

THE VISUAL SYSTEM



Developmental Psychopathology

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Development of eye-movement control

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Abstract

Cognitive control of behavior continues to improve through adolescence in parallel with important brain maturational processes including synaptic pruning and myelination, which allow for efficient neuronal communication and the functional integration of widely distributed executive-supporting top-down control of behavior. This is also a time when psychiatric disorders, such as schizophrenia and mood disorders, most often reflecting a particularly vulnerable ability to improve in development during adolescence. Computational studies provide a unique neuroscientific approach to make precise associations between cognitive control and brain circuitry during development that can inform us of important systems in psychopathology. In this review, we first describe the development of pursuit, fixation, and visually-guided saccadic eye movements, which collectively indicate early maturation of basic visuomotor processes supporting reflexive, exogenously-driven eye movements. We then describe the literature on the development of the cognitive control of eye movements as reflected in the ability to inhibit a prepotent eye movement in the antisaccade task, as well as making an eye movement guided by on-line spatial information in working memory in the oculomotor delayed response task. Computational models highlight evidence that the ability to make eye movements in a voluntary fashion driven by endogenous goals shows a protracted development into adolescence. Characterizing the transition



NEUROSCIENCE BIOLOGY AND BEHAVIOR

VISUAL DEVELOPMENT

- Fixation
 - A few seconds at birth
 - Duration of fixation increases from 4-15 years of age, indicating developmental improvement in the stability of fixations
- Smooth pursuits (tracking)
 - First two weeks after birth tracks using optokinetic nystagmus
 - First two months tracks via a series of saccadic movements
 - Eye-head gaze shifts at 7 mos
 - Predictive tracking around 8 mos & continues to improve through childhood and into adolescence; especially at higher speeds of pursuit tracking
 - Vertical pursuits start to dev - 9-11 mos

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VISUAL DEVELOPMENT

- Saccades
 - In infancy velocity is slower
 - Saccade latency (rxn time to initiate eye movement) decreases exponentially from birth to 14-15 yrs
 - Saccade accuracy (cerebellar): Hypometria is evident in infancy
- Anti-saccades (inhibitory control)
 - Age 8, one correct AS
 - Childhood to - 15 yrs significant reduction in inhibitory errors (= improvement in cognitive control)
- VOR
 - Intact - 1 year

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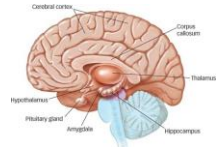
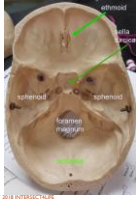
VISUAL SYSTEM

Reflex Review!

- Moro
- ATNR
- TLR
- STNR
- Oculo-Headrighting

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- Each optic tract represents half of the visual field from each eye.
 - Left tract = Right visual field
 - Right tract = Left visual field
- Each optic tract sends fibers to the LGN (Lateral Geniculate Nucleus in the thalamus) before heading to the Primary Visual Cortex in the Occipital Lobe.
 - A small amount of fibers bypass the LGN instead for the superior colliculus (midbrain area with many other connections) which is important in eye movement control as well as helping to integrate kinesthetic, vestibular, proprioceptive, tactile, and ambient visual information.

Think Crawling

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There are over 30 areas of the cerebral cortex and over 10 areas of the brainstem directly involved in vision

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VISUAL SEQUELAE AFTER BRAIN INJURY

Functional Vision Skills / Visual Efficiency Skills

- Refractive Conditions – small prescriptions become much more important
- Focusing Dysfunction – occurrence in TBI=41%, CVA=12.5%
- Oculomotor (tracking) Dysfunctions – occurrence in TBI=51%, CVA=57%
- Binocular Dysfunction – occurrence in TBI=56%, CVA=37%
- Strabismus – occurrence in TBI=26%, CVA=37%
- Cranial Nerve Palsies – occurrence in TBI=07%, CVA=10%
- Nystagmus

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SITE OF INJURY

Frontal Lobe

- Voluntary eye movement deficits (smooth pursuits, saccades, Optokinetic nystagmus, vestibular reflex, convergence)
 - OKN
 - Heading loss, tilt, & vertigo = peripheral
 - Vertical & torsional = central
 - Horizontal = central or peripheral
- Apraxia (can affect eyes)
- Visual inattention deficits
- Cognitive deficits in visual problem solving and judgment
- Slowed responses to visual stimulus in periphery
- Reduced speed in visual motor tasks

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Think Enuresis

SITE OF INJURY

Thalamus / Cerebellum / Brainstem

- Eye movement deficits / nystagmus
- Vestibular and balance problems
- Visual and cognitive processing deficits
- Laterality (right/left) difficulties
- Reading difficulties

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TRACKING

- Monitor head and body movement
- Monitor accuracy and ability
- Watch eyes cross midline plane
- Girls will be more advanced than equally aged boys

Add Load

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SMOOTH PURSUITS

- 12-18" from face
- All cardinal fields of gaze
- Clockwise, counterclockwise, lazy eights
- Look for: smooth, borderline smooth, or jerky
- Add noise



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SACCADE ARRESTATION

- During horizontal pursuits, stop the pencil after crossing the midline in each direction.
- Eyes should stop on target- not "past point"



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CONVERGENCE/DIVERGENCE

- Start w/pencil ~18" out and move toward face
- Watch for the eyes to stay fixed & converge equally on target
- At what point does pt see double
- Repeat 5-6 times





assessment only. The reason why you repeat the procedure three times is because the Near Point of Convergence tends to recede (move backward) over time due to fatigue, particularly when the patient has convergence insufficiency.

3-Step Screening for Convergence Insufficiency

Place red/green glasses on patient

Instruct patient to watch light and state when they see a green light and a red light (X2)

On the third trial, record the distance where the patient reports two lights.

<p>↓</p> <p>Patient reports two lights closer than 4 inches (10 cm)</p> <p>↓</p> <p>Patient passes screening</p>	<p>↓</p> <p>Patient reports two lights further out than 4 inches (10 cm)</p> <p>↓</p> <p>Have patient complete Convergence Insufficiency Symptom Survey (CISS) (Form 5400)</p> <p>↓</p> <p>Doctor will retest 60s with patient</p>
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Reference: Schwabok M, Sullivan H, Perry M, et al. Near point of convergence: test procedure, target location, normative data. Optometry and Vision Science 2003; 80(2):214-222.

Convergence Insufficiency Symptom Survey (CISS)

Name: _____ Date: / /

CONJUGATE LATERAL GAZE

- Pt turns head back and forth and keeps both eyes focused on object
- Repeat 5-6 times



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ESOTROPIA AND EXOTROPIA



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EARLY INTERVENTION

- Any vestibular stimulation is good for binocular development, however ROTATIONAL is best for ESOTROPIA and LINEAR is best for EXOTROPIA.
- Which way to spin
 - Eyes open (Dominant eye patched)
 - Right Esotropia – spin counter-clockwise
 - Left Esotropia – spin clockwise
 - Follow with a tracking activity –
 - Both eyes closed:
 - Right Esotropia – spin clockwise
 - Left Esotropia – spin counter-clockwise
 - Follow with a tracking activity – Or just complete the entire Arcanum
- More intense response with chin tilted down about 30 degrees
- Most cases of early strabismus will be ESOTropia (rotational)
- Maximize effectiveness by following with a basic tracking activity.

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ESOTROPIA: OLDER PATIENT

Mirror swivels

- Stand with your back to a mirror, with your feet set wide enough apart that you won't lose your balance when you twist around.
- Cover your healthy eye and look straight ahead with your weak eye.
- Turn your upper body around toward the side of your weak eye (for example, if your left eye is weak, rotate to the left to look behind you).
- Move your weak eye until you can see your eye in the mirror. Then turn back to the starting position.
- Repeat this process up to six times, then cover your weak eye and repeat the exercise using your strong eye.

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ESOTROPIA: OLDER PATIENT

Side Bends:

- Stand with your feet about shoulder-width apart.
- Lift your hands straight out to each side, at shoulder height.
- Turn your head and weak eye to look at whichever hand is in the opposite direction of where your weak eye points (for example, if it points to the left, look toward your right hand).
- Bend your upper body down to the other side so that the hand you are looking at goes toward the ceiling and your other hand goes down toward the floor.
- Slowly return to the starting position.
- Repeat the exercise looking at the other hand and bending the other direction.

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VESTIBULAR INPUT

- Linear movement activities
 - Rocking (chair, horse)
 - Swinging (swing, hammock, blanket)
 - Bouncing (BOUS, trampoline, swiss/thera-ball)
- Other vestibular ideas:
 - Wobble board
 - Baby wearing
 - Hanging upside down
 - Dancing
 - Bilbo toy
 - Wagon rides
 - Walking rail, infinity walk, etc.



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Let's talk brain development.....

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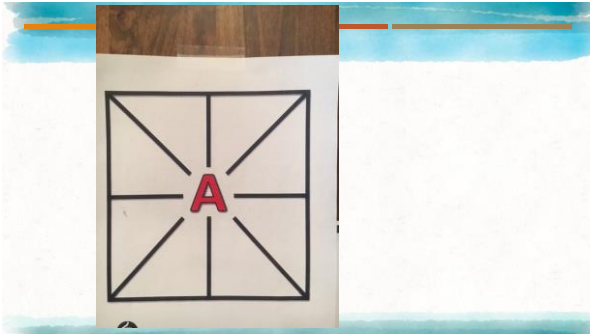
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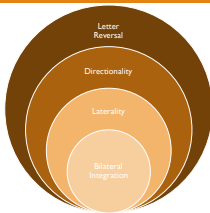


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VISUAL-SPATIAL HIERARCHY



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EARLY INTERVENTION

Ambient is the sub-system that integrates visual information with all of our other senses and systems. It is learned, and is also responsible for our peripheral vision and our normal perception of 3D vision.

- Activities:
 - Peripheral awareness (scarves, finger puppets from behind, wrecking ball, ball pass, clapping game)
 - Proprioception: pulling, pushing, climbing, squeezing, pinching, sucking/blowing, heavy pressure & heavy work

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FOCAL VS AMBIENT

FOCAL:

- Used for object recognition
- Attracted to high spatial frequencies (details)
- Only involves central visual field (foveal area)
- Operates consciously, and works primarily in isolation, much less integrated with other sensory systems.
- Not a learned process; innate
- Tells us, "What is it?"

AMBIENT:

- Responds to global information
- Attracted to low spatial frequencies
- Very fast
- Involved in the perception of motion.
- Thought to control eye movements, and operated mostly nonconsciously
- Involves entire visual field and must constantly integrate with other sensory systems, which is a **LEARNED PROCESS.**
- Tells us, "Where am I?" & "Where It Is"

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EARLY INTEGRATION

Bilateral Integration, Midline Crossing, VMI, Primitive Reflexes, & Gross Motor

- Any age-appropriate bilateral integration, midline, gross motor activity is beneficial and supportive to development of the visual and binocular system.
- Tummy time is particularly important for cases of esotropia, even for those walking well.
- Activities of daily life often allow for the presentation of objects encouraging reach and grab across midline (food, toys, paci, etc).

Ask about how long patient crawled before walking.

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EARLY INTERVENTION EXERCISES

- Fixation and Eye Movements
- Fixation:
 - Fixation/Tracking is the most foundational visual skill and should be made a daily part of the patient's life.
 - For really young patients place fixation targets in strategic areas (crib, dining room, changing table) to encourage eye movement and fixation in the restricted gaze. (These patients will likely have to have dominant eye patched to allow them to fixate and follow with their strabismic eye)
- Stretches:
 - Encourage movements toward the area of restriction; increase overall range of movement.
 - Doll's Eye Movement: Move patient's head instead of target (ex: watching TV, sticker on parent's nose)
 - Patient can be laying down, sitting, standing, balancing to change vestibular load
 - Tummy time is an optimal position

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EARLY INTERVENTION EXERCISES: FIXATION & PURSUITS

- Flashlight games (follow the leader, racetrack, drawing on wall, tracing objects)
- Hanging/Swinging ball (laying down, side to side, around the world)
- Marble Roll (or with balls, cars, trains, etc)
- Cup Shuffle (toy hidden under one of two or more cups, keep their eye on the one with the toy)
- Marble spinning in a frisbee

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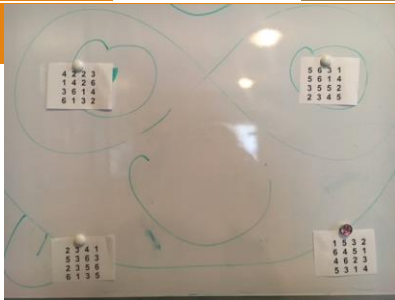




EARLY INTERVENTION EXERCISES: SACCADES

- Symbol or Picture strip
- Add motor; bilateral coordination activities (Icicle - X)
- Quick jumping flashlight tag

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CONVERGENCE & DIVERGENCE

A	V	3	N	M	H	5	4	F	C
O	P	U	8	3	S	2	X	P	U
N	B	5	B	8	V	4	2	C	3
7	N	7	8	C	E	3	W	P	I
M	N	U	Y	B	8	7	5	V	C
4	S	X	Z	W	P	O	L	J	U
T	R	G	J	K	F	D	E	8	W

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EARLY INTERVENTION: VM

- Bubble pop
- Tweezer/Rice or Chopsticks/Cheerios
- Spearing raisins/marshmallows
- Hanging Ballgame activities
- Flashlight Games (Follow the leader,tag, trace objects, hands and knees)

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AUTISM: VISUAL S&S

- | | |
|--|---|
| <ul style="list-style-type: none"> ▪ Squints or closes an eye ▪ Distorted posture when doing near work ▪ Omits small words when reading ▪ Rubs eyes often ▪ Poor handwriting skills ▪ Uses finger to keep place while reading ▪ Inconsistent or poor at sports ▪ Blurred or double vision ▪ Excessive blinking ▪ Looks at things in quick glances ▪ Looks at objects sideways | <ul style="list-style-type: none"> ▪ Avoids doing near point work ▪ Holds objects very close ▪ Crossing of the eyes ▪ Stares at certain objects or patterns ▪ Resistance to occlusion ▪ Sensitivity to light ▪ Hand flicking or waving in front of eyes ▪ Uneven gross/fine motor control (may not want to kick a ball, but can stack blocks) ▪ Visual spatial difficulties (knowing where they are in space.) |
|--|---|

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AUTISM

- Binocular Vision Abnormalities (Convergence Insufficiency) and Strabismus
- They often show an inability to properly use both eyes together to attain sensory fusion.
- Children with Autism are 50% more likely to have strabismus.
- Lack of organization between the visual motor and visual sensory systems (ambient and focal processing) are more likely the root cause, compared to traditional muscle imbalances
- 50% of children with autism have a binocular vision disorder
 - (Schulman, Ready (1994) "Optometry's Role in the Treatment of Autism," JOVD)

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AUTISM

- Oculomotor Dysfunctions
 - Inefficient visual abilities in tracking and following visually presented information can affect abilities in gross and fine motor coordination.
 - Many children with Autism have difficulty fixating; therefore rely on the scanning of visual information to derive meaning.

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AUTISM

- Toe Walking – visual spatial theory would define that these children are unable to determine exactly where they are in space, particularly in relation to other objects. Therefore they touch the walls when they walk for proprioceptive feedback, or put their toe inward for balance. This is an adaptive behavior to try to determine "depth."

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AUTISM

- Hand flapping & Rocking
- These children do not know where they are in space. The ambient visual process is not synchronized with the focal visual process. They may adapt by rocking side to side or front and back to help create depth perception, and spatial/body awareness, through proprioceptive stimuli. This helps create better judgment of space.

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AUTISM

OCD/Hyperfocus

- Due to the inability to process ambient visual information, these children often also have trouble gaining access to focal information. (Ambient helps to tell the Focal system WHERE to direct attention.) Therefore, once the access is achieved, they typically further shut down the ambient system and can remain attentive to a task or visual stimuli for excessive amounts of time.

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AUTISM: OCULOMOTOR ACTIVITIES

- Fixation Sticker on nose
- Pursuits
 - Magic Statue Ballgame (floor, arc, wrecking ball)
- VMI Ballgame
 - Bubble pop/avoid

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AUTISM: VISUAL SPATIAL ACTIVITIES

- Bilateral Integration Double Doodle
 - Board circles
 - Lazy 8's
- Laterality: Hand rule "Show me YOUR right hand."
- Floor maze (directing self)
- Directionality: "Show me MY right hand."
- Floor maze (direction other person)

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AUTISM: AMBIENT ACTIVITIES

- Peripheral Awareness:
 - Finger tag
 - Flashlight games
 - Scarf juggling
- Add vestibular & proprioception

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GENERAL EXERCISES

- Pursuits
 - Doll's Eye Stretch / Mirror
 - Saccades
 - Wall Saccades (loads, infinity walk)
 - Book Saccades
 - Metronome
 - Infinity Walk
 - Michigan Charts
 - VMI
 - Multi-Matrix
- Add vestibular, proprioception & auditory input**

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GENERAL EXERCISES

- Binocularity
 - Brock String
 - Peripheral Awareness
 - Mirroring
 - Beanbags
 - Laser Hart Chart
 - Ballgame Bunting
 - Press lights
- Add vestibular, proprioception & auditory input**

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To the world you may be one person, but to one person you may be the world!



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