



READING EYE MOVEMENTS

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THIS CHAPTER INCLUDES A REVIEW OF:

- Characteristics of Normal Reading Patterns
- Foveal and Parafoveal Contributions to reading
- Abnormal Reading Eye Movements and Related Oculomotor Parameters
- Training Reading Eye Movements

CHARACTERISTICS OF NORMAL READING PATTERNS

A 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 non-invasive 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 children 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, 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

A. FIXATIONS	<ul style="list-style-type: none"> • Refers to the 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 movements themselves is only 7-10%
B. REGRESSIONS	<ul style="list-style-type: none"> • These are fixations that go from right to left by backward movements during reading. • Most are just a few characters in length; reflect text confusion or comprehension problems; also maybe rechecking the material. • Children learning to read and poor readers make lots of regressions. Normally, only 10-15% of saccades or fixations are regressive. • Uncommon words are fixated on more often than common words.
C. RETURN-SWEEP SACCAD	<ul style="list-style-type: none"> • A 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 6th character space on the next line. • Saccadic duration for these movements is 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	<ul style="list-style-type: none"> • 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 span considered during a fixation, i.e. the area that is processed versus the number 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	<ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> - Word ambiguity - Grammatical function - Predictability • Fixation duration doesn't really vary with: <ul style="list-style-type: none"> - Line length - Illumination - Colour - Typography
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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	<ul style="list-style-type: none"> • 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	<p>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.</p>

FOVEAL AND PARAFOVEAL CONTRIBUTIONS TO READING

- 'Foveal' is +/- 1 degree and 'parafoveal' is +/- 5 degrees
- These areas are crucial to the reading process
- 1-2 degrees left-to-right, reading saccades take place to resolve (make clear) and then process the fixated letter groups.

Some experiments revealed 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 centred on the fovea, then the effects on reading are the greatest, and the reading rate decreases significantly.
- If there is a scotoma on either side of the fovea (which simulates hemi-field loss), then the reading rate can also be impaired, even if the fovea is intact. It is especially difficult if the scotoma is on the right. Why might this be?



CLINICAL NOTE:

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

ABNORMAL READING EYE MOVEMENTS AND RELATED OCULOMOTOR PARAMETERS

Abnormal reading eye movements may occur as a result of any of the following:

- 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 have an adverse impact on all near-vision tasks. Binocular vision problems especially impact on reading because reading involves sustained bifixation, focus, and attention.



The following are some binocular vision problems you will see during clinic that can negatively impact on reading ability:

- Aniseikonia
- Anisometropia
- High near heterophoria (especially exophoria)
- Poor fusional ability
- Large fixation disparity
- Reduced near point of convergence (NPC)
- Strabismus (especially intermittent)
- Suppression
- Poor binocular coordination
- Convergence insufficiency

However, there are binocular vision problems 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 reduce symptoms.

B. DYSLEXIA

There are two basic categories of dyslexia:

1. Developmental/Congenital
2. Acquired

1. DEVELOPMENTAL/CONGENITAL DYSLEXIA

This is the most commonly encountered type of dyslexia and refers to a specific reading disability, such that the child is at least 2 years behind the expected level of reading for his/her age, but has normal intelligence and sensory vision. Another important feature of developmental dyslexia is that there are NO associated neurological or emotional disorders.

Developmental dyslexia is further divided into

- Language-deficit dyslexia
- Visual-spatial dyslexia

Language-deficit dyslexia:

Patients with language-deficit dyslexia have an increased number 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. This confirms that it is really a problem with processing information, rather than a true eye movement problem. This is the most common type of developmental dyslexia.

Visual-spatial dyslexia:

Patients with visual-spatial dyslexia have inaccuracies of the return sweep saccade. The abnormal reading eye movement pattern essentially reflects a basic problem in processing visual-spatial relations. The eye movement problems manifest in both reading and non-reading sequential eye movement tasks. These patients will present with abnormal eye movement patterns that reflect either language or spatial problems (or maybe both in a minority of people) but the eye movements themselves DO NOT cause dyslexia.

2. ACQUIRED DYSLEXIA

- Acquired dyslexia is much less common and 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/or head movements required to read.

In people with dyslexia, there is a very disorganized pattern when traced using a Visagraph.

C. CENTRAL NEUROLOGICAL DISORDERS	<p>Many central neurological problems like MS and cerebellar disorders often produce oculomotor problems. The following oculomotor problems can cause reading difficulties:</p> <ul style="list-style-type: none"> • Nystagmus • Disease-related field loss (hemifield, etc.) • Multiple Sclerosis • Duane's Syndrome • EOM palsies or paresis • Spinocerebellar degeneration • Wilson's disease
D. PERIPHERAL NEUROLOGICAL DISORDERS	<p>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.</p>
E. RETINAL AND CORTICAL DISEASES	<p>These can cause either central (macular disease) or peripheral (retinitis pigmentosa) scotomas and can cause great difficulty with reading.</p>


CLINICAL NOTE:

People with central/macular disease have real challenges comprehending what they read (i.e. word processing), while people with peripheral disease find more difficulty guiding their eyes to the next saccade and fixation; therefore, the accuracy of the saccade as well as the span of recognition goes down.

TRAINING READING EYE MOVEMENTS

There is much evidence that reading eye movements and reading efficiency can be improved by certain intervention techniques. These typically include the exercises to improve relative vergence during reading, special training to improve reading eye movements using a moveable rate-controlled shutter and techniques to improve rapid perception of visual stimuli by tachistoscopic presentation. This therapy can have a tremendous impact on reading performance which is why it is so important to detect these problems in children as early as possible.

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