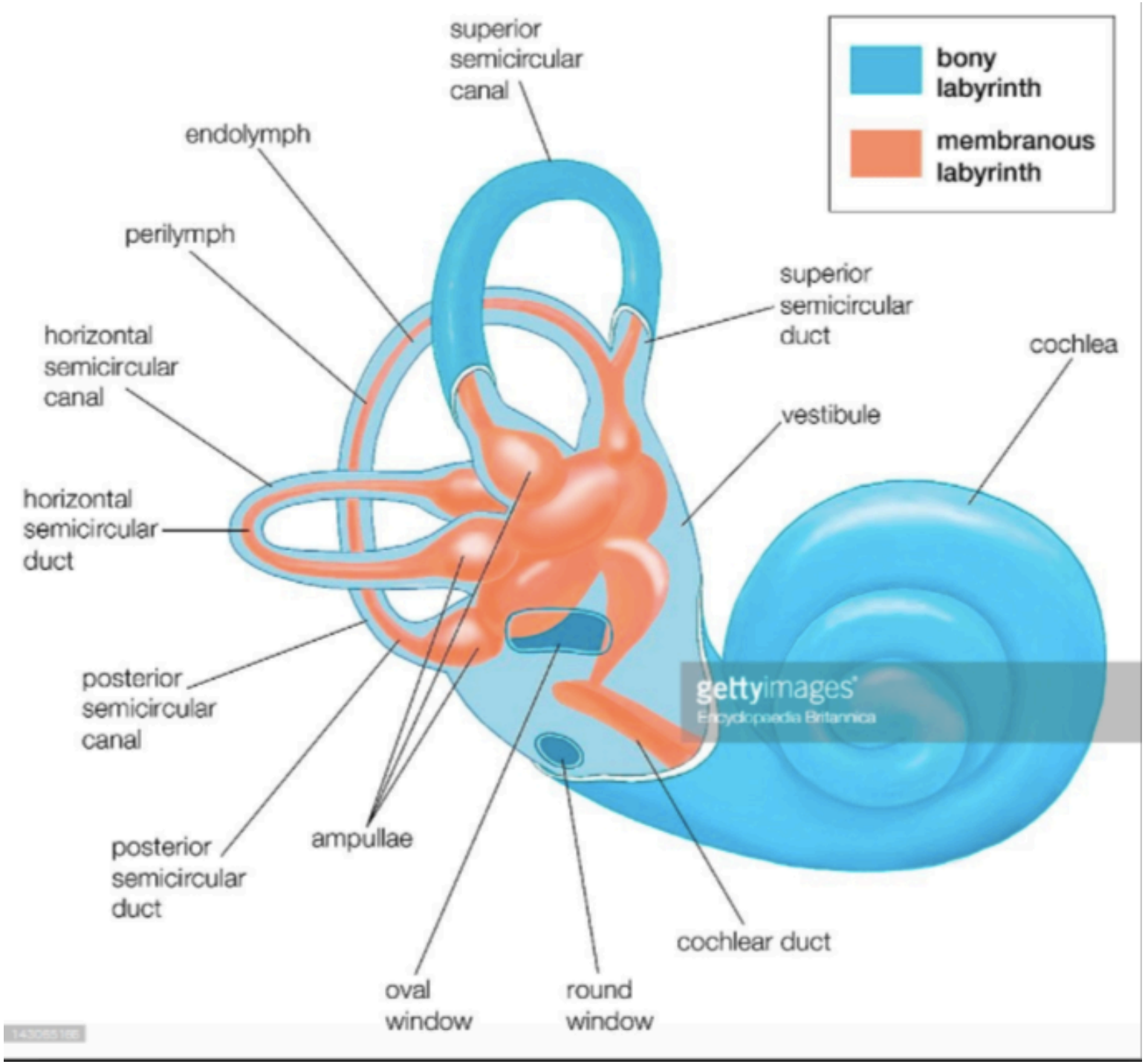
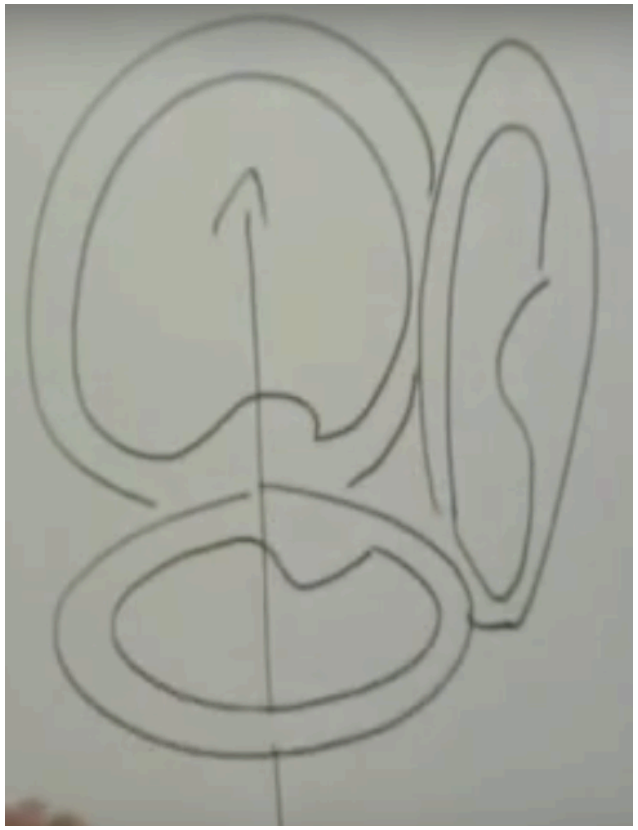
The Vestibular System and Attention and Auditory Processing

A Look at the Science

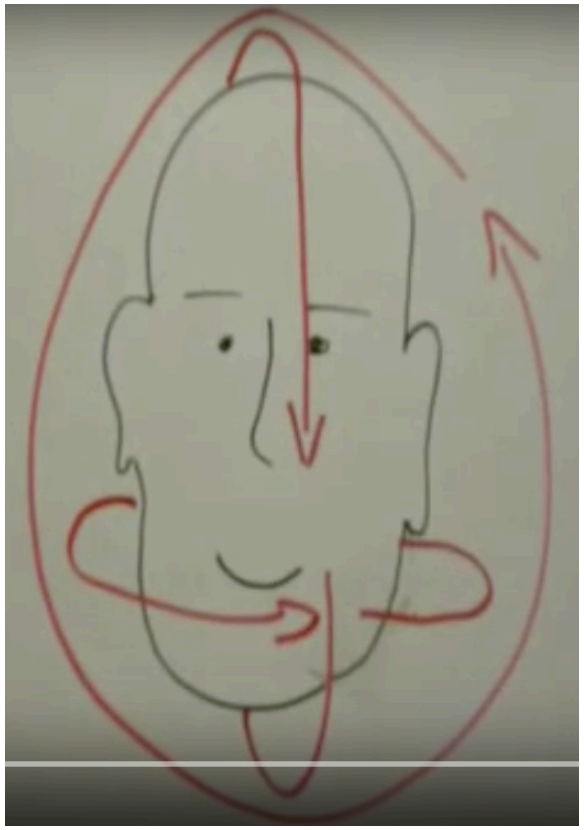

superior semicircular canal
endolymph
perilymph
horizontal semicircular canal
horizontal semicircular duct
posterior semicircular canal
posterior semicircular duct
ampullae
oval window
round window
cochlear duct
vestibule
superior semicircular duct
cochlea
bony labyrinth
membranous labyrinth
gettyimages
Encyclopaedia Britannica

Simplified Version for Vickie

Semicircular Canals-90 degrees



Direction in which they respond

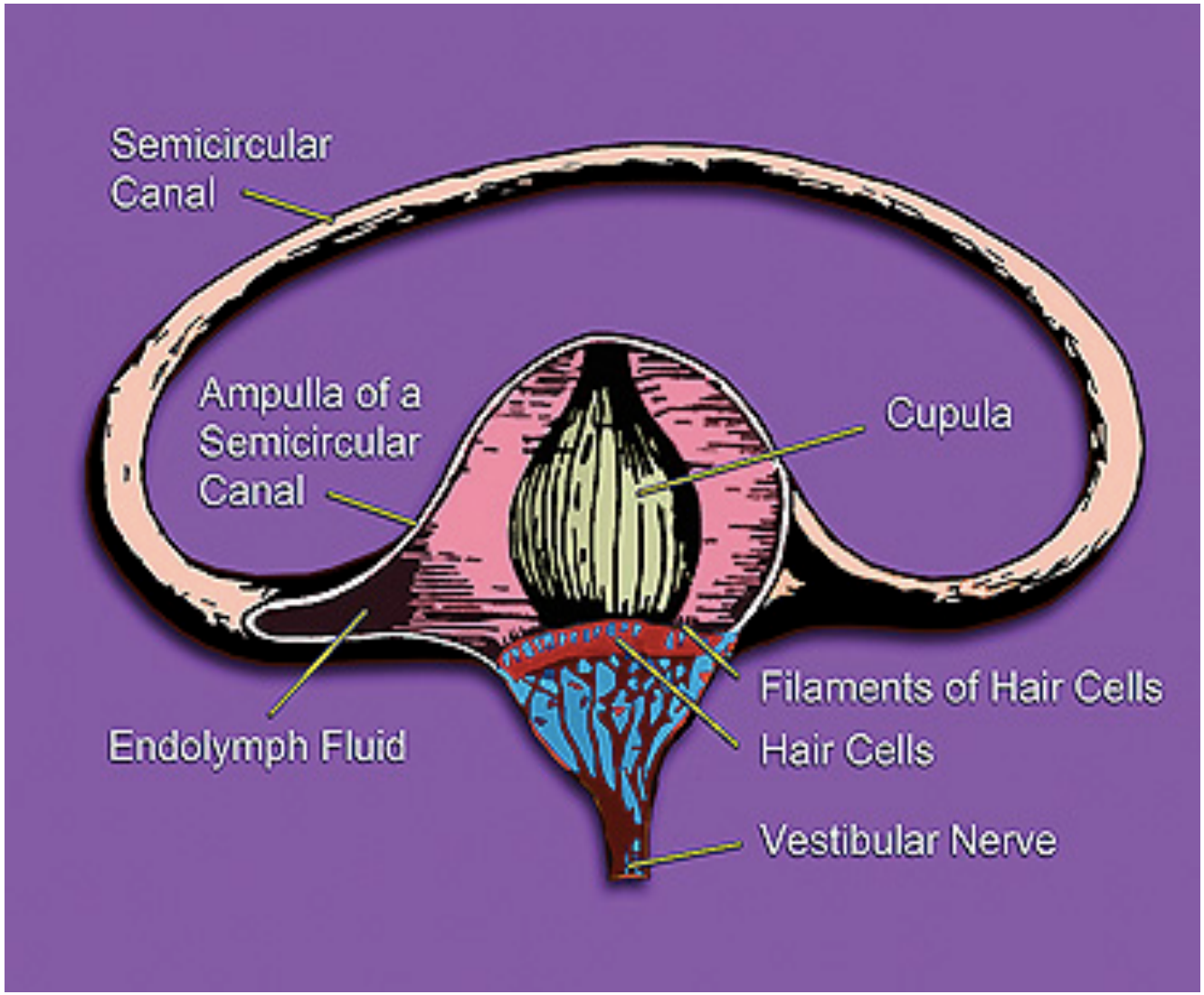


TWO MORE THINGS TO KNOW

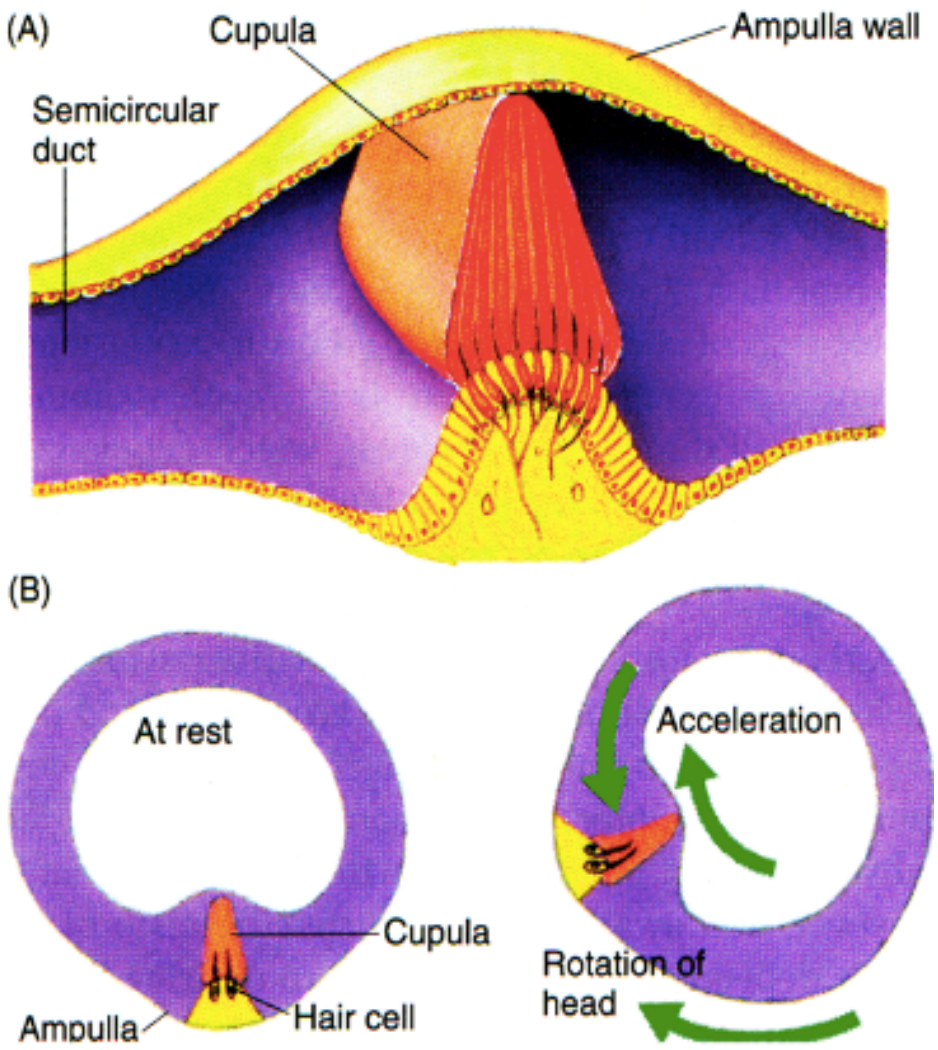
There is a thing called the Utricle in the vestibular system which responds to horizontal motion, like a skate boarder who boards in a sane manner.

There’s another thing called a Saccule that responds to vertical motion, like an elevator or a skate boarder who is insane.

Ampulla of the Semicircular Canal



Affect of Rotation of the Head

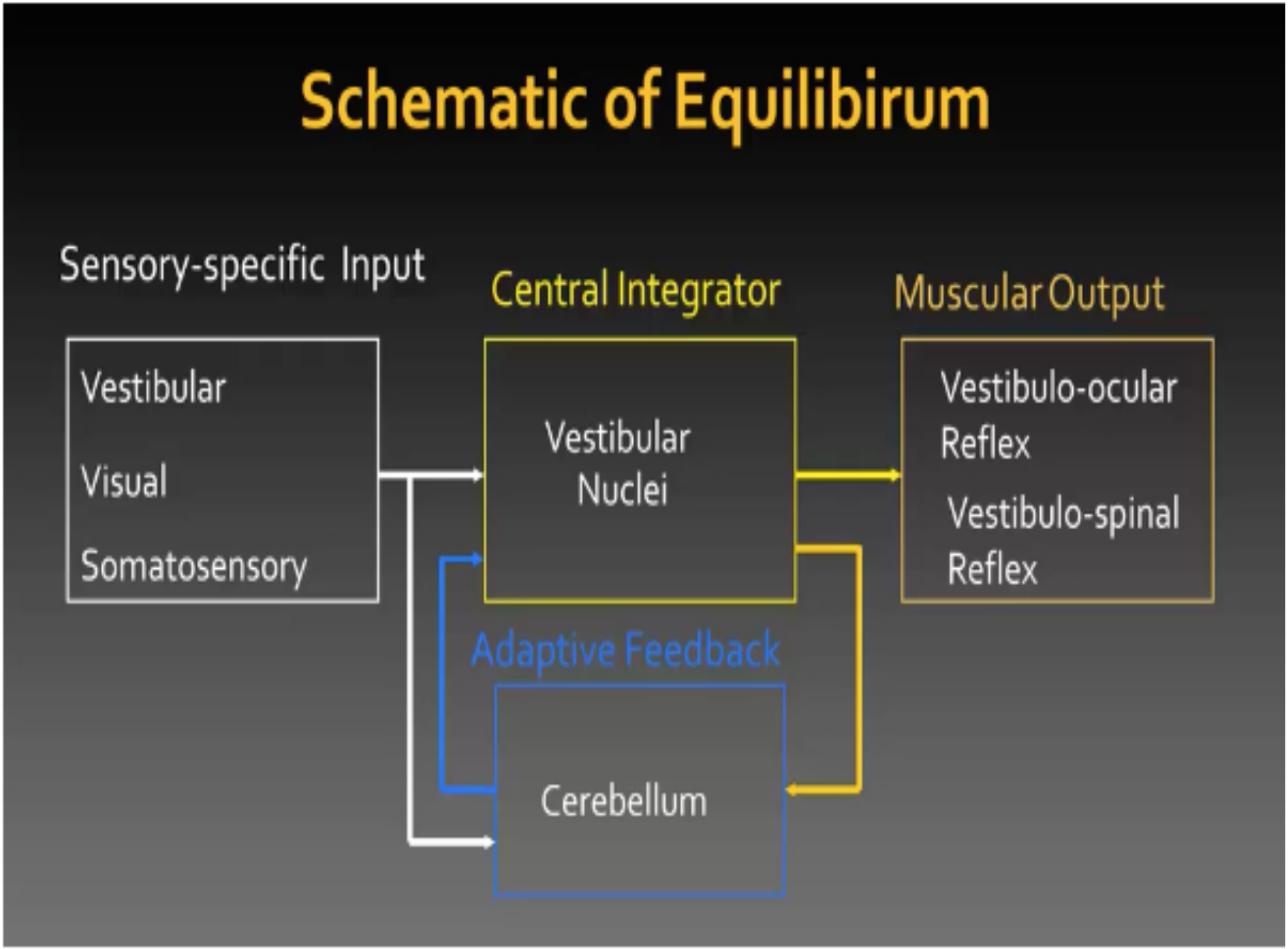


Vestibular Insults So We Can Understand How This Thing Works

Riding In A Car

Drinking Too Much

Hitting Your Head


Schematic of Equilibirum
Sensory-specific Input
Central Integrator
Muscular Output
Vestibular
Visual
Somatosensory
Vestibular Nuclei
Vestibulo-ocular Reflex
Vestibulo-spinal Reflex
Adaptive Feedback
Cerebellum

Journal of Pediatrics 2016
Healthy People 2020 Initiative

Epidemiology of Dizziness and Balance Problems in Children in the United States: A Population-Based

N = 10,954; Ages 3 – 17
5.3% had dizziness and/or balance and/or vertigo
This translates into 3.3 million U.S. children
20.3% Hispanic; 13.5 % Black; 53.3% White

Poor coordination- 46%; Light- headedness -35%; Poor balance -31%; Vertigo- 29%; Frequent falls -25%

Single episode- 54.4%; Small problem -39.8%, Big problem -20.6%

20.9% of children with hearing loss have balance issues compared to 4.9% of normal hearing children

Headaches, migraines, low birthweight and seizures are associated with dizziness

Vestibular Issues We See in Children

Rose Marie Rine, P.T., Ph.D. and Jennifer Braswell Christy, P.T., Ph.D.

Middle ear effusion – the thick fluid in the middle ear space presses on the oval and round window thus displacing the endolymph and stimulating the horizontal semicircular canal of the vestibular system which the brain interprets as motion.

Visual Overload (long sessions with video games , television or reading) can result in a feeling of imbalance. This is thought to be due to a mismatch between the visual system and the somatary system. Another theory is that is due to a discrepancy between what the person expects and what is actually happening in the visual space.

Bilateral Peripheral Vestibular Hypofunction occurring shortly after birth will cause significant delays in walking and other motor functions involving balance.

Oscillopsia - Gaze instability due to interruption of the vestibular system. Franco and Panboca found that 68% of children who were underperforming in school had vestibular deficits.

Vestibular Migraines
Mild Head Trauma
Vestibular Neuritis

Let's Regroup

- *The vestibular system provides us with information about motion, equilibrium and spatial orientation (three semicircular canals, utricle and saccule)*

- *What we typically see in the audiology clinic in terms of balance issues due to vestibular insult does not result in a case history suggesting auditory processing weaknesses. Also, it does not suggest increased "squirming", but rather the opposite effect: "Please do not move me because I will get sick".*

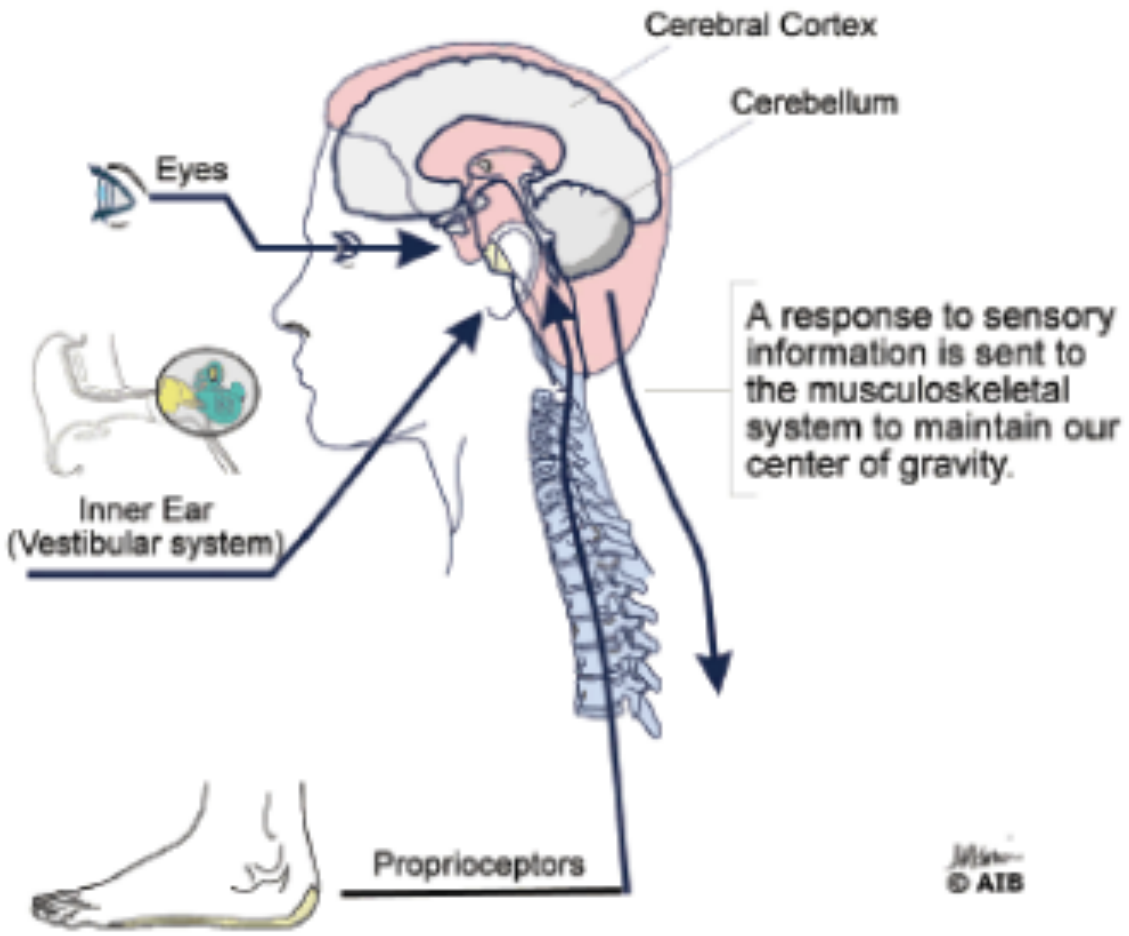
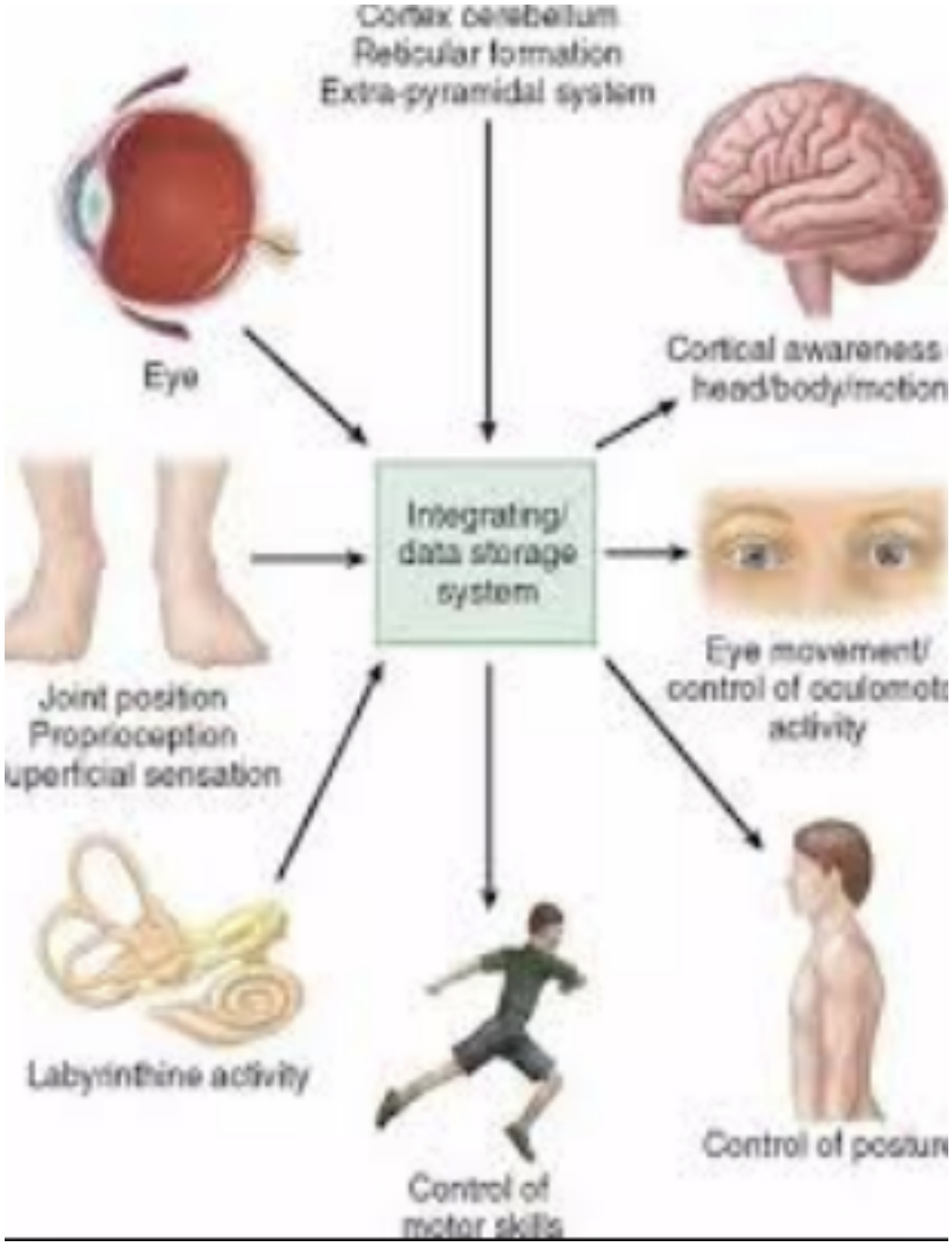


Figure 4: Normal equilibrium requires correct input from sensory modalities.

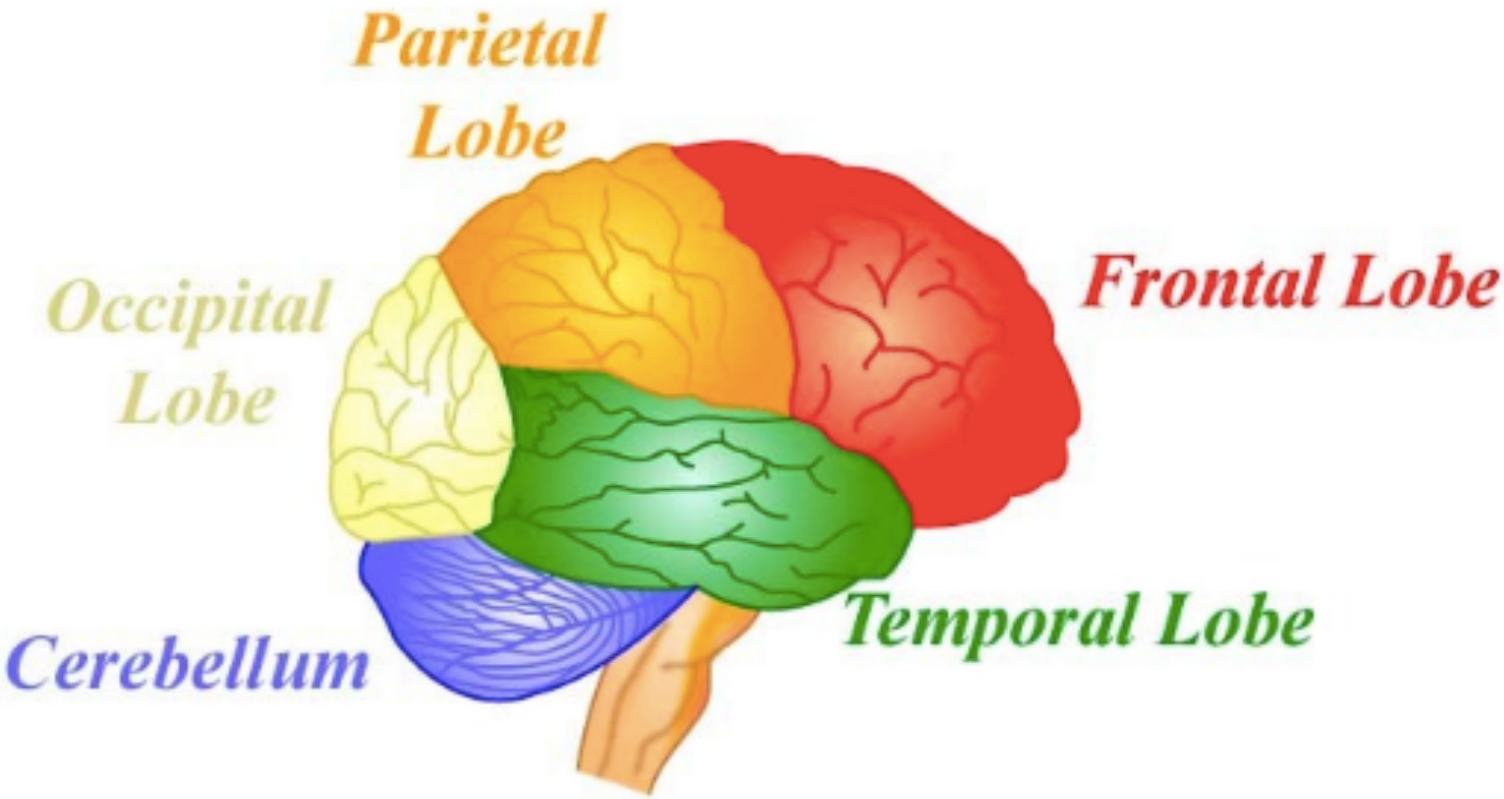

Cortex cerebellum
Reticular formation
Extra-pyramidal system
Eye
Cortical awareness
head/body/motion
Integrating/
data storage
system
Joint position
Proprioception
uperficial sensation
Eye movement/
control of oculomot
activity
Labyrinthine activity
Control of
motor skills
Control of postur

The Integrating Data Storage System

Thalamus

Vestibular Nuclei

Cerebrum


Parietal Lobe
Occipital Lobe
Frontal Lobe
Temporal Lobe
Cerebellum

The Four Lobes of the Brain

Frontal Lobe

Organization
Mental Flexibility
Execution of Behavior
Planning
Judgment
Inhibition
Expressive Language
Attention

Occipital Lobe

Visual Processing
Visual Discrimination
Visual Spatial Skill
Facial Discrimination
Visual Perception

Temporal Lobe

Auditory Processing
Language Comprehension
Emotion
Spatial Processing
Memory and New Learning
Attention

Parietal Lobe

Reading
Calculation
Attention
Cross Modal Processing
(reading, writing, listening)
Spatial Navigation
Visual Perception and
Discrimination

Two More Lobes

Limbic Lobe

Emotion

Behaviors Essential to Life

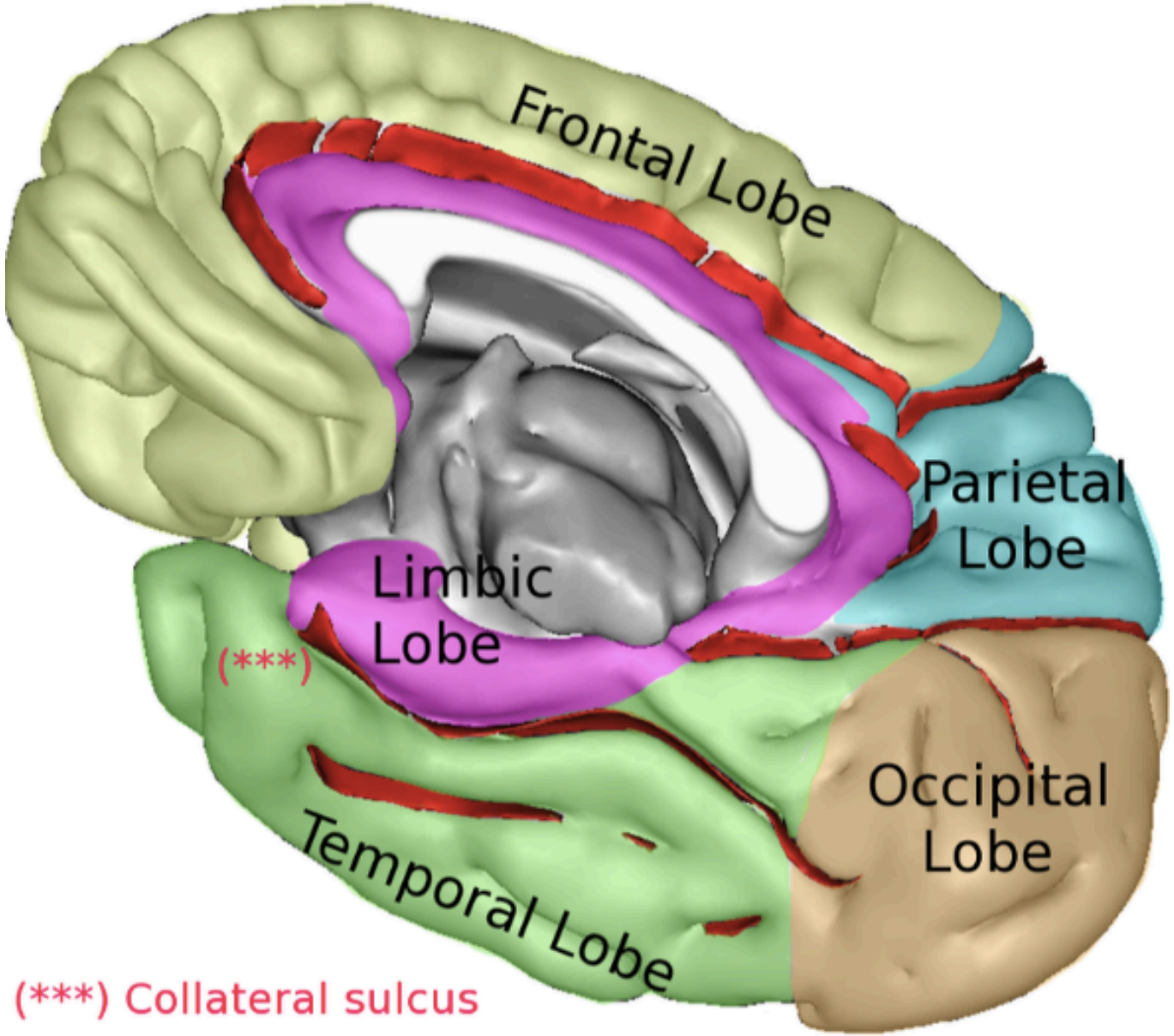
Motivation

Olfaction

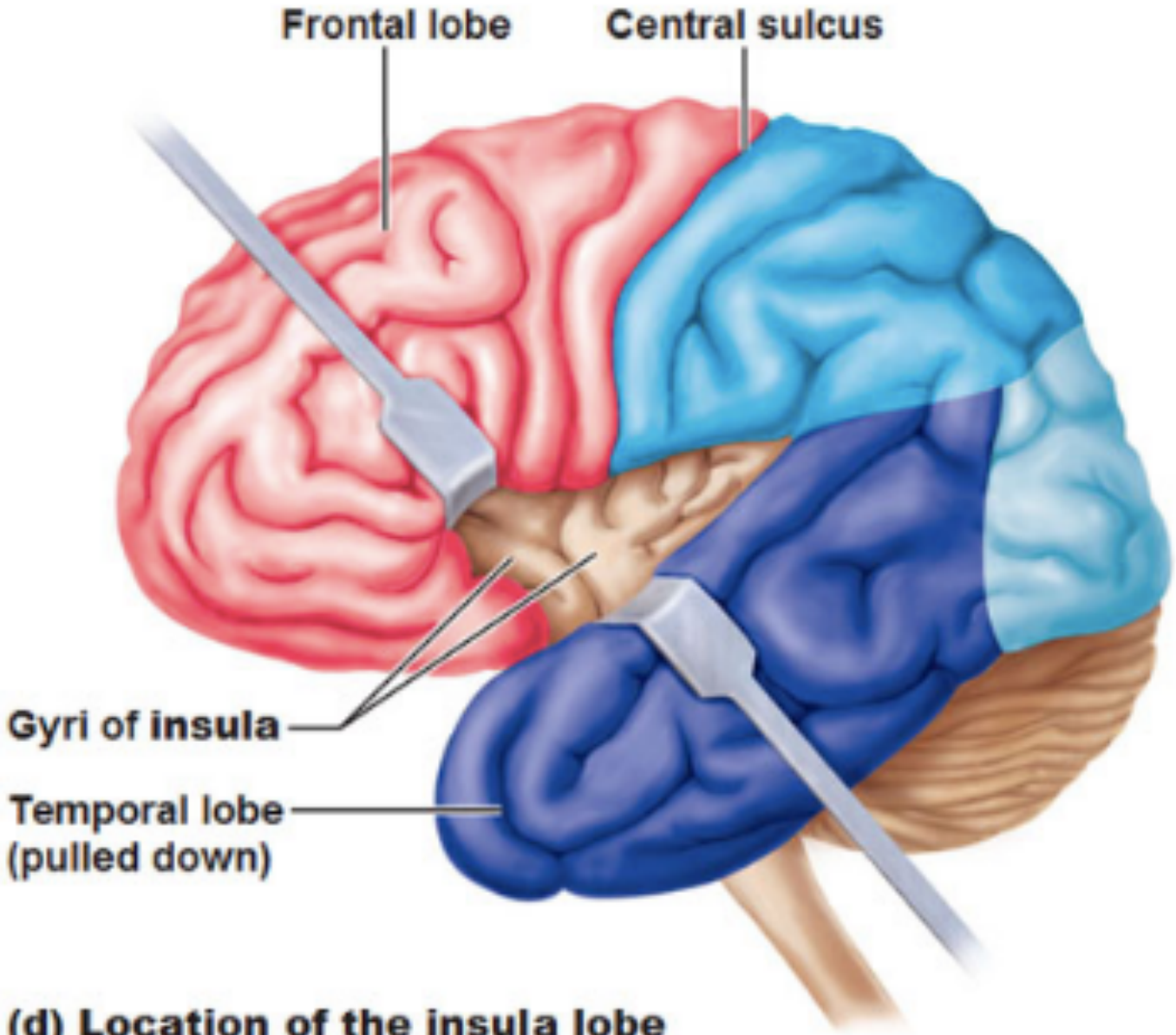
Longterm Memory

Insular Lobe (Cortex)

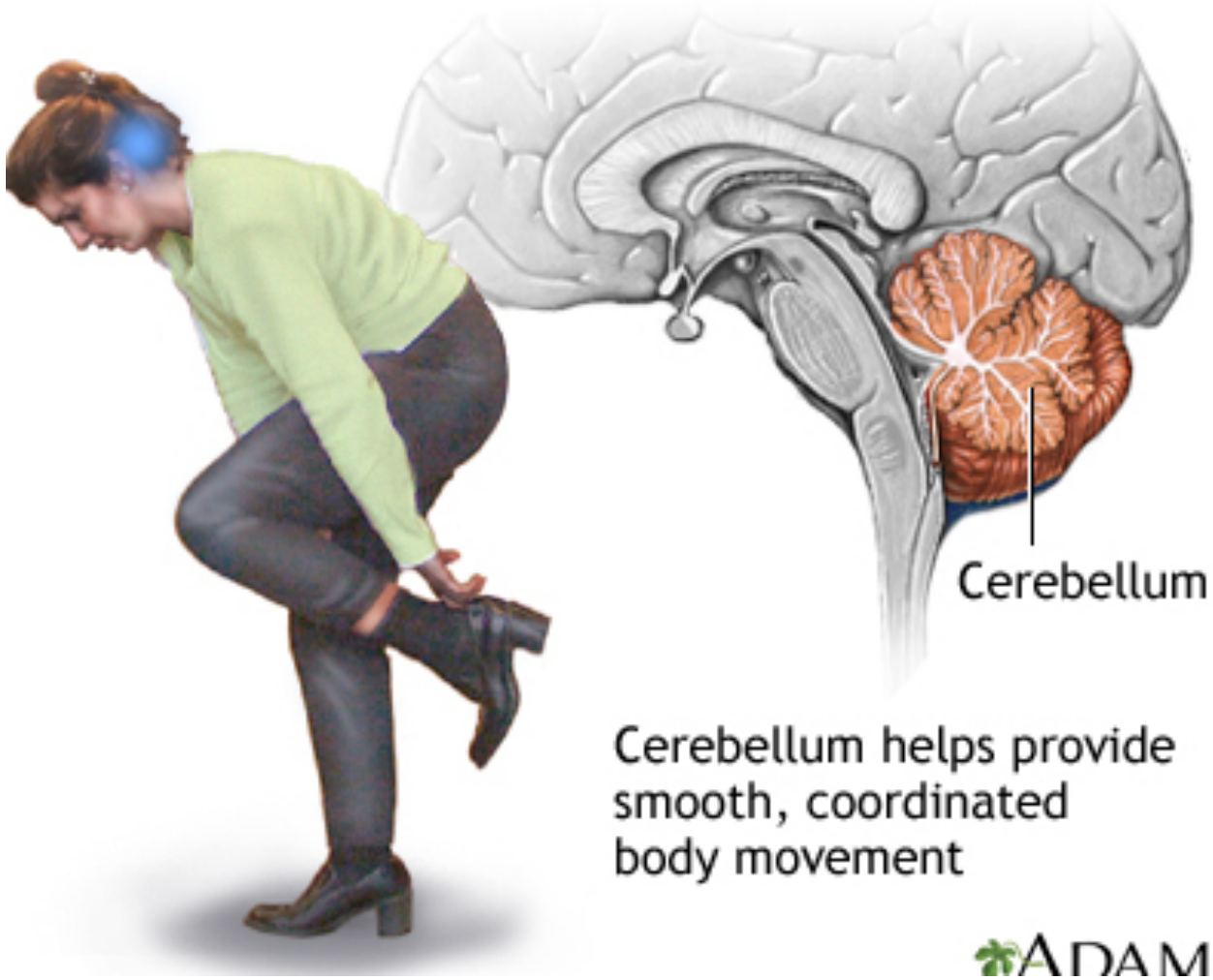
Process convergent information to produce an emotionally relevant context for sensory experience


Frontal Lobe
Parietal Lobe
Limbic Lobe
(***)
Occipital Lobe
Temporal Lobe
(***) Collateral sulcus

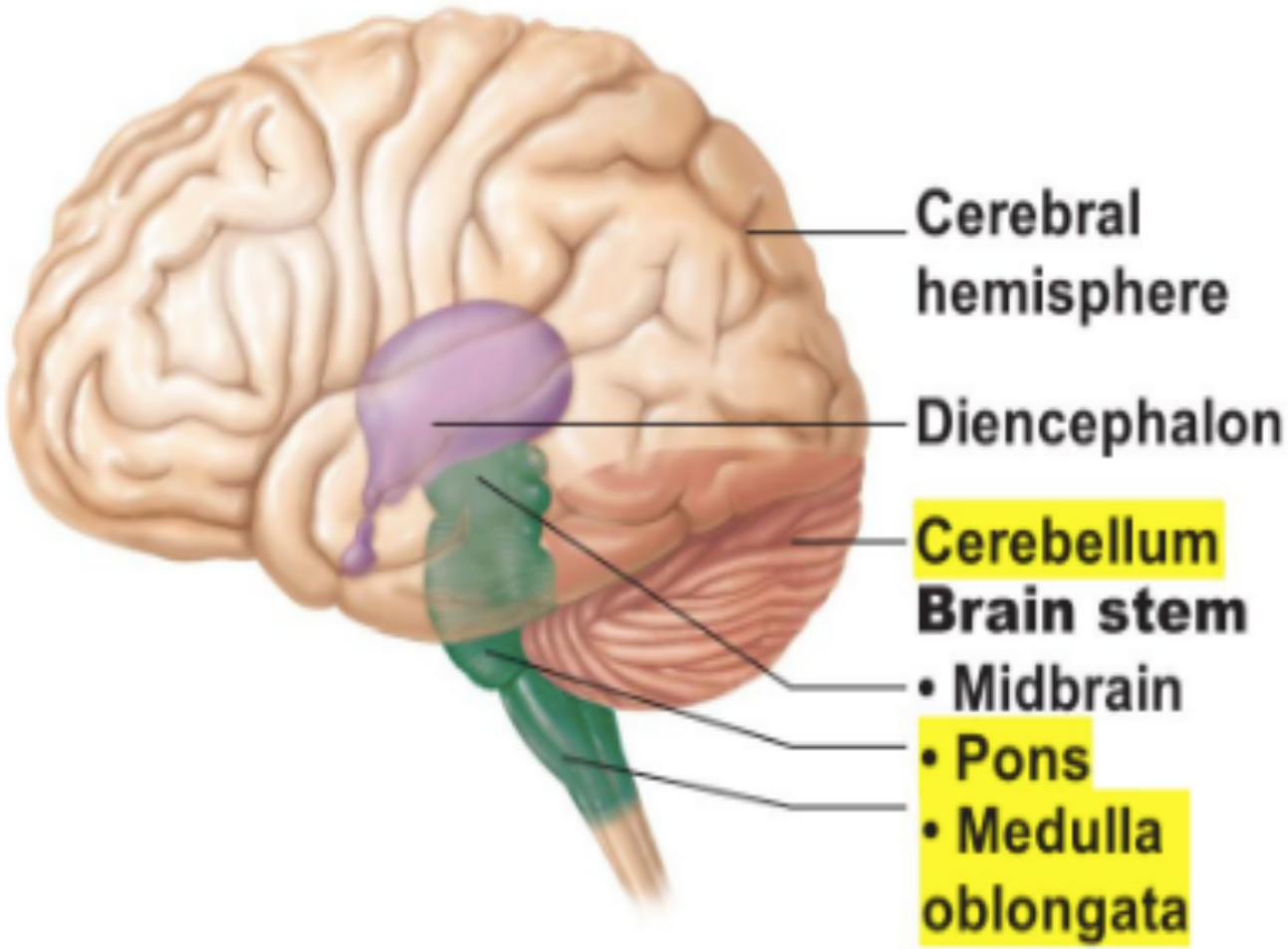
The Cerebral Hemispheres – one more lobe



(d) Location of the insula lobe



Let’s Not Forget the Cerebullum


Cerebral hemisphere
Diencephalon
Cerebellum
Brain stem
• Midbrain
• Pons
• Medulla oblongata

So Let's Regroup Again

- The Cortex, Cerebellum, Reticular Formation and Extra-Pyramidal System are also involved in our ability to maintain balance and locate ourselves in space.

- There is a Networking System that integrates the above mentioned along with the Vestibular, Visual and Proprioception Systems

- This Networking System includes the Vestibular Nuclei, Thalamus and the Cerebrum

- The ability to attend is located in three of the six lobes of the brain

Auditory Processing is:

"What we do with what we hear"

Sensory Processing is:

"What we do with what we are stimulated with"

Does Vestibular Damage Cause Cognitive Dysfunction in Humans?

University of Otago, New Zealand, Osaka University Medical School, Japan 2005

Animal studies have long shown that vestibular damage leads to deficits in the ability to move (spatial navigation). It is proposed that this can lead to deficits in spatial learning and spatial memory.

Direct evidence from recent research has demonstrated that:

- Vestibular insult can lead to cognitive impairment outside of spatial awareness, such as object recognition memory.
- Increased attentional demands can worsen the postural sway that can result from vestibular insult.
- Bilateral vestibular damage results in atrophy of the hippocampus which correlates with the patient's degree of impairment in spatial memory

Their Conclusion

Review of animal and human studies regarding vestibular insults indicate that humans with vestibular disorders are likely to experience cognitive dysfunction, even in patients that are compensated. The authors feel that these findings may be related to the high incidence of depression and anxiety in patients with vestibular deficits.

A Case-Control Study on Balance Function of ADHD Children

Wang J, Wang Y. Ren Y / Peking University, Beijing, China

*Subjects were 80 ADHD children and 80 non ADHD children matched by age and sex

*Evaluated stability in different conditions

*Used the CART to find a relationship between balance and symptoms

*Found that sway velocity of ADHD children was significantly higher than normal children. The condition of foam surface with eyes closed correlated with soma sensory dysfunction, performance IQ, verbal comprehension and freedom from distractibility.

Their Conclusion

*ADHD children have poor stability, abnormal sensory integration, somatosensory differences, and vestibular function deficits.

*More importantly, a correlation between the balance dysfunction and the clinical symptoms and deficits in behavior and cognition.

Cerebral Functional MRI of Vestibular, Auditory and Nociceptive Areas During Galvanic Stimulation

Brain Research Reviews, Volume 42, Issue 2, May 2003

(Nociceptive areas are areas with receptors which register pain that can be harmful to the body)

METHOD

The Galvanic stimulation (electrical) was to the mastoid bone (behind the ear) bilaterally

FMRI used to monitor changes in the brain

Control used was FMRI of cutaneous stimulation at the neck

FINDING

Activation to the bilateral stimulation occurred in three different sensory systems in the insula thalamic region- the vestibular, auditory and nociceptive systems.

Low Intensity Ultrasound Activates Otolith Organs Through Acoustic Radiation Force

Journal of the Acoustical Society, June 2017 Iverson, Parker

PURPOSE

Looked at the efficiency of using a 5 MHz stimulus to elicit activation of the Otolith organs (saccule and utricle)

METHOD

Subjects used were Oyster Toadfish

Neural impulses were equivalent to direct mechanical stimulation of the saccule and utricle

FINDINGS

This stimulation can mimic directional forces occurring naturally in head movements, hearing loud sounds and bone conduction vibration.

Auditory Hypersensitivity and Autism Spectrum Disorders: An Emotional Response Lucker, Doman The Journal of Autiem

- Overview of what is currently known about auditory hypersensitivity (AH)
- AH is not an auditory system disorder but rather a disorder of the emotional system
- Nonclassical auditory pathways (as opposed to classical auditory pathways) are invloved, which begin at VIII nerve and end at the limbic system and the cerebellum.
- Nonclassical pathways are highly active in young children and become suppressed as we get older.

Good Articles to Read

The response of guinea pig primary utricular and saccular irregular neurons to bone conduction vibration and air conducted Vibration - Hearing Research 2016 January; 331:131-143

A possible correlation between vestibular stimulation and auditory comprehension in children with attention deficit/ hyperactivity disorder – Psychol. Neurosci. vol 7 no. 2 Rio de Janeiro Jzn/June 2014

Now We Really Need to Regoup Again!

Reasons (proven and not proven) Why Children Squirm More Than What Is Expected

- ADHD
- Sensory Processing
- Postural Instability (weak core, primitive reflexes not integrated)
- Anxiety
- Habit

And More Reasons

- Lack of adequate exercise
- Poor breathing
- Visual problems
- Immature nervous system
- Having to sit still for too long

(10 minutes for a six year old)

Even More Reasons

- Allergies
- Poor sleep habits
- Hunger
- Anger
- Too much time in front of screens
- Lack of respect for adults

Neurological vs. Naughty

P R O B L E M I S

Neurological	Behavioral
Child Gives Up, Thinks You Do Not Understand, Self Esteem Goes Down	**Behavior is changed**
Child Feels Supported, Is Willing To Try	**Child Feels Successful In Pulling One Over You**
Kathleen Plazman,Ph.D Sherri Pruitt, Ph.D.	

B E H A V E

N E U R O

T R E A T A S

Comorbidity – more on this in the next presentation

Fifty percent of those diagnosed with ADHD may also have APD, but ...

ADHD and APD issues primarily originate from different parts of the brain.

It is proposed that while APD can affect attention by making listening more difficult, ADHD can affect auditory processing by taking away resources.

Forty percent of children with Dyslexia have APD.

About 50% of children with APD (Frequency Pattern Test) have a reading disorder and a language disorder.

Jay to the Rescue, or so I thought…

Jay was providing the statistical analysis for a study in progress which is looking at impact of Sound Intervention training on Auditory Processing abilities in ED/LD students using bone conduction vs. air conduction stimulation and classical unmodulated vs. classical modulated music. The subjects would be given a standard auditory processing battery at the beginning and conclusion of the study. But then *#@$^%& happens!

My Humble Conclusions

A deficit vestibular system (semicircular canals, sacculle and utricle) does appear to directly cause auditory processing difficulties, ADHD or sensory processing issues (ie no direct connection to the kiddo sqirming in their seat)

Insults to the vestibular system can totally screw up the information sent to the integrated system that controls our movement and our balance.

Studies suggest strengthening or activating of the vestibular apparatus boosts our integrated system to enhance and support the other systems it partners with.

Juggling


UNDER
ARMOUR

Resources to Read Concerning Screen Time and Brain Development

Ted Talk by Demetrious Christakis, M.D.

Digital Heroin https://nypost.com/.../its-digital-heroin-how-screens-turn-kids-into-psychotic-junkies/

Brain Hijacking
www.businessinsider.com/screen-time-limits-bill-gates-steve-jobs-red-flag-2017-10

As much as we want it to all be SCIENCE...