VIRTUAL REALITY TEST FOR CONCUSSION DETECTION USING SENSOR-BASED ARTIFICIAL INTELLIGENCE

ABSTRACT ID : MHSRS 25-16584

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DISCLOSURE

- W Andrew Pruett, Ph.D. Founder of HC Simulation LLC and intellectual property holder
- Jennifer Reneker, PT, PhD. Owner of Alter VIST, LLC and intellectual property holder
- This presentation was made possible by the Health Resources and Services Administration (HRSA) of the US Department of Health and Human Services (HHS) as part of the National Telehealth Centers of Excellence Award (U66RH31459). The contents are those of the authors do not necessarily represent the official views of nor an endorsement by the HRSA, HHS or the US Government.

ACKNOWLEDGEMENTS

- Jennifer Reneker, PT, Ph.D.
- David Chambers, MS
- Christopher Gonzalez, Ph.D.

BACKGROUND: DEFINITION AND INCIDENCE

- Concussion (mild traumatic brain injury) results from mechanical insults
- The Defense and Veterans Brain Injury Center (DVBIC) reported nearly 414,000 TBIs among U.S. Service Members worldwide between 2000 and late 2019
- Concussion may affect different brain functions, depending on specifics area injured, the mechanism, and the individual
  - Oculomotor control
  - Ocular reflexes
  - Vestibular (balance) reflexes
  - Neural processing speed and function

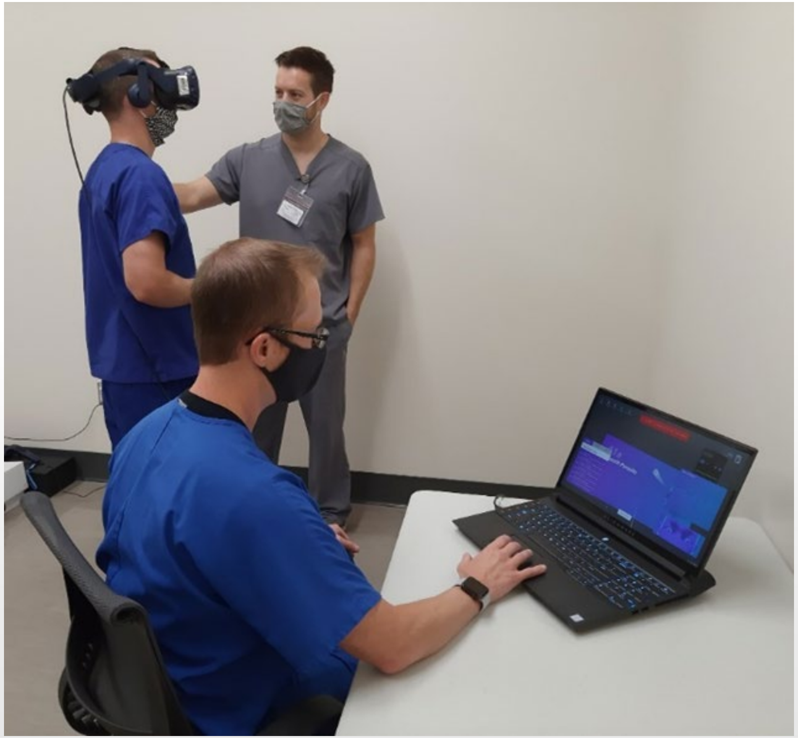
BACKGROUND: CURRENT DIAGNOSTIC STANDARDS

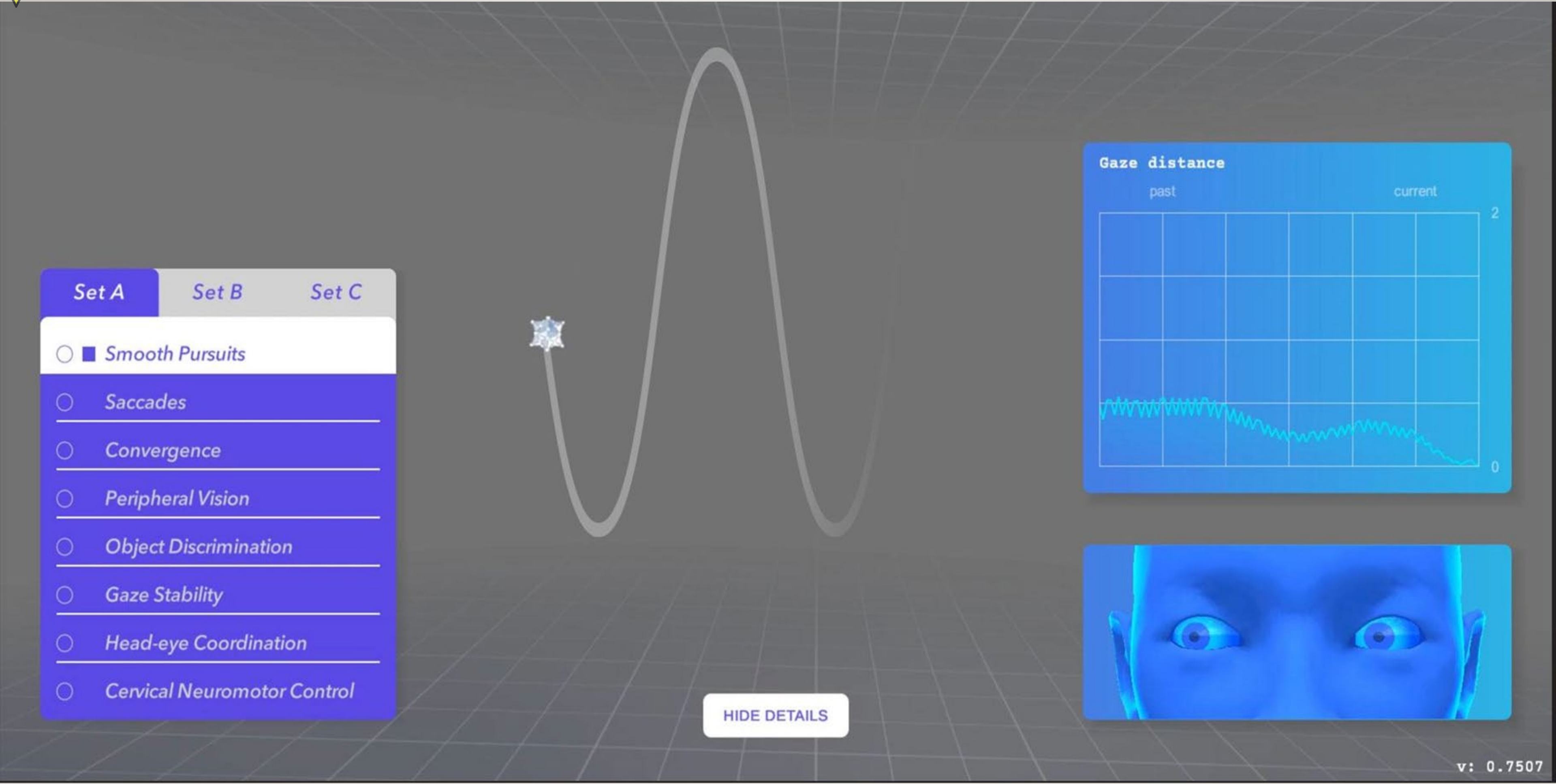
- Concussion is a clinical diagnosis; often coined an *invisible injury*.
- As defined by the 2025 NIH classification system:
  - 13 – 15 on the Glasgow Coma Scale
  - Normal levels of blood-based biomarkers
  - No structural abnormalities on neuroimaging
  - Variety of clinical symptoms and modifiers
    - Symptomatic presentation, cognition, vestibular function
    - Injury factors, past medical history, social determinants of health, etc. will continue to be used to identify and characterize concussions.
- Risk of missed detection

SOLUTION DEVELOPMENT

Guiding principles

- Test the multidimensional nature of concussion
- To identify specific impairments to drive therapy and recovery
- Without a need for baseline measurements
- Using remote assessment

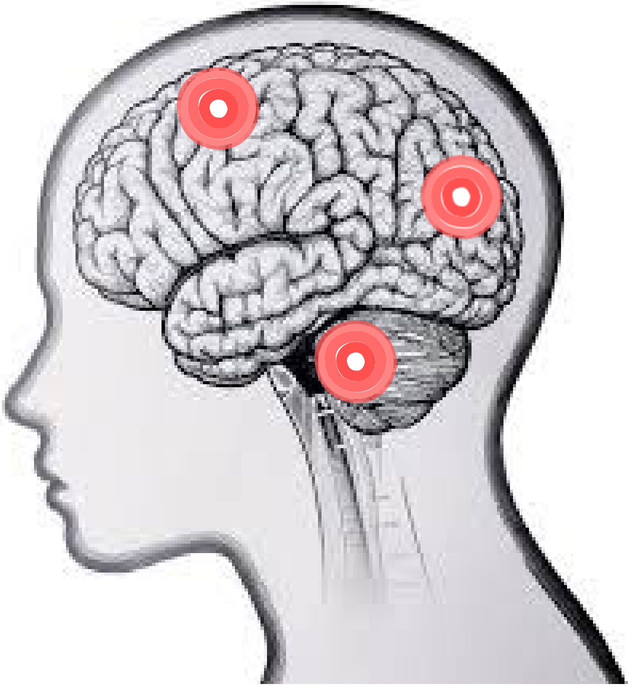




Set A
Set B
Set C
Smooth Pursuits
Saccades
Convergence
Peripheral Vision
Object Discrimination
Gaze Stability
Head-eye Coordination
Cervical Neuromotor Control
HIDE DETAILS
Gaze distance
past
current
2
0
v: 0.7507

OCULOMOTOR CONTROL TESTS

- 8 tests with integrated sensory, cognitive, and motor control components
  - Smooth pursuit
  - Saccadic reflex
  - Binocular convergence

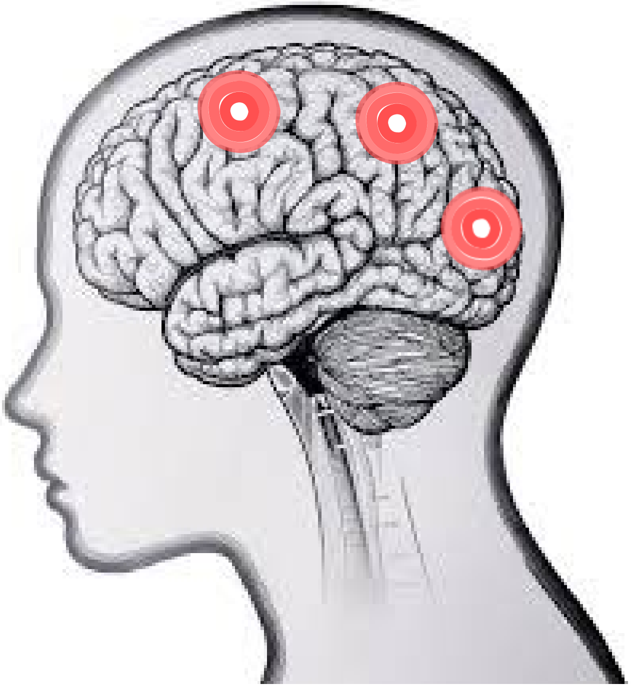


PERIPHERAL VESTIBULAR TEST

- 8 tests with integrated sensory, cognitive, and motor control components
  - Smooth pursuit
  - Saccadic reflex
  - Binocular convergence
  - Gaze stability (VOR)

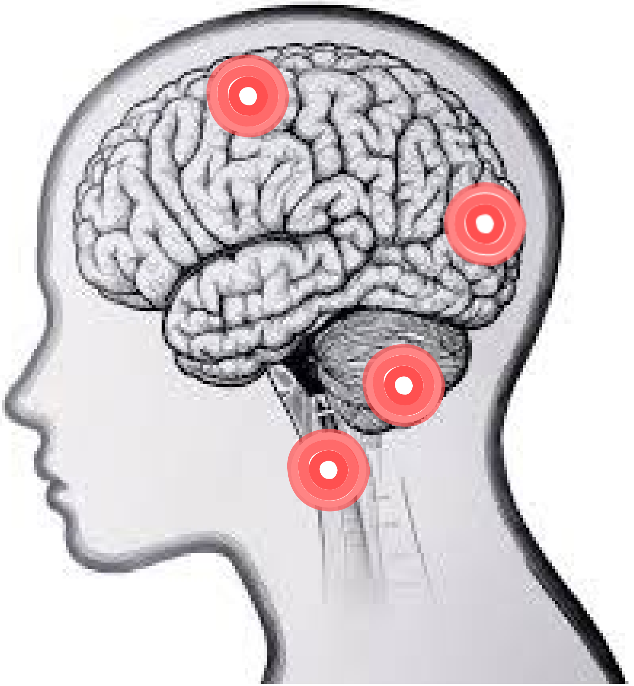
VISUAL PERCEPTION TESTS

- 8 tests with integrated sensory, cognitive, and motor control components
  - Smooth pursuit
  - Saccadic reflex
  - Binocular convergence
  - Gaze stability (VOR)
  - Peripheral vision
  - Object discrimination



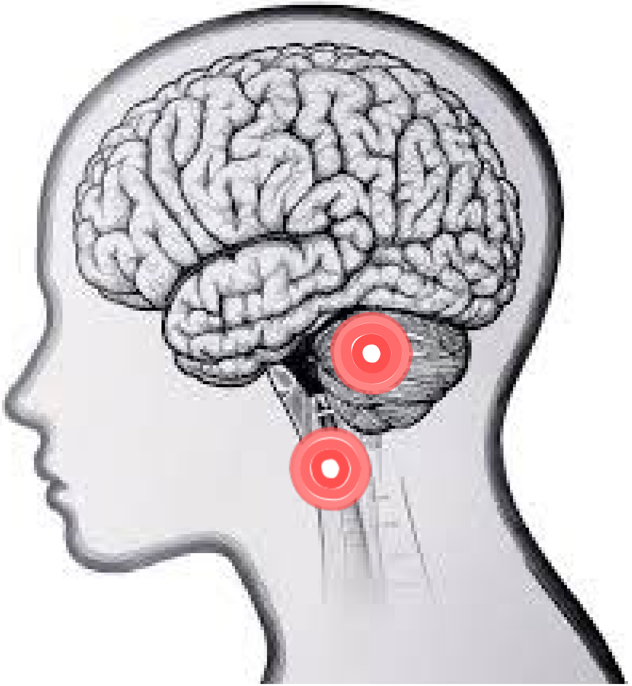
VESTIBULAR AND PROPRIOCEPTION TEXT

- 8 tests with integrated sensory, cognitive, and motor control components
  - Smooth pursuit
  - Saccadic reflex
  - Binocular convergence
  - Gaze stability (VOR)
  - Peripheral vision
  - Object discrimination
  - Head-eye coordination



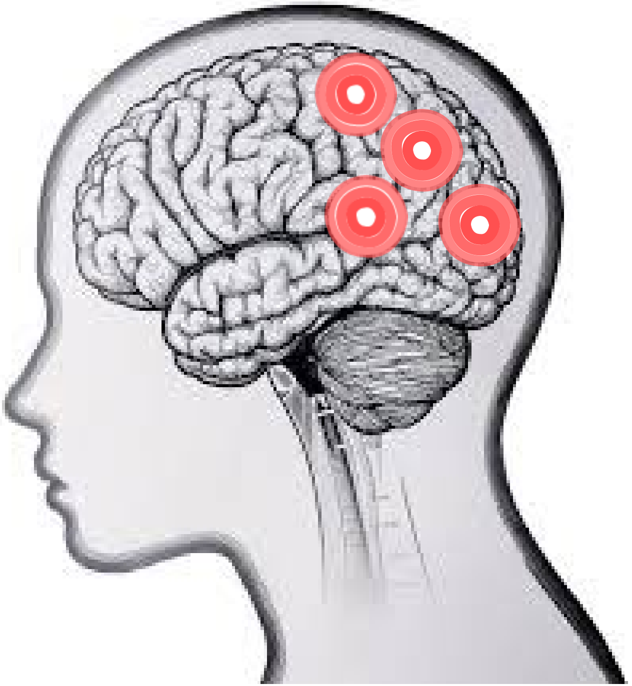
CERVICAL PROPRIOCEPTION TEST

- 8 tests with integrated sensory, cognitive, and motor control components
  - Smooth pursuit
  - Saccadic reflex
  - Binocular convergence
  - Gaze stability
  - Peripheral vision
  - Object discrimination
  - Head-eye coordination
  - Cervical joint proprioception



FAMILIAR SYMPTOM PROVOCATION

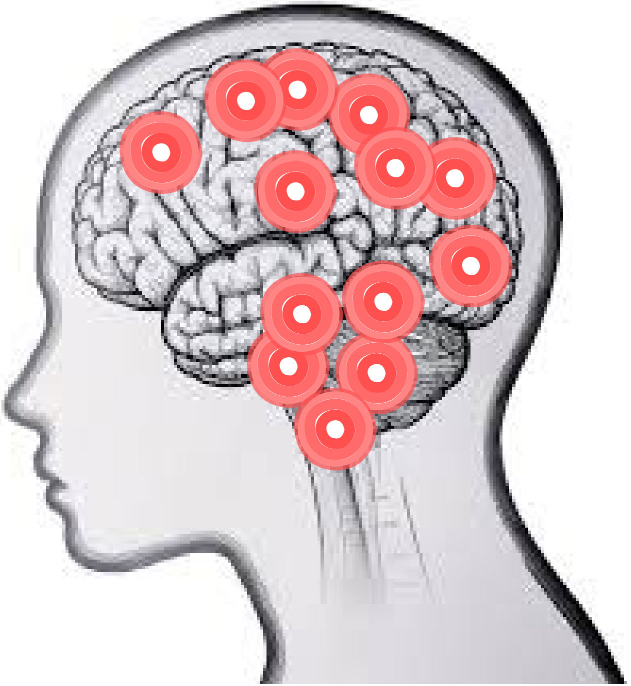
- 8 tests with integrated sensory, cognitive, and motor control components
  - Smooth pursuit
  - Gaze stability
  - Saccadic reflex
  - Binocular convergence
  - Peripheral vision
  - Object Discrimination
  - Head-eye coordination
  - Cervical joint proprioception
  - Symptom provocation



TESTS THE ENTIRE BRAIN

- VIST tests the whole brain for signs of injury *because any part of the brain can sustain an injury.*

- The specific results give evidence for where the injury is located.



STUDY DESCRIPTION

- Civilians aged18-40 with (30) and without (690) acute concussion (physician diagnosed), enrolled from University and hospital populations
- Enrollment from February 2022 - February 2025
- Eligibility: Convenience sample, must be able to stand and maintain balance; no history of seizures
- Performed under a central IRB at University of Mississippi Medical Center (FWA#00003630) with reliance agreements at other institutions

DATA

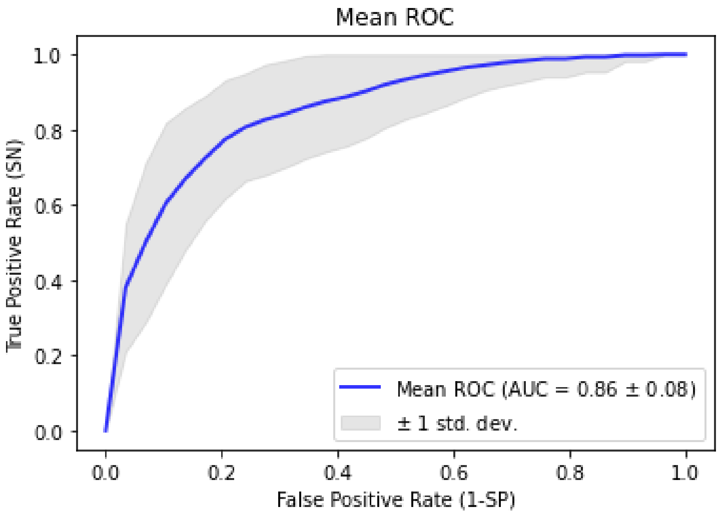
- 18-26 types of continuous or discrete sensor data gathered (depending on test)
- Raw features were cleaned and internally normalized
- Additional hand-crafted features were extracted from the raw data to measure specific functional neurological defects
- Data divided into "full", "VR only", " Objective VR", "Subjective VR", and "Demographic" buckets

TRAINING THE CLASSIFIER

- Histogram gradient boost classifier.
  - Trained on each data "bucket" to dissect source of signal
- Validation: 20 iterations of 5-fold cross validation, resulting in 100 folds; average performance reported

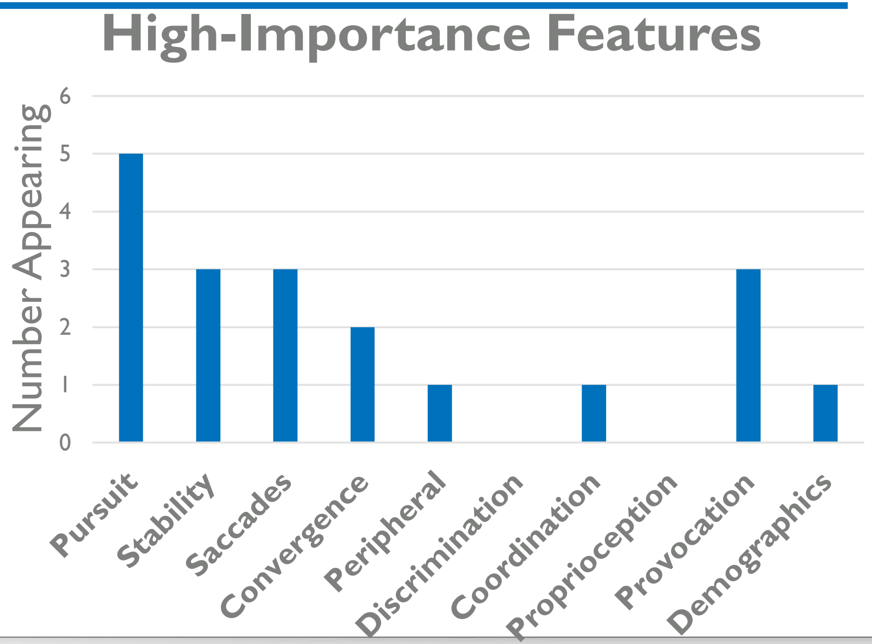
RESULTS

- **Model created using all data**
  - **AUROC = 0.86 (95% CI 0.73 ,0.95)**
- Model created using all data except demographic
  - AUROC = 0.82 (95% CI 0.68, 0.95)
- Model created using VR objective data
  - AUROC = 0.64 (95% CI 0.50, 0.80)
- Model created only using subjective VR data
  - AUROC = 0.85 (95% CI 0.71, 0.97)



RESULTS

- Features responsible for classification are distributed across all tests
- Indicates the diffuse nature of concussion and the multimodal approach necessary for testing it



DATA COLLECTION

- With no pre-injury baseline, we have attained 0.86 accuracy with the classification of acute concussion
- **This is only the preliminary model**
- Grant funding is being pursued to collect data from Service Members, children, youth, and additional civilians
  - We will add 1000 additional participants
  - Use deep-learning methods to optimize the model

KEY CONSIDERATIONS FOR THE MILITARY

- Need for technology solutions that do not add weight or require additional space.
- We will enable the VIST Neuro-ID to operate on any eye-tracking enabled VR hardware being utilized for other purposes by DOD.
- This ensures that if the DOD is using a VR device for another reason the VIST software can be added to this device; adding no weight or space while providing decision support for on-field concussion identification.