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Vestibular Function in Patients with Traumatic Brain Injury: current state of the literature, challenges, and future directions

Daniel J. Romero, AuD, PhD

Daniel Romero, AuD, PhD

Daniel J Romero is an Assistant Professor and licensed audiologist for the Department of Hearing and Speech Sciences at Vanderbilt University Medical Center. His primary research interests focus on understanding the role of the vestibular system and its impacts on dizziness and cognition in adults with chronic traumatic brain injury, as well as the clinical application of objective vestibular measures to improve vestibular screenings. Dr. Romero serves as Programs Chair for the American Academy of Audiology and on the Board of Directors for the American Balance Society. He also co-hosts a vestibular-focused podcast called a dose of dizzy.

Disclosures

- **Presenter Disclosure:** Financial: Daniel Romero is employed by Vanderbilt University. AudiologyOnline has made a donation to Vanderbilt University's student educational program in appreciation of the presenters donating their time to the Vanderbilt Audiology Journal Club. Non-financial: Daniel Romero serves as the Programs Chair for AAA 2025, VASC committee, Vestibular Guidelines Panel.
- **Content Disclosure**: This learning event does not focus exclusively on any specific product or service.
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Learning Outcomes

After this course, participants will be able to:

1. Describe the impact of heterogeneity of TBI on vestibular function test findings.
2. Identify key challenges in diagnosing and treating vestibular dysfunction in chronic TBI.
3. Discuss the role of cortical vestibular dysfunction in chronic TBI.

Today's Timeline and Agenda

1 — 2 — 3

1	2	3
What is a TBI?	**Current state of TBI literature**	**Future directions**
Definitions, prevalence, pathophysiology, common myths	Current diagnosis, treatment, clinical audiologic recommendations?	Impact on cognition and self-motion perception, future research

Traumatic Brain Injury (TBI)

Mild TBI/Concussion

- Most TBIs that occur each year are mild TBIs or concussions.
  - "A bump, blow, or jolt to the head, or
  - By a hit to the body that causes the head and brain to move quickly back and forth
  - This sudden movement can cause:
    - The brain to bounce around or twist in the skull
    - Chemical changes in the brain
    - Stretching and damaging brain cells

Moderate-Severe TBI

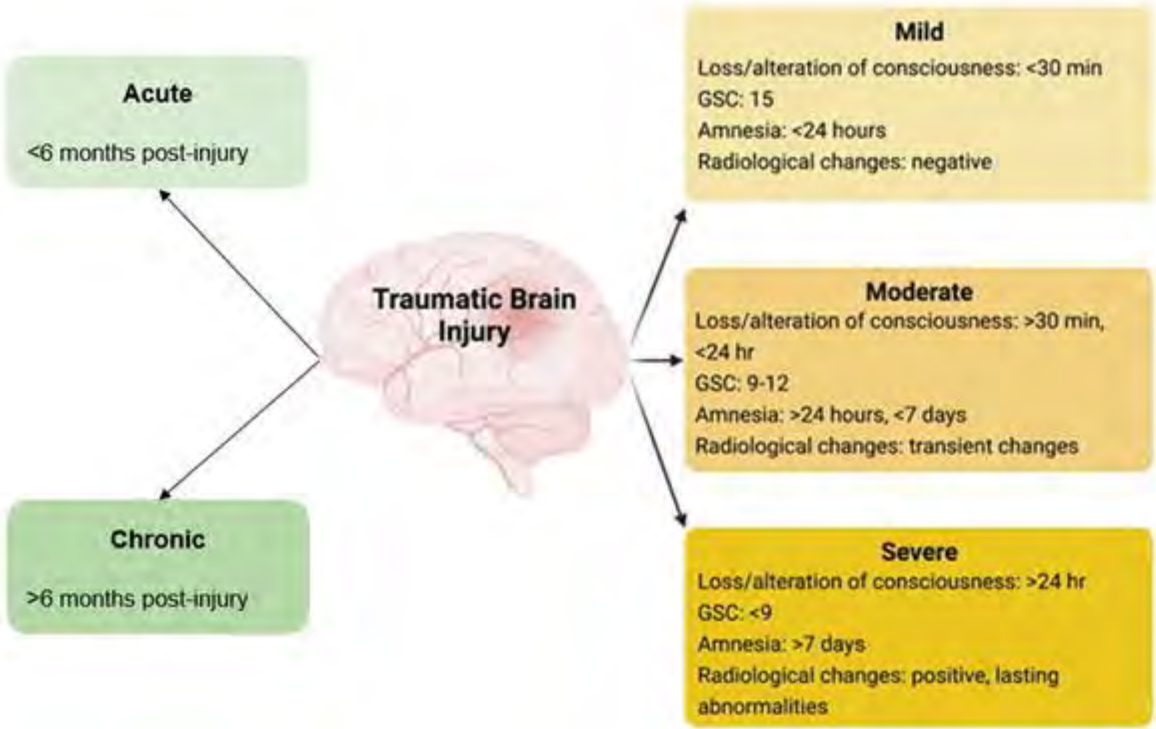
- A moderate or severe TBI is caused by a bump, blow, or jolt to the head or by a penetrating injury to the head.
- In the United States, severe TBIs are linked to thousands of deaths each year
  - Falls
  - Motor vehicle accidents
- Can lead to long-term health problems/symptoms

These changes in the brain lead to symptoms that may affect how a person thinks, learns, feels, acts, and sleeps

CDC, 2024

TBI classification

- TBI can be classified by degree and/or time course of symptoms



Mofatteh, M. (2021)

Moderate-Severe TBI

CDC, 2024

Prevalence of TBIs

- 42 million people are diagnosed with concussion worldwide every year (NIH, 2020)
- 223,135 hospitalizations related to TBIs in 2019 (CDC)
  - Out of 330 million Americans
- TBI does not affect only one population
  - People aged 75 years and older have the highest rates of TBI-related hospitalizations (32%) and deaths (28%)

Economic impact

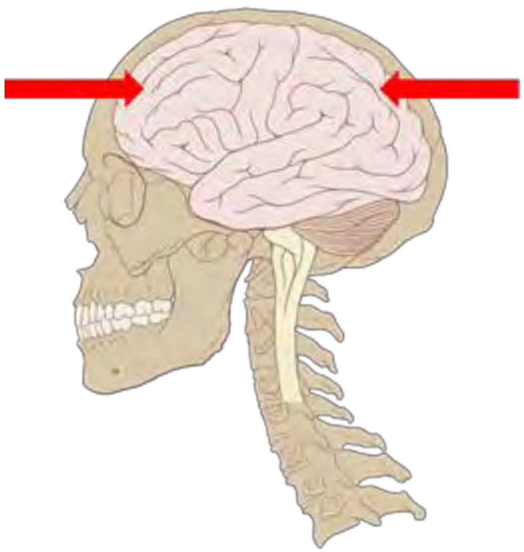
- TBIs, especially moderate-severe, are costly!
- Economic consequences, costing approximately $81 million in direct healthcare costs and up to $2.3 billion in indirect healthcare costs (Humphreys et al., 2013).
- Economic implications of proper treatment for patients with TBI are estimated as approximately $11,000 per patient in medical savings and total societal medical cost savings of more than $3 billion (Faul et al., 2007).

Common Causes of TBIs

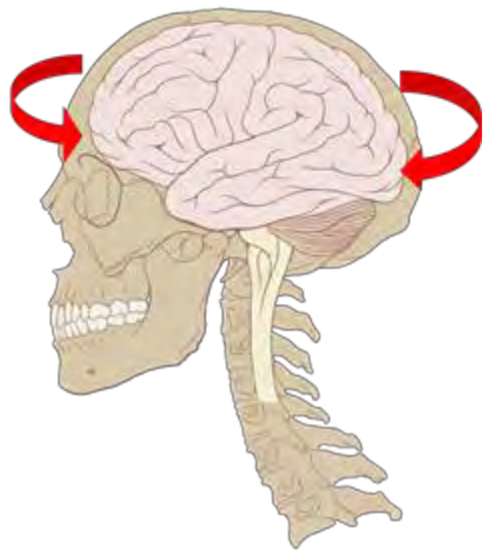
- Motor vehicle accidents
- Sports
- Falls
- Military/combat
- Assault

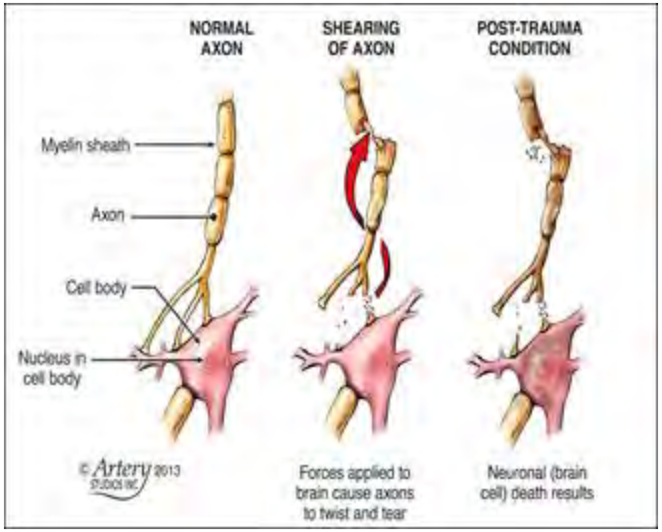
Types of Injuries

Deceleration Injury



Rotational Injury





Forces lead to a wave of energy that passes through the brain tissue triggering neuronal dysfunction with shearing/tearing of axons

pic : sites.nd.edu

Common myths

FALSE

A direct head impact is necessary for diagnosis of mild TBI/concussion.

It is the acceleration, deceleration or rotation of the brain inside the skull that causes injury to the brain's function. This movement can happen secondary to direct or indirect head impact.

TRUE

A concussion is technically classified as a mild traumatic brain injury.

A concussion is a type of injury to the brain, usually mild in nature due to symptom presentation and recovery prognosis.

FALSE

Loss of consciousness is required for a true diagnosis of TBI.

More than 90% of concussions do not involve loss of consciousness.

CDC 2006

Common symptoms

TBI can result in numerous cognitive and physical symptoms, and dizziness is the second most reported symptom and most linked to a protracted recovery (Gianoli, 2022).

- Cogntive impairment
- Dizziness
- Imbalance
- Disorientation
- Blurred vision
- Tinnitus
- Noise sensitivity

Team-Based Evaluation

- Neuropsychological/Neurocognitive evaluation
  - ImPACT, King Devick, SCAT5, etc.
- Neurologic evaluation
  - Symptom pathology, reflexes, balance, oculomotor, etc.
- Imaging
  - MRI/CT scan
- Symptom Evaluation
  - Written, computerized, or verbal

General goals of a vestibular assessment post-TBI

1. Evaluate vestibular and ocular reflex pathways
2. Functional VOR and Balance measures

Goals:

- Identify abnormalities to guide recommendations for therapy/intervention types
- Establish baseline to measure and track recovery
- Rule in and out otologic involvement

Clinical test recommendations vary, and this is likely due to the inherent variability of TBI

Challenges in TBI Diagnosis

There is no **one** objective test to determine whether a TBI has occurred.

1. Multi-disciplinary approach
2. Utilizing multiple types of tools and evaluations

No **two** TBIs are the same.

1. Injury mechanism (cause, direct vs. indirect, etc.)
2. Symptom profile / clinical presentation
3. Pre-existing medical conditions
4. Prolonged recovery risk factors (previous concussions, hx of migraines, etc.)

TBI and the Vestibular System

Considering the complexity of subcortical and cortical vestibular and oculomotor pathways

There is not a consensus on which part of the vestibular system is most affected post-TBI

These questions are unclear in the literature:

- Which part of the vestibular system is most vulnerable?
- Which tests are best to evaluate this population?
- What are the most common vestibular test results?

Gralapp, 2024

What do we know?

- Traditional view is that TBI can affect multiple levels of the vestibular pathway, from trauma affecting the ***inner ear and brainstem*** pathways

TBI is associated with:

- Ruptured otoliths and membranes (Kerr and Byrne, 1975)
- Degenerative changes in otoliths (Schuknecht et al, 1956)
- Displaced otoconia from otoliths into semicircular canals (Hughes and Proctor, 1997)

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Review > Int J Audiol. 2021 Jul;60(7):479-494. doi: 10.1080/14992027.2020.1811905. Epub 2020 Sep 9.

Frequency of peripheral vestibular pathology following traumatic brain injury: a systematic review of literature

Bojana Šarkić [1], Jacinta M Douglas [2, 3], Andrea Simpson [2], Alexandra Vasconcelos [2], Bethany R Scott [2], Lauren M Melitsis [2], Stephanie M Spehar [2]

Peripheral Vestibular Disorders in Children and Adolescents with Concussion

Jacob R. Brodsky, MD[1,2], Talia N. Shoshany[1,2], Sophie Lipson[1,2], and Guangwei Zhou, ScD[1,2]

Vestibular-Evoked Myogenic Potential Outcomes Associated with Pediatric Sports-Related Concussion

Amanda I. Rodriguez PhD, AuD, Jonathan Chiao MD, MPH, Gretchen Spencer MS

Otolith dysfunction in recurrent benign paroxysmal positional vertigo after mild traumatic brain injury

Gang Chen, Xuening Zhao, Gang Yu, Huirong Jian, Yun Li & Guangming Xu

Objective Vestibular Testing of Children with Dizziness and Balance Complaints Following Sports-Related Concussions

Guangwei Zhou, MD, ScD[1,2], and Jacob R. Brodsky, MD[1,2]

Peripheral Vestibular And Balance Function In Athletes With And Without Concussion

Jennifer B. Christy, PT, PhD[a], Graham D. Cochrane[a], Anwar Almutairi, PT, MS, PhD[a], Claudio Busettini, PhD[b,c], Mark W. Swanson, OD, MSPH, FAAO[b], and Katherine K. Weise, OD, MBA FAAO[b]

Post-Concussive Vestibular Dysfunction Is Related to Injury to the Inferior Vestibular Nerve

Anna Gard,[1,*] Ali Al-Husseini,[1] Evgenios N. Kornaropoulos,[2] Alessandro De Maio,[3] Yelverton Tegner,[4] Isabella Björkman-Burtscher,[5] Karin Markenroth Bloch,[6] Markus Nilsson,[2] Måns Magnusson,[7] and Niklas Marklund[1]

Patterns of vestibular dysfunction in chronic traumatic brain injury

Rachael L. Taylor[1,2,3,4*], Kim J. Wise[1,2], Denise Taylor[1,3,4], Shikha Chaudhary[1,5] and Peter R. Thorne[1,3,4,7]

Vestibular and balance function in veterans with chronic dizziness associated with mild traumatic brain injury and blast exposure

Faith W. Akin[1,2*], Owen D. Murnane[1,2], Courtney D. Hall[1,3], Kristal M. Riska[4] and Jennifer Segal

Patterns of Vestibular Dysfunction Post-TBI

PERIPHERAL DYSFUNCTION PATTERN
~30% of the time

- Increased likelihood for those with a skull-base fracture, 3rd window, or blast injuries
- Otolith dysfunction (cVEMP) more commonly abnormal in non-SRC chronic TBI (Akin et al., Sarkic)
- H-SCC impairment – vHIT and Caloric testing
- Other studies suggest that caloric testing is normal in SRC

Taylor et al.; Akin et al.; Gard et al.

CENTRAL DYSFUNCTION PATTERN
~13.75% of the time

- Greater oculo-motor abnormalities in SRC (e.g., smooth pursuit)
- VOR suppression are most often abnormal

Christy et al.; Rodriguez et al.

BPPV
~24% of the time

Greater occurrence of previous BPPV Hx in all TBI patients

Chen et al; Sarkic

MIXED
< 5 % of the time

Otolith impairments:

- Chronic mild TBI: **25% (19/77) cVEMP** and **18% (14/77) oVEMP** abnormalities (Akin et/ al., 2022)
- Acute mild TBI: **22% (14/63) had both cVEMP and oVEMP** abnormalities; 3% (2/63) had isolated oVEMP abnormalities (Ernst et. al., 2005)

SCC impairments:

- Chronic mild TBI: between **5% (4/77; calorics) and 8% (6/77; SHA) hSCC** abnormalities (Akin et/ al., 2022)

Functional Deficits

FUNCTIONAL VOR
6.57 % of the time

- Most reported in SRC
- SVV indicated in SRC and pediatrics

Christy et al.; Brodsky et al.; Zhou et al.

POSTURAL STABILITY
~49.69% of the time

- SOT most commonly abnormal either composite score or condition-based score

Gard et al.; Akin et al.; Taylor et al.

How does TBI affect the Vestibular system?

- Clinical evidence outside of experimental studies **vary widely** and is largely associated with the **heterogeneity of TBI**.

- Yet, the most **consistent** finding is that patients with TBI have difficulty **maintaining balance** during tasks that require a **high use of vestibular input** (e.g., condition 5 on the sensory organization test or SOT) – despite a large proportion of these patients having clinically normal vestibular exams.

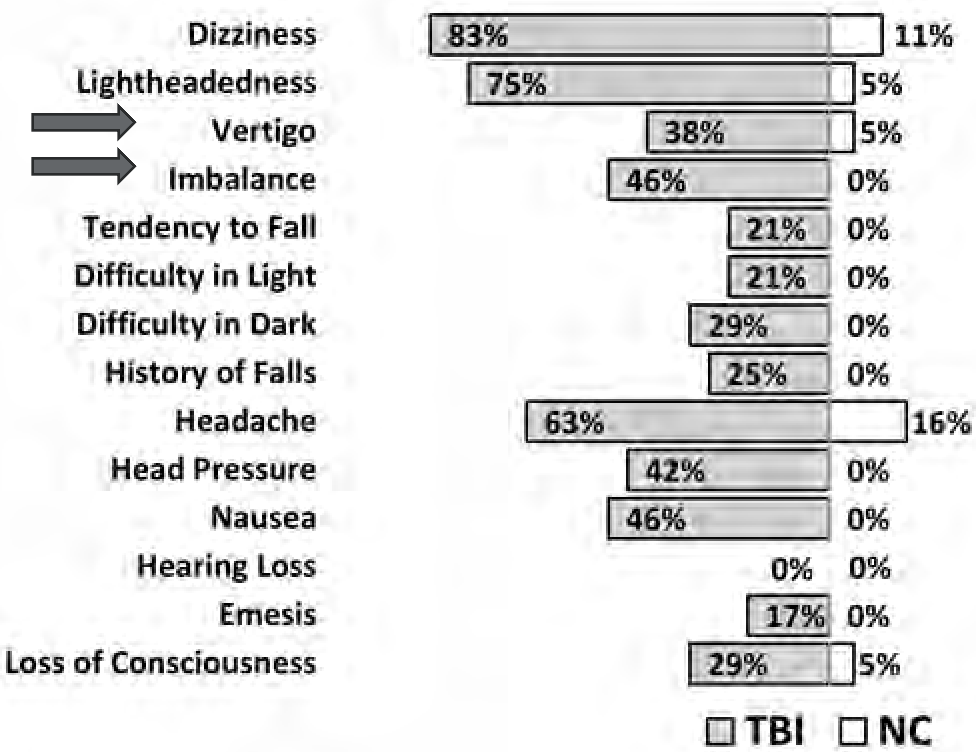
Challenges in TBI-related research

1. Mechanism of injury, severity, and phase of injury not controlled for in studies
2. Vast majority of studies are retrospective which are faced with challenges of internal validity
3. Most studies are retrospective design
4. Lack of inclusion of objective vestibular-specific measures

Self-Reported Symptoms of Vertigo and Imbalance Are Prevalent Among Adults With Chronic Moderate–Severe Traumatic Brain Injury: A Preliminary Analysis

Daniel J. Romero, Jessica Feller, Sharice Clough, Gary Jacobson, Richard A. Roberts and Melissa Duff

- Twenty-four adults with chronic moderate–severe TBI and a group of 19 age-, sex-, and education-matched noninjured comparison participants were recruited
- Self-reported dizziness and imbalance were measured using a modified version of a standard case history



Romero et al., 2023

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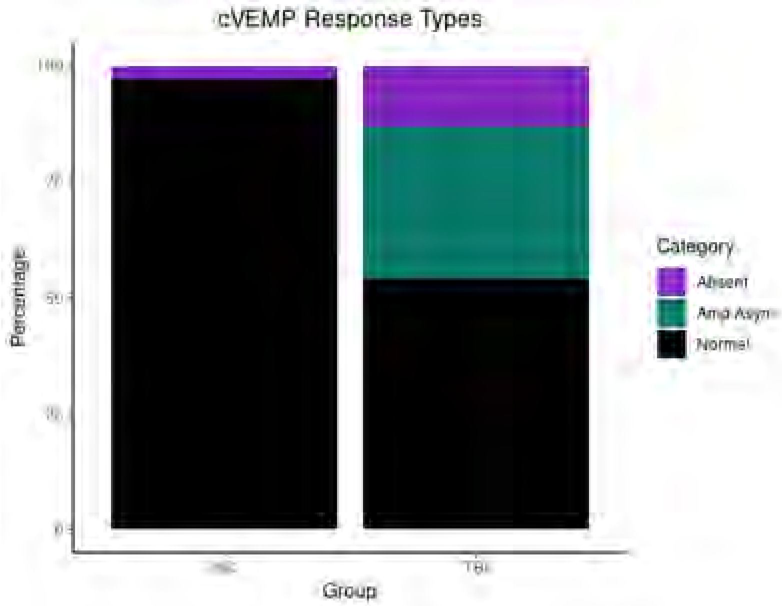
Evidence of Peripheral Vestibular Impairment Among Adults With Chronic Moderate–Severe Traumatic Brain Injury

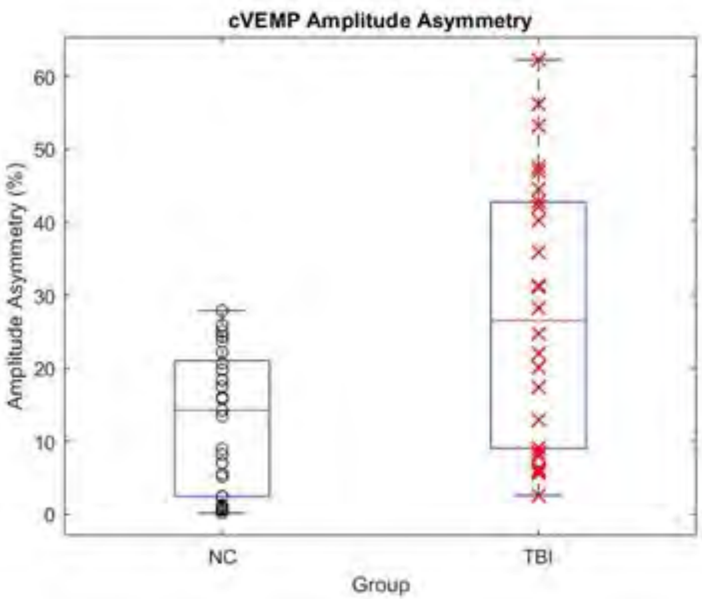
Jessica J. Feller, Melissa C. Duff, Sharice Clough, Gary P. Jacobson, Richard A. Roberts and Daniel J. Romero

- 30 patients with chronic moderate-severe TBI matched 1:1 to 30 controls
- Cervical and ocular vestibular evoked myogenic potentials (VEMPs) and video head impulse test (vHIT) were used to assess the function of otolith organ and horizontal semicircular canal (hSCC) pathways
- Determine prevalence of vestibular symptoms and quality of life associated with those symptoms.

cVEMP amplitude asymmetry was significantly higher in the TBI group.



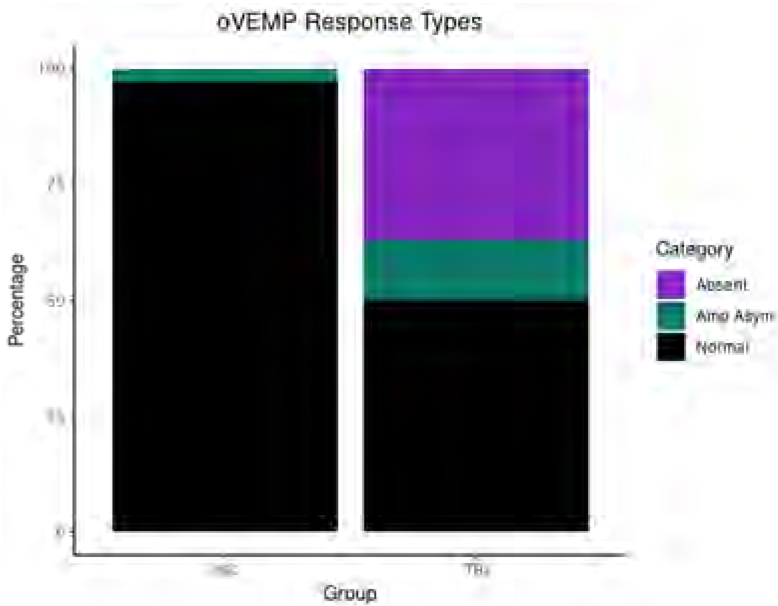
Fisher's Exact: **$p < 0.001$*****



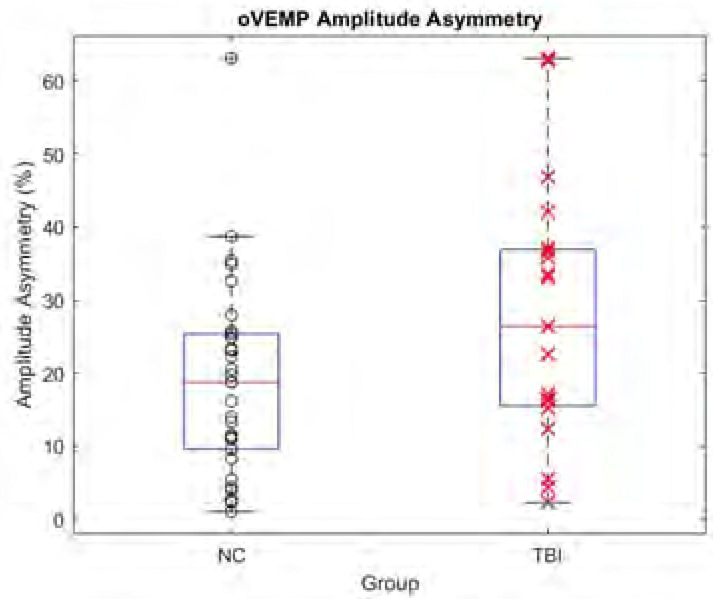
Wilcoxon Rank Sum: Z= 3.573; **$p < 0.001$*****
Abnormal Cutoff: 31.76% (based on 95% CI of NC data)

Feller et al., 2024

Results: oVEMP amplitude asymmetry was higher in the TBI group.



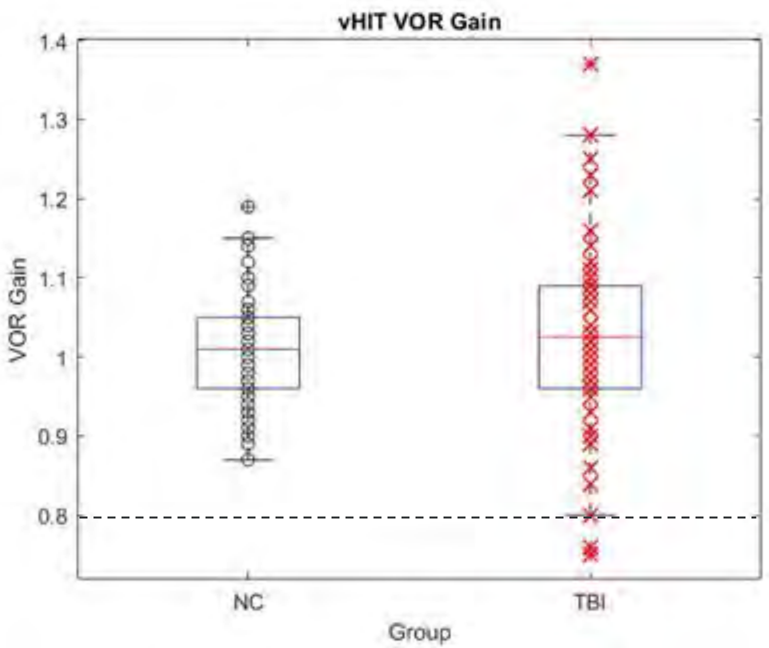
Fisher's Exact: **p < 0.001*****



Wilcoxon Rank Sum: Z= 2.118; **p = 0.034***
Abnormal Cutoff: 38.72% (based on 95% CI of NC data)

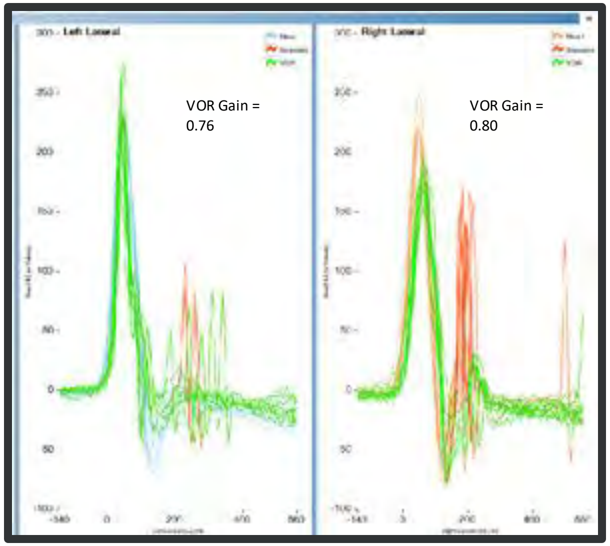
Feller et al., 2024

Results: 7% (2/30) of TBI participants had abnormal vHIT.



Wilcoxon Rank Sum: Z= 1.108; p = 0.268

Exemplar vHIT from TBI Participant



Feller et al., 2024

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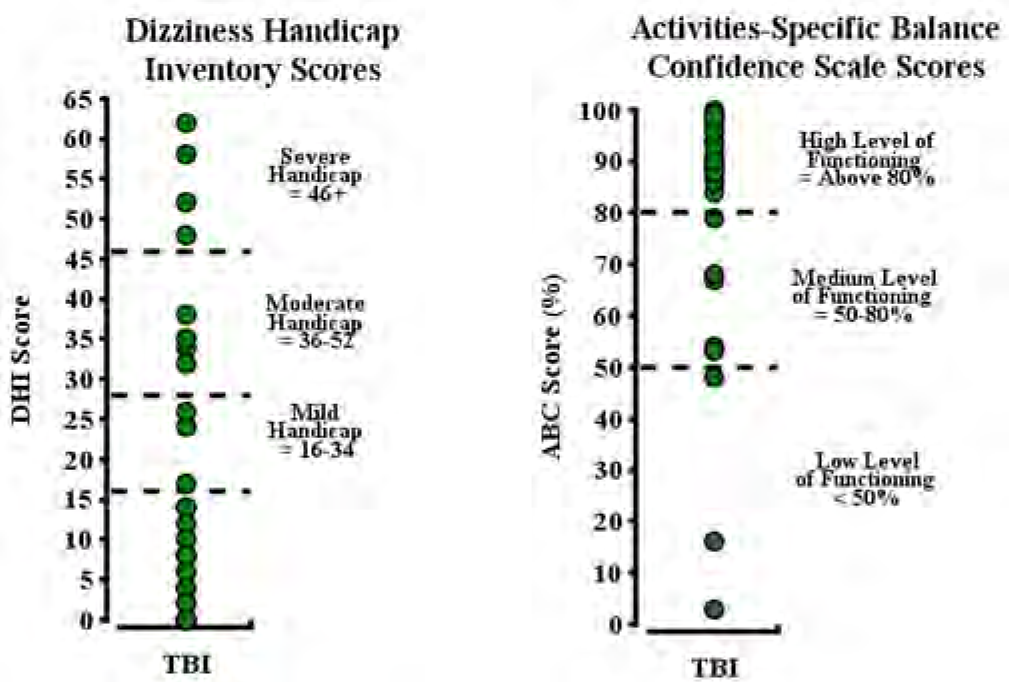
Results: 63% (19/30) of TBI participants had at least one peripheral vestibular impairment.

TABLE 3. Response categories for all vestibular tests for each participant with TBI.

Participant	cVEMP		oVEMP		vHIT	
	Left	Right	Left	Right	Left	Right
1	Normal	Normal	Normal	Normal	Normal	Normal
2	Absent	Normal	Absent	Normal	Normal	Normal
3	Normal	Normal	Normal	Normal	Normal	Normal
4	Amplitude Asymmetry (R > L)		Absent	Normal	Normal	Normal
5	Normal	Normal	Normal	Normal	Normal	Normal
6	Normal	Normal	Amplitude Asymmetry (R > L)		Normal	Normal
7	Normal	Normal	Normal	Normal	Normal	Normal
8	Normal	Absent	Normal	Normal	Abnormal	Abnormal
9	Normal	Normal	Normal	Normal	Normal	Normal
10	Normal	Normal	Normal	Normal	Normal	Normal
11	Normal	Normal	Absent	Normal	Normal	Normal
12	Amplitude Asymmetry (L > R)		Normal	Absent	Normal	Normal
13	Amplitude Asymmetry (L > R)		Absent	Absent	Normal	Normal
14	Normal	Normal	Absent	Normal	Normal	Normal
15	Amplitude Asymmetry (L > R)		Normal	Normal	Normal	Normal
16	Amplitude Asymmetry (L > R)		Normal	Normal	Normal	Normal
17	Normal	Normal	Normal	Absent	Normal	Normal
18	Normal	Normal	Normal	Normal	Normal	Normal
19	Amplitude Asymmetry (L > R)		Normal	Absent	Normal	Normal
20	Amplitude Asymmetry (L > R)		Amplitude Asymmetry (L > R)		Abnormal	Normal
21	Normal	Normal	Absent	Absent	Normal	Normal
22	Amplitude Asymmetry (R > L)		Normal	Normal	Normal	Normal
23	Normal	Absent	Normal	Absent	Normal	Normal
24	Amplitude Asymmetry (R > L)		Amplitude Asymmetry (R > L)		Normal	Normal
25	Amplitude Asymmetry (L > R)		Amplitude Asymmetry (L > R)		Normal	Normal
26	Normal	Absent	Absent	Absent	Normal	Normal
27	Normal	Normal	Normal	Normal	Normal	Normal
28	Normal	Normal	Normal	Normal	Normal	Normal
29	Normal	Normal	Normal	Normal	Normal	Normal
30	Normal	Normal	Normal	Normal	Normal	Normal

Feller et al., 2024

Results: More than 37% (11/30) of TBI participants reported dizziness handicaps and 30% (8/27) reported low- or medium-level balance confidence.



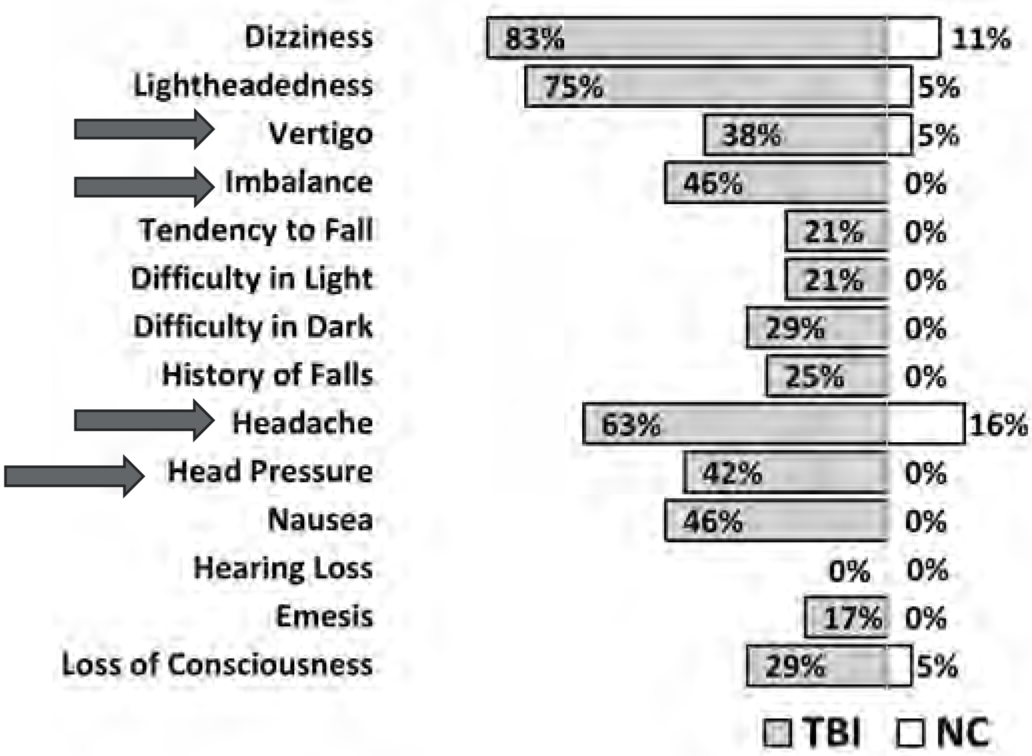
Feller et al., 2024

Combined Results for Each TBI Participant

Subject	L. cVEMP	R. cVEMP	L. oVEMP	R. oVEMP	L. vHIT	R. vHIT	Mo. Since TBI	
1	Present	Present	Present	Present	Normal	Normal	22	
2	Absent	Present	Absent	Present	Normal	Normal	77	
3	Present	Present	Present	Present	Normal	Normal	61	
4	Amplitude Asymmetry		Absent	Present	Normal	Normal	29	
5	Latency Asymmetry		Amplitude Asymmetry		Normal	Normal	48	
6	Present	Present	Amplitude Asymmetry		Normal	Normal	18	
7	Latency Asymmetry		Amp. & Lat. Asymmetry		Normal	Normal	14	
8	Present	Absent	Amplitude Asymmetry		Abnormal	Abnormal	60	5 yrs
9	Present	Present	Present	Present	Normal	Normal	73	
10	Present	Present	Amplitude Asymmetry		Normal	Normal	24	
11	Latency Asymmetry		Absent	Present	Normal	Normal	98	
12	Amp. & Lat. Asymmetry		Present	Absent	Normal	Normal	32	
13	Amp. & Lat. Asymmetry		Absent	Absent	Normal	Normal	75	
14	Present	Present	Absent	Present	Normal	Normal	13	
15	Amplitude Asymmetry		Latency Asymmetry		Normal	Normal	117	
16	Amplitude Asymmetry		Latency Asymmetry		Normal	Normal	49	
17	Present	Present	Present	Absent	Normal	Normal	50	
18	Present	Present	Present	Present	Normal	Normal	276	
19	Amplitude Asymmetry		Present	Absent	Normal	Normal	50	
20	Amplitude Asymmetry		Amplitude Asymmetry		Abnormal	Normal	248	20 yrs
21	Present	Present	Absent	Absent	Normal	Normal	236	
22	Amplitude Asymmetry		Present	Present	Normal	Normal	72	
23	Present	Absent	Present	Absent	Normal	Normal	23	

Feller et al., 2024

What else could be contributing?



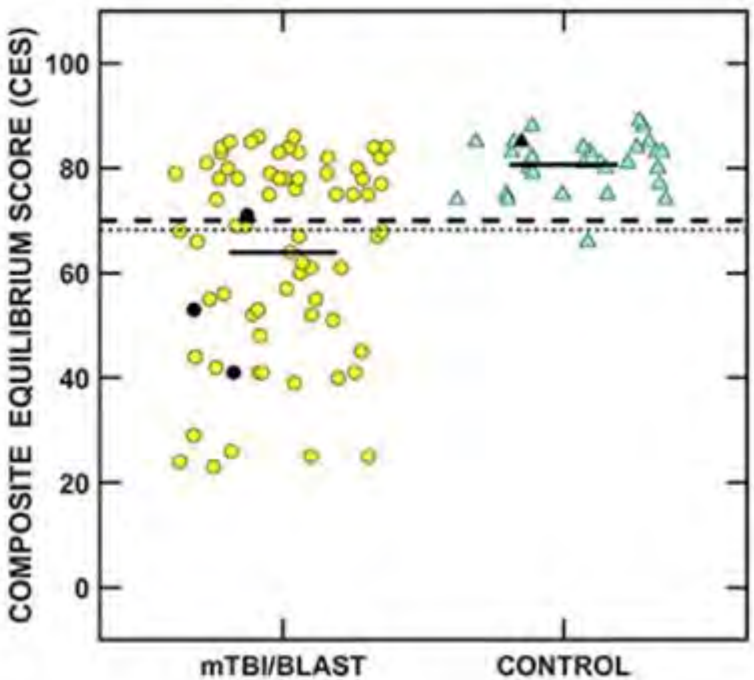
Romero et al., 2023

What do we know?

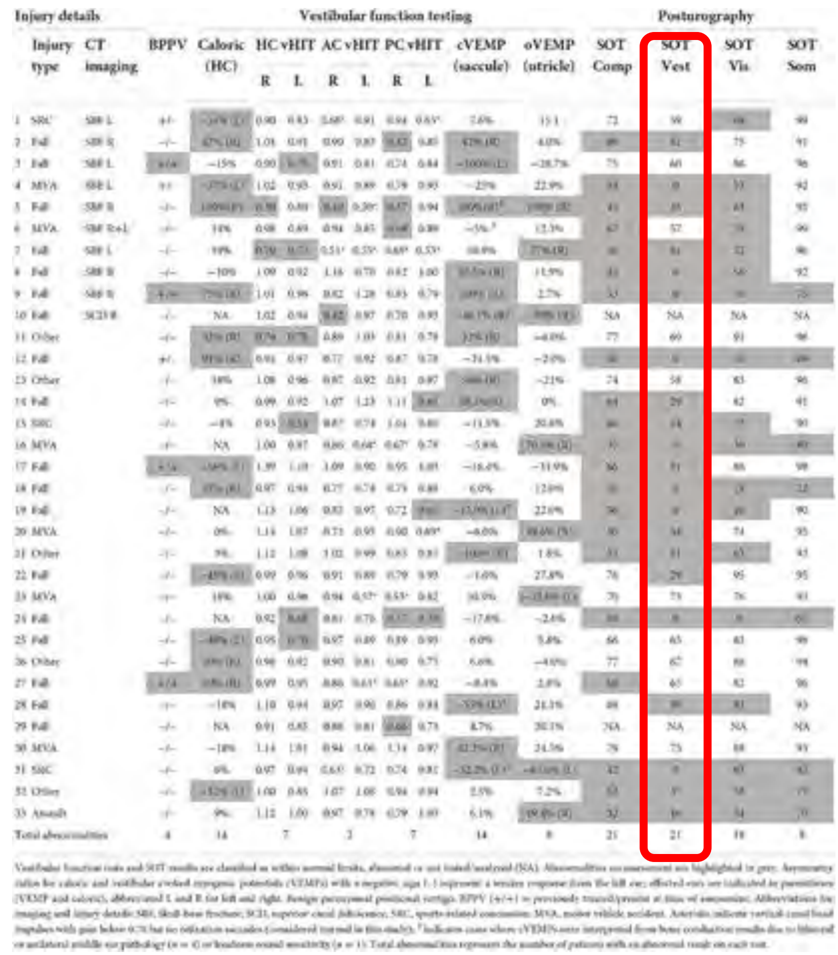
- Traditional view is that TBI can affect multiple levels of the vestibular pathway, from trauma affecting the ***inner ear and brainstem*** pathways

- Recent evidence suggests ***cortical regions involved in the processing and integration of vestibular signals*** (Hadi et al., 2024)

Figure 8



Akin et al., 2022



Taylor et al., 2021

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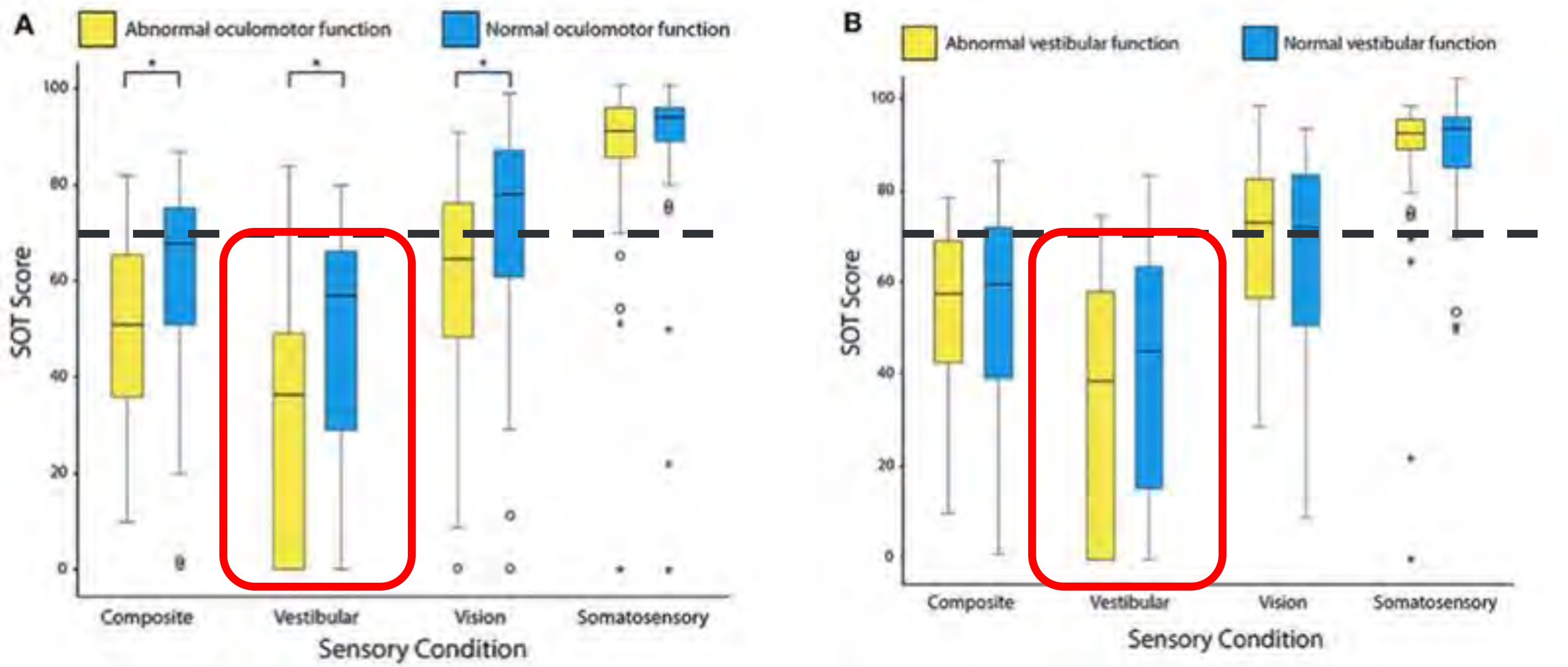

Taylor et al., 2021

Vestibular cognition and its role on postural stability

Cognitive functions that use vestibular input

- Complex, multisensory integration in the brain
- Integrates with visual/somatosensory systems
- However, it's become increasingly clear that vestibular signals influence a range of higher-level cognitive functions
  - Self-motion perception
  - Spatial memory and navigation
  - Mental rotation/bodily self-consciousness
  - Executive function

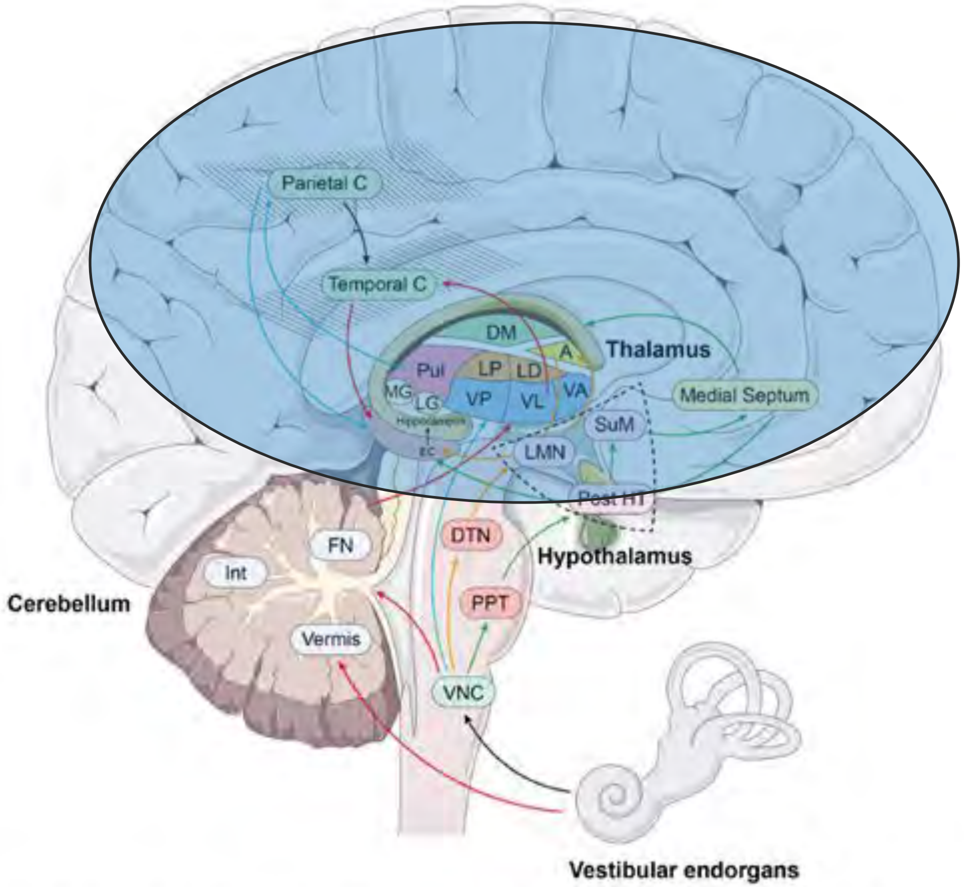

Figure 2. Overview showing the four proposed pathways to transmit vestibular information to cortical centers involved in cognition: i) Thalamo-cortical pathway (blue arrows); ii) theta generating pathway (green arrows); iii) cerebello-cortical pathway (red arrows); and iv) head direction pathway (orange arrows) [reproduced from (178)]. ADN, anterodorsal nucleus of the thalamus; DTN, dorsal tegmental nucleus; Int, interpositus; FN, fastigial nucleus; LMN, lateral mammillary nuclei; EC, entorhinal cortex; MG, medial geniculate nucleus; Parietal C, parietal cortex; Post HT, posterior hypothalamus; PPT, pedunculopontine tegmental nucleus; Pulv, pulvinar; RPO, reticularis pontis oralis; SuM, supramammillary nucleus; VLN, ventral lateral nucleus of the thalamus; VNC, vestibular nucleus complex; VP, ventral posterior nucleus.

Nakul et al., 2021

Absence of self-motion perception

- Described as "vestibular agnosia" (Calzolari et al., 2021), "nystagmus-sensation disassociation" (Takeda et al., 1995) or "vestibular neglect" (Chiarovano et al., 2016)
- Has been observed in older adults, acute TBI, white matter disease, falls, BPPV without vertigo (Hadi et al., 2024, Chiarovano et al., 2016, Seemungal et al., 2024)
- Self-motion perception is thought to be mediated by:
  - Functional brain networks rather than a specific brain region
    - Altered functional connectivity between multiple brain regions including temporoparietal lobes, corpus collosum, frontal regions (Hadi et al., 2024)
- Impact on postural stability

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Research Article

The Clinical Significance of the Failure to Perceive Vertigo in the Postcaloric Period Despite a Robust Caloric Response

Erin G. Piker,[a] Gary P. Jacobson,[b] Daniel Romero,[a]
Ye Wang,[b] and Kaylee Smith[c]

- 25 older adults with normal vestibular function tests
- Groups were divided based on the presence or absence of self-motion perception of vertigo during the caloric test

Table 1. Participant groups and demographics.

Patient group	*N*	Age (*SD*)	Sex
Motion Perception Group	14	50.64 (15.2)*	6 males
Absent Perception Group	11	67.73 (8.4)*	4 males
All participants	25	58 (15.1)	10 males

*$p < .01$.

Table 2. Means and standard deviations for assessments of the lateral semicircular canal.

Patient group	maxSPV caloric (°/s)	RC gain 0.02 Hz	RC phase 0.02 Hz (°)	RC symmetry 0.02 Hz (%)	vHIT gain
Motion Perception Group	31.1 (13.2)	54.4 (10.2)	23.8 (9.4)	.92 (13.8)	1.05 (.20)
Absent Perception Group	23.9 (8.2)	47.1 (10.7)	25.7 (11.6)	2.8 (14.5)	1.05 (.13)

Note. No significant group differences were observed. maxSPV = maximum slow phase velocity; RC = rotary chair; vHIT = video head impulse testing.

Table 3. Means and standard deviations for assessments of otolith function.

Patient group	oVEMP amplitude (μV)	oVEMP latency (ms)	oVEMP IAA (%)	cVEMP amplitude (μV)	cVEMP latency (ms)	cVEMP IAA (%)
Motion Perception Group	13.9 (9.4)	10.7 (1.0)	16.9 (11.7)	176.4 (86.8)	15.0 (0.85)	15.5 (8.9)
Absent Perception Group	16.9 (14.9)	10.8 (.54)	18.4 (13.4)	206.9 (103.8)	15.2 (1.0)	15.1 (9.0)

Note. No significant group differences were observed. oVEMP = ocular vestibular evoked myogenic potential; IAA = interaural amplitude asymmetry; cVEMP = cervical vestibular evoked myogenic potential.

Research Article

The Clinical Significance of the Failure to Perceive Vertigo in the Postcaloric Period Despite a Robust Caloric Response

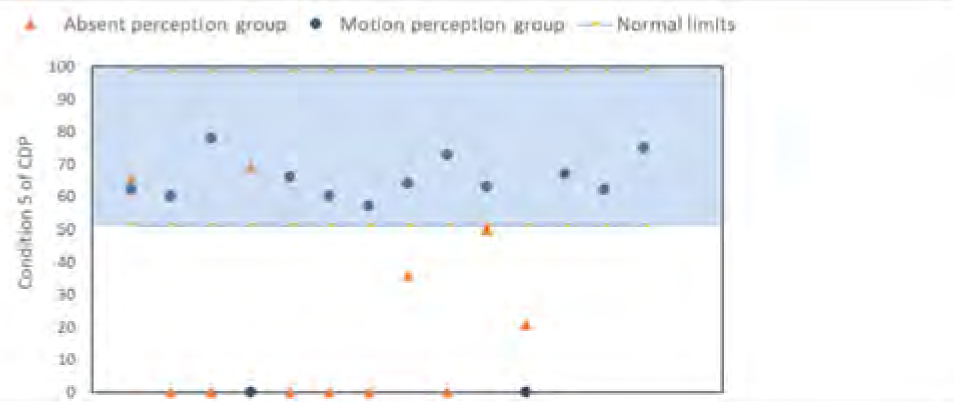
Erin G. Piker,[a] Gary P. Jacobson,[b] Daniel Romero,[a]
Ye Wang,[b] and Kaylee Smith[c]

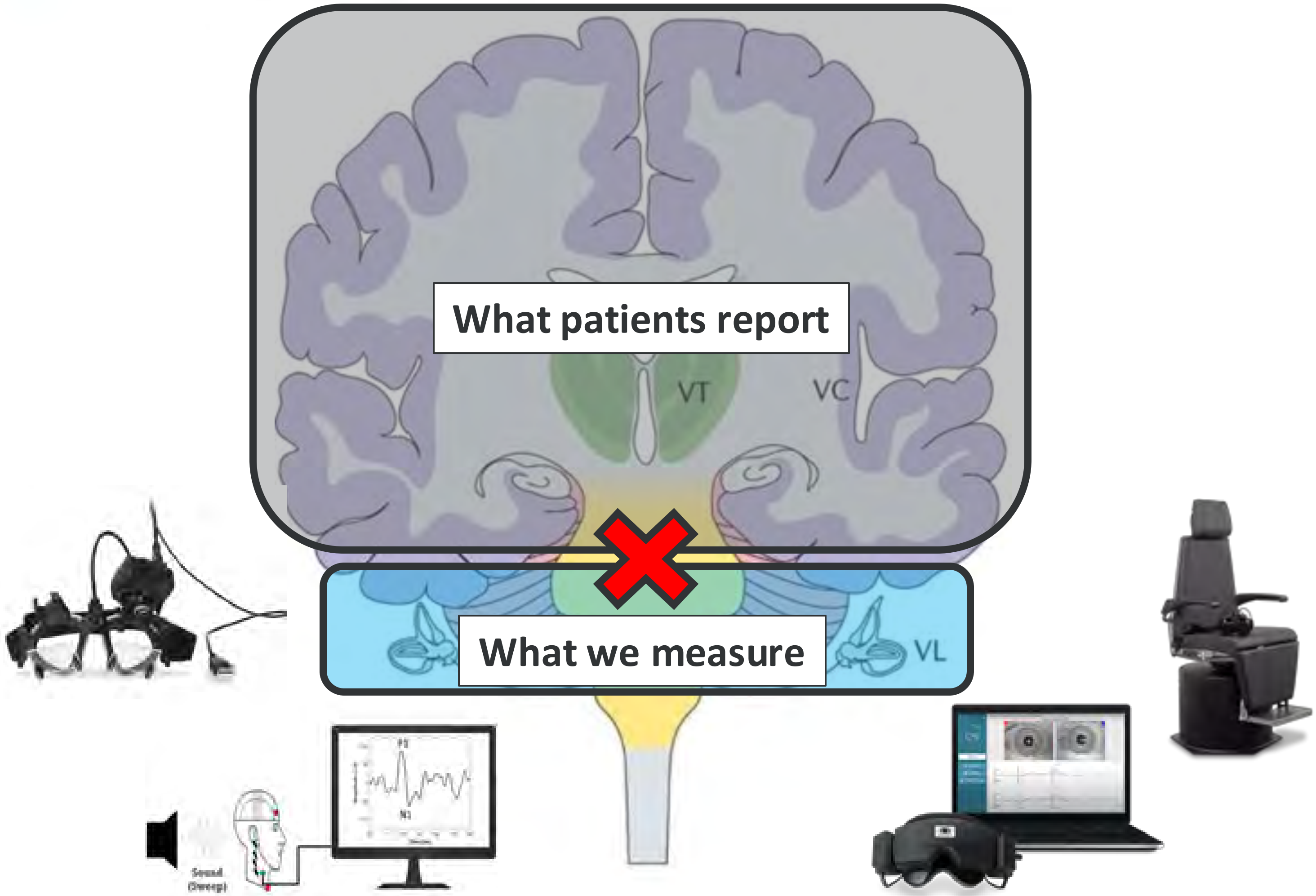
- Despite no significant differences between groups on any measures of peripheral vestibular function, **Absent Perception Group** showed **greater postural instability** during **Condition 5** of posturography

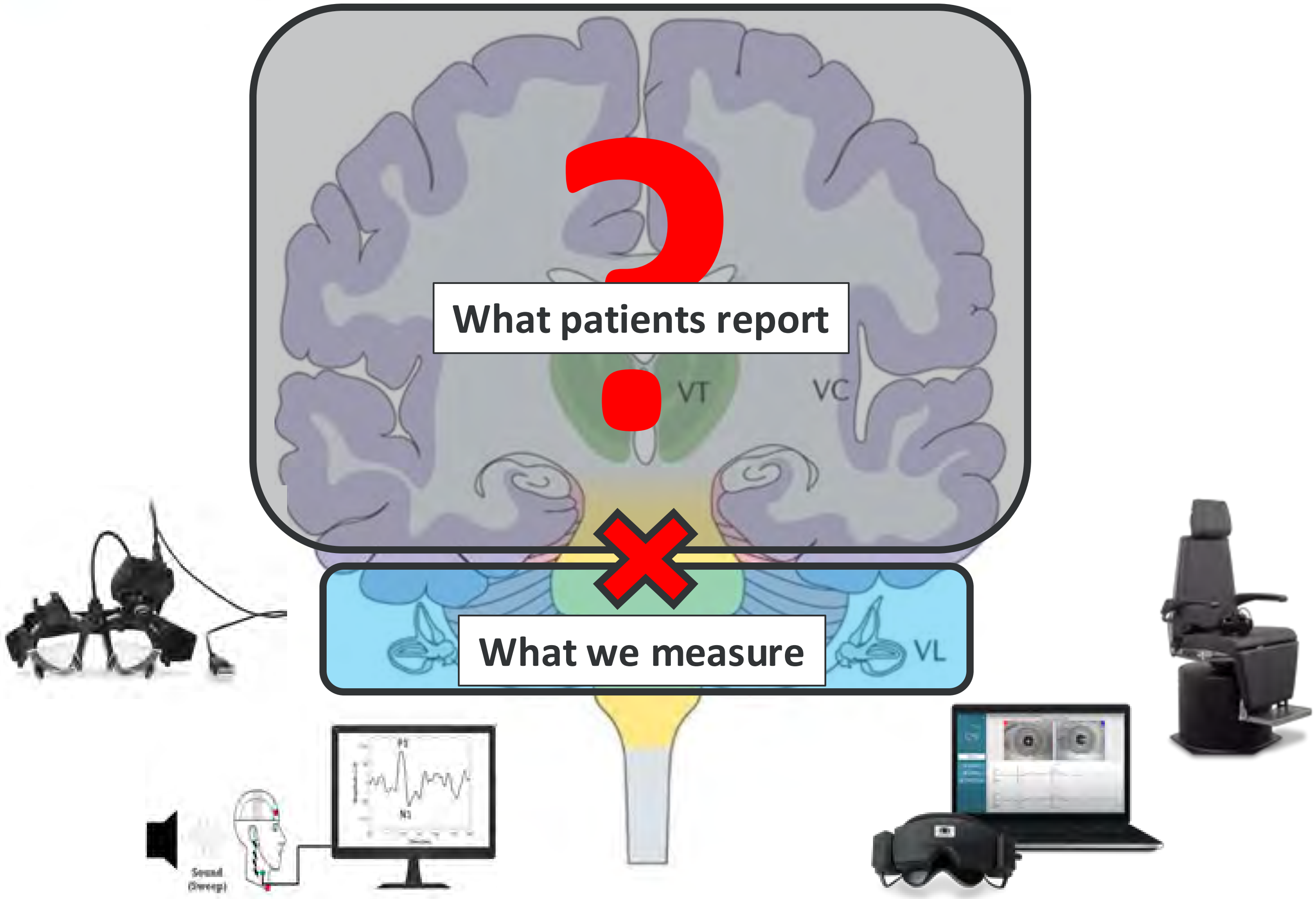
Table 4. Means and standard deviations of functional measures of dizziness handicap, postural stability, and visuospatial memory.

Patient group	DHI	Memory match (s)	CDP 1	CDP 2	CDP 4	CDP 5
Motion Perception Group	38.5 (18.7)	34.38 (10.4)*	92.5 (2.6)	86.9 (3.2)	79.4 (7.8)	56.2 (24.5)*
Absent Perception Group	33.8 (24.9)	52.94 (14.0)*	91.6 (4.1)	85.2 (7.5)	73.7 (9.1)	21.9 (28.3)*

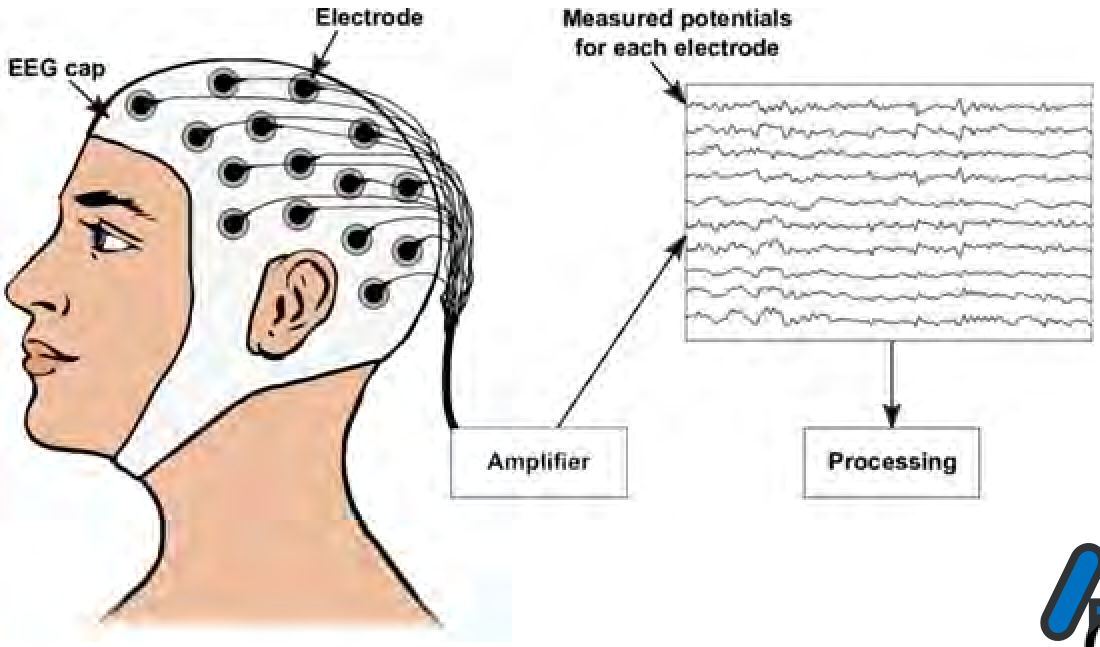
Note. Significant differences between the two patient groups were observed only between Condition 5 of CDP and the Memory Match game. DHI = Dizziness Handicap Inventory; CDP = computerized dynamic posturography.
*$p < .01$.



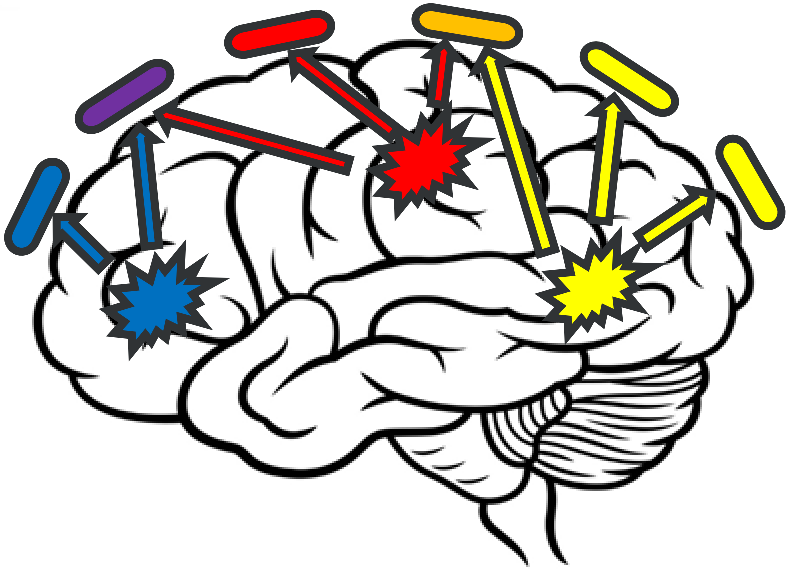

What patients report
VT
VC
What we measure
VL


What patients report
VT
VC
What we measure
VL

Electroencephalogram (EEG)



Nagel, 2019



Quantifiable cortical-vestibular biomarkers.
Cognitive-vestibular interactions.

https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0221909

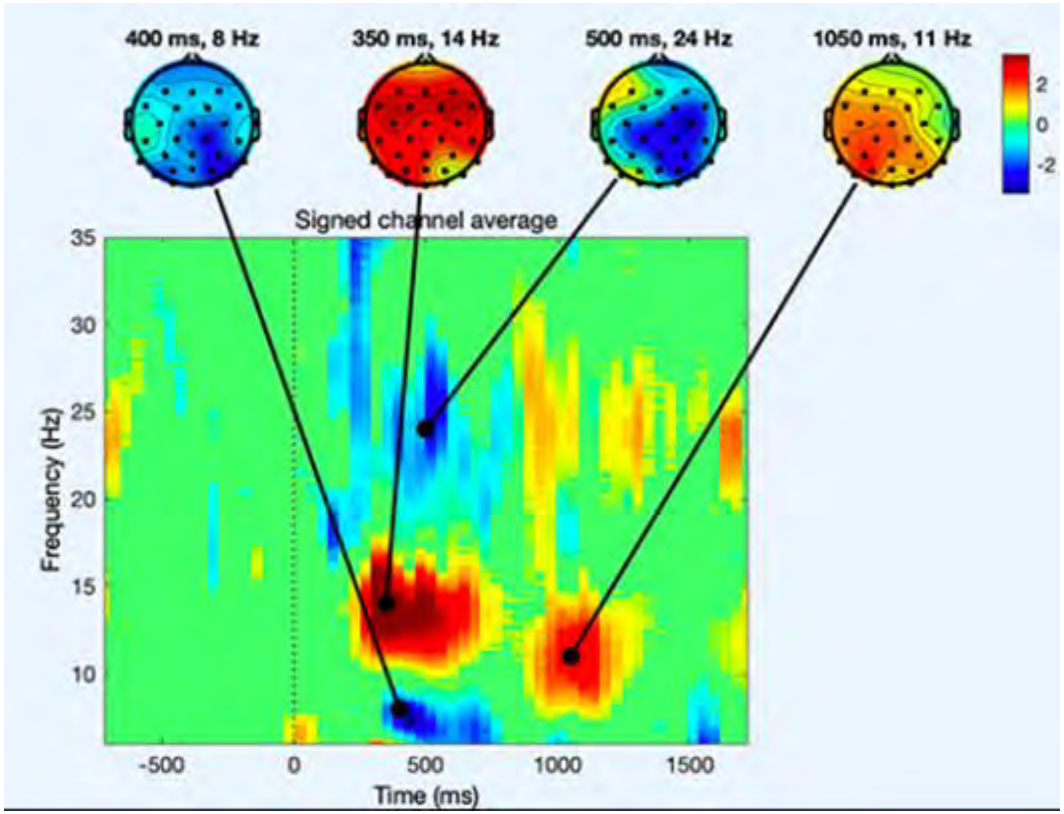
Electroencephalogram (EEG)

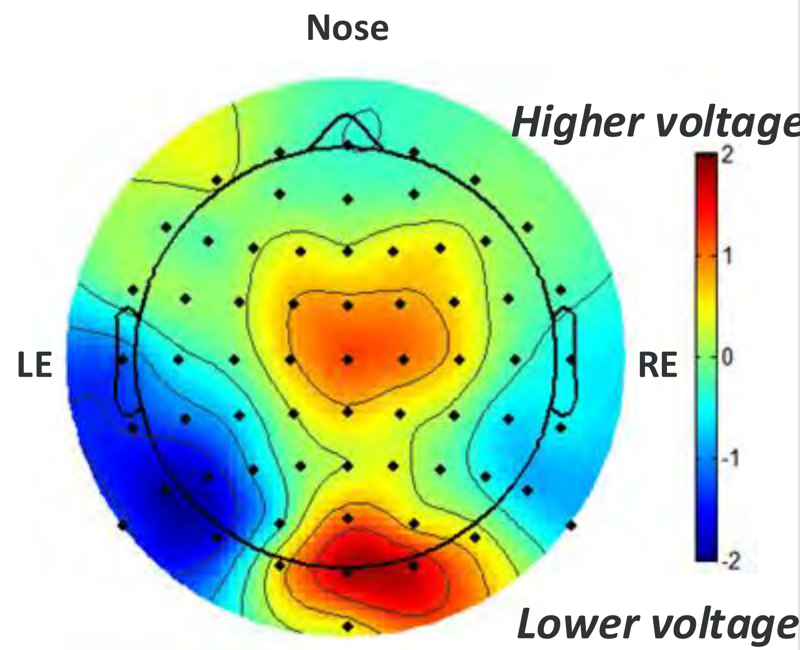
Voltage potential over space

Voltage potential over time

Nagel, 2019

https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0221909





So much rich data!!

Feature extraction (EEG rhythms)

- Patterns of electrical activity produced by the brain for processing, communication, state of mind, coordination, and much more!
- Essential for various forms of cognitive function
- Activity forms waves, or rhythms, that vary in frequency

Nalwaya et al., 2022; Neidermeyer, 2011

Advantages of EEG

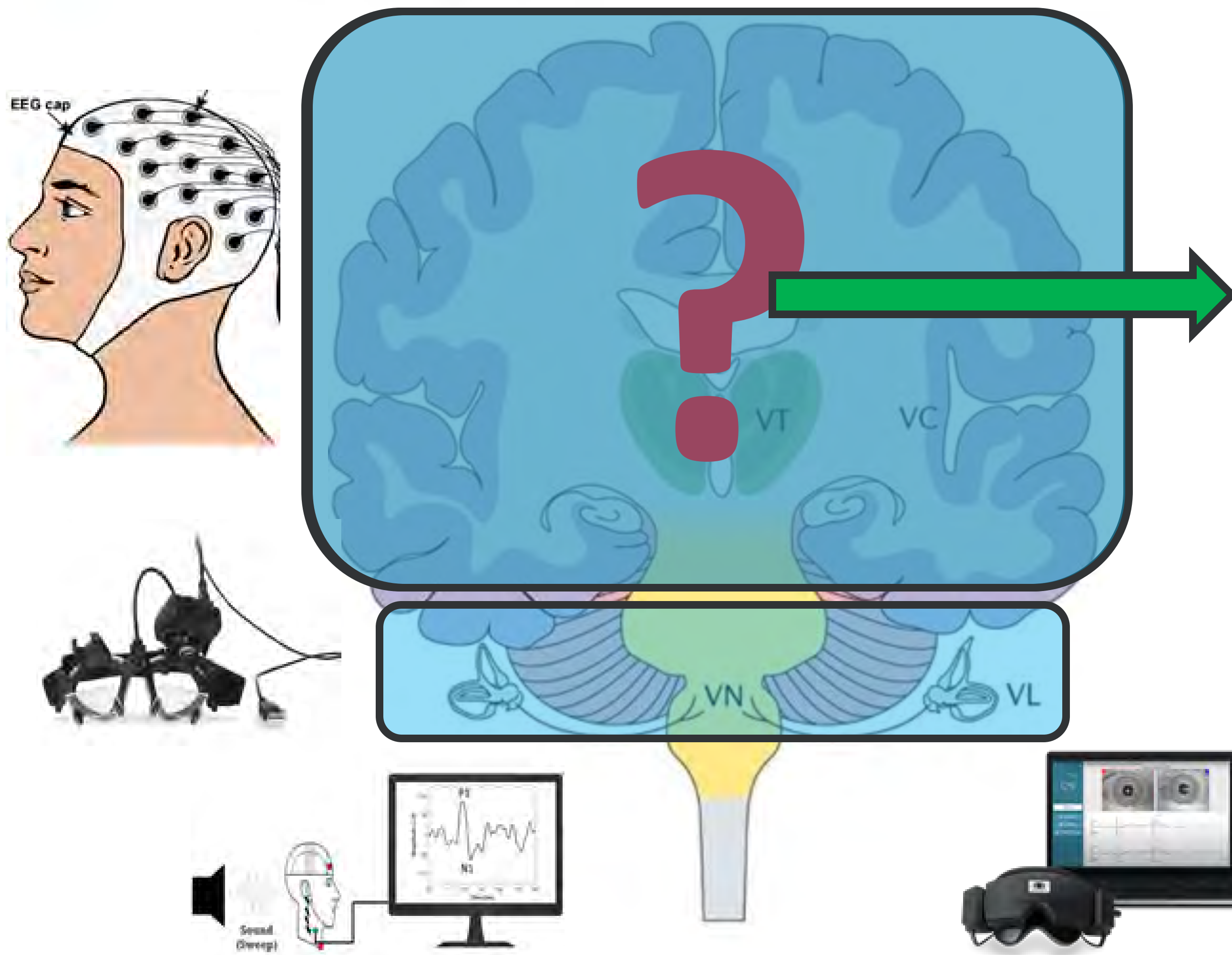
- Direct measure of electrical brain activity
- High temporal precision
  - Can match speed of cognition
- Rich data obtained
- Can link findings across species

Disadvantages

Limited to large scale potentials

Uncertainties in anatomical localization (poor spatial resolution)

Cohen, 2014; Neidermeyer, 2011



- Symptoms
- Self-motion perception
- Functional performance

Thank you

Daniel J. Romero, AuD, PhD

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