Fixation and Reading

Purpose of Fixation Control

- 80% of our visual experience is during fixation; the other 20% of the time vision is degraded (during saccades).
- Velocity and position errors must be kept to a minimum to optimize acuity for stationary objects.
- However eyes move constantly despite attempt to fixate on a stationary object.
- Perhaps these eye movements prevent fading.
- Much of the activity involved in fixation involves movements on the scale of a few arc minutes.
Components of Visual Fixation

- High frequency tremor of the eyes
  - smallest amplitude component.
  - occurs at a rate of 30-100 Hz.
  - The movements are only about half an arc minute in amplitude and are uncorrelated in the two eyes.
  - This movement is too small to have much visual effect.
- Slow Drift movements
  - usually in the range of 10-15 arc minutes.
  - During fixation of a point, drift will sometimes generate errors (moving the target away from the central fovea) and sometimes correct errors (moving the target toward the central fovea).
  - They may be conjugate or disconjugate, so we think of them as a combination of version and vergence drift.
- MicroSaccades
  - they are not strictly necessary for maintaining fixation on a spot
  - Probably part of saccadic system.
- Slow oscillatory movement
  - 0.04-0.1Hz; ~0.1-0.2deg in amplitude
  - Appears to be conjugate vertically and disconjugate horizontally
Mechanisms

• We don’t really have a good idea of mechanisms underlying fixational eye movements, except perhaps microsaccades.
• Microsaccades are driven through normal saccade circuitry
• One hypothesis was that fixation was simply smooth-pursuit (gaze-holding eye movement) at zero velocity
  – Not well supported
  – fixation may be a separate oculomotor control system

Disorders of Fixation control

• Amblyopes exhibit decreased microsaccades and increased drifts in the amblyopic eye.
  – reports of rapid fading of targets during monocular fixation with the amblyopic eye
• Fixation is disrupted whenever inappropriate eye movements occur on attempted steady gaze.
  – square wave jerks occur occasionally in normals
  – Other pathological saccadic intrusions
  – Nystagmus - example is congenital nystagmus, in which the eye drifts away from the desired fixation point and must be reset with a saccade.
Disorders of Fixation control

• Eccentric Fixation occurs when patients have a central scotoma, such as occurs for example with Age Related Maculopathy.
  – Typically such patients will pick a particular spot outside their fovea to fixate with, called a Preferred Retinal Locus (PRL).
  – Young patients with central scotomas tend to develop more stable PRLs, while older patients tend to be more variable.
  – In a patient with a stable PRL, saccades become recalibrated, so that saccades made to a peripheral target will cause the target to land directly on the PRL.
  – Strabismics will also sometimes show eccentric fixation, even though the fovea may be intact.

Reading

• During scanning eye movements, a series of saccades are made in order to inspect a scene.
• Reading constitutes a special case in which the eyes scan across a line of text with a series of saccades, forming an eye movement trace that resembles a staircase.
• It is still poorly understood how the information from each discrete fixation is integrated to form our perception of a smooth flow of information.
Patterns of reading eye movements

Normal reading eye movements

• Fixations
  – periods when the eyes are relatively still
  – do not necessarily correspond to individual words in the text.
  – over 90% of the time spent reading is spent in fixation periods.
• Inter-fixation movements
  – small saccades which take the eye from one fixation to the next.
  – About 90% of these are left to right movements which may jump over just part of a word or over several words.
• Return Sweeps
  – large saccades which take the eye to the beginning of the next line of text.
  – start a few characters from the end of the line and the first fixation is a few characters in from the beginning of the next line.
• Regressions
  – small saccades which go in the reverse direction (i.e. right to left)
  – associated with relatively difficult passages and relatively uncommon words.
  – Represent about 10% of all inter-fixation movements, but this depends on reading difficulty.
  – Normal Regressions tend to be smaller than the inter-fixation saccades that precede them.
Causes of reading difficulty

- Loss of visual clarity is probably the first thing to suspect. For example, amblyopia, refractive error and presbyopia are obvious causes of reading difficulty.
- Binocular anomalies at near can produce diplopia and interfere with reading, even in individuals with normal monocular vision. For example, patients with vertical phoria often report that they lose their place at the beginning of a line of text.
- Restricted motility can also make reading more difficult. For example, Superior Oblique paresis or palsy is commonly noticed by patients as a difficulty with reading because the affected eye(s) cannot depress adequately.
- Acquired or Congential Nystagmus may disrupt reading by reducing the effectiveness of fixations.
  - However, many patients adapt to the problem.
- Dyslexia is a condition in which there is reading difficulty without an obvious visual or oculomotor defect.

Reading in patient with amblyopia – more regressions; increased fixation duration

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Kanonidou et al, IOVS 2010
Apparently normal reading in a patient with congenital nystagmus (INS)

Thomas et al; IOVS 2011

Reading in a patient with Visual-Spatial Dyslexia

• Patterns of reading in dyslexia include large regressions, inaccurate return sweep saccades and reverse staircase patterns
Speed reading

Filled bars: experimental group before and after a speed reading class.
Open bars control group.
Speed reading training reduced the overall number of saccades made, particularly regressions.
From Calef et al JAOA 1999.