Children's Vision and the Neural Basis for Vision Therapy

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Neural Basis for Vision Therapy

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  - Center Director, Center of Vision Development – Referral center for pediatrics and brain injury
  - Husband to Heidi Clopton, OTR/L (pediatric occupational therapist)
  - Father to Casey, Ella, Leah, Jason Jr.
  - Great cyclist
  - Master/Rescue scuba diver
  - Eye doctor

Neural Basis for Vision Therapy

- AOA [link](http://en.wikipedia.org/wiki/Vision_therapy)
- College of Optometry in Vision Development
- Orthoptics vs. Vision Therapy [link](http://en.wikipedia.org/wiki/Vision_therapy)
Neural Basis for Vision Therapy

• Vision therapy is a sequence of neuro-sensory and neuromuscular activities individually prescribed and monitored by the doctor to develop, rehabilitate and enhance visual skills and processing. The vision therapy program is based on the results of a comprehensive eye examination or consultation, and takes into consideration the results of standardized tests, the needs of the patient, and the patient's signs and symptoms.

Neural Basis for Vision Therapy

• The use of lenses, prisms, filters, occluders, specialized instruments, and computer programs is an integral part of vision therapy. The length of the therapy program varies depending on the severity of the diagnosed condition(s), typically ranging from several months to longer periods of time. Activities paralleling in-office techniques are typically taught to the patient to be practiced at home, thereby reinforcing the developing visual skills.

Neural Basis for Vision Therapy

• Orthoptics is not vision therapy
  – Orthoptics is the aligning of the eyes
  – Mostly with Monocular tasks, Bi-ocular, MFBF, binocular eye movements without other senses involved.
• Vision therapy (including neuro rehabilitation) includes the other senses and movement within treatment
  – Tactile/proprrioception
  – Vestibular
  – Auditory
Neural Basis for Vision Therapy

• What is the Neural basis for Vision Therapy?
  – We treat, but what is the basis
  – Reputation of “lack of studies” or voodoo
  – Neurological pathways involved in eye movements
    • Evidence based treatment of those pathways
  – Duality of all sensory motor systems for treatment
    • Tactile, proprioception, auditory, vestibular, visual

Neural Basis for Vision Therapy

• VOR – Vestibulo-ocular reflex (16 msec)
  – Maintains fixation and stability by registering very short period of time
  – Sub-cortical response at birth
  – Gain is ratio of head to eye movement
    • Two types rotational and translational
    • 1.0 at birth down to 0.6 when affected by other responses
    • Gain is changed by lenses and therapy
      – Low plus/minus
      – Prism affects in one plane
      – BU, BD, BI, BO – implications
      – Affects entire body

Neural Basis for Vision Therapy

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

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**Neural Basis for Vision Therapy**

• VOR
  - Maintenance of posture
  - Kinetic/transitory contractions of muscles for maintenance of equilibrium and EOM during movement - phasic
  - Maintains muscular tone of EOMs – tonic posture
    • Specifically a saccule function with proprioception
    • Muscle tone basis for CI?

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**Neural Basis for Vision Therapy**

- Vestibular system is fully myelinated at birth
- Velocities 10-40 degrees per second
- 60% of compensatory eye movements
- Supplemented with OKN and smooth pursuits to provide stable eye movements
- Smooth pursuits overrides
  • If SP is overriding mechanism
  • Patients with poor SP ability can only marginally suppress/override/integrate with VOR

• Summary
  - Short transient eye stabilization and movement that is suppressed by SP system
Neural Basis for Vision Therapy

• OKN- Latency of 140 msec
  – Registers sustained stimulus through sub-cortical with cortical integration (along with the continuum of development)
    • Indirect in infants (sub-cortical) and direct SP pathway in adults (cortical)
  – Stimulated by visual motion input on retina
  – Involves optokinetic system, smooth pursuit, and saccades (see latency breakdown)
  – OKN drum 60 degrees per second UP TO 180 degrees per second

Neural Basis for Vision Therapy

• OKN
  – “hard wired?” lateral to nasal
    • Developed nasal to lateral at 2-3 months
    • Can be asymmetry up to 6 months, but should be symmetric at 9 months
  – Deficiencies found in strabismus or deprivation amblyopia (commonly early onset)
Neural Basis for Vision Therapy

• Pursuits – 90-150 msec latency –
  – Cortical
  – Driven by retinal slip (motion)
  – 50-60 degrees per second
  – Thought to cancel 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

Neural Basis for Vision Therapy

• Saccade – 150-250 msec latency –
  – Sub-cortical and cortical
  – Smooth tracking interrupted from at 51 inches per second at 250 milliseconds up to 86 inches per second at 150 milliseconds performed at 1/3 meter (33 cm)
  – 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
Neural Basis for Vision Therapy

- **Neural Integrator**
  - Prolongs/decreases signal from peripheral vestibular apparatus
  - Signals from SCC/otoliths
  - Velocity signal aligns eye to speed of rotation
    - Horizontal oculomotor – Nucleus Prepositus Hypoglossi
    - Vertical and torsional oculomotor – Interstitial Nucleus of Cajal
  - Integrates signals from VOR/OKN/SP to allow for normal eye movements
  - Eye movement abilities can be monitored or changed via this mechanism – *“Neurology of Eye Movements”* – Leigh and Zee

- **“Velocity signals from SCC or acceleration signals from otoliths, need a signal encoding eye position”* – Herdman, Vestibular Rehabilitation

  - Feldenstruktur fibers role?
  - The brain receives direction of gaze information, proprioception within the extraocular muscles and/or from the oculomotor neurons that drive the muscles.

Core concepts for applications in VT

- **VOR-16 msec latency**-
  - Registers brief stimulus through sub-cortical and is overridden by smooth pursuit system
- **OKN-140 msec latency**-
  - Registers sustained stimulus through sub-cortical with cortical integration (along with the continuum of development)
Core concepts for applications in VT

- **Pursuits** – 90-150 msec latency –
  - Cortical (with attention)
- **Saccade** – 150-250 msec latency –
  - Sub-cortical and cortical
- **Multiple inputs with vision**
  - Stationary central visual input with moving periphery, vice versa (watching a moving target)
  - Linear/rotary vestibular input with stationary eyes (driving a car)

Core concepts for applications in VT

- **Post Rotary Nystagmus latency (?? Msec)**
  - Nystagmus caused by suddenly stopping (pulse step) of the rapid rotation of the body (head) (i.e. sudden large vestibular input)
  - Affected by nVOR and OKN (OKAN)
  - Use PRN in our office as a model for visual/vestibular integration and treatment via duality of systems
  - Norms are 7-10 seconds up to 3rd decade
  - Isolation of each pair of canals to the horizontal

Duality of systems

- Each sense has two pathways, a sub-cortical one that travels through the limbic system and thalamus, helping the person to orient, and a cortical one that travels to a part of the cortex for higher processing
  - Tactile/proprioception to somatosensory cortex, etc
  - Auditory to temporal cortex
  - Vestibular to vestibular cortex
  - Visual to superior colliculus and occipital cortex
- Each cortical pathway is further divided into two portions – a central (focal) and a peripheral (ambient) pathway
Duality of systems

• In each sense, the peripheral pathway signals used for awareness of surroundings travel faster than the central signals which are used for identification.
• The person selectively filters out what they want to (able to) pay attention to from the general background stimuli. Then, they aim their eyes (ears, balance, body) and focus in on their chosen target.
• Is there ever a purely sympathetic function or parasympathetic function?

Duality of systems office treatment

• For vision therapy we use each sensory system as a primer for visual function/activities
  – We always use vestibular for prepping visual function
  – Sometimes use tactile, proprioception, auditory, vestibular in conjunction with visual function
    • Proprioception - Weighted vests, weights on periphery, joint compressions
    • Tactile – Brushing PRP (protective regimen protocol)
    • Auditory - Therapeutic listening, calming music
    • Vestibular - Swinging

Duality of Systems

• Tactile
  – Light touch system (sympathetic/ambient/where/excite/protective) - dopamine releasing
  – vs. Deep touch system (parasymp/latent/what/calm/discriminative) - serotonin releasing
    • Serotonin can be released with self injury (basis for pinch, bite, head bang?)
  – Basis for PRP (protective regimen protocol)
Duality of Systems – tactile pathways

<table>
<thead>
<tr>
<th>Protective Pathway</th>
<th>Discriminative Pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curie pain, temperature, light touch</td>
<td>Cancer vibration, proprioception, pressure touch</td>
</tr>
<tr>
<td>Older, more primitive system</td>
<td>Newer, more sophisticated system</td>
</tr>
<tr>
<td>Faster, can't tell exactly where contact was made</td>
<td>Slower, precise, can tell exactly where contact was made</td>
</tr>
<tr>
<td>Tactile in therapy</td>
<td>Light touch stimulates F/F (symp) response</td>
</tr>
<tr>
<td>We all use it, let's know why</td>
<td>Can trigger sympathetic response</td>
</tr>
<tr>
<td>Tickling</td>
<td>Can trigger parasympathetic response</td>
</tr>
<tr>
<td>Tags in shirts, lines in socks</td>
<td>Evaluates information — do we need to be concerned</td>
</tr>
<tr>
<td>Suppression of vision</td>
<td>Causes information that encourages us to learn and explore</td>
</tr>
<tr>
<td>Deep touch stimulates R/D (para) response</td>
<td>Activities and exercises</td>
</tr>
<tr>
<td>Grabbing</td>
<td>Calms and organizes</td>
</tr>
<tr>
<td>Big hugs</td>
<td>Horseback riding</td>
</tr>
<tr>
<td>Weighted vests (10% of body weight)</td>
<td></td>
</tr>
<tr>
<td>Finger thumb</td>
<td></td>
</tr>
</tbody>
</table>

Duality of Systems – tactile pathways

• Tactile in therapy
  – We all use it, let's know why
    – Light touch stimulates F/F (symp) response
      • Tickling
      • Tags in shirts, lines in socks
      • Suppression of vision
    – Deep touch stimulates R/D (para) response
      • Grabbing
      • Big hugs
      • Horseback riding
      • Weighted vests (10% of body weight)
      • Finger thumb

Duality of Systems

• Proprioception system – second power sensation
  – Pushing - extension
    (sympathetic/ambient/where/excite/protective)
  – vs. Pulling - flexion
    (parasymp/focal/what/calm/discriminative)
  – release of GABA
  – Signals movement and disposition of body forming internal map of body
Duality of Systems

• Proprioception in therapy
  • Pushing-extension (sympathetic/ambient/where/excite/protective)
    – Phasic?
    – Arm portion of wheelbarrow walking
    – Wall pushups
    – Reach portion of reach and grab
    – BI
    – Release part of turn and catch
    – Immediately after birth

Duality of Systems

• Proprioception in therapy
  • Pulling-flexion (parasymp/focal/what/calm/discriminative)
    – Tonic?
    – Hand part of wheelbarrow walk
    – Grab portion of reach and grab
    – BO
    – Catch portion of turn and catch
    – In utero

Duality of Systems

• Vestibular – first (strongest) power sensation
  – Rotational (phasic)
    • sympathetic/ambient/where/excite/protective – triggers dopamine
  – Linear (tonic)
    • parasymp/focal/what/calm/discriminative – triggers serotonin
    – 15 minutes of linear vestibular stimulation releases serotonin that lasts up to 8 hours in the brain. Many patients at our office gets this as the primer for therapy.
    – Rotary stimulation releases dopamine and can occur in seconds. This is why children spin themselves. Should be used cautiously in treatment. Can happen in seconds
Duality of Systems

- Vestibular in therapy
  - Rotational (phasic)
    • Used **PRIMARILY** in esotropia
    • With smooth pursuits
    • With monocular, MFBF, binocular
  - Linear (tonic)
    • Used **PRIMARILY** in exotropia
    • With saccades
    • With monocular, MFBF, binocular

Duality of Systems

- Auditory
  - Peripheral
    (sympathetic/ambient/where/excite/protective) –
    • Dopamine – protects against over activation -phasic
  - Central (parasymp/focal/what/calm/discriminative) –
    • Serotonin from otolith and cochlea inhibits amygdala response –tonic
  - Higher serotonin levels with sleep, lower levels with waking in cochlea
    • Stressors rapidly increases serotonin in auditory system in auditory (inferior) colliculus

Duality of Systems

- Auditory therapy
  - Auditory integration (binaural hearing) happens in the inferior colliculus
    • Does binaural hearing happen before or with binocular vision?
  - Rhythm is tonic
  - Melody is phasic
  - Direct connections from inferior colliculus to superior colliculus
Duality of Systems

• Vision

• Peripheral – Retina – Superior colliculus (sympathetic/ambient/where/excite/protective)
  – Retina—Optic Nerve—20% to Superior Colliculus
  – These fibers integrate with other sensory input from:
    • Vestibular
    • Proprioception
    • Kinesesthetic
    • Tactile
  For therapy with balance and orientation.

• Central - Cortical pathway (parasymp/focal/what/calm/discriminative)
  – Retina—Optic Nerve—80% to LGN—then Visual Cortex (V1)
  – V1 Projects to 30 distinct visual areas including:
    • Temporal lobe
    • Parietal lobe
    • Frontal lobe
    • Amygdala
  • For diagnosing pathology and disease

• Vision – peripheral/central processing
  – Peripheral processes “first” faster
    • Larger connection to vestibular
    • Involuntary attention
    • Where information
    • Stimulus driven
  – Central processes later
    • Larger connection to cortex
    • Voluntary attention
    • What information
    • Motivation driven
Duality of Systems summary

- Each system is connected to every other system – we have to be able to evaluate and treat each system to work on the whole
- All systems are reciprocally interwoven
- Vision is linked everywhere
- Growth happens, development is interwoven

Thank You

- Comments, criticisms, complaints, or confusion…
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