

VS III: Ocular Motility and Binocular Vision  
Spring 2006

Saccades, Part II:  
Reading Eye movements

**I. Characteristics of Normal reading patterns**

- Visagraph is an innovative instrument used to record eye movements while reading.  
→The device employs goggles that detect reflected light from the cornea.
  - That positional information is then sent to a recording device.
  - The advantage is that it is noninvasive and non-threatening to the patient.

\*\*\*\*Clinical note: As powerful a tool as this instrument is, you also need to know a drawback in its variability: good readers have very reproducible results with the Visagraph, and the poorest readers typically hug the "Grade 1" line repeatedly. However, the majority of kids tested in between these two categories will show wide variability from test to test. A possible explanation is that the cognitive demands of the paragraph slow down the eye movements. This means that you must be very careful in 1) what level you have your patient read, and 2) that if you have a poor result to retest on a lower level in order to see if the movements improve.

The Visagraph can detect the following areas:

- Fixations
- Regressions
- Return-sweep saccade
- Average span of recognition and perceptual span
- Fixation duration
- Reading rate
- Vergence dynamics

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A. Fixations

- Total number of “eye stops” or pauses during reading. The more difficult the material, the more fixations occur.
- Poor readers make more fixations than good readers do.
- As word length increases, the probability of fixating the word increases (although most are fixated only once)
- Eyes generally move from one fixation point to another left to right via saccades
- Average saccade length is 8 characters, with a range of 1-18 characters
- Percentage of total reading time taken up by the eye mvts themselves is only 7-10%

B. Regressions

- Fixations that go from right to left by backward mvts during reading.
- Most are just a few characters in length; reflect text confusion or comprehension problems; also maybe rechecking the material
- Kids learning to read and poor readers make lots of regressions. Normally, only 10-15% of saccades or fixations are regressive.
- Uncommon words are refixated more than common words

C. Return-sweep saccade

- Large right-to left slightly oblique saccade that shifts the eyes from the end of the line to the beginning of the next one.
- Sweep begins 6 character spaces from the end of one line and moves the eyes to the 6<sup>th</sup> character space on the next line.
- Saccadic duration for these mvts are 40-54msec
- Small corrective saccades can sometimes be found on return sweeps; this reflects a basic eye positioning correction

D. Average span of recognition and perceptual span

- The amount of print that the patient can perceive and process with each fixation
- Span of recognition is in units of “words” and is calculated by dividing the number of fixations into the number of words per paragraph
- Perceptual span is the maximum effective text processing field during a fixation (e.g. the area that is processed, Vs the numbers of words processed)
- Perceptual span is asymmetric: 4 characters to the left and 15 characters to the right of the fixation point→ this means that the next fixation goes into an area that has already been processed to some extent on the previous fixation.
- Exact mechanism is a mystery.....

E. Fixation duration

- The length of time in msec that the eye remains fixed on a word while reading.
- Average fixation duration is 225 msec (shorter for easy text and longer for hard text)
- Fixation duration can vary with:
  - Word ambiguity
  - Grammatical function
  - Predictability
- Fixation duration doesn't really vary with:
  - Line length                      Color
  - Illumination                      Typography

\*\*\*\*\*It is only during fixation periods that visual information is extracted; during interfixational saccades, saccadic suppression and omission occur, so you don't see a big "smear" of visual information.

#### F. Reading rate

- Number of words read per unit time
- Specified by words/minute
- Also called the rate of comprehension
- Average reading rate for college students is 200-350 wpm
- Varies with level of difficulty of the material: harder material is slower and easier material is faster
- Most folks skim at 400-500 wpm, and some can go up to 1000-2000 wpm
- Speed-readers can skim up to 2000-10,000 wpm! They may be fixating only one word per line, however, to just give an overall sense of the reading material, with little comprehension for average details.

#### G. Vergence dynamics

- During large return sweeps, there is a transient over-convergence of the eyes immediately followed by a corrective dynamic divergence response (lasts 300 msec) to attain more accurate fixation.

### II. **Foveal and Parafoveal Contributions to reading**

- "Foveal" is +/- 1 degree and "parafoveal" is +/- 5 degrees
- These areas are crucial to reading process
- 1-2 degree left-to-right reading saccades take place to resolve (make clear) and then process the fixated letter groups.
- Some experiments showed the following:
  - The fovea and near parafovea are involved in word processing, but the far parafovea is involved mostly in guiding your eye movements to the next fixation location.
  - If a scotoma is centered on the fovea, then the effects to reading are the greatest, and reading rate decreased significantly.
  - If there is a scotoma on either side of the fovea (which simulates hemifield loss), then the reading rate can also be impaired, even if the fovea is intact. It is especially bad if the scotoma is on the right. Why?????

\*\*\*\*Clinical note: These findings have great implications for folks who have disease or trauma-related visual field loss. The good news is that there are techniques to help these folks to regain their reading ability. The area of Optometry concerned with helping these folks is called "Neuro-Optometric Rehabilitation." Or just "Vision Rehab" for short. You can play a HUGE part in helping these folks to regain such a precious thing: reading.

### III. **Abnormal reading eye movements and related oculomotor parameters**

- A. Binocular anomalies
- B. Dyslexia
- C. Central Neurological Disorders
- D. Peripheral Neurological Disorders
- E. Retinal and Cortical Diseases

### A. Binocular anomalies

Any impediment to binocular sensorimotor processing can adversely impact all near-vision tasks; binocular vision problems especially impact upon reading, for reading involves sustained bifixation, focus, and attention.

The following are some binocular vision problems that can negatively impact reading ability: (you will see ALL of these in clinic)

- Aniseikonia
- Anisometropia
- High near phoria (esp. exophoria)
- Poor fusional ability
- Large fixation disparity
- Receded near point of convergence (NPC)
- Strabismus (esp. intermittent)
- Suppression
- Poor binocular coordination
- Convergence insufficiency

However, there are a few things that don't seem to affect reading ability as much:

- Esophoria at near
- Distance lateral phoria
- Vertical phoria

Vision Therapy and/or appropriate lenses/prisms can remediate ALL of the above listed problems with respect to motor response dynamics and accuracy, as well as reducing symptoms. That's the bottom line.

### B. Dyslexia

Two basic categories of dyslexia: developmental/congenital and acquired.

**Developmental/congenital dyslexia** is the most commonly encountered and refers to a specific reading disability, such that the child is at least 2 years behind expected grade level of reading, but has normal intelligence and sensory vision. Another important caveat is that there are NO neurological or emotional disorders.

**Developmental dyslexia** is further divided into

- Language-deficit dyslexia
- Visual-spatial dyslexia
  - **Language-deficit dyslexia**: patients have an increased amount of regressions, small amplitude saccades, and prolonged fixation duration when reading text appropriate for their age level.
  - However, when you give them material that is appropriate for their reading level, then the overall pattern tends to normalize. So...it's really a problem with processing information, rather than a true eye movement problem. This is the most common type.
- In **Visual-spatial dyslexia**, the patient has inaccuracies of the return sweep saccade. The abnormal reading eye movement pattern essentially reflects a basic problem in processing visual-spatial relations. So....the eye movement problems will manifest in both reading and in nonreading sequential eye movement tasks.

→ bottom line is that in folks with dyslexia, the abnormal eye movement patterns reflect either language or spatial problems (or maybe both in a few folks), but the eye mvts themselves DO NOT cause dyslexia.

### **Acquired dyslexia**

- Much less common; refers to a reading disability in a previously normal reader after neurological dysfunction or damage (e.g. a stroke).
- They usually complain of reading difficulty, reduced comprehension, and problems in sequencing their eye movements, problems maintaining fixation, and head mvt required to read.

→ In folks with dyslexia, there is a very disorganized pattern to the Visagraph tracing.

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The thing to note with all of these is that the eye movement problem itself is partly what is causing the difficulty in reading, and not just dyslexia. Having an extraocular muscle dysfunction means that the patient literally doesn't know where the eyes are on the page, loses his place while reading and cannot get much meaning from what he manages to read. In dyslexia, the dyslexia itself does not cause the eye movement problems, but it does interfere in processing what the patient sees and tries to understand. Many patients with dyslexia have BOTH an eye movement and binocular vision dysfunction AND true dyslexia, so not only can they not physically read what is on the page due to their vision, but they also cannot process what they see in a meaningful way.

### C. Central Neurological Disorders

Many central neurological problems like MS and cerebellar disorders often produce oculomotor problems (remember our discussion of abnormal fixations?) The following can cause reading problems:

- Nystagmus
- Disease-related field loss (hemifield, etc)
- MS
- Duane's Syndrome
- EOM palsies or paresis
- Spinocerebellar degeneration
- Wilson's disease

### D. Peripheral Neurological Disorders

The most common peripherally based neurologic condition is paresis or paralysis of an EOM. This limits the ability of the eye to make normal saccades.

#### E. Retinal and Cortical Diseases

These can cause either central (macular disease) or peripheral (retinitis pigmentosa) scotomas and can really cause problems with reading.

\*\*\*\*Clinical note: folks with central/macular disease have real problems in comprehending what they read (e.g. word processing), while folks with peripheral disease have much more problem with guiding their eyes to the next saccade and fixation; therefore, the accuracy of the saccade goes down, as well as the span of recognition.

#### IV. **Training reading Eye Movements**

There is much evidence that reading eye mvts and reading efficiency can be improved by intervention. Procedures typically include the training of relative vergence during reading, training reading eye mvts using a moveable rate-controlled shutter, and training rapid perception of visual stimuli by tachistoscopic presentation. This therapy can have a tremendous impact on performance in reading, so don't let these kids slide by you. They usually do not get better.

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