Vestibular Development: A Look Beyond the Traditional View

Date: Friday, September 30, 2016
Time: 1:00 PM - 3:00 PM
Session ID & Location: 3D: MtgRm3
CEU Eligibility: 0.20

Presented by: Jason Clopton, OD, FCOVD, ABO

Session Description: This lecture will provide in depth knowledge of vestibular/visual function to allow the therapist to be able to better understand the functioning of their patients.

Attendees will:

1. Learn how the neurology of the vestibular/visual system applies to their patients functioning
2. Learn how the development of the vestibular/visual system applies to their pediatric patients
3. Be able to utilize the vestibular system in daily therapies.
4. Know when to refer out for potential difficulties with vestibular/visual functioning
5. Be able to apply therapy techniques to patients with vestibular/visual problems
6. Have an in depth knowledge of how to look for vestibular/visual problems

Presenter Bio(s): Dr. Jason Clopton is a 1999 graduate of Southern College of Optometry. He is the director of the Center of Vision Development, PLLC. and managing partner of the Centers of Development, PLLC. referral centers for pediatrics and neurorehabilitation in Cookeville, Tennessee, USA. Dr. Clopton has presented numerous lectures worldwide on the Optometric subjects of neurological pathways for vision, neuro-optometry, visual function with brain injury, vestibular interactions with visual function, practice management in a therapy office, pediatrics, strabismus, amblyopia, nutrition and vision, and coding and billing for vision therapy and neuro-rehabilitation. In 2002 he was awarded the Tennessee – “Young Optometrist of the Year”. Dr. Clopton has attained Fellow of the College of Optometrists in Vision Development and a Diplomate of the American Board of Optometry. He is a former board member of the College Of Optometrists in Vision Development and Tennessee Brain Injury Association. He is currently on the Executive Council for the American Optometric Association Vision Re/habilitation Section. Along with 5 others, he is authoring the AOA Concussion Manual (to be released) and co-wrote the AOA Guidelines for - Coding and Billing for Vision Therapy and Neuro-re/habilitation. He has co-authored chapters Optometric Management of Functional Vision Disorders and The
Vestibular Development: A Look Beyond the Traditional View
Presented by Jason Clopton, OD, FCOVD

Pre/Post Test

1) How important is the vestibular system to child development? To visual development?

2) What effect does vestibular processing have on visual development and re/habilitation?

3) What is the minimal amount of arousal needed to learn & develop?

4) This term is used for the ratio of perceived output (eye velocity) to perceived input (head velocity).
   a. rVOR
   b. GAIN
   c. tVOR
   d. OKN

5) This abbreviation is what occurs when the eye attempts to fixate objects traveling through the visual field.
   a. rVOR
   b. GAIN
   c. tVOR
   d. OKN

6) True or False: VOR gain increases linearly from age 3 to 9 years.

7) What patient complaints would lead you to test VOR?

8) How do you look for vestibular/visual problems in patients?
Vestibular Development

A look beyond the traditional view

“He who sees things grow from the beginning, will have the finest view of them.”

Aristotle 384-322 B.C.

Introduction

• Introduction
  Jason’s story
  • Wife is sensory based peds OT
  • As we say in the south “Lookin’ fer ainsers”
  • Neurology of Eye Movements, Leigh and Zee
  • Vestibular Rehabilitation, Herdmann
  • OT/PT courses
  • New ways of thinking about vision and visual functions
  • Dr. Curtis Baxstrom
Why is the Vestibular system so powerful?

Questions to ponder

• What keeps eyes aligned at birth?
• How important is the vestibular system to child development?
  — To visual development?
• What effect does vestibular processing have on visual development and re/habilitation?

Questions to ponder

• What is the minimal amount of arousal needed to learn and develop?
  — How do you obtain arousal?
• Is there a vestibular, motor, auditory, and visual space world?
  — How do they work together?
• What is underlying etiology(ies) of strabismus?
  — Could there be a vestibular component?
TERMS AND ABBREVIATIONS

• These are given to help you in understanding some of the concepts we will be covering.
  
  – GAIN - This is ratio of perceived output (eye velocity) to perceived input (head velocity).
  
  – rVOR or Rotational VOR - Angular acceleration of the head that evokes the sub-cortical reflex which stabilizes visual images on the retina.
    • It can be overridden by cervical ocular reflex (COR), which develops before voluntary eye movements.
  
  – tVOR or Translational VOR - Linear acceleration of the head that evokes the sub-cortical reflex which stabilizes visual images on the retina.

OVERVIEW OF VOR/OKN TERMS AND ABBREVIATIONS

– POST-ROTATIONAL RESPONSE – Nystagmus induced by offset (sudden cessation) of a velocity-step rotation (post movement reaction).
– PER-ROTATIONAL RESPONSE-Nystagmus induced by onset of a velocity-step stimulus (initial movement reaction).
– OKN- Occurs when eye attempts to fixate objects traveling through the visual field.
– Velocity Storage - central vestibular mechanism whereby step peripheral labyrinthine (rotational) response is prolonged or perseverated and OKAN is generated.

Can we talk vestibular vision?

• All senses are a sub-cortical to cortical process
  – All therapies should be sub-cortical to cortical process
• There is no vestibular cortex
  – It is everywhere
  – It is the core sense
• Primitive reflex basis
• Integrative or disruptive
• Motion processing is a very important process
Peripheral Vestibular Anatomy

• Bony Labyrinth
  – SCC, vestibule, cochlea (hearing)

Peripheral Vestibular Anatomy

• Peripheral Anatomy
  – Semi-circular canals
    • Cupula, endolymph
  – Vestibule
    • Otoliths
      – Saccule & Utricle
      – Otolithic macula (bppv)
  – Cochlea
    • Ear drum
    • Tensor timpani
    • Stapedius

Peripheral Vestibular Physiology

• Inner ear - 3 semicircular canals that sense angular acceleration via cupula (lateral/ anterior/superior/posterior)
  – Rotational movement
    • Turning your head, getting out of bed, spinning, etc.
• Inner ear – 2 otolith organs that sense linear acceleration via macula (saccule/utricle)
  – Sense gravity changes (static tilt), linear acceleration
  – Horizontal movement, vertical jumping, walking up stairs, lateral movement, swinging, etc.
• Multi-factorial functions
  – Similarly is anything purely accommodation or convergence?
Semi-circular canal physiology
“The semicircular canals respond to angular acceleration and the otoliths respond to linear acceleration. Together they provide inputs for the VOR.”

r-VOR and t-VOR respectively

The Neurology of Eye Movements - Leigh and Zee

Peripheral Vestibular Physiology

- Semi-Circular Canals (SCC) (r-VOR)
  - Lateral isolation – 30° down to be horizontal
  - Superior/posterior isolation:
    - 30° down from horizontal and 45° head tilt right isolates right posterior and left superior to horizontal plane
    - 30° down from horizontal and 45° head tilt left isolates left posterior and right superior to horizontal plane
    - Side tilted makes posterior on same/superior on opposite side as if horizontal
  - Sustained movement does not stimulate rVOR
  - Acceleration/deceleration does stimulate rVOR
SCC Input to EOM's

Otolithic Physiology

- Otoliths (t-VOR) 2 ways to register movement
  - Saccule
    - Registers vertical linear acceleration/deceleration movement with head upright
    - Registers tilt
  - Utricles
    - Register horizontal linear acceleration/deceleration movement with head upright
    - Registers tilt
- Vestibular registration of head movement is based on acceleration/deceleration only.
- Sustained linear movement does not stimulate tVOR
- Sustained tilt does give sustained input to tVOR
Peripheral Vestibular System

- VOR – slow component is generated by vestibular stimulation and routinely seen at birth, the fast (saccadic return) is centrally mediated and is variably present at birth.
- The speed of the slow component as well as the frequency of beats increase as a function of age until age 6 to 12 months, after which values reach a plateau and stabilize.
  - Ie – speed of tracking (SP) and frequency of saccades increase with age.
- Poor suppression of VOR is seen due to immature visual-vestibular interaction.
- VOR gain increases linearly from age 3 to 9 years. (Casselbrant et al. -new study in contrast to older studies)

Peripheral Vestibular System

- Review - what do we get out of this?
  - rotational or angular VOR = SCC
  - translational or linear VOR = Otoliths (saccule & utricle)
- SCC isolation is rotation-rVOR and PRN
  - Lateral-30 deg to horizontal
  - Posterior/Superior-30 forward and 45 deg left/right to horizontal/vertical
- Otolith isolation is linear – tVOR
  - Vertical (saccule mostly) and horizontal (utricle mostly)
- Acceleration triggers reflexes that are sub-cortical responses until they are cortically integrated....
- Can you have SCC stimulation without otolithic involvement? Vice

“In the vestibular nuclear complex, processing of the vestibular sensory input occurs concurrently with the processing of extra-vestibular sensory information (proprioceptive, visual, tactile, and auditory)".

Herdman – Vestibular Rehabilitation
VOR stabilizes the retinal image during BRIEF and SHORT head or body movements.

How about SUSTAINED and LONGER Durations?

Motion Processing

- OKN
  - Results from sustained movement of visual object on retina
  - Smooth pursuit and optokinetic system contribute (includes reflexive saccade)
  - OKN pathway neurology
Motion Processing

- OKN
- Pursuits
- Motion VEP
- Born with monocular asymmetries (T-N), N-T develops with stereopsis at about 4 months
- Basis for Latent Nystagmus
- MONOCULAR!!!
How do we prevent blur with head movement?

- VOR motion sensing
- OKN motion sensing
- Mismatching with the systems = blur, nausea, etc

Motion Processing

- Pursuits – 90-150 msec latency –
  - Cortical
  - Driven by retinal slip (motion)
  - ≥60 degrees per second
  - Thought to override VOR response
  - Motion processing area to flocculus and ventral paraflocculus in cerebellum via VM nuclei in the pontine nuclei.
  - Motor output to EOMs via the VESTIBULAR nucleus.
- Many other pathways
• Saccade – 150-250 msec latency –
  – Sub-cortical and cortical
  – Smooth pursuit tracking interrupted at:
    • 51 inches per second for 250 millisecond latency
    • 86 inches per second for 150 millisecond latency
    • Performed at 1/3 meter (33 cm)
  – Mediated by the vestibular system through SP/VOR/OKN

• Saccade – 150-250 msec latency –
  – Immature at birth and develops to adult like by at least 2 years old
  – Large visual-motor movement planned and implemented without peripheral feedback during movement (Brooks, 1986, p. 127)
    • Implies peripheral “map” with schema holding muscle tension, velocity, size information to get to point B.
    • Predictive saccades possible in 12-14 week olds
Pathways and neurology

• Neural Integrator (NPH & INC)
  – Prolongs/shortens signal from peripheral apparatus
  – Signals from SCC/otoliths
  – Velocity signal to align eyes to speed of head rotation
  – Horizontal oculomotor integrates in the Nucleus Prepositus Hypoglossi
  – Vertical and torsional oculomotor integrates in the Interstitial Nucleus of Cajal
• “Velocity signals from SCC or acceleration signals from otoliths, need a signal encoding eye position” – Herdman (feldenstruktur fibers role?)

Functional development/embryology

• Feldenstruktur fibers
  – Findings with electron microscopy (thanks to Dr. Richard Brunech)
    • 1:1 or 1:2 neuron to motor unit
  – So far only found in the ear (remember the stapes and tensor tympani) and EOM’s
    • tensor tympani - constricts when too loud (pupils)
  – 20% of all motor neurons in EOMs
  Not fully developed till 6-8 years of age
  Should this be how much and when we do near work?
• Proprioceptive feedback loop for EOM position
  – should we cut? grow back?

Pathways and neurology

– VOR + OKN = integration of fast/brief acting + slow/long term processing of angular movement/motion
– Mechanics of eye movements
– Example of relationship-Infantile eT
  • OKN- motion asymmetries & LN means poor integration of OKN
Summary of Eye Movement

- VOR - 16 msec latency -
  - Registers brief stimulus through subcortical

- OKN - 140 msec latency -
  - Registers sustained stimulus through subcortical with cortical integration (along with development)

- Pursuits – 90-150 msec latency –
  - Subcortical and cortical

- Saccade – 150-250 msec latency –
  - Subcortical and cortical

- What if hyper or hypo registering?

Take home message

- Peripheral vestibular apparatus
  - SCC, Otoliths
    - Motion detectors - rotational and linear
    - Basis for VOR

- Central vestibular
  - Processes signals from vestibular, ocular, proprioception
  - Neural connections to all sensory motor systems

- Motion processing

- All the above makes VOR + OKN = stabilized imagery

Why is OKN important?

- Birth T to N present, N to T begins 2-3 mo.
- Symmetry about 9 mo.
- Visual experience needed for maturation
- *Stereo parallels development of OKN 4-6 mo.
- *Can be used as differential test for time of onset / type of esotropia
- Likely on a continuum
- Right and left not necessarily symmetrical
Neurology of Eye Movements

• VOR
  – Testing
    • DVA 2 hertz
    • Head thrust on infants
  • ENG
  – Patient complaints – dizziness, lack of coordination, vertigo, reading delays, hx of ear infection, and blur with motion
  – Almost always affected with ABI
  – Sometimes causative in oculomotor deficiencies
  – Primarily reflexive early on, cortical develops control later on a continuum

DOLL'S EYE TESTING: When the head is rotated to the left, the endolymph moves toward the left ampulla and away from the right ampulla. When the head is rotated to the right, the endolymph moves toward the right ampulla and away from the left ampulla.
Neurology of Eye Movements

- Vestibular system is fully myelinated at birth
- Sensory system for acceleration/deceleration
- 60% of compensatory eye movements
- Supplemented with OKN and smooth pursuits to provide stable eye movements
- Smooth pursuits overrides (integrates) VOR
  - If SP is overriding mechanism, patients with poor SP ability can only marginally suppress VOR

• Summary
  - Short or transient eye stabilization and movement that is suppressed or integrated by SP system

Duality of the Systems

Spatial Worlds are all found in all sensory systems and are reciprocally interwoven
Proprioception/Tactile, Motor, Vestibular, Auditory, Visual
• Developed vs. acquired
  - Differences for early onset vs. late onset strabismus vs. acquired (ABI)?
  - When is the initial onset of amblyopia? What’s the trigger?
  - Asymmetry-small amount is needed for ideal performance, but overly asymmetric can be a concern as well
• Motor/Proprioception theories
  - Flexion / Extension
  - Tonic (tone) / Phasic (motion)

Duality of the Systems

• Tonic vs. Phasic Receptors
  - Tonic Receptors ("Slow Adapting")
    - The neuron continues to fire until the stimulus is removed
    - Example: You poke yourself with a needle. It will hurt until it is removed.
  - Tonic receptors are constantly on
  - Phasic Receptors ("Fast Acting")
    - Fire only when stimulus first is perceived or removed
    - Example: Putting your clothes on; you are only aware of them for a short period of time.
    - Phasic receptors are usually "off" until a stimulus turns them "on".
      - Example: You are not aware of the temperature until it becomes hot or cold.
Duality of the Systems

- Vestibular - Keiner, et al., Herdmann
  - SCCanals are “phasic”, Otoliths (saccule and utricle) are “tonic”
- Visual – Sensory-Motor theories
  - Motor fusion
  - Sensory fusion
  - All appear to have both phasic and tonic components!

Duality of the Systems

- Visual - Binocular Rivalry
  - The development of OKN and stereo
- Visual - Accommodation/Convergence – Slow/Fast Vergence
  - Tx - traditionally we just vergence think about ranges and adaptation?
- Visual - Spatial
  - Ambient/Focal processes
  - Size of target attended to can be variable
  - Spatial Awareness x, y and z-axis
  - Tx Considerations
Duality of the Systems

• Visual-EOM-
  – Input from EOM proprioception and vestibular input to EOM
    • Horizontal Tx
    • Linear vs. Rotational
  – Why does it sometimes appear to worsens?
• Other EOM and SCC relationships – each one to one
• Considerations
  • Surgical intervention upon proprioception
  • Ear infections upon strabismus

Adaptations

• Short and Long Term Adaptations
  – Older patients - diplopia
  – Younger patients - may learn to suppress
  – Recovery of initial cause (decreased swelling, circulation, rewiring, etc.)
  – Fast Vergence - phasic
  – Slow Vergence - tonic
  – Muscle Length changes with contracture
  – Spreading of commitance
  – Surgical Concerns
  – Other
Thank You

• Comments, criticisms, complaints, confusion...
  – Jason Clopton (Jason)

drclopton@drclopton.com

• 931-372-2020
Vestibular Development: A Look Beyond the Traditional View
Presented by Jason Clopton, OD, FCOVD

Pre/Post Test

1) How important is the vestibular system to child development? To visual development?

2) What effect does vestibular processing have on visual development and re/habilitation?

3) What is the minimal amount of arousal needed to learn & develop?

4) This term is used for the ratio of perceived output (eye velocity) to perceived input (head velocity).
   a. rVOR
   b. GAIN
   c. tVOR
   d. OKN

5) This abbreviation is what occurs when the eye attempts to fixate objects traveling through the visual field.
   a. rVOR
   b. GAIN
   c. tVOR
   d. OKN

6) True or False: VOR gain increases linearly from age 3 to 9 years.

7) What patient complaints would lead you to test VOR?

8) How do you look for vestibular/visual problems in patients?