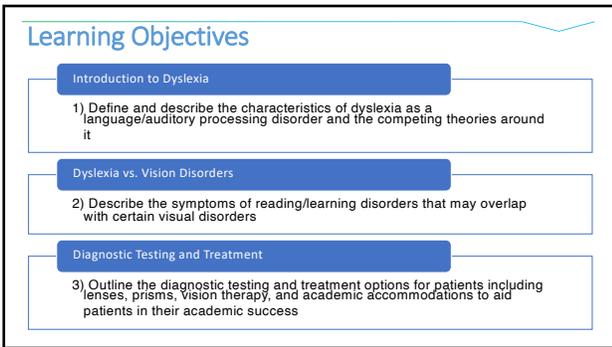




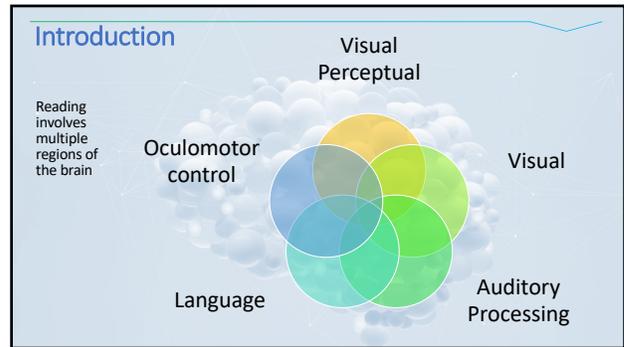
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4



5



6

### Dyslexia: Epidemiology

- 6-7% of the school population in special education has a learning disability
  - 85% have a primary learning disability in reading and language processing
- ~10% of population has dyslexia
  - Up to 15-20% of population as a whole may have some symptoms of dyslexia
- Genetic component?
  - ~40% of siblings, children or parents of an affected individual will have dyslexia

Dyslexiaida.org

7

### Signs/Symptoms of Dyslexia

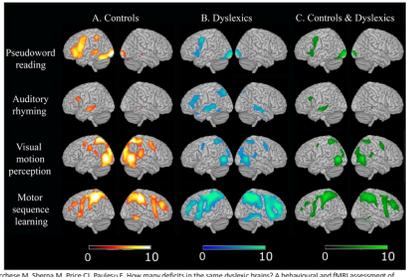
- Trouble learning nursery rhymes
- Trouble remembering the names of the letters in the alphabet
- Difficulty with rhyming
- Trouble sounding out words
- Slow reading skills
- Trouble learning new words
- Avoids reading out loud
- Reduced comprehension/laborious reading
- Poor concentration



8

### Dyslexia: Etiology

Figure 2. Activation patterns for normal readers and dyslexic readers. On the right-hand side commonalities between normal readers and developmental dyslexics are reported. Effects were thresholded at  $p < .05$  corrected for multiple comparisons (FWE-corrected). On the bottom, the colour scales indicate the significance of the SPMs[2] maps. Only voxels surviving a FWER  $p < 0.05$  threshold are visualized.



Danelli L, Berlinger M, Bottini G, Bongheise NA, Lucchese M, Sberna M, Price CJ, Paulsen O. How many deficits in the same dyslexic brain? A behavioural and fMRI assessment of comorbidity in adult dyslexics. Cortex. 2017 Dec;97:125-142. doi: 10.1016/j.cortex.2017.08.038. Epub 2017 Sep 22. PMID: 29107746; PMCID: PMC5722195.

9

### Dyslexia: Diagnosis

- Comprehensive education evaluation including language skills
  - Receptive (listening) skills
  - Expressive language skills
- Phonological skills
  - Phonological awareness
    - Phonological or language-based memory
- Rapid number naming
- Receptive vocabulary
- Phonic skills
- Decoding
- Oral reading fluency
- Spelling
- Writing



10

Comparative Study > Am Ann Deaf. 2012 Summer;157(3):289-306. doi: 10.1353/aad.2012.1621.

### A comparison of phonological processing skills of children with mild to moderate sensorineural hearing loss and children with dyslexia

Jungjun Park <sup>1</sup>, Linda J Lombardino

Affiliations + expand  
PMID: 22978204 DOI: 10.1353/aad.2013.0013

> Am Ann Deaf. 2013 Spring;158(1):20-40. doi: 10.1353/aad.2013.0013.

### Phonology matters: a comprehensive investigation of reading and spelling skills of school-age children with mild to moderate sensorineural hearing loss

Jungjun Park <sup>1</sup>, Linda J Lombardino, Michaela Ritter

Affiliations + expand  
PMID: 23858701 DOI: 10.1353/aad.2013.0013

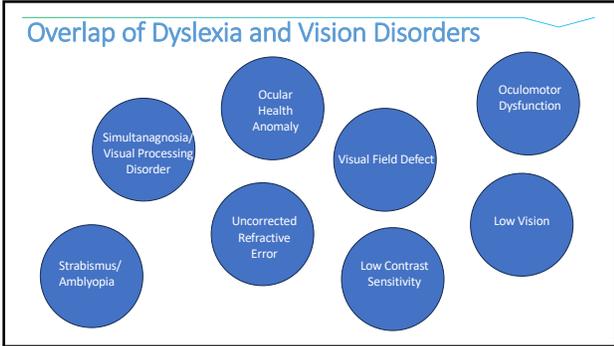
11

### Do Vision problems cause dyslexia?



NO! Vision is **FUNDAMENTAL** to reading, but there is no evidence that suggests visual problems cause dyslexia

12



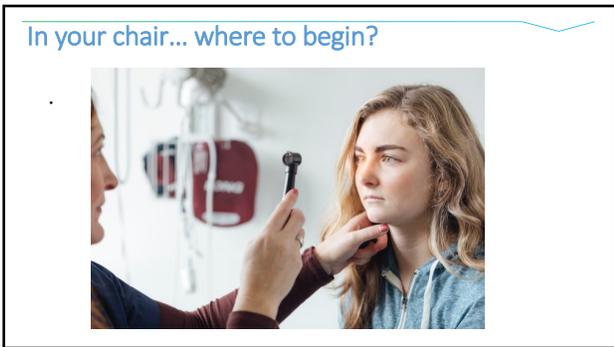
13

### Symptoms of Ocular Motor Dysfunction

- **Visual Motion Sensitivity**
  - Cant tolerate visual motion in the car, on the screen or on the TV
  - Difficulties with scrolling
  - Dizziness/nausea in the car
  - Objects in motion have a trail or afterimage
- **Reading difficulties**
  - Headache
  - Eyestrain
  - Dizziness
  - Nausea
  - Eye pain
  - Loss of place
  - Excessive fatigue
  - Closing an eye
  - Short attention span
  - Cant remember what was read

Cal has really great athletes. They are smart and enjoy going to class and to practice. When they are not on the field they are in the library.

14



15

### Visual Acuity

- Distance OD/OS
- Monocular OD/OS
- Optotypes
  - Letters vs. Lea
  - Isolated (single symbol) vs Crowded
- Pinhole?
  - Ocular Health

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### Refractive Error

Condition	Refractive errors (diopeters)		
	<1 year	1-2 years	2-3 years
<b>IsoAnisotropia</b>			
Myopia	≥-3D	≥-3D	As per refraction
Hyperopia (no manifest deviation)	≥+4D	≥+4D	≥+4D
Hyperopia with esotropia	≥+1.5	≥+1.5	≥+1.5
Astigmatism	≥3D	≥2D	≥2D
<b>Anisometropia (without strabismus)</b>			
Myopia	≥-3D	≥-3D	As per refraction
Hyperopia	≥+2D	≥+1.5D	≥+1.5D
Astigmatism	≥2.5D	≥2D	≥2D

Age	Symmetric	Asymmetric Difference
Less than 1 year old	M>-5, H>+6, A 3D	M -2.50, H +2.50, A 2.50
1-2 years old	M>-4, H>+5, A 2.5D	M -2.50, H +2.00, A 2.00
2-3 years old	M>-3, H>+4.50, A 2D	M -2.50, H +1.50, A 2.00
3-5 years old	M>-2, H>+4.00, A 2D	any aniso of 1.5
5-9 years old	M>-1, H>+3.00, A 1.5D	any aniso of 1.5
9+	M>-0.50, H>+2.00, A 1.5D	any aniso of 1.5

M = myopia, H = hyperopia, A = Astigmatism

VIP-HIP Study Group, Kulp MT, Cimer E, et al. Uncorrected Hyperopia and Preschool Early Literacy: Results of the Vision in Preschoolers-Hyperopia in Preschoolers (VIP-HIP) Study. *Ophthalmology*. 2016;123(4):681-689. doi:10.1016/j.ophtha.2015.11.023

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### Cover Test - Size Matters

Distance Cover Test Target

- Isolated Supra-threshold Target (2-3 lines above Threshold)

18

### Examination

#### Ocular Posture

- Primary Gaze
  - Distance Cover Test
    - OD Fixating
    - OS Fixating
    - Right Tilt
    - Left Tilt
  - Near Cover Test
- Eccentric Gazes

#### Duane White Classification

ESOTROPIA	
Basic	DCT=NCT
Convergence Excess	NCT>DCT
Divergence Insufficiency	DCT>NCT
EXOTROPIA	
Basic	DCT=NCT
Convergence Insufficiency	NCT>DCT
Divergence Excess	DCT>NCT

Duane A. A new classification of the motor anomalies of the eye, based upon physiologic principles. Ann Ophthalmol Otol. Part 1. 1987. Part II Jan.

19

### Cover Test/Ocular Motility

Clinical H	Cover Test/Maddox Rod in 9 fields of Gaze
<ul style="list-style-type: none"> <li>Restriction - ductions</li> <li>Endgaze nystagmus</li> <li>Stability of gaze</li> </ul>	<ul style="list-style-type: none"> <li>Distance – patient moves head</li> <li>Near – patient moves their eyes</li> </ul>

20

### Comitancy

- Comitant Strabismus – nonparalytic, deviation remains similar in different gazes and relative to each eye
- Clinical Tests of Comitancy
  - Primary vs. Secondary Angle
  - CT in 9 Fields of Gaze
- Incomitant Strabismus
  - Difference in deviation >5pd
  - Anomalous head posture is not a clinical diagnostic test of comitancy



4LHyper/4Eso	4Eso	Ortho
5LHyper/6Eso	5LHyper/4Eso	3Eso
8LHyper/8Eso	5LHyper/6Eso	6Eso

Ortho      10LHyper

21

### Symptoms of Ocular Motor Dysfunction

- Difficulty/slowed ability to change focus from one distance to another
- Eye Pain
- Balance Problems
- Blurred vision after prolonged near work
- Anxiety in visually crowded areas or with visually crowded text
- Hypersensitivity to visual and noise crowding
- Symptom provocation with eye contact or social situations
- Dizziness/nausea with eye/head movements



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### Developmental Oculomotor Problems

- 5-13% Convergence insufficiency
  - Prevalence 2.5-33%
- 17% Accommodative disorders
  - Prevalence <1% up to 61.7%
- AI and CI co-morbidity between 1.9% and 14.7%

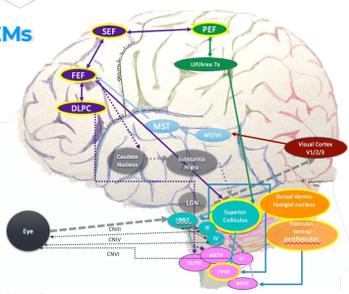
Galcho-Marinova P, Garcia-Muñoz A, Ruiz-Cantero M. Do we really know the prevalence of accommodative and nonstrabismic binocular dysfunctions? J Optom. 2010;3(4):185-197. doi:10.1016/j.optom.2010.03.008-5  
Nieder G, Schrimm M, Galloway M, et al. Vision diagnoses are common after concussion in adolescents. Clin Pediatr (Phila). 2016;55(3):260-267.  
Marras D, De Looze PM, Naguyen AL. Accommodative insufficiency is the primary source of symptoms in children diagnosed with convergence insufficiency. Optom Vis Sci. 2006;83(3):289-289. Husain-IBR, Murari A. Accommodative insufficiency: Prevalence, Impact and treatment options – Review. Clin Optom. 2020  
Rogier J, Jans R. Convergence insufficiency – a major review. Optometry. 2012;83(6):127-136.  
Bojeman M, Galloway M, Franz KA, et al. Nearpoint of convergence: test procedure, target selection, and normative data. Optom Vis Sci. 2003;80(3):214-225.

23

### THE EYE-BRAIN CONNECTION

#### Pathophysiology of FEMs

BRAIN STRUCTURE	ROLE
OMNIPAUSE NEURONS in PPRF	<ul style="list-style-type: none"> <li>Sustained firing during fixation</li> <li>Inhibitory influence on Saccades</li> </ul>
SUPERIOR COLLICULUS	<ul style="list-style-type: none"> <li>Contains retinotopic map</li> <li>Bursts during saccades to re-foveate</li> </ul>
MEDIO-POSTERIOR CEREBELLUM	<ul style="list-style-type: none"> <li>Determine exact direction of gaze</li> <li>Adaptive control of gaze</li> </ul>
CEREBRAL CORTEX	<ul style="list-style-type: none"> <li>Frontal eye fields</li> <li>Parietal/Frontal cortex</li> <li>Subcortical control</li> </ul>



© Owen Wilson J, Prosser SG, Mearns JL, Sanchez-Pedraza J, Marinkovic-Gardic S. Secondary and tertiary pathways linking visual stimuli, oculomotor, and motoric transformations for a coordinate second generation. PLoS One. 2018;13(10):1-18. doi:10.1371/journal.pone.0204622. PMID: 30446222

Image Courtesy of Jacqueline Theis

24

### Symptoms of Fixational Eye Movement Dysfunction

Example of visual fading: Trovler fading

If the eyes do not move enough

THEN

VISUAL LOSS due to neural adaptation and visual fading



Trovler, D. (1994). Ueber das Verschwinden gegengerer Gegenstände. *Zeitschrift für wissenschaftliche Optik*, 41, 101-105. <https://doi.org/10.1007/BF01171044>. Springer, 2004. 264 pp. 0-521-81400-0. <https://www.springer.com/9780521814000>.  
 Hartmann-Ott, A., Macknik, S.L., Martinez Trujillo, J.C. (2017) Microsaccades Counteract Visual Fading during Fixation. *Neurosci* 2008 Jan 15;19(2):297-305. doi:10.1006/ncnu.2007.1028. PMID: 16427052.

25

### Symptoms of Fixational Eye Movement Dysfunction

If the eyes move too much

THEN

Blurred and unstable vision



The goal of FEMs is to overcome neural adaptation while maintaining

- (1) precision vision and
- (2) optimize visual processing

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### Visual Performance – what is normal?

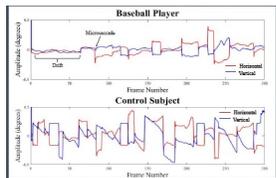
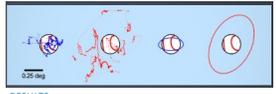


Figure 2: Eye traces from an individual DP and CS. Selection Criteria: These had average microsaccade frequency and amplitude for its cohort.

Image courtesy of Nicole Putnam, PhD

#### Microsaccades can impact high precision vision



RESULTS

Baseball players had more stable fixations as measured by amplitude, velocity, acceleration and drift when comparing fixation patterns of D1 baseball players (n=26) versus age-matched control (n=31)

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### COMPARISON SACCADDES

**"MACRO" SACCADDES**

Voluntary  
Clinically visible  
Moving fixation/Visual Exploration from one object to another

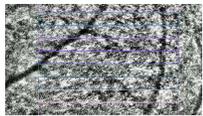
>2°



**MICROSACCADDES**

Involuntary  
Microscopic  
During Fixation/Control retinal motion

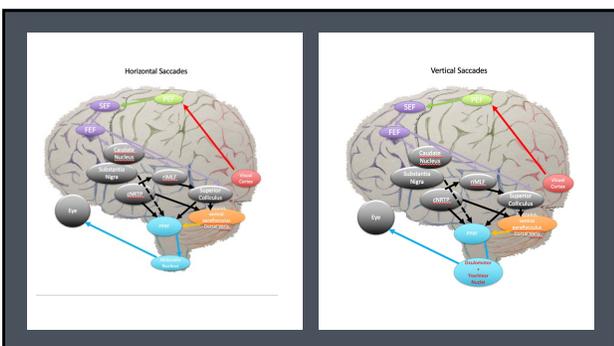
<1-2°



VS

Orsini Milan, J., Trovler, D., Macknik, S.L., Martinez Trujillo, J.C. (2008) Saccades and microsaccades during visual fixation, exploration, and search: foundations for a common saccadic generation. *J Vis* 2008 Dec 15;8(12):1338-461. doi:10.1167/8.12.1338. PMID: 19143322.

28



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### Saccades

- Symptoms of Saccadic Dysfunction
  - Can't track multiple quickly moving objects → slowed reaction time
  - Difficulty with scrolling on the computer or scanning a visually crowded computer
  - Losing place while reading, re-reading, can't comprehend reading material
  - Difficulty with eye contact



30

Cal has really great athletes. They are smart and enjoy going to class and to practice. When they are not on the field they are in the library.

31

Cal has really great athletes. They are smart and enjoy going to class and to practice. When they are not on the field they are in the library.

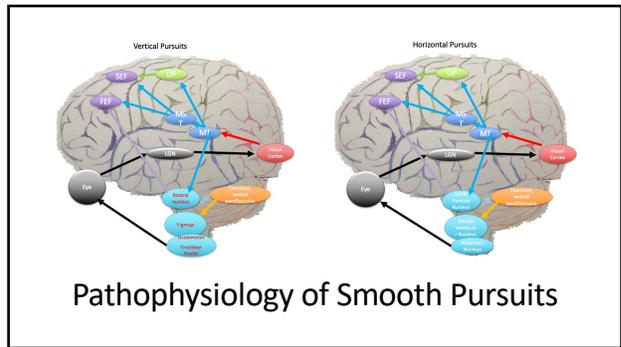
32



### Smooth Pursuit

- Function
  - Stabilizes image of a small moving target onto the eye
  - Cancels the VOR/OKN during combined eye/head tracking
    - Tracking a target that moves in the same direction as the head
- Used to track objects
- Slow, smooth, steady

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### Smooth Pursuit

- Symptoms of Pursuit Dysfunction
  - Visual motion sensitivity
  - Dizziness/Nausea in the car
  - Difficulty with scrolling on the computer/phone



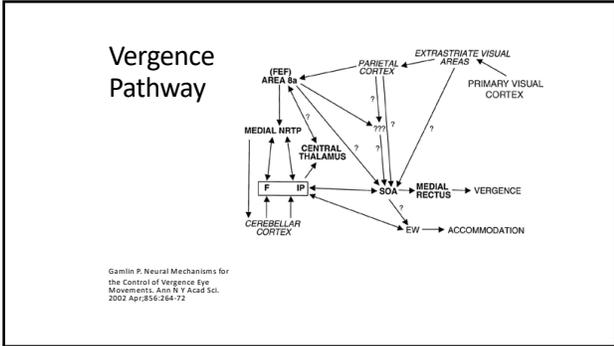
35



### Vergence

- Function
  - used to track an object that is moving towards or away from a person as well as allow a person to change their gaze from one object to another that is located at a different distance away.

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### Symptoms of Convergence Insufficiency

- Headache
- Eyestrain
- Double vision
- Blurry vision
- Loss of place while reading/words moving on the page
- Excessive tiredness when reading
- Closing an eye
- Short attention span for reading

Scheiman M, Mitchell GL, Cotter S, et al. The convergence insufficiency treatment trial (CITT) study group. A randomized clinical trial of treatments for convergence insufficiency in children. *Arch Ophthalmol*. 2005; 123:14-24.  
 Rouse MW, Borsting E, Hyman L, et al. Frequency of convergence insufficiency among fifth and sixth graders. *Optom Vis Sci*. 1999;76 (9):643-9.  
 LeBlouneau JL, Ducic S. Prevalence of convergence insufficiency among elementary school children. *Can J Optom*. 1988;50:194-7.  
 McGrover ML. Convergence insufficiency and vision therapy. *Pediatr Clin N Am*. 2014; 61:621-639.

38

Double vision makes it difficult to read and comprehend.

double vision can look like this:

### Convergence Insufficiency Vergence Dysfunction

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### Vergences

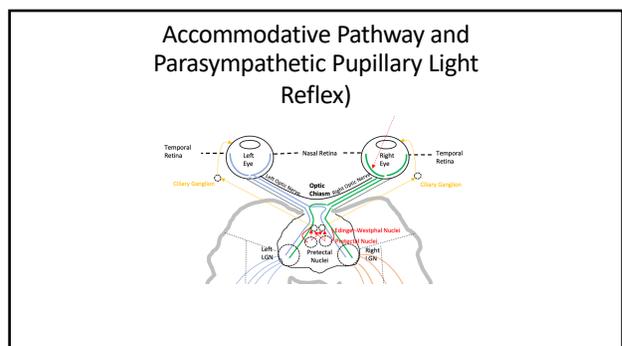
- Movement of the eyes in opposite directions – can be horizontal, vertical, and cyclorotational
- Types
  - Tonic Vergence
    - Distance phoria – physiological position of rest
    - Phoria = error of binocular alignment, only manifest on monocular viewing
    - Tropia = error of binocular alignment manifest on binocular and monocular viewing
  - Proximal Vergence
    - Course adjustment/perceived distance – gaze shift
  - Fusional or Disparity Vergence
    - Fine adjustment – gaze correction
    - Maintains/holds and corrects for small changes in disparity
  - Accommodative Vergence

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### Accommodation

- Function
  - Clearly focus an image of an object onto the retina
  - Changes refractive power of the eye by altering the shape of the lens to focus on objects at different distances
- ie – How the eye focuses on things
  - Dependent on age
  - Dependent on refractive error
  - Dependent on target distance

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### Accommodative Insufficiency OU

Sometimes when a patient is reading both eyes can be blurry because of accommodative insufficiency. However, if only one eye is blurry and the other is clear, the patient may not have "blur" complaints at all, but rather fatigue/eye pain/headaches with reading

### Accommodative Insufficiency OD or OS

Sometimes when a patient is reading both eyes can be blurry because of accommodative insufficiency. However, if only one eye is blurry and the other is clear, the patient may not have "blur" complaints at all, but rather fatigue/eye pain/headaches with reading

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### Accommodative Infacility/Spasm

- Can't Change focus quickly from distance to near Or from near to distance (spasm)
  - Taking notes in class
  - Office boardroom meeting
  - Eye pain with prolonged tasks
  - Distance blur after prolonged reading

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CLINICAL CONSIDERATIONS

### Eye Tracking – Seeing the Unseen

52 y/o Female, complains of world "jittering" with fatigue, nothing detected in clinic

Images Courtesy of Christy Sheehy, PhD

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### Eye Tracking Pros

- Objective, easier to track changes over time
- Detect subtle abnormalities we cannot see with our clinical eye
- Help patients understand what we see

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### Eye Tracking - Cons

1. Not all eye trackers are accurate or sensitive enough to detect eye movement abnormalities
2. Difficulties with repeatability depending on the tracker
3. Pupil tracking is easily influenced with artifacts
  1. Thick glasses
  2. Eyelashes
  3. Face Masks
4. No eye tracker is specific to eye movement dysfunction from dyslexia, brain injury vs other neurologic disorders
5. No eye tracker can differentiate pre-existing conditions
6. Other systems influence eye movements (vestibular/cervical)
7. Eye movements may fatigue with time but be normal on short test durations

Key: Eye tracking is a tool that can help a clinician in their diagnostics and decision making, but still warrants clinical interpretation and rigor to ensure accuracy in metrics reported

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### VOR – Vestibular Ocular Reflex (From the Eye's perspective)

- Stabilizes images on the retina during head movements
  - Eye movement in an equal velocity (gain)/opposite direction of head movement
- If the image slips on the retina (blurs) then VOR must adapt to stabilize the image on the retina to see
- Involves
  - Vestibular (afferent/efferent)
  - Oculomotor (efferent)

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### VOR

- Dynamic Visual Acuity Test
  - Shake head side to side and read a letter chart
- Normal
  - Able to read 1 line above threshold
  - Asymptomatic
- Abnormal
  - Able to read >2 lines above threshold due to blur
  - Symptomatic – oscillopsia, headache, nausea, dizziness, etc
- Other Tests down in Physical Therapy
  - Head Thrust Test
  - Head Shake Nystagmus Test

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### Symptoms of Abnormal VOR

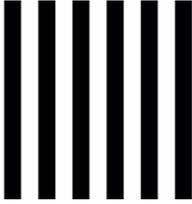
- Blurry vision with head movement
- Dizzy/nausea with head movement
- Anxiety in visually crowded areas
- Hypersensitivity to visual and sound stimulus
- Imbalance



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### Optokinetic Nystagmus (OKN)

- Oculomotor reflex linked to vestibular system
- Stabilizes images on the retina during image movement



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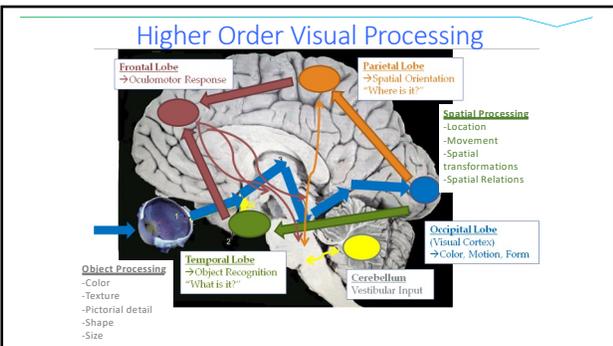
### Visual-Motion Sensitivity

- Difficulties with visual motion in the car
  - Saccades, pursuits, VOR
- Difficulties with visual motion on electronics (scrolling)
  - Saccades, pursuits
- Difficulties with visual motion with head/body in motion
  - Saccades, pursuits, VOR



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### Higher Order Visual Processing



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### Visual Processing

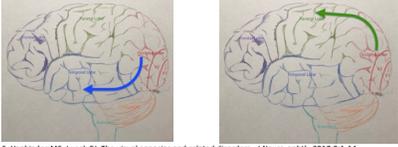
#### Ventral Stream – What?

- Fixed properties of an object
  - Ex: size, color, orientation
  - Recognition via combination with previous visual memories
- Runs inferiorly along occipital and temporal lobes

#### Dorsal Stream - Where?/How?

- Spatial information about the object/environment
  - Position, distance, movement
  - Visuomotor control/visual search
- Runs superiorly along occipital and (posterior) parietal lobes

*\*Model is too simplistic, but useful clinically*



Haque S, Vaphiades MS, Lueck CJ. The visual agnosias and related disorders. J Neuro-ophth. 2017;0:1-14.

54

### Simultanagnosia: Symptoms of Visual Crowding

- Cant find a friend in a crowd
- Gets lost in crowded places
- Cannot see items in the distance
- Impaired reading of small text
- Can cause anxiety in supermarkets (Visual and auditory), social anxiety for family events and parties, distress on car rides, etc



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### Visual Processing Skills

<p><b>Diagnostic Tests</b></p> <ul style="list-style-type: none"> <li>• Test of Visual Processing Skills (TVPS) – 7 subtests</li> <li>• Motor-Free Visual Processing Test (MVPT)</li> <li>• Others                             <ul style="list-style-type: none"> <li>• Beery VMI</li> <li>• Trail Making Test</li> <li>• Star Cancellation/Bells Test</li> <li>• VADS</li> </ul> </li> </ul>	<p><b>Individual Skills</b></p> <ul style="list-style-type: none"> <li>• Visual discrimination</li> <li>• Visual figure ground</li> <li>• Visual form constancy</li> <li>• Visual memory</li> <li>• Visual sequential memory</li> <li>• Visual closure</li> <li>• Visual spatial relations</li> </ul>
---	---

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### Visual Treatment Options

<p><b>Fix it!</b></p> <ul style="list-style-type: none"> <li>• Glasses/Contacts</li> <li>• Prisms</li> <li>• Vision Therapy</li> </ul>	<p><b>Accommodate For It!</b></p> <ul style="list-style-type: none"> <li>• Increased font size</li> <li>• Increased spacing</li> <li>• Increased contrast</li> <li>• Use of a line guide</li> <li>• Isolated space for testing/reading</li> <li>• More time on tests and assignments</li> <li>• Book vs computer</li> <li>• Breaks</li> </ul>
--	---

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### Dyslexia Treatment Options

Multidisciplinary management – discuss the role of each and when to refer to them

- § Parents
- § Educators
- § Pediatricians
- § Optometrists
- § Audiologists
- § Speech pathologists/therapists
- § Neuropsychologists

Early identification and intervention can make a significant difference in managing dyslexia.

- § By providing appropriate support and accommodations, individuals with dyslexia can develop strategies to overcome their challenges and thrive academically and personally.

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### Dyslexia Treatment Options

<p>Role of assistive technology</p> <ul style="list-style-type: none"> <li>§ text-to-speech software</li> <li>§ speech recognition tools</li> </ul> <p>Other accommodations/treatment options for dyslexia</p> <ul style="list-style-type: none"> <li>§ Specialized reading programs</li> <li>§ Tutoring</li> <li>§ Auditory processing treatment</li> </ul>	
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