BIOS3001 Advanced Visual Neuroscience

Psychophysics of Reading

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Outline

- Psychophysics of reading with normal vision
  - Legibility and fonts
  - Bandwidth and other factors
- Reading with impaired vision
  - Role of retinal sensitivity
  - Fixation location and stability
  - Eye movements in low-vision reading
  - Visual span

Reading Researchers

- Miles Tinker, University of Minnesota
  - Published from 1926 to 1963
  - "Studies of typographical factors influencing speed of reading" (1 – 13)
- George McConkie, University of Illinois
  - Visual span, eye movements, and reading
- Keith Rayner, University of Massachusetts
  - "EZ Reader" model of eye movements in reading
- Kevin O'Regan, CNRS Paris
  - Optimal landing position
- Gordon Legge, University of Minnesota
  - "Psychophysics of reading" (1 – 20)
  - "Mr Chips" model of eye movements in reading

Factors that Influence Text Legibility

- Letter size
- Contrast of text vs background
- Colour of text and background (contrast again)
- Letter spacing and spacing between lines
- Layout
- Font

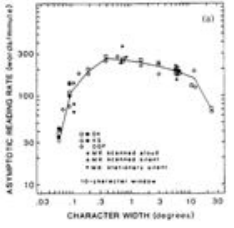
The Obvious Importance of Letter Size

No one would question the importance of letter size as a primary determinant of text legibility.

But surprisingly, print size is often too small to be read by the target population.

This problem is especially evident in informational labelling such as medicine warning labels.

Reading Rate vs Letter Size



- Range covered from 2 mm – 20 cm @ 40cm
- Broad peak at 12 pt. equivalent (6/12)
- Decline at smaller letter size due to resolution
- Decline at larger letter size due to eye movements

G. E. Legge, D. G. Pelli, G. S. Rubin, M. M. Schleske, Psychophysics of reading. I. Normal vision. *Vision Res* **25**, 239 (1985).

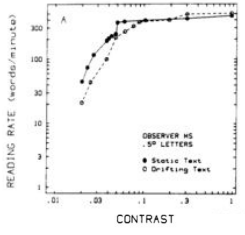
The Importance of Contrast

Second in importance after letter size is the role of contrast

The importance of contrast is often overlooked because people with normal vision are very tolerant of reduced contrast

But people with low vision can have great difficulty reading low contrast text, even if the letters are sufficiently large

Reading Rate vs Contrast



fortune
working
tearful
visible

G. E. Legge, G. S. Rubin, A. Luebker, Psychophysics of reading V. The role of contrast in normal vision. *Vision Res* **27**, 1165 (1987).

Confusion over Colour

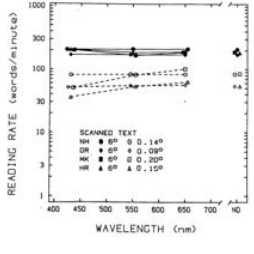
People often have strong feelings about the importance of colour

Readers have definite preferences for text and background colour combinations

Graphics designers like to use colour for aesthetic and informational purposes

But the evidence suggests that it all comes down to contrast

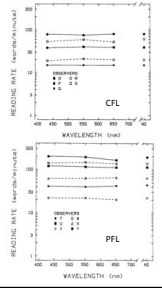
Reading Rate vs Text Colour

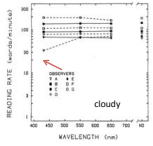


- **Despite preferences, there is no difference in reading rates according to text colour**
- **Provided that luminance and luminance contrast are controlled**

G. E. Legge, G. S. Rubin, Psychophysics of reading. IV. Wavelength effects in normal and low vision. *J Opt Soc Am* **3**, 40 (1986).

Text Colour and Low Vision





- **No significant differences for most people with low vision**
- **Except those with corneal opacity**
- **Due to Rayleigh scattering**

G. E. Legge, G. S. Rubin, Psychophysics of reading. IV. Wavelength effects in normal and low vision. *J Opt Soc Am* **3**, 40 (1986).

Tricks with Fonts

10 point
FFS Beware of those who use the truth to deceive.
HV Beware of those who use the truth to deceive.
TPC Beware of those who use the truth to deceive.
TNR Beware of those who use the truth to deceive.

12 point
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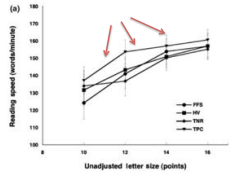
The claims

- **Serifs "guide" eye movements**
- **Sans serif subject to less crowding**
- **Fonts can be optimized for low vision**

Data Supporting the Importance of Font Design



- Tiresias is read faster than other fonts
- Tiresias is preferred to other fonts

G. S. Rubin, M. Feely, S. Perera, K. Ekstrom, E. Williamson, The effect of font and line width on reading speed in people with mild to moderate vision loss. *Ophthalmic Physiol Opt* **26**, 545 (Nov, 2006).

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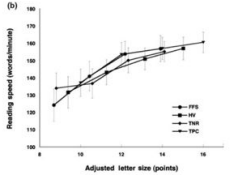
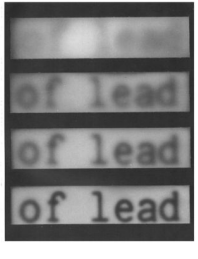
Data Supporting the Un-Importance of Font Design

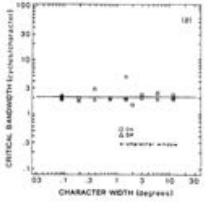


- When adjusted for space occupied there is no difference in reading speed
- Font design has minimal influence on reading speed
- With some exceptions

G. S. Rubin, M. Feely, S. Perera, K. Ekstrom, E. Williamson, The effect of font and line width on reading speed in people with mild to moderate vision loss. *Ophthalmic Physiol Opt* **26**, 545 (Nov, 2006).

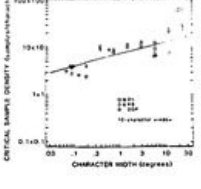
Bandwidth





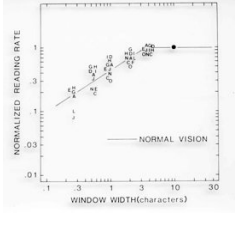
G. E. Legge, D. G. Pelli, G. S. Rubin, M. M. Schleske, Psychophysics of reading. I. Normal vision. *Vision Res* **25**, 239 (1985).

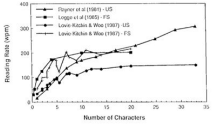
Sampling Density



G. E. Legge, D. G. Pelli, G. S. Rubin, M. M. Schleske, Psychophysics of reading. I. Normal vision. *Vision Res* **25**, 239 (1985).

Number of Characters Visible





G. E. Legge, D. G. Pelli, G. S. Rubin, M. M. Schleske, Psychophysics of reading. I. Normal vision. *Vision Res* **25**, 239 (1985).

Summary

- Reading is amenable to well-controlled psychophysical study
- Many of the factors that determine text legibility are well understood – for people with normal vision
- Size, contrast, bandwidth are important
- Colour *per se* and font are not
- Other important factors not discussed – spacing, crowding and layout
- What can we learn from studying reading in people with visual impairments?

Scotoma Simulation (1985)

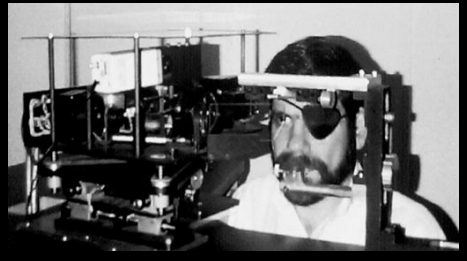
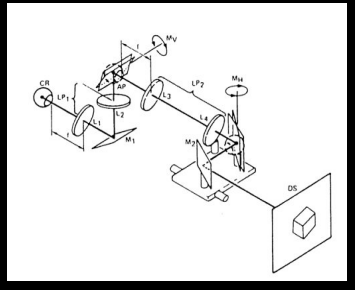


Image Stabilizer Optics

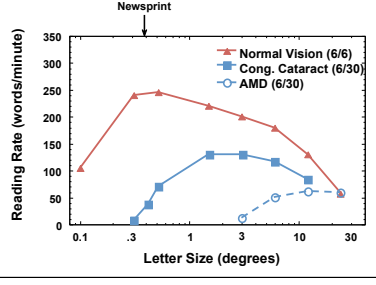


Scotoma Simulation (2001)

(Dis)Advantages of Scotoma Simulation

- **Advantages**
  - Accurate control of scotoma size/density
  - Within-subject experimental design
  - Normal peripheral retina
  - Remove age effects
- **Disadvantages**
  - Technical limitations – delay, slew rate
  - Static simulation vs. dynamic disease process
  - Limited practise and adaptation
  - Normal peripheral retina

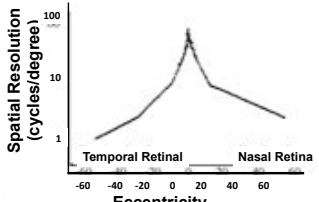
Reading with Visual Impairment



Why is it Difficult to Read without a Fovea?

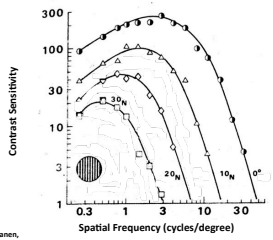
- Reduced Sensitivity of Peripheral Retina
- Impaired Spatial / Temporal Processing in the Periphery
- Poor Eccentric Fixation
- Disrupted Eye Movements
- Reduced Visual/Perceptual Span

Acuity vs. Eccentricity



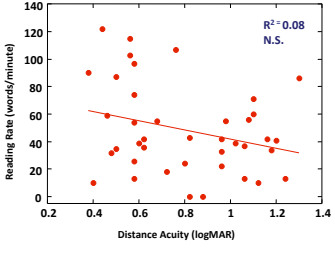
F.W. Weymouth, *Am J Ophthalmol*, 46,102-113 (1958).

Contrast Sensitivity vs Eccentricity

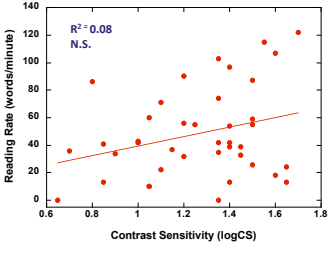


J. Rovamo, V. Virsu, R. Nasanen, *Nature* 271, 54-56 (1978).

Visual Acuity vs Reading Rate



Contrast Sensitivity vs Reading Rate

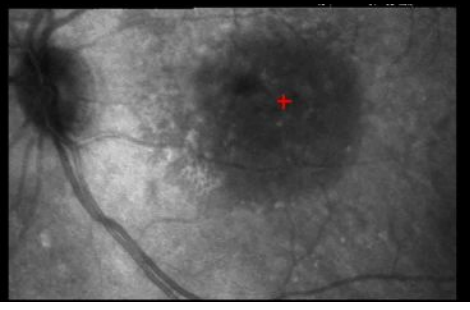


Eccentric Fixation

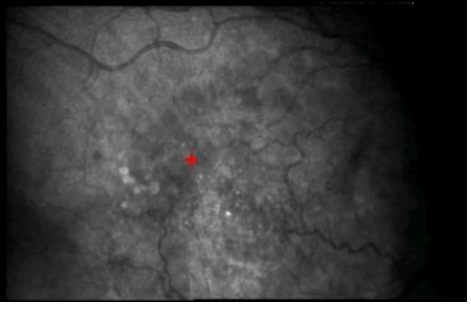
- Patients with AMD and central scotoma must learn to use peripheral retina as a "pseudo fovea" (preferred retinal locus or PRL)
- Efficient use of PRL is important for successful rehabilitation
  - PRL location
  - Fixation stability

Scanning Laser Ophthalmoscope

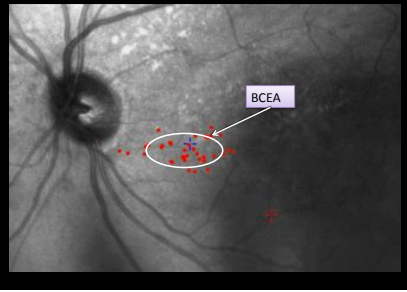
Good Fixation Stability



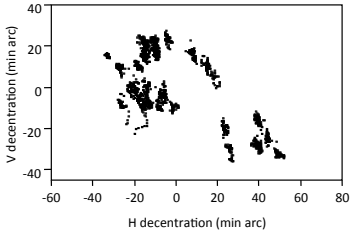
Poor Fixation Stability



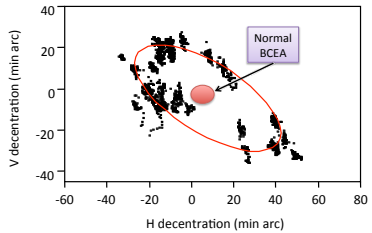
Fixation Area from SLO Map



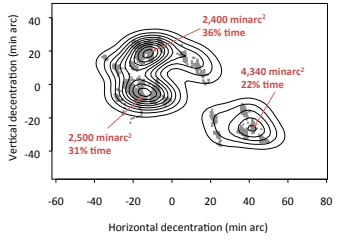
Fixation Data from Eye tracker



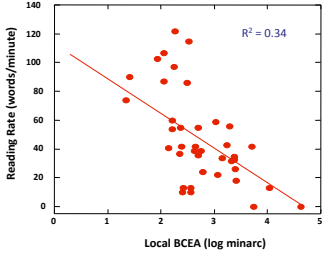
Global BCEA – 21,725 minarc^2



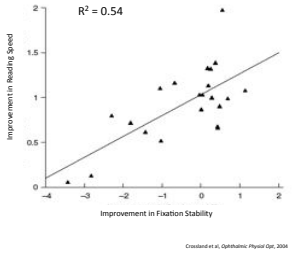
Local BCEA – 9,240 minarc^2



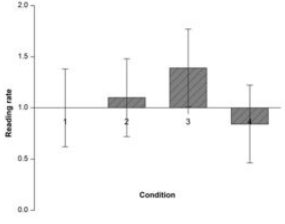
Reading Rate vs Local BCEA



Change in Fixation Stability Predicts Change in Reading Rate

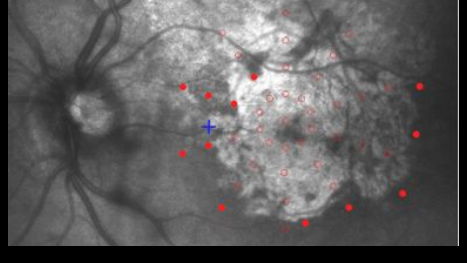


Compensation for Fixation Instability



1: No compensation
2: Full compensation
3: Compensation for fixation only
4: Overcompensation

Scotoma Map



PRLs and Reading

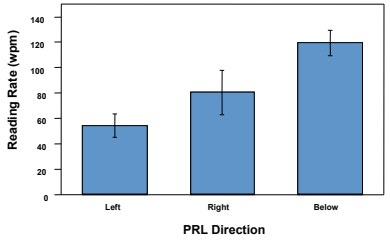
- **Normal vision subjects acquire more information from area to right of fixation (Rayner, et al, 1980)**

You must type precisely one word

≈ 5L 15R

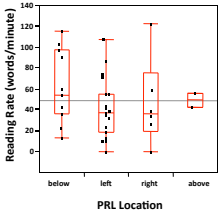
- **PRL below the scotoma gives the largest uninterrupted field of view of to-be-read text**

Reading Rate with Simulated Scotomas



Reading Rate at Different PRL Locations

- PRL location
  - 49% left
  - 28% below
  - 18% right
  - 5% above
- Reading rate does not differ significantly according to PRL location



Disrupted Eye Movements

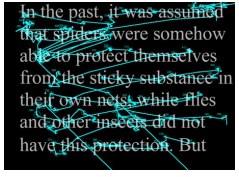
Normal Reading Eye Movements

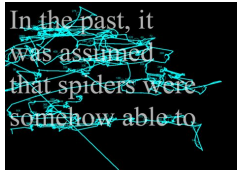
Your mouth is so so big you could swallow a tiger whole

Abnormal Reading Eye Movements

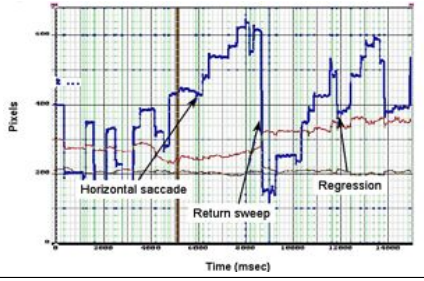
On the poster one may see a splash of red we made there

Eye Movements in Patients

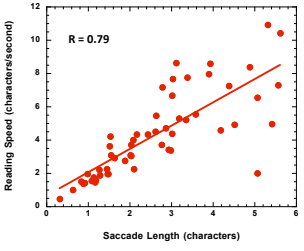




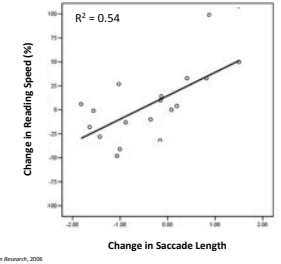
Reading Eye Movements



Reading Speed vs Saccade Length

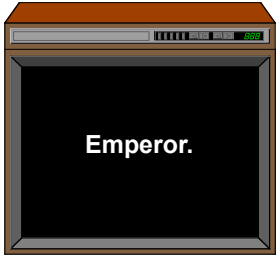


Change in Saccade Length

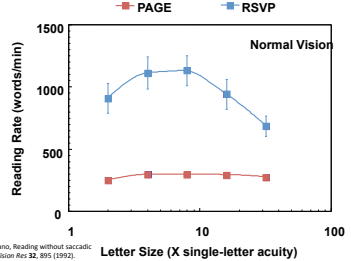


Crossland and Rubin, *Vision Research*, 2006

RSVP Reading

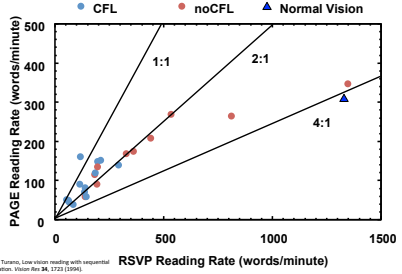


RSVP vs. PAGE Reading Speed



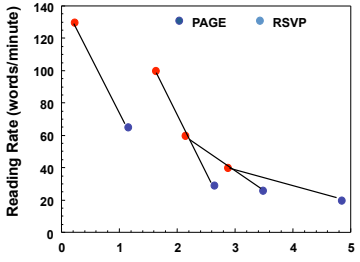
G. S. Rubin, K. Turano, Reading without saccadic eye movements. *Vision Res* **32**, 895 (1992).

RSVP Results



G. S. Rubin, K. Turano, Low vision reading with sequential word presentation. *Vision Res* **34**, 1723 (1994).

Saccades for Page vs. RSVP



G. S. Rubin, K. Turano, Low vision reading with sequential word presentation. *Vision Res* 34, 1723 (1994).

Visual Span and Perceptual Span

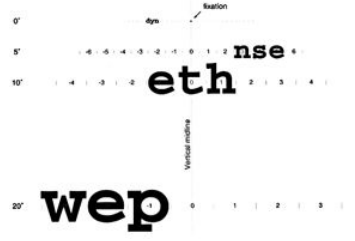
You must type precisely one word

Visual Span
≈ 4L 6R

You must type precisely one word

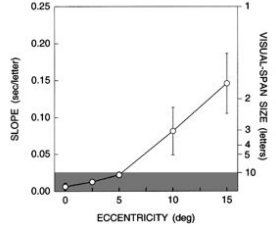
Perceptual Span
≈ 5L 15R

Measuring Visual Span vs. Eccentricity



G. E. Legge, J. S. Mansfield, S. T. Chung, *Vision Res* 41, 725-43. (2001).

Visual Span in Normal Vision



G. E. Legge, J. S. Mansfield, S. T. Chung, *Vision Res* 41, 725-43. (2001).

Summary 2

- **Reading speed in people with central scotomas is much lower than in people with other types of vision impairment**
- **The deficit cannot simply be explained by reduced sensitivity of the peripheral retina**
- **Eye movement factors, such as fixation instability and inefficient oculomotor control may play a role**
- **However, reduction in information processing capacity of the peripheral retina (reduced visual span and information transfer rate) are also likely to be important.**
- **Identifying the causes of difficulty reading without a fovea has lead to useful suggestions for reading rehabilitation in patients with central field loss.**