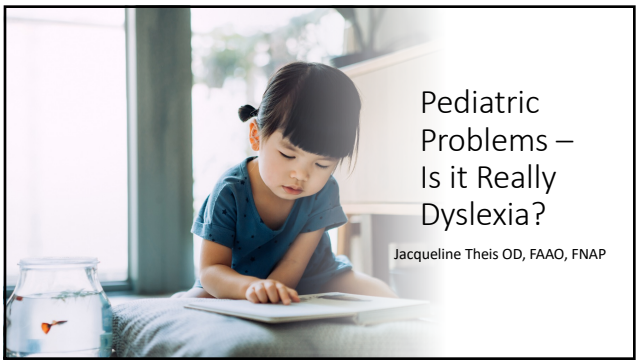


Pediatric Problems – Is it Really Dyslexia?

Jacqueline Theis OD, FAAO, FNAP

1

Financial Disclosures

- C. Light Technologies – Chief Medical Officer
- Myze – Advisory Board
- Dompe - Speaker Bureau
- Tarsus – Speaker Bureau, consulting/advisory board
- Oculus – Speaker Bureau
- Vision Science Labs - Prior Advisory Board Member
- Alcon – Speaker Bureau, Consulting/Advisory Board
- Abbvie – Advisory board

All risks have been mitigated

2

Learning Objectives

Introduction to Dyslexia

1) Define and describe the characteristics of dyslexia as a language/auditory processing disorder and the competing theories around it

Dyslexia vs. Vision Disorders

2) Describe the symptoms of reading/learning disorders that may overlap with certain visual disorders

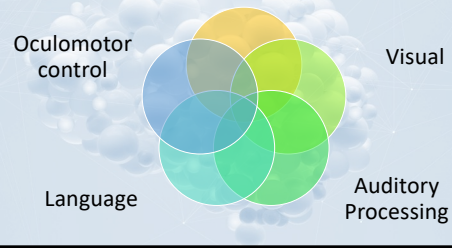
Diagnostic Testing and Treatment

3) Outline the diagnostic testing and treatment options for patients including lenses, prisms, vision therapy, and academic accommodations to aid patients in their academic success

3

Introduction

Reading involves multiple regions of the brain



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Dyslexia: Definition

- Type of learning disability/disorder
- Auditory processing/language disorder
- Neurobiological origin
- Affects the way individuals process and interpret specific language skills including
  - Reading
  - Spelling
  - Writing
  - Pronouncing words
  - Math
  - Organizational skills

Dyslexiaida.org

5

Dyslexia: Definition

- Characterized by
  - Difficulties with accurate and/or fluent word recognition
  - Poor spelling
- Individuals are intellectually, emotionally, and medically normal
- Main deficits include
  - Inability to process sensory input (acoustic information) that comes into the nervous system rapidly
- If severe, qualify for special education, accommodations or extra support services

Dyslexiaida.org

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

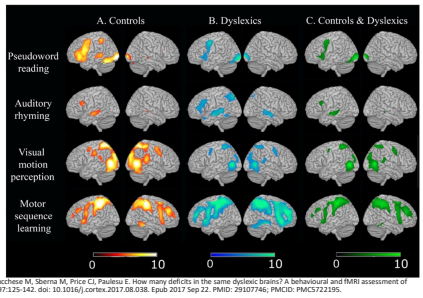
Signs/Symptoms of Dyslexia

- 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 (FWER-corrected). On the bottom, the colour scales indicate the significance of the SPMs[Z] maps. Only voxels surviving a FWER p<0.05 threshold are visualized.



Danelli L, Berlingeri M, Bottini G, Borghese NA, Lucchese M, Sberna M, Price CJ, Paulesu E. How many deficits in the same dyslexic brains? 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 [1], Linda J Lombardino

Affiliations + expand
PMID: 22978204 DOI: 1

> 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 [1], Linda J Lombardino, Michaela Ritter

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

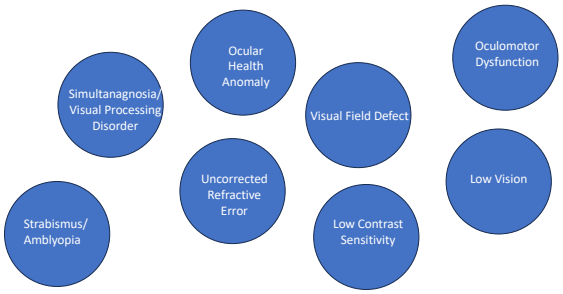
11

Do Vision problems cause dyslexia?

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

12

Overlap of Dyslexia and Vision Disorders



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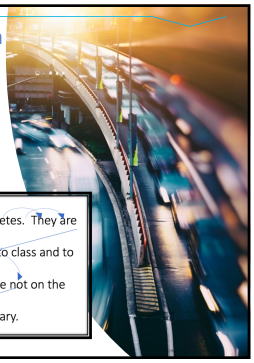
Symptoms of Ocular Motor Dysfunction

- Reading difficulties
  - Headache
  - Eyestrain
  - Dizziness
  - Nausea
  - Eye pain
  - Loss of place
  - Excessive fatigue
  - Closing an eye
  - Short attention span
  - Cant remember what was read
- 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



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.

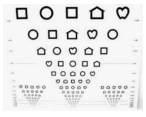
14

In your chair… where to begin?

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

Expected acuity in an infant

- 600/age in months = Snellen denominator
- Ex: 6 months old = 20/100
- 3yo= 20/40
- 4yo= 20/30-20/25
- 5yo=20/20

Condition	Refractive errors (diopters)		
	<1 year	1-2 years	2-3 years
Isoametropia			
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
Anisometropia (without strabismus)			
Myopia	≥ -3D	≥ -3D	As per refraction
Hyperopia	≥ +2D	≥ +1.5D	≥ +1.5D
Astigmatism	≥ 2.5D	≥ 2D	≥ 2D

Age	Symmetric	Asymmetric Difference
Less than 1year 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, Ciner 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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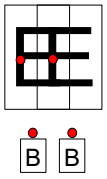
Cover Test - Size Matters



Distance Cover Test Target

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

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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 I. 1987. Part II Jan.

19

Cover Test/Ocular Motility

Clinical H	Cover Test/Maddox Rod in 9 fields of Gaze
• Restriction - ductions • Endgaze nystagmus • Stability of gaze	• Distance – patient moves head • Near – patient moves their eyes

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	

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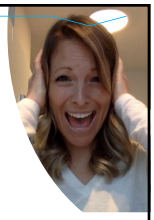
Symptoms of Ocular Motor Dysfunction



- Difficulty/slowed ability to change focus from one distance to another
- Balance Problems
- Eye Pain
- 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%

Cacho-Martínez P, García-Muñoz Á, 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/s1888-4296(10)70028-5
Master CL, Scheiman M, Gallaway M, et al. Vision diagnoses are common after concussion in adolescents. *Clin Pediatr* (Phila). 2016;55(3):260-267.
Marran LF, De Land PN, Nguyen AL. Accommodative insufficiency is the primary source of symptoms in children diagnosed with convergence insufficiency. Optom Vis Sci. 2006;83(5):281–289. Hussaindeen JR, Murali A. Accommodative Insufficiency: Prevalence, impact and treatment options – Review Clin Optom 2020
Cooper J, Jamal N. Convergence insufficiency—a major review. Optometry. 2012;83(4):137-158.
Scheiman M, Gallaway M, Frantz KA, et al. Nearpoint of convergence: test procedure, target selection, and normative data. Optom Vis Sci. 2003;80(3):214-225.

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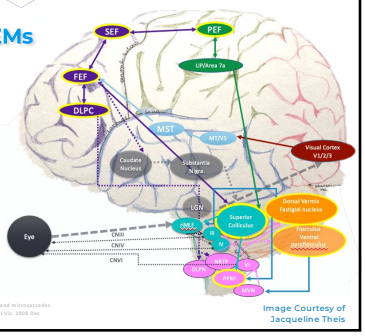
THE EYE-BRAIN CONNECTION

Pathophysiology of FEMs

BRAIN STRUCTURE	ROLE
OMNIPAUSE NEURONS in PPRF	• Sustained firing during fixation • Inhibitory influence on Saccades
SUPERIOR COLLICULUS	• Contains retinotopic map • Bursts during saccades to re-foveate
MEDIO-POSTERIOR CEREBELLUM	• Determine exact direction of gaze • Adaptive control of gaze
CEREBRAL CORTEX • Frontal eye fields • Parietal/frontal cortex	• Subcortical control



Otero-Millan J, Troncoso XG, Macknik SL, Serrano-Pedraza I, Martinez-Conde S. Saccades and microsaccades during visual fixation, exploration, and search: foundations for a common saccadic generator. J Vis. 2008 Dec 18;8(14):21.1-18. doi: 10.1167/8.14.21. PMID: 19146322.

Image Courtesy of Jacqueline Theis

24

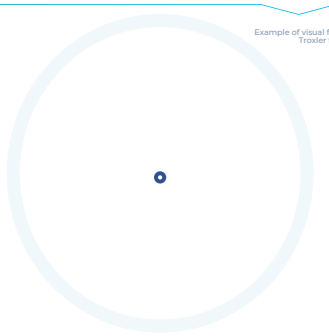
Symptoms of Fixational Eye Movement Dysfunction

If the eyes
do not move enough

THEN

VISUAL LOSS
due to neural adaptation and visual fading

Example of visual fading: Troxler fading



Troxler, D. (1804). Ueber das Verschwinden gegebener Gegenstande innerhalb unseres Gesichtskreises. In: Himley, K. and Schmidt, J.A. (Eds.), Ophthalmologische Bibliothek, Springer, Jena, pp. 1–53.
Martinez-Conde S, Macknik SL, Troncoso XG, Dyar TA. Microsaccades counteract visual fading during fixation. Neuron. 2006 Jan 19;49(2):297-305. doi: 10.1016/j.neuron.2005.11.033. PMID: 16423702.

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?

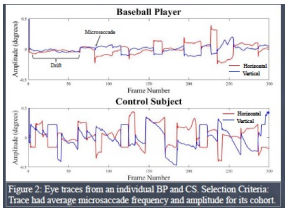
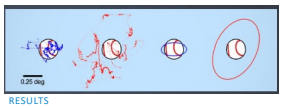


Figure 2: Eye traces from an individual BP and CS. Selection Criteria: Trace had average microsaccade frequency and amplitude for its cohort

Eric Van Meter, Judy Tran, Zachary Green, Christy Sheehy, Jacqueline Theis, Ethan A Rossi, Hope Reecher, Min Zhang, Charlotte Bolch, Nicole M Putnam Comparing fixational stability of D1 baseball players as measured by Tracking Scanning Laser Ophthalmoscopy to healthy controls. Invest. Ophthalmol. Vis. Sci. 2021;62(8):506.

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)

Eric Van Meter, Nicole Putnam, Charlotte Bolch, Zachary Neth, Jacqueline Theis, Christy Sheehy "Fixational eye movements of D1 baseball players predicting in-game hitting statistics" American Academy of Optometry Abstract presentation 2022

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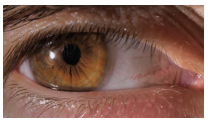
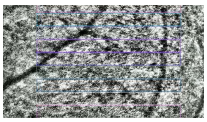
COMPARISON

SACCADES

"MACRO" SACCADES		MICROSACCADES
Voluntary		Involuntary
Clinically visible		Microscopic
Moving fixation/Visual Exploration from one object to another >2°	VS	**During Fixation/Control retinal motion** <1-2°





Otero-Millan J, Troncoso XG, Macknik SL, Serrano-Pedraza I, Martinez-Conde S. Saccades and microsaccades during visual fixation, exploration, and search: foundations for a common saccadic generator. J Vis. 2008 Dec 18;8(14):21.1-18. doi: 10.1167/8.14.21. PMID: 19146322.

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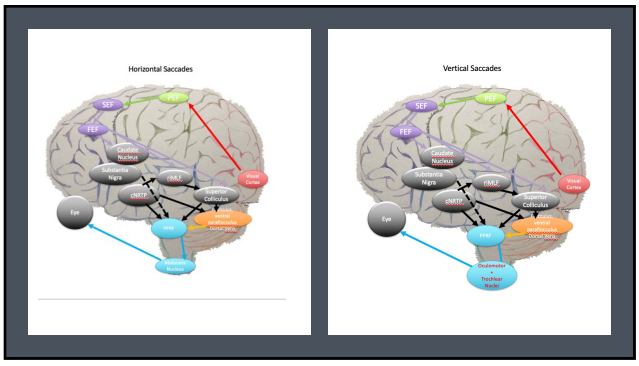

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Saccades

- 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.

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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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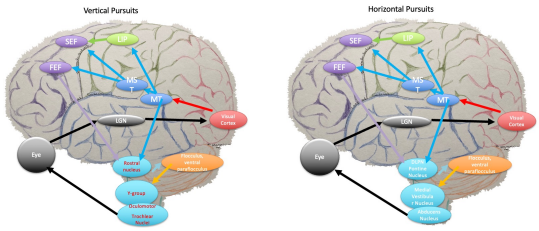

Pathophysiology of Smooth Pursuits

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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

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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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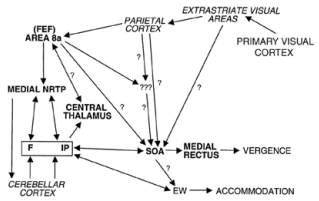
Vergence Pathway



Gamlin P. Neural Mechanisms for the Control of Vergence Eye Movements. Ann N Y Acad Sci. 2002 Apr;856:264-72

37

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.

Letourneau JE, Ducic S. Prevalence of convergence insufficiency among elementary school children. *Can J Optom*. 1988;50:194-7.

McGregor ML. Convergence insufficiency and vision therapy. *Pediatr Clin N Am*. 2014; 61:621-630

38

Double vision makes it difficult to read and comprehend.

double vision can look like this:

double vision
double vision
double vision
double vision
double vision

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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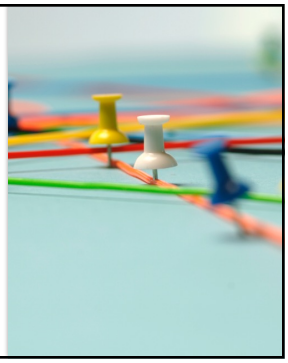
Accommodation

- 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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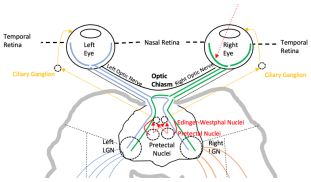
Accommodative Pathway and Parasympathetic Pupillary Light Reflex)



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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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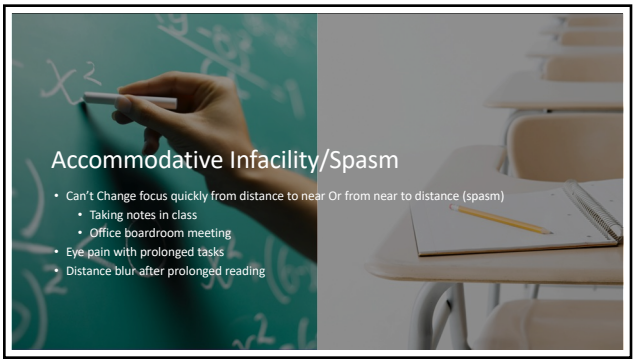

Accommodative Infacility/Spasm

- 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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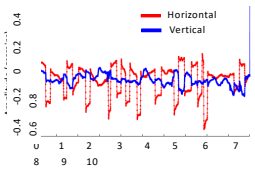
CLINICAL CONSIDERATIONS

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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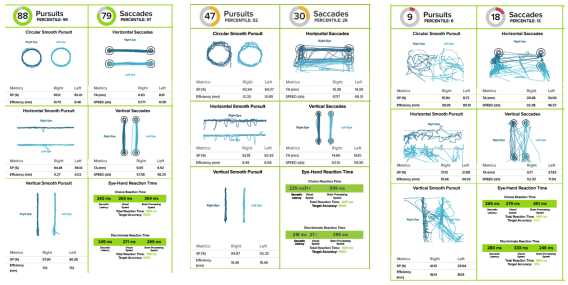
Eye Tracking Pros

- 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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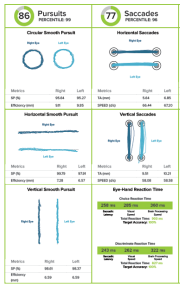
Eye Tracking - Cons



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
- Involves
  - Vestibular (afferent/efferent)
  - Oculomotor (efferent)

- If the image slips on the retina (blurs) then VOR must adapt to stabilize the image on the retina to see

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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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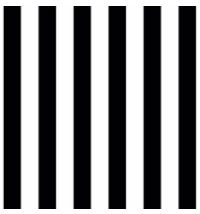
Optokinetic Nystagmus (OKN)

- 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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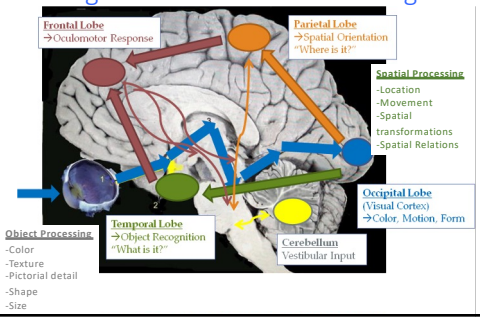
Higher Order Visual Processing



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Visual Processing

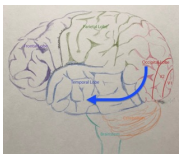
Ventral Stream – What?

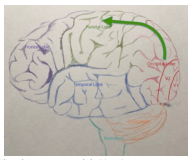
- Fixed properties of an object
  - Ex: size, color, orientation
  - Recognition via combination with previous visual memories
- Runs inferiorly along occipital and temporal lobes

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.

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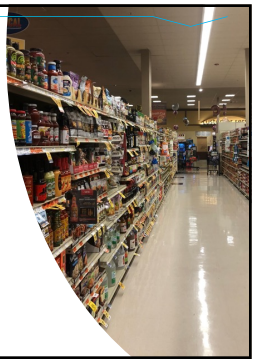
Simultanagnosia: Symptoms of Visual Crowding

- 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

Diagnostic Tests
- Test of Visual Processing Skills (TVPS) – 7 subtests
- Motor-Free Visual Processing Test (MVPT)

- Others
  - Beery VMI
  - Trail Making Test
  - Star Cancellation/Bells Test
  - VADS

Individual Skills
- Visual discrimination
- Visual figure ground
- Visual form constancy
- Visual memory
- Visual sequential memory
- Visual closure
- Visual spatial relations

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Visual Treatment Options

Fix it!
- Glasses/Contacts
- Prisms
- Vision Therapy

Accommodate For It!
- Increased font size
- Increased spacing
- Increased contrast
- Use of a line guide
- Isolated space for testing/reading
- More time on tests and assignments
- Book vs computer
- Breaks

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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

Role of assistive technology
§ text-to-speech software
§ speech recognition tools

Other accommodations/treatment options for dyslexia
§ Specialized reading programs
§ Tutoring
§ Auditory processing treatment

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