EYE TRACKING AS A BIOMARKER FOR CONCUSSION

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DISCLOSURES

Dr Hunfalvay is Chief Science Officer at RightEye, LLC.

LEARNING OUTCOMES

At the conclusion of this activity, participants will be able to:

1. **Understand oculomotor behavior specifically reflecting mTBI using eye tracking**
2. **Identify oculomotor metrics of importance related to brain mapping mTBI locations**
3. **Discuss or translate opportunities into specific oculomotor therapies to improve symptomology**

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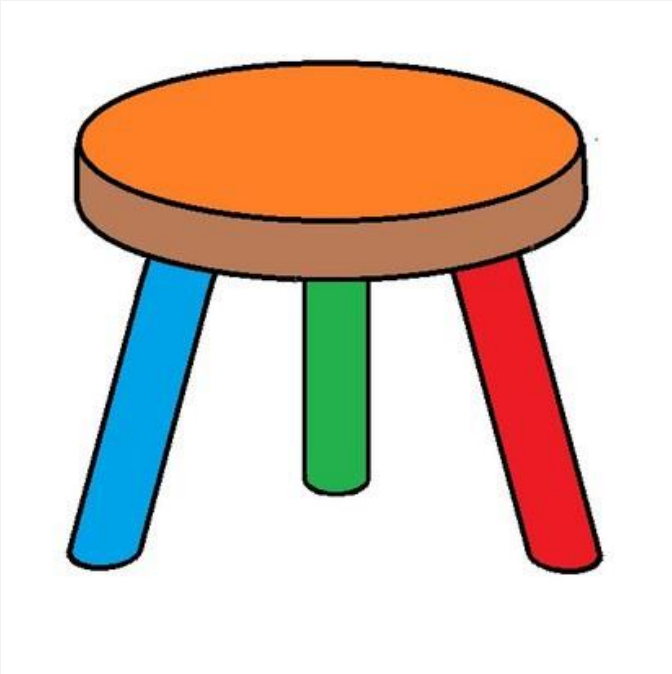
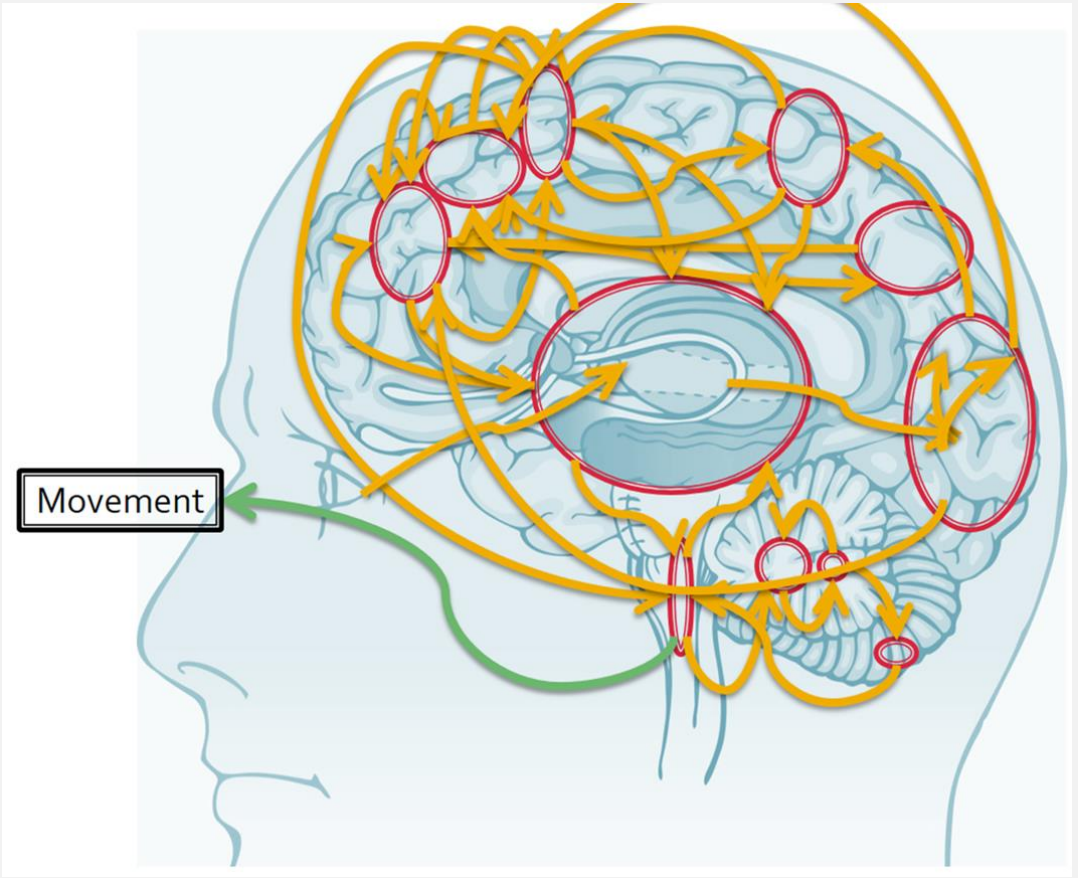


Assessing TBI:

- Cognitive
- Vestibular
- Eye Movements

The Eyes and the Brain

- The eye is not independent of the brain
- The retina is part of the brain
- The brain is highly involved in vision and visual processing
- 80%+ of the brain is reflected in eye movements



The Research

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Concussion

Horizontal and vertical self-paced saccades as a diagnostic marker of traumatic brain injury

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Aim: Eye tracking tests to measure horizontal and vertical saccades as a proxy for neural deficits associated with traumatic brain injury (TBI) were evaluated in the present study. **Methodology:** A total of 287 participants reporting either no TBI, mild, moderate or severe TBI participated in a suite of eye tracking tests to measure horizontal and vertical saccadic performance. **Results:** The horizontal saccades test offered a sensitivity of 0.77 and a specificity of 0.78, similarly the vertical saccades tests offered a sensitivity of 0.64 and a specificity of 0.65. **Conclusion:** The results indicated that using eye-tracking technology to measure these metrics offers an objective, reliable and quantifiable way of differentiating between individuals with different severities of TBI, and those without a TBI.

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Keywords: concussion • eye tracking • horizontal saccades • TBI • vertical saccades • VOMS

The rising incidence of traumatic brain injury (TBI) is an international public health concern and a significant cause of morbidity and mortality [1]. In the USA alone, about 1.7 million people suffer from a TBI every year with 52,000 of these cases resulting in death [2]. According to the CDC, the number of hospitalizations and deaths related to TBI increased by >50% from 2006 to 2014 [3]. Oculomotor research contributes to the growing understanding of TBI by providing insight into neural functioning for clinicians and neuroscientists. Oculomotor behavior is a promising neuropsychological endophenotype, as it reflects abnormalities of complex neurocircuitry [4]; for example, oculomotor impairments have been associated with functional neuroimaging of the brain to examine the effect of neural dysfunction on oculomotor performance [5].

Oculomotor behavior is commonly broken down into the following eye movement categories: fixations, smooth pursuits and saccades [6]. Fixations keep the eye position in a relatively still state to hold the image of a stationary target on the fovea, a site of high visual acuity [7]. Smooth pursuits occur when the eyes track a moving stimulus to stabilize the image on the fovea [8–10]. Finally, saccades are rapid movements of the fovea between fixation points [11]. Depending on the type of eye movement, different brain regions become activated; for example, several structures

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Concussion

Vertical smooth pursuit as a diagnostic marker of traumatic brain injury

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Aim: Neural deficits were measured via the eye tracking of vertical smooth pursuit (VSP) as markers of traumatic brain injury (TBI). The present study evaluated the ability of the eye tracking tests to differentiate between different levels of TBI severity and healthy controls. **Methodology:** Ninety-two individuals divided into four groups (those with mild, moderate or severe TBI and healthy controls) participated in a computerized test of VSP eye movement using a remote eye tracker. **Results:** The VSP eye tracking test was able to distinguish between severe and moderate levels of TBI but unable to detect differences in the performance of participants with mild TBI and healthy controls. **Conclusion:** The eye-tracking technology used to measure VSP eye movements is able to provide a timely and objective method of differentiating between individuals with moderate and severe levels of TBI.

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Keywords: concussion • eye tracking • TBI • vertical smooth pursuit

Worldwide, traumatic brain injury (TBI) contributes to death and disability more than any other traumatic insult [1]. In order to increase the likelihood of more positive outcomes for TBI patients, the key is early detection and diagnosis. While many traditional diagnostic approaches for TBI rely heavily on subjectivity, the objective measurement of eye movements can detect neural dysfunction [2] associated with head injuries [3]. Oculomotor behavior assessment for clinical purposes encompasses the following eye movement types: fixations, saccades and smooth pursuits [4]. Fixations involve maintaining gaze on a single location of high visual acuity [5]. Saccades

Research Question

- Past research has examined saccades but not *self-paced saccades*.

- **Purpose:** to examine differences in horizontal saccades (HS) between patients with TBI (mild, moderate and severe) and no history of TBI.

- Other papers examine vertical saccades, pursuits, fixations and an overall BHEQ score.

Methodology

Table 1. Demographic data by age and gender.

Group (n)	Mean age (SD)	Females
Mild (51)	41.68 (18.57)	34
Moderate (64)	39.31 (19.37)	28
Normal (57)	38.30 (18.71)	31
Severe (23)	43.33 (16.50)	7

SD: Standard deviation.

Participants:

- Clinically verified TBI by Board Certified Neurologist or Neuro-Optometrist
- Within 30 days of event

Apparatus:

RightEye eye tracking device

Data Analysis:

- One-way ANOVA $p < .05$
- Post hoc: Tukey HSD $p < .05$
- Logistic regression, ROC, sensitivity & specificity for predicting TBI

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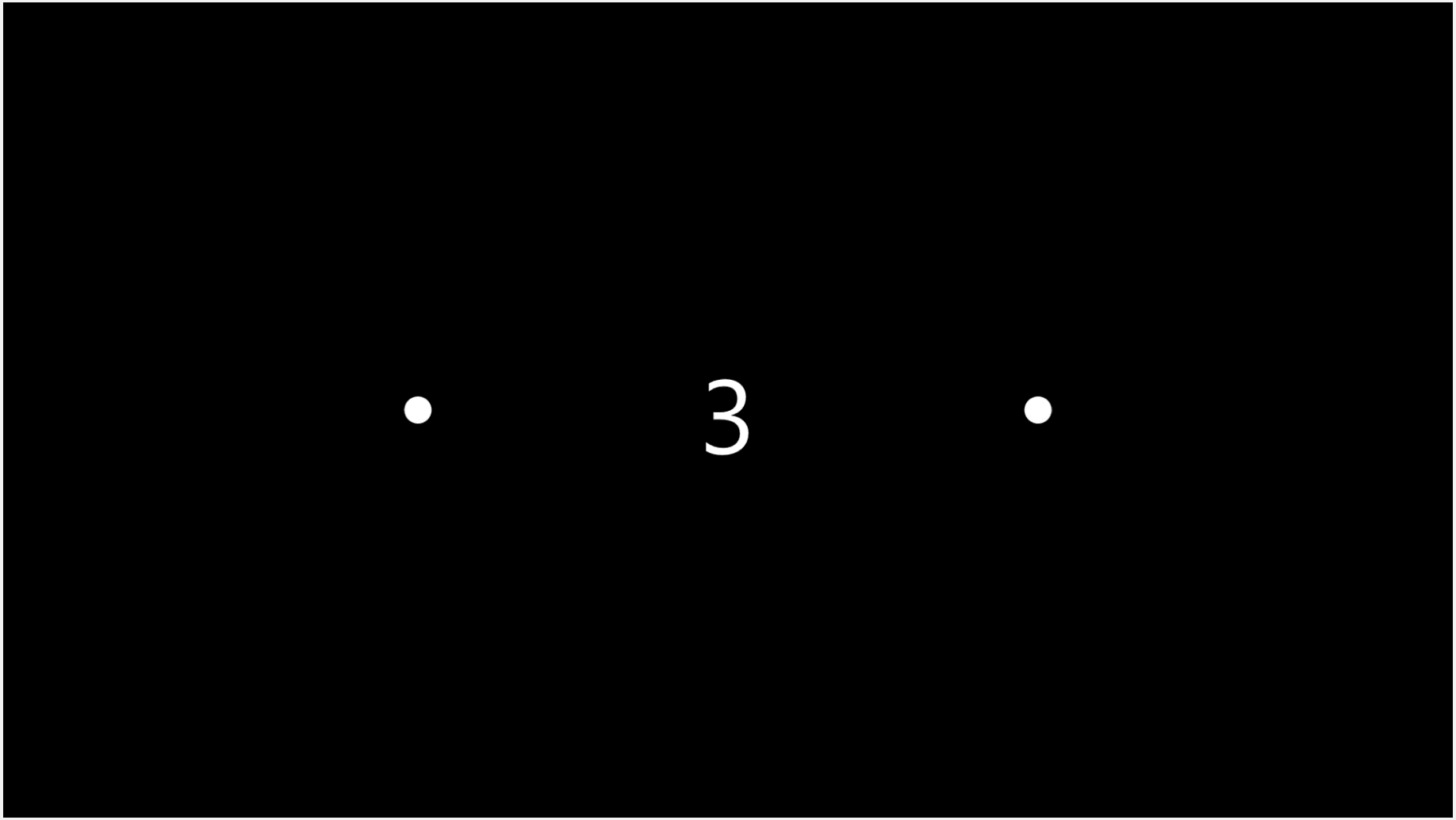
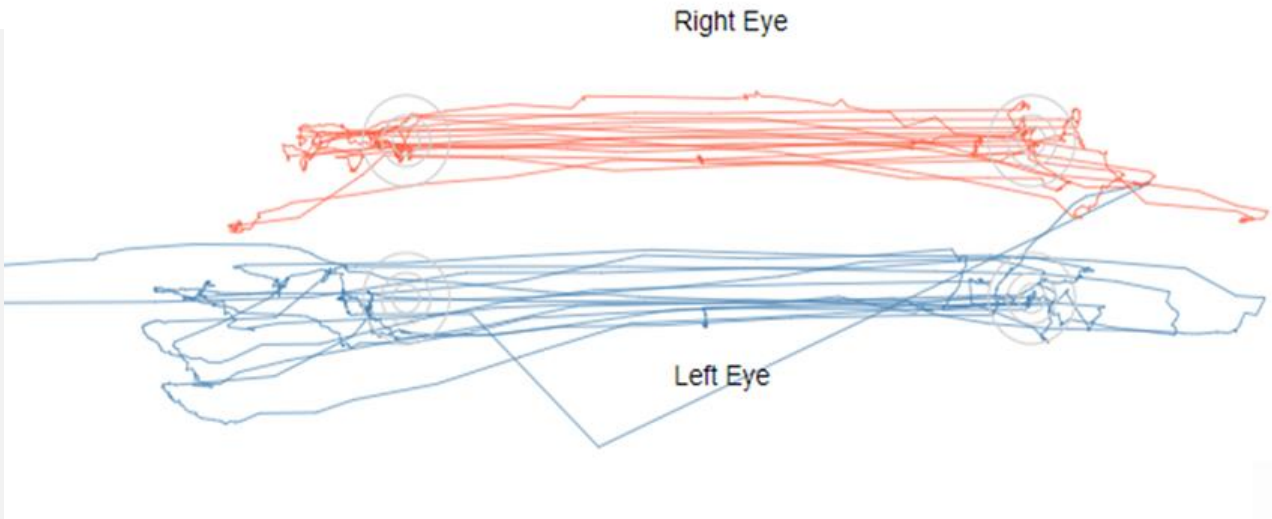
Methodology



Results

- Fixation #: tally of stopping points * Targeting: distance metric of eye from target
- S/A ratio: speed accuracy ratio * Efficiency: pathway taken to saccade



Results

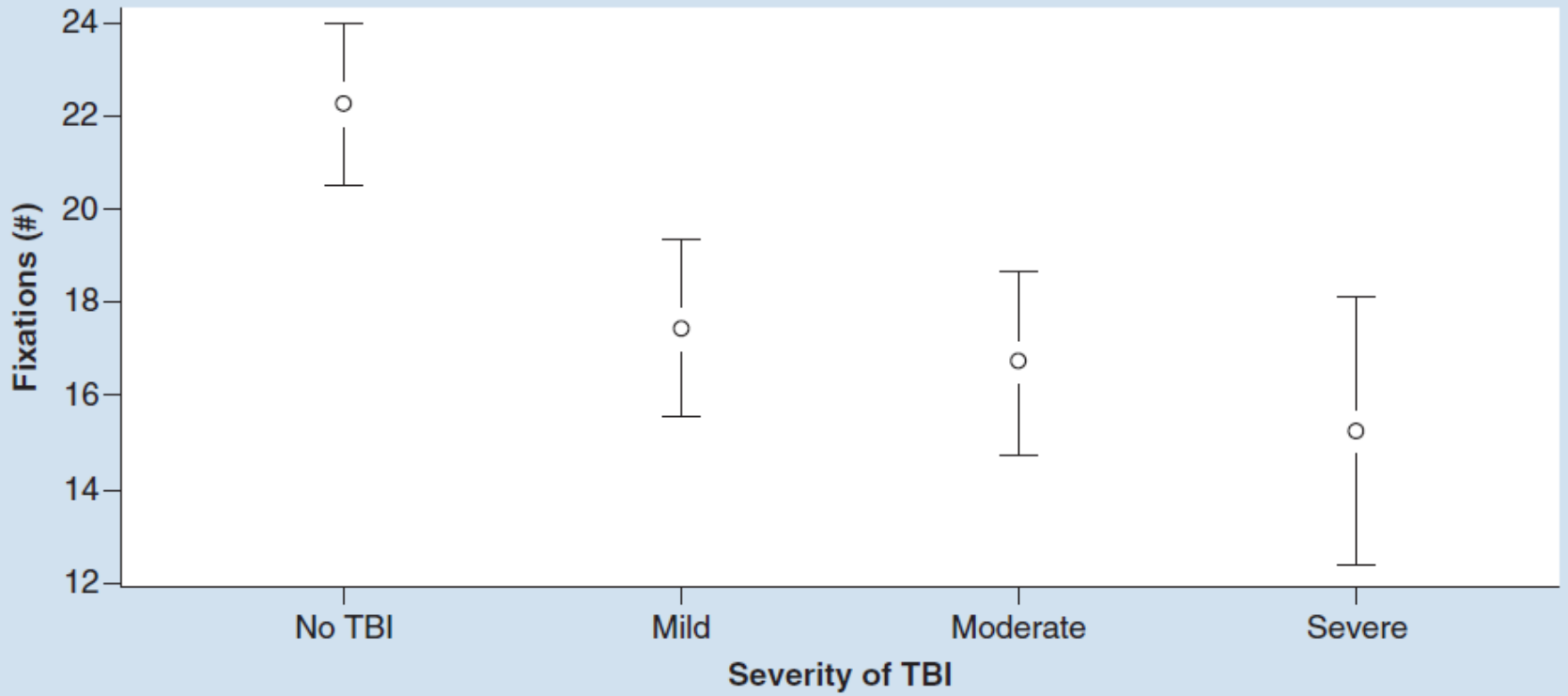


Figure 1. Mean values of fixation (#) at each level of traumatic brain injury severity, with 95% CI.
For fixation (#) metrics – a higher value is better.
TBI: Traumatic brain injury.

Significant main effect. Tukey post hoc showed differences between moderate and severe, and no-TBI but no differences in no-TBI versus mild.

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Results

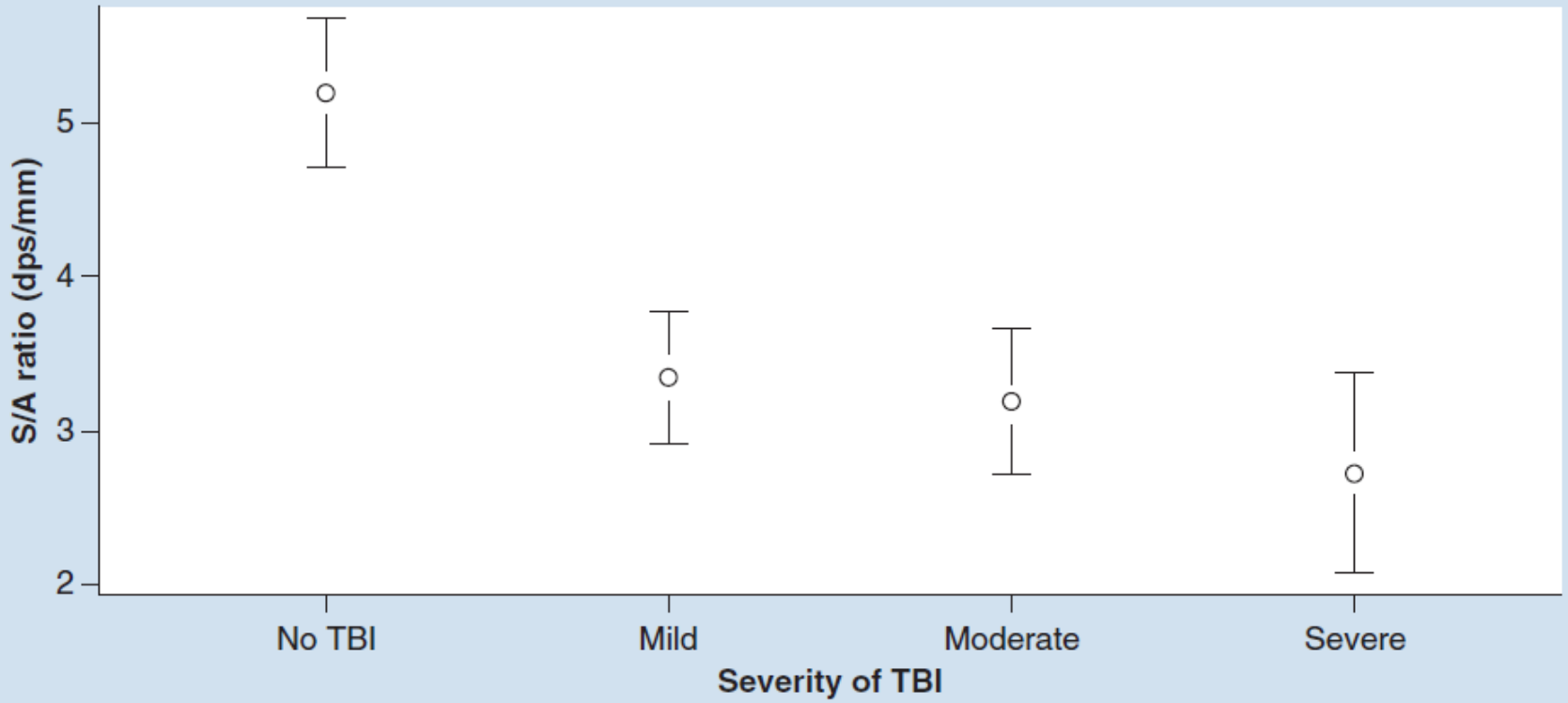


Figure 2. Mean values of saccadic velocity to accuracy ratio at each level of traumatic brain injury severity, with 95% CI. For saccadic velocity to accuracy ratio metrics – a higher value is better.
dps: Degrees per second.

Significant main effect. Tukey post hoc showed differences between all TBI groups and no-TBI

RightEye

Results

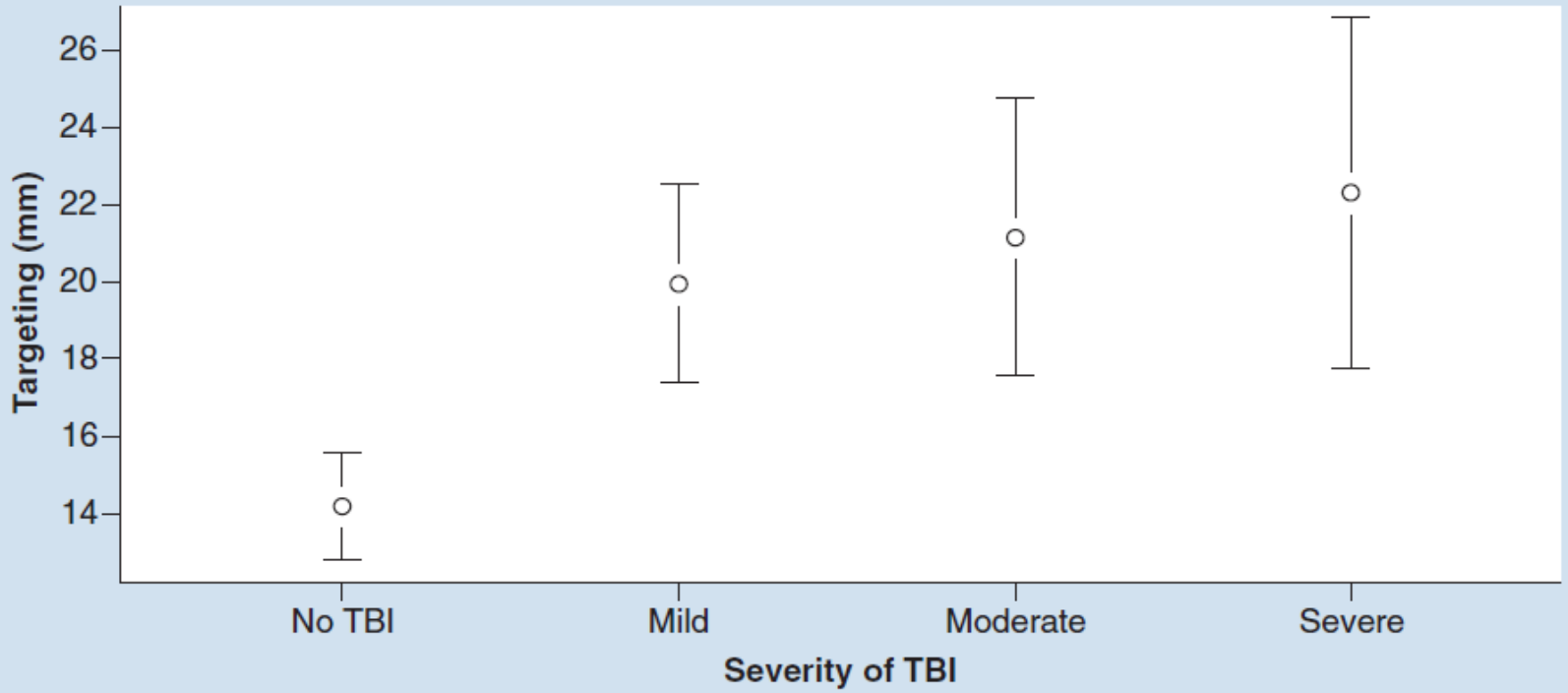


Figure 3. Mean values of targeting (mm) at each level of traumatic brain injury severity, with 95% CI. For targeting metrics – a lower value is better.
TBI: Traumatic brain injury.

Significant main effect. Tukey post hoc showed differences between all TBI groups and no-TBI

RightEye

Results

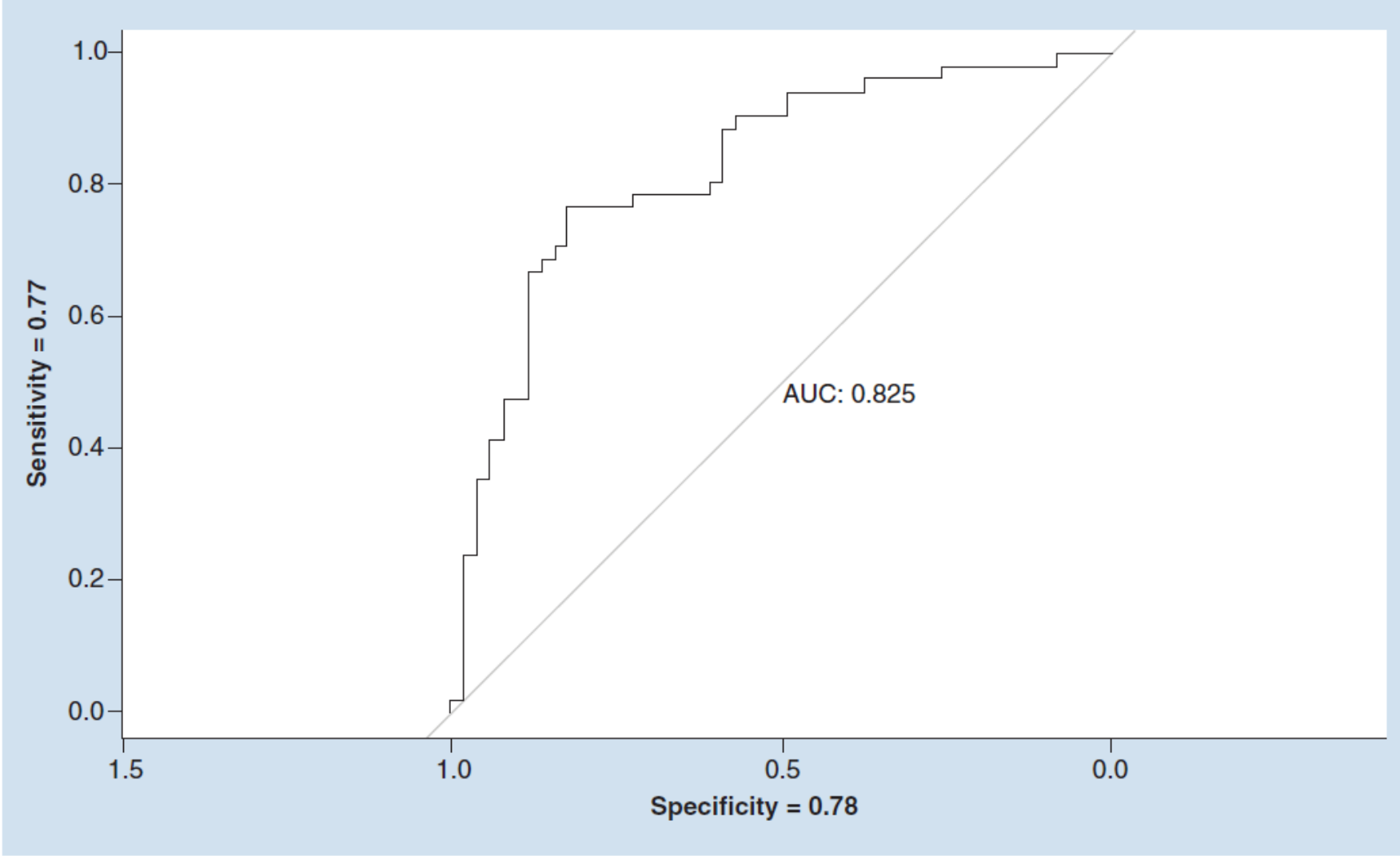
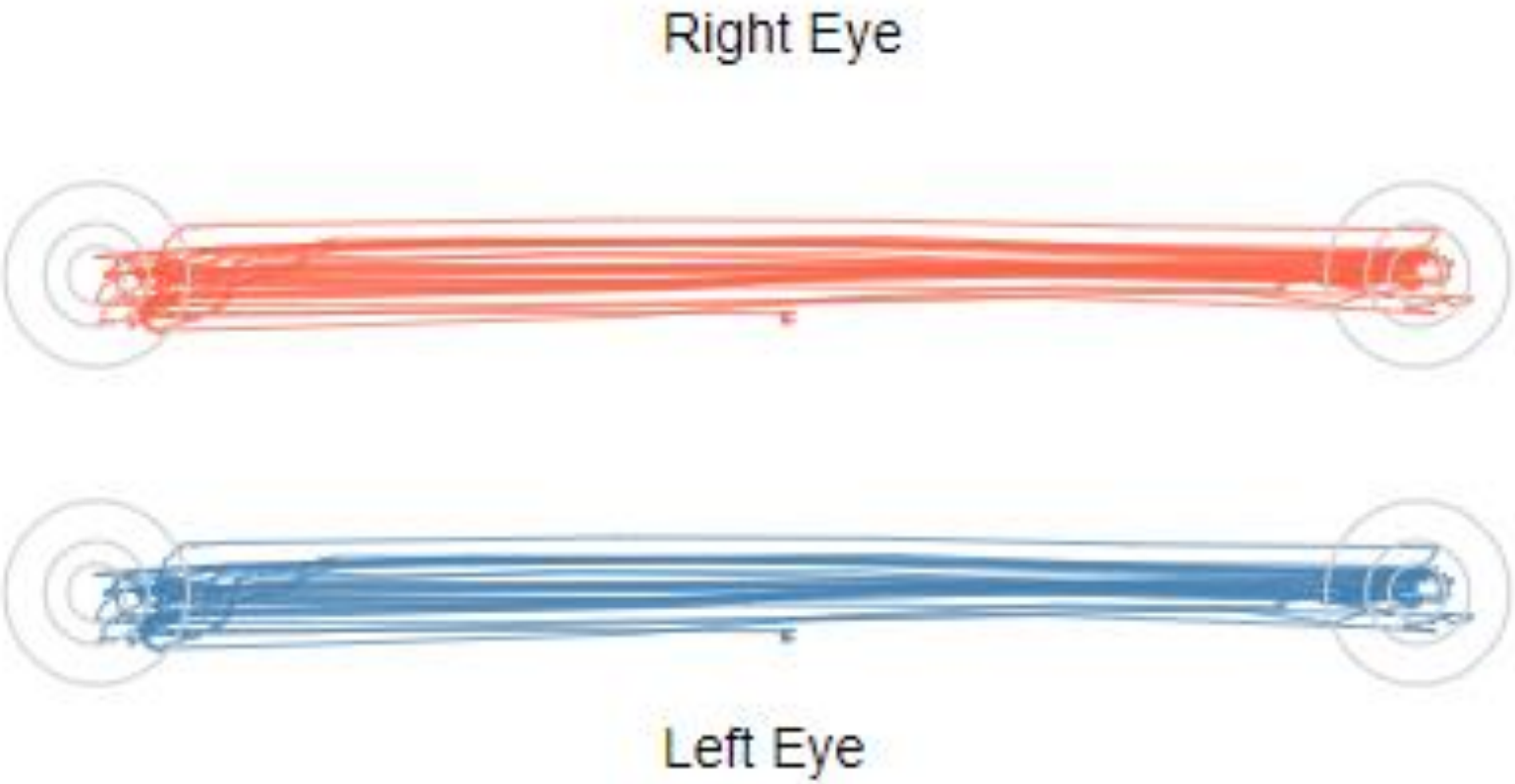
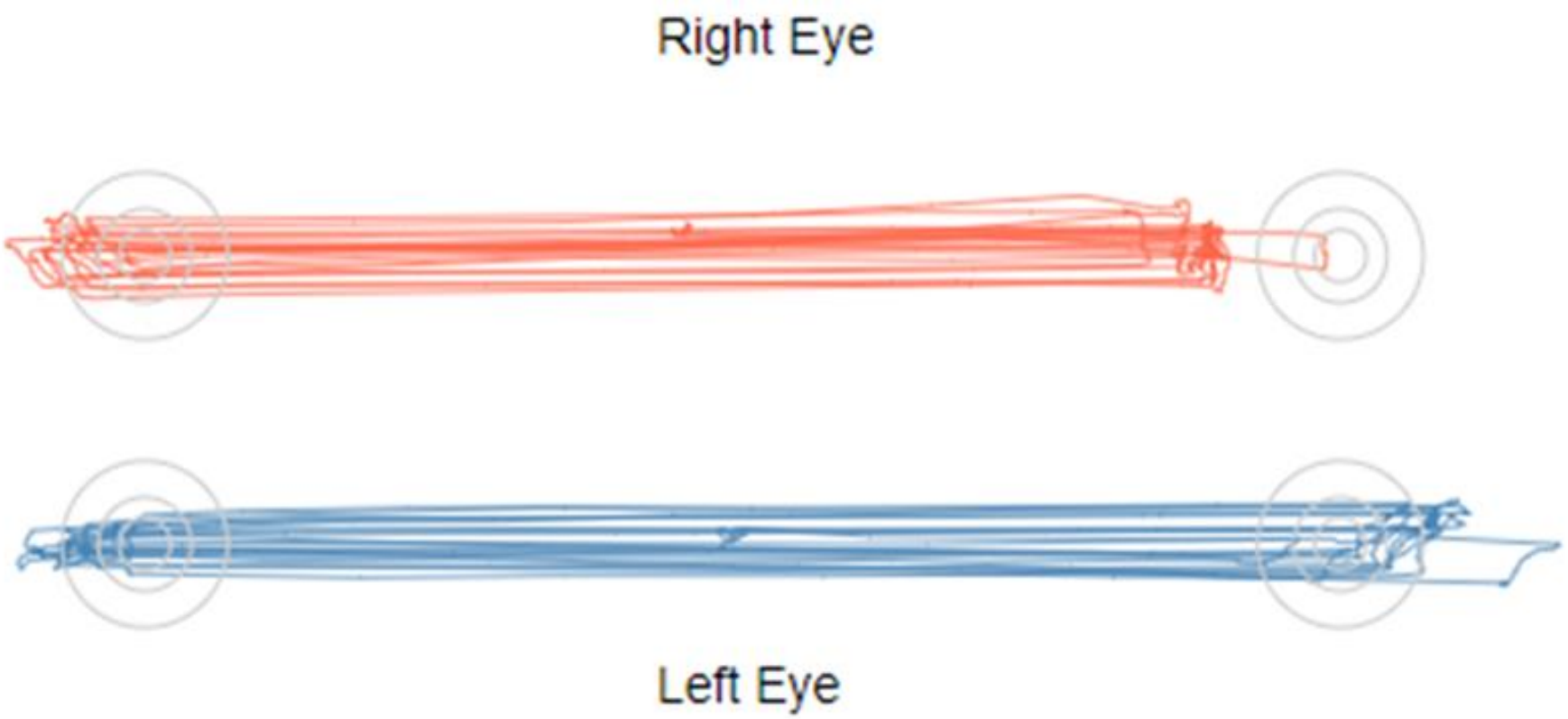


Figure 4. Receiving operating characteristic for horizontal saccades (fixation # and saccadic velocity to accuracy ratio) – no-traumatic brain injury versus traumatic brain injury.
AUC: Area under the curve.

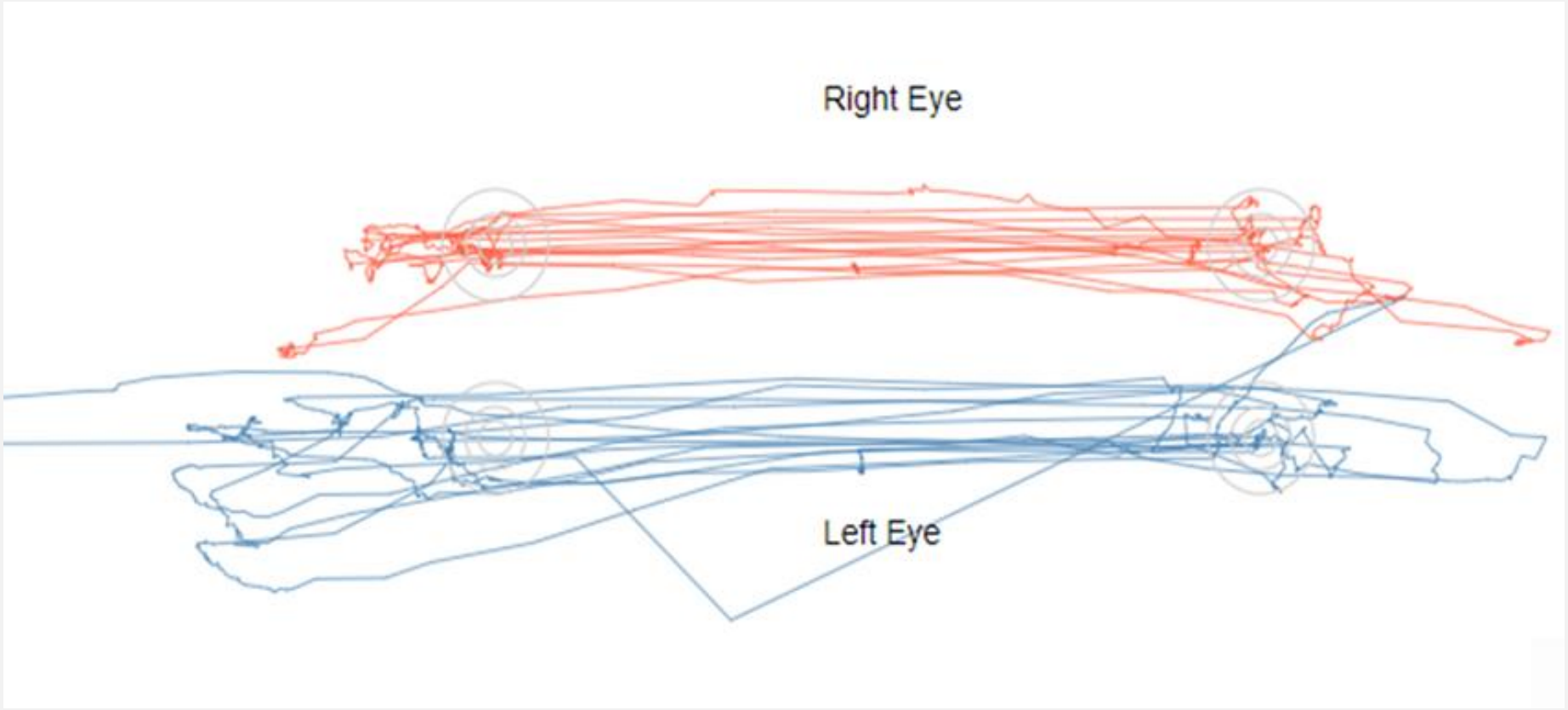
Horizontal Saccades – Control



Horizontal Saccades: mild TBI



Horizontal Saccades: Severe TBI



Horizontal Saccades – Dysfunctional: Brain Location

- Cerebellum and/or frontal lobe

Primary Role of Brain Areas Identified

- **Frontal Lobe:** The cortical area called frontal eye field (FEF) plays an important role in the control of visual attention and eye movements. Electrical stimulation in the FEF elicits saccadic eye movements. The FEF have a topographic structure and represents saccade targets in retinotopic coordinates.
- **Cerebellum:**
  - Receives and regulates eye movements
  - guarantees the precision of ocular movements to optimize visual performance and occupies a central role in all classes of eye movements both in real-time control and in long-term calibration and learning (i.e., adaptation).

Horizontal Saccades– Dysfunctional: Lifestyle

- Eyes are not working optimally when they need to move quickly and may affect accuracy when targeting objects (**hypometria** or **hypermetria**).
- The brain areas that may be affected are the cerebellum, brain stem and frontal lobe.
- **Typical symptoms:** fatigue, slow to react, slower information processing, impaired executive function, multi-tasking issues, lack of mental clarity, brain “fog”, emotional lability.
- **Typical risks:** reading difficulties, slower to complete tasks (e.g. student may need extra time for exams), quicker to anger, more impulsive.

Interventions

- Eye movement training – called EyeQ Trainer.