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

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.

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

Reading Researchers

- Miles Tinker, University of Minnesota
  - Published from 1926 to 1963
  - “Studies of typographical factors influencing speed of reading” (1–15)
- George McGonigle, University of Illinois
  - Visual span, eye movements, and reading
- Keith Rayner, University of Massachusetts
  - “Eye 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)
  - “VR Chips” model of eye movements in reading
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

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

Reading Rate vs Text Colour

No significant differences for text people with low vision. Except those with corneal opacity. Due to Heidler scattering.

Text Colour and Low Vision

- No significant differences for text people with low vision.
- Except those with corneal opacity.
- Due to Heidler scattering.

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.

Tricks with Fonts

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

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 poor coupling

Bandwidth

Sampling Density

Number of Characters Visible
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)

(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, slow rate
  - Static simulation vs. dynamic disease process
  - Limited practice and adaptation
  - Normal peripheral retina

Image Stabilizer Optics

Scotoma Simulation (2001)

Reading with Visual Impairment

<table>
<thead>
<tr>
<th>Letter Size (degrees)</th>
<th>Reading Rate (words/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>30</td>
</tr>
<tr>
<td>1</td>
<td>30</td>
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<td>20</td>
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<td>15</td>
<td>200</td>
</tr>
<tr>
<td>20</td>
<td>300</td>
</tr>
</tbody>
</table>

- Normal Vision (N/6)
- Cong. Cataract (6/36)
- AMD (6/30)
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**

**Contrast Sensitivity vs Eccentricity**

**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 minarc²
Local BCEA – 9,240 minarc²

Reading Rate vs Local BCEA

Change in Fixation Stability Predicts Change in Reading Rate

Compensation for Fixation Instability

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
- 45% left
- 28% below
- 18% right
- 5% above
- Reading rate does not differ significantly according to PRL location

Disrupted Eye Movements

Normal Reading Eye Movements

Abnormal Reading Eye Movements
On the poster one may see a splash of red we made there

Eye Movements in Patients
In the past, it was assumed that spiders were somehow able to weave their webs while they were asleep. This idea did not have any scientific backing.
Once upon a time there lived a vain Emperor.
Saccades for Page vs. RSVP

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

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 saccadic 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.