.

This area located in the peripheral retina is known as the "Preferred retinal locus".



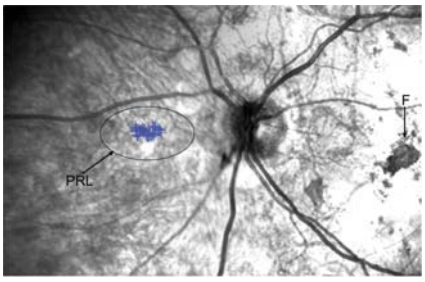
Preferred retinal locus (PRL)

Regions of functioning retina.

Repeatedly aligned with a visual target for a task.

Acts as a ocular motor reference.

Would happen only when the fixation has stabilized

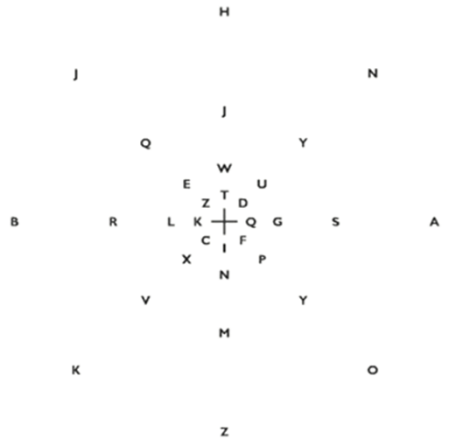


Linnæus University

Background

Resolution acui

- Primarily
- Off-axis
- Poor fixa



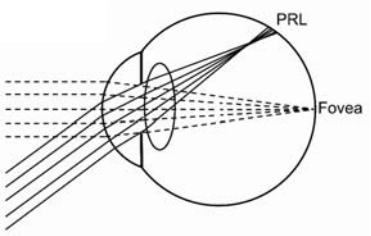
In normal subje
because of eye

Linnæus University

Improving vision at PRL

PRL: low resolution capacity
- Primary limitation is the retina
- Help: magnifying

Optics: poor image quality
- Important when off-axis aberrations are large
- Additional help: off-axis correction



Fixation Stability

The eye is never completely static during a 'fixation task': small involuntary eye movements are made whilst fixating.

These fixational eye movements include drift, physiological tremor, and microsaccades, as well as correcting movements to compensate for movement of the head.

In those without eye disease, despite fixational eye movements, fixation mostly remains within the foveola.

Why fixation stability is important?

In people with central vision loss due to macular disease, this locus of fixation is shifted to an area of relatively healthier retina.

Fixation characteristics such as stability and location are relevant parameters to fully understand the individual quality of vision, especially

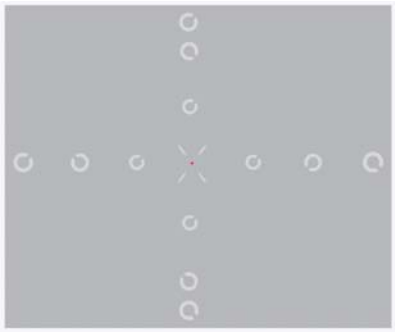
- Reading ability
- Visual acuity

Linnæus University

How to measure fixation stability?

There are multiple ways to measure the stability of fixation but each method has its own advantages and disadvantages.

In general, the subject/patient is asked to look at a specific target for a period ranging from 10 – 30 seconds during which the eye movements are recorded.



Remember that, stability of fixation decreases as retinal eccentricity increases in CFL patients.

Linnæus University

Instruments

Many instruments have been used for measuring eye position and stability

- Eye trackers
  - Infrared eye trackers
- Retinal imaging systems
  - SLO
  - Microperimetry
- Electrophysiological methods
  - Search coils

Infrared eye trackers

Uses cameras with infrared light source illuminating the eye to measure the size of the pupil, position of the pupil and corneal reflection.

High temporal resolution

The faster the temporal resolution of the eye tracker, the more samples it records per second (e.g. 1000Hz = 1 sample per 1ms).

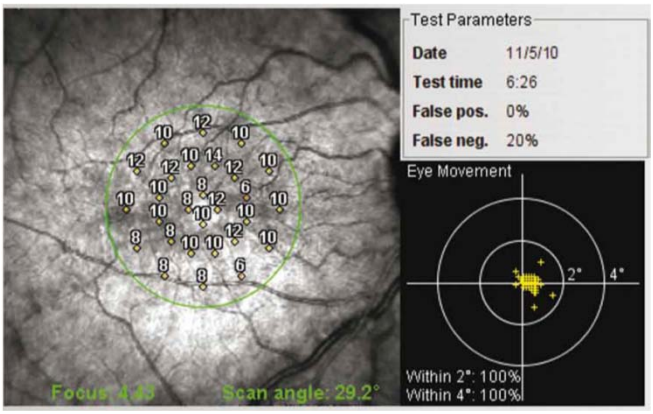
Cannot track the retinal location at the same time.

Retinal imaging systems

Provides both retinal location as well as fixation stability measurements.

Can also perform microperimetry measurements.

Has low temporal resolution of 25 Hz for MP1 and 8 Hz for OCT/SLO system.



Linnaeus University

Quantifying fixation stability

Simplest method is to observe the eye movement trace during a fixation trial and to report qualitative judgement on its stability.

Standard deviation of Euclidean distance (SDED) from the horizontal and vertical meridian can be also used.

Bivariate contour ellipse (BCEA) can be calculated by finding the area of an ellipse that encompasses a given percentage of fixation points. (68%, 95%)

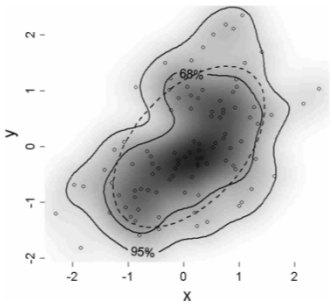
$$BCEA = 2\chi 2\pi\sigma H\sigma V(1-\rho 2)0.5$$

Linnaeus University

Quantifying fixation stability

Fujii classification is a semi-quantitative method and classifies stability as stable or unstable.

- Stable when 75% of fixation falls within a 2° circle.
- Relatively unstable when 75% of fixation falls within a 4° circle.
- Unstable when less than 75% of fixation falls within a 4° circle.



Kernel density estimation (KDE) based on bivariate calculations.

Linnaeus University

Fixation stability in different diseases (BCEA)

Normal subject (foveal fixation) – 150 minarc^2 – 553 minarc^2 (2.10 – 2.74 logminarc^2)

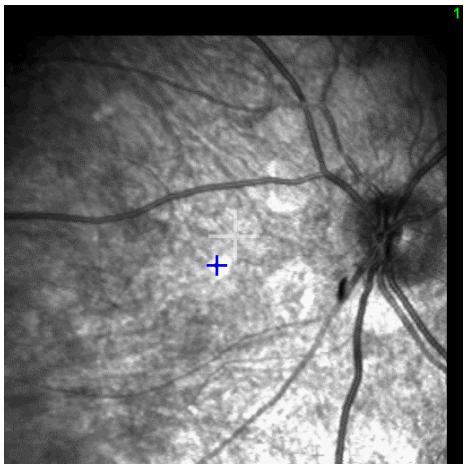
AMD with established PRL – 1770 minarc^2 to 7220 minarc^2 (3.25 – 3.86 logminarc^2)

JMD with established PRL – 1150 minarc^2 to 3705 minarc^2 (3.06 – 3.57 logminarc^2)

Early macular disease <4 weeks – 14500 minarc^2 to 21700 minarc^2 (4.16 – 4.34 logminarc^2)

Linnaeus University

Fixation stability in JMD patient



Unstable fixation

Stability during a fixation task varies according to many ocular and non-visual factors.

- Type of target used for fixation has an effect
- Amount of head immobilization
- The instrument used for measurement

Under dark-adapted conditions, eye stability is poorer.

Small eye movements are beneficial in reducing the effect of Troxler's fading in the periphery but increased fixation instability is detrimental.

Visual acuity and reading speed is reduced when simulating reduced eye stability by jittering text.

New instruments

New novel low cost technologies to measure fixation stability and scotometry are currently researched.

Using a digital light projector (DLP) as the imaging source, a series of lines are rapidly projected onto the retina to simulate line scanning.

Light return is spatially filtered by the electronic rolling shutter of a CMOS sensor to achieve high contrast confocal imaging.

Linnaeus University

Study 1 with the new device

To perform kinetic perimetry (scotometry) and assess fixation stability using a low cost confocal retinal imaging device.

The Digital Light Ophthalmoscope for Low Vision (DLO-LV) achieves real-time confocal imaging at 20 frames per second.

It uses a digital light projector for illumination that provide a wide range of custom stimuli with simultaneous retinal imaging.

Fixation stability can be estimated using various methods, such as BCEA, SDED and KDE.

Linnaeus University

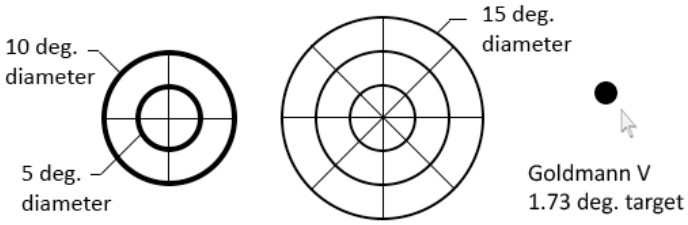
DLO – LV

Methods

Kinetic perimetry was performed on 13 undilated normal subjects aged 25 – 63 year.

Fixation stability was also assessed with subjects fixating on a cross for a duration of 4 seconds.

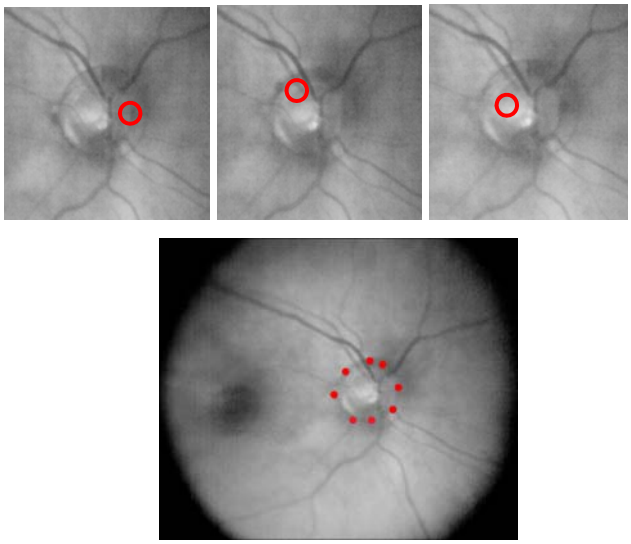
Bivariate Contour Ellipse Area (BCEA) was calculated for determining fixation stability.



Results - Scotometry

Stimuli were visible on the image frames, providing precise visual function testing.

Superimposing the fundus images agreed with the boundaries of the optic nerve head.



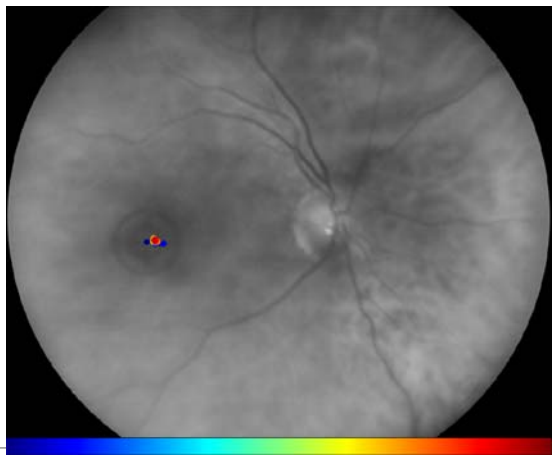
Linnaeus University

Results – Fixation Stability

Eye positions were obtained by aligning a region of interest (ROI) in the first image to the remaining images by a method of cross-correlation.

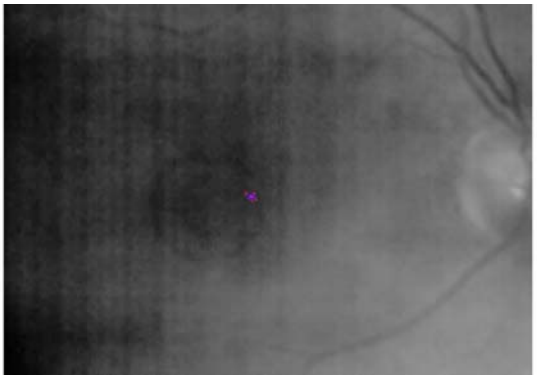
The mean fixation stability was 2.10 log min arc^2.

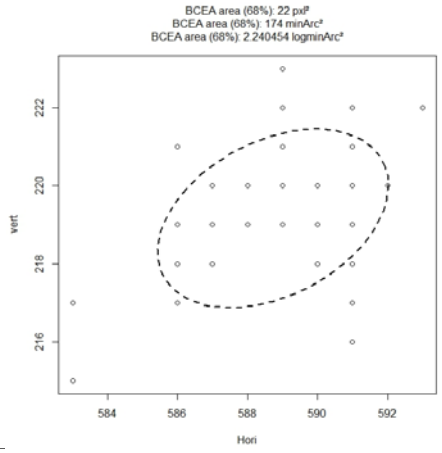
Dunbar et al. showed similar findings with a SLO 2.26 log min arc^2.



Linnaeus University

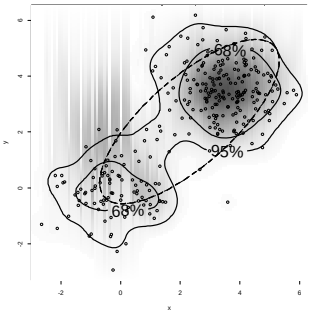
Results – Fixation Stability

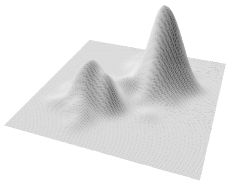


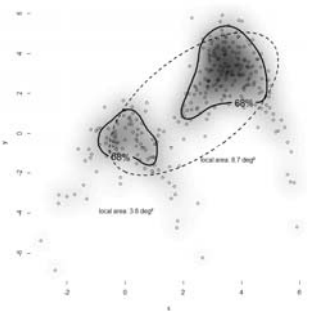


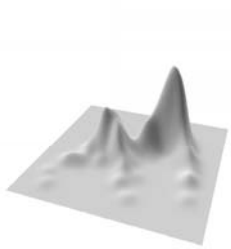
Linnæus University

KDE isoline contours for multiple PRL's estimation









Linnæus University

Study 2 with the new device

To identify whether patients with diabetic macular edema(DME) have poorer fixation stability compared to patients without DME

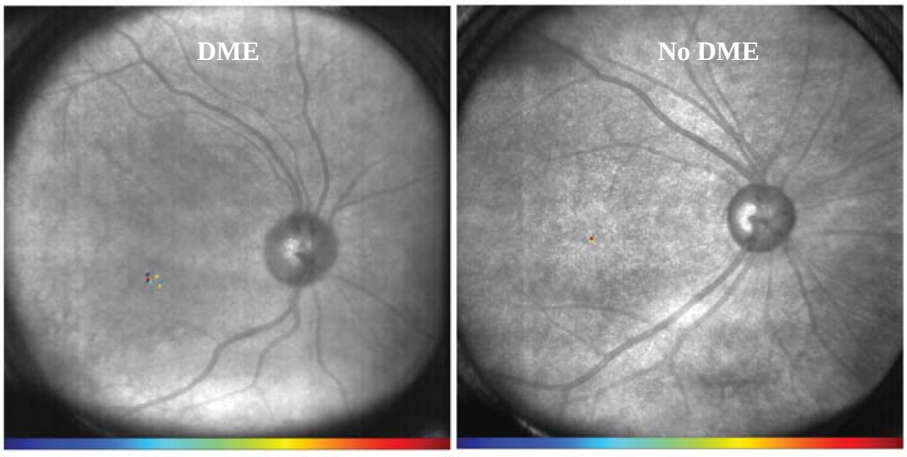
Fifty patients with DME and fifty patients without DME were included in this study

A series of 20 images (36 deg field, 1024 X 1024 pixels, and 850 nm) were acquired at 11 fps.

Eye positions were obtained by selecting a region of interest in the first image of each series and aligning the remaining images to that region by cross-correlation (image stacking).

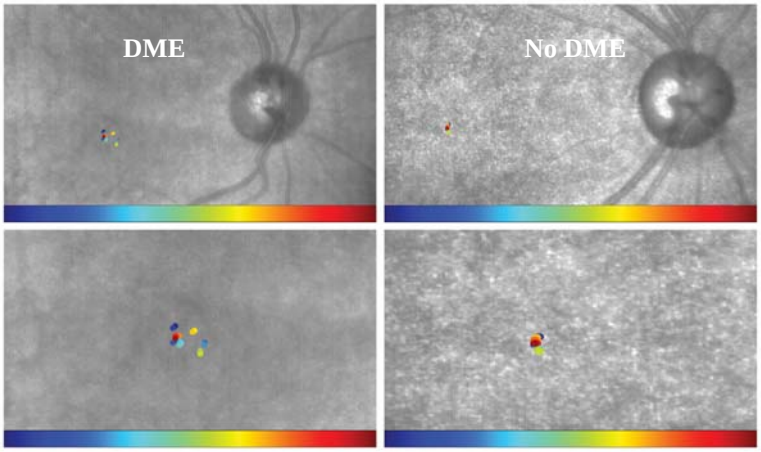
Linnaeus University

Fundus Image



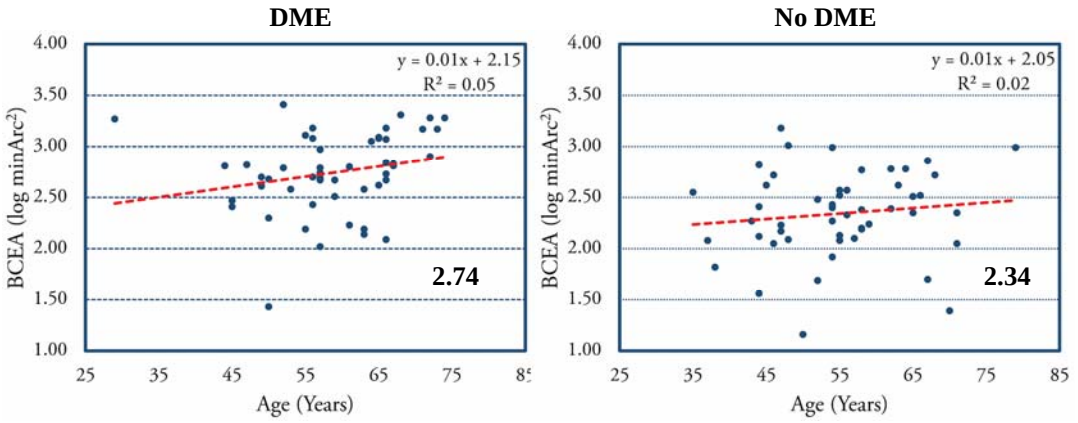
Linnaeus University

Fixation stability



Linnæus University

Age vs Fixation stability



Linnæus University

Conclusion

The DLO – LV with integrated visual function testing is a flexible and cost-effective platform.

The device can be used for conducting kinetic perimetry, scotometry and fixation stability assessment in low vision subjects.

Summary

Fixation stability is reduced in people with central vision loss who use a non-foveal PRL.

In people with macular disease, better fixation stability is associated with a faster reading speed.

The importance of fixation stability on other visual tasks is not well understood and is a subject in need of further research.

References

1. E. Castet & M. Crossland Seeing and Perceiving 25 (2012) 449–469.
2. Bellmann et al Fixation Stability in Age-Related Macular Degeneration, Ophthalmology Volume 111, Number 12, December 2004.
3. Liu, Hongting et al. “Fixation Stability Measurement Using Two Types of Microperimetry Devices.” Translational Vision Science & Technology 4.2 (2015): 3. PMC. Web. 16 Sept. 2015.
4. Elsner, Ann E. et al. “Fixation Stability and Scotoma Mapping for Patients with Low Vision.” Optometry and vision science : official publication of the American Academy of Optometry 90.2 (2013): 164–173. PMC. Web. 16 Sept. 2015.

Linnæus University

Linnæus University

INDIANA UNIVERSITY
SCHOOL OF OPTOMETRY

AEON
AEON IMAGING, LLC






Linnæus University

Thank You!