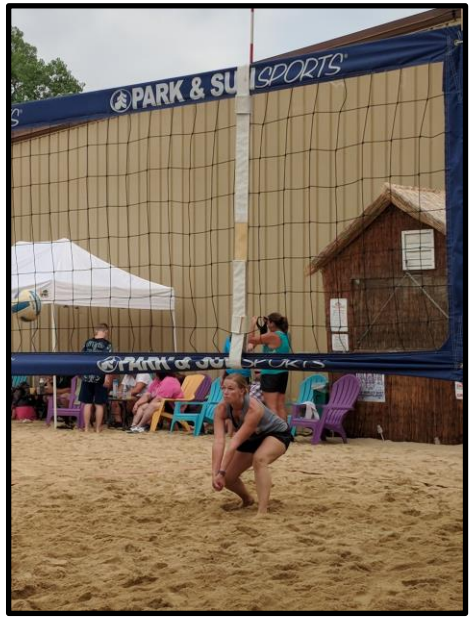
Return to Play Evaluations after Sports Related Concussion: What Can We Learn from Dual Task Assessments of Brain & Behavior?

Jaclyn Stephens, PhD OTR/L
Associate Professor
College of Health and Human Sciences
Colorado State University

Learning Objectives

- After attending this presentation, attendees will be able to:
  - Summarize current goal standard approaches for determining return-to-play readiness after sport-related concussion and describe risk of repeat concussion after initial concussion.
  - Restate new research methods that are being used to evaluate brain and behavioral performance in athletes with and without concussion.
  - Appraise research findings and discuss potential implications for future concussion evaluation practices.

Personal Motivation for Research with Athletes



A Sports-Related Concussion (SRC) is a Traumatic Brain Injury

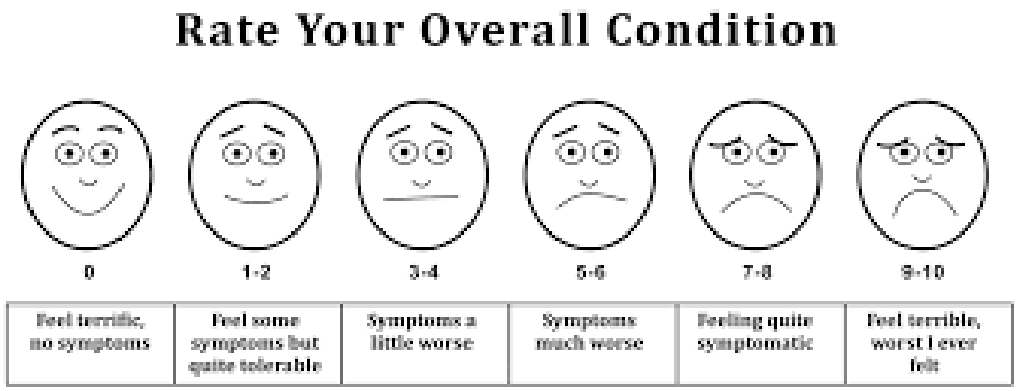
ED evaluations are most useful for ruling out a more severe brain injury.

Return to Play Evaluations – the Gold Standard

- Determining return-to-play readiness should include (Phillips et al, 2015):
  - Subjective symptom reports
  - Objective assessment of cognitive capacities:
    - Memory
    - Attention
    - Processing
  - Objective assessment of motor abilities:
    - Balance
    - Gait
    - Reaction Time

The Problem with Symptom Reports

Symptom reports are the most frequently used approach



Many symptoms are non-specific

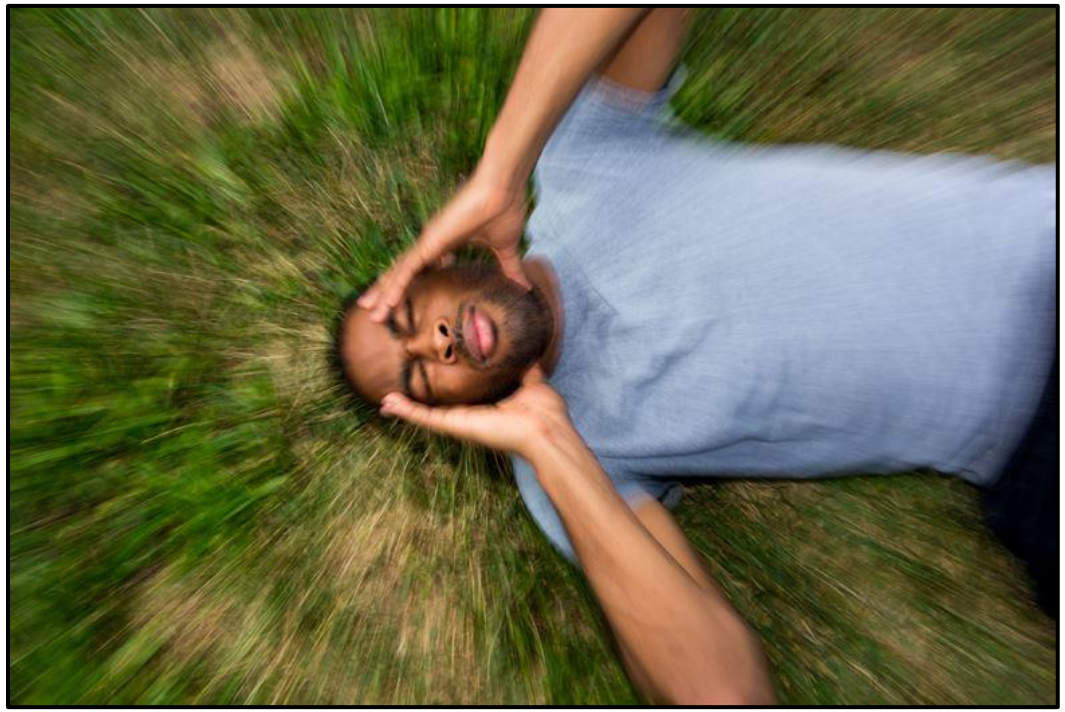
AND….collegiate athletes frequently underreport symptoms

The Problem with Objective Assessments

- Rely on *accurate* baseline testing

- Many measures have poor test-retest reliability

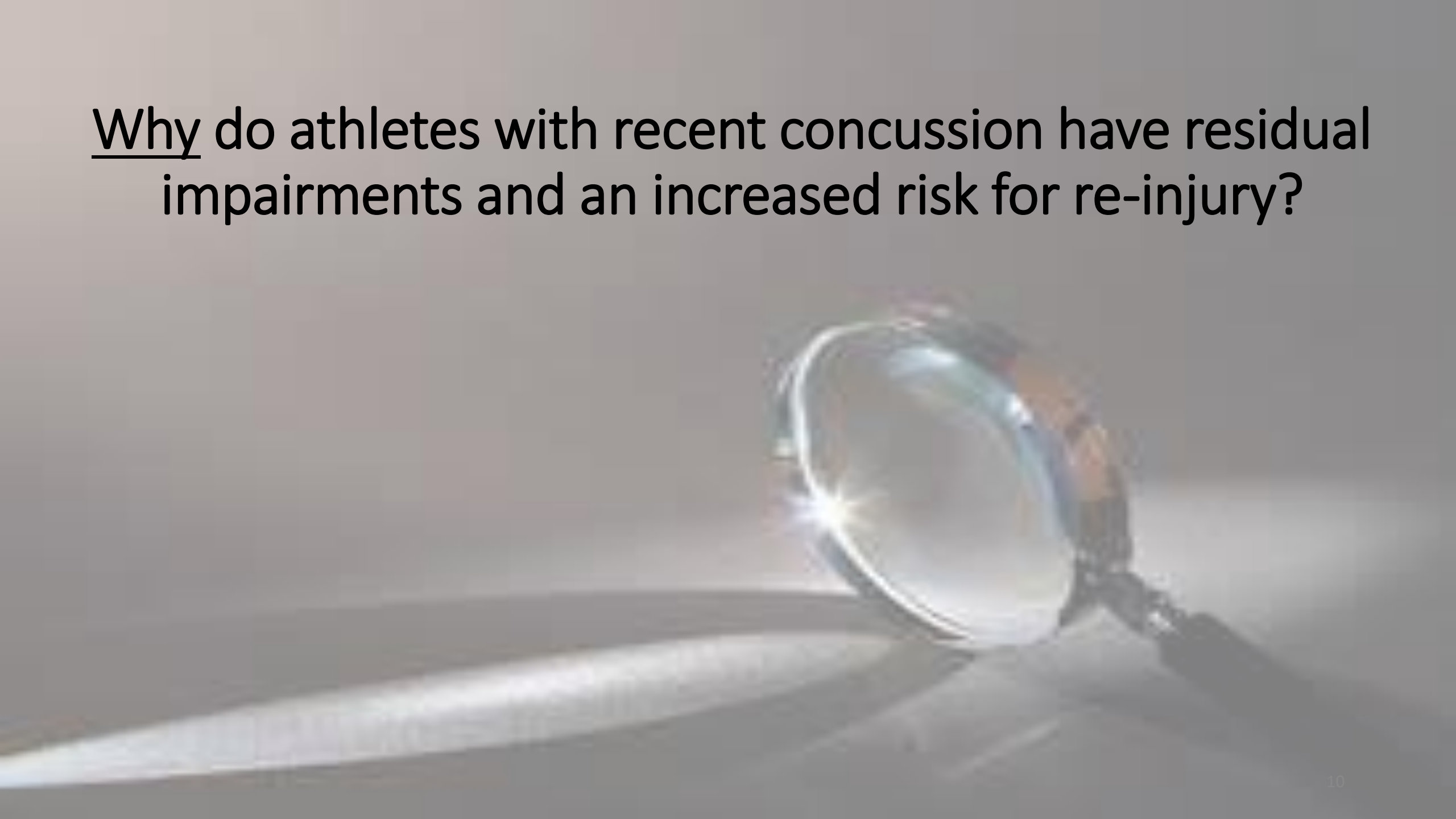
Significantly Increased Risk of Re-Injury at Return to Play



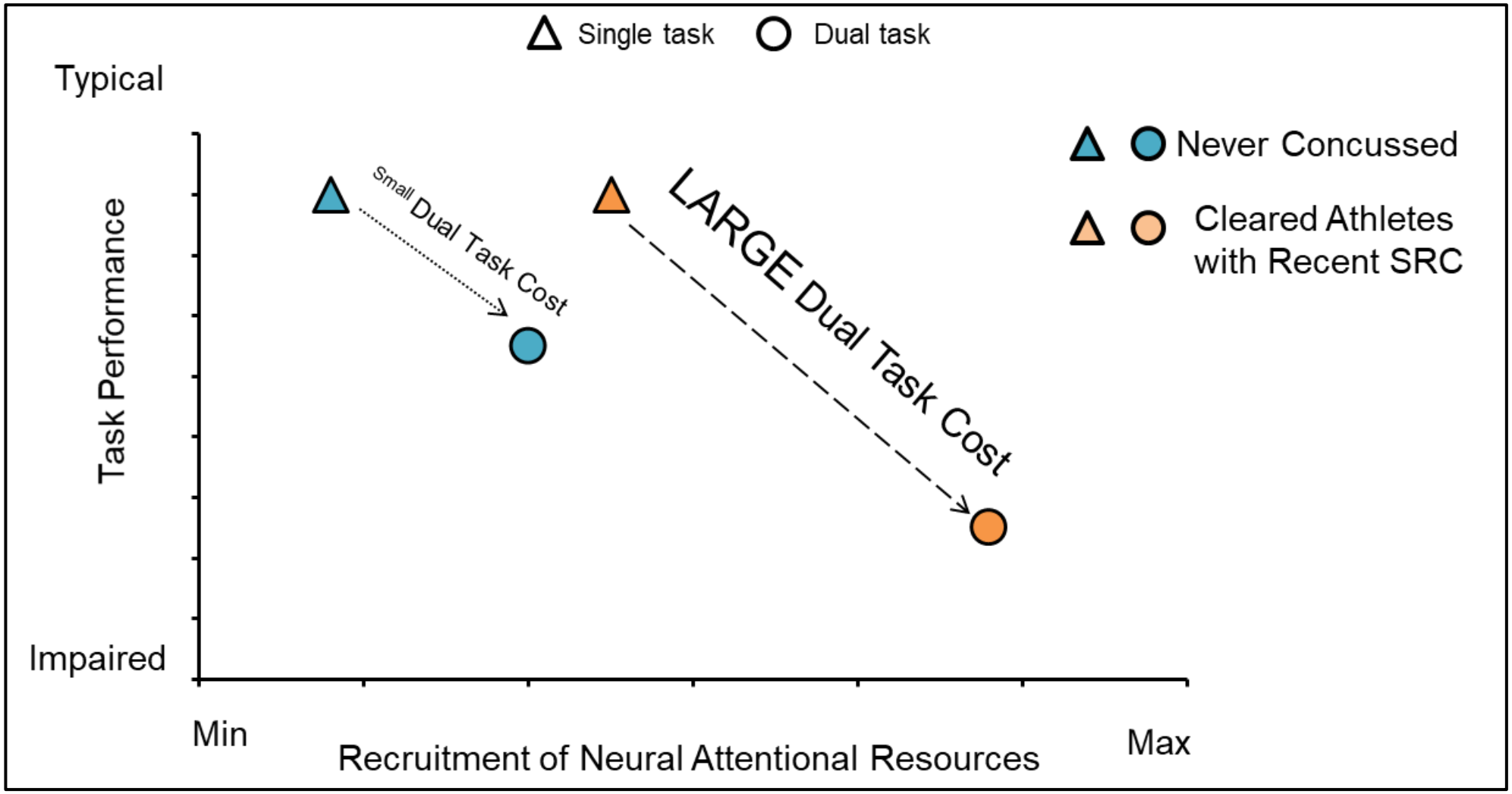
Sports Medicine Research Finds Subtle Deficits, Including Impaired Multitasking Abilities in “Recovered” Collegiate Athletes

This could reflect impaired motor performance, impaired cognitive performance, or both.

Why do athletes with recent concussion have residual impairments and an increased risk for re-injury?



Testable Theoretical Model

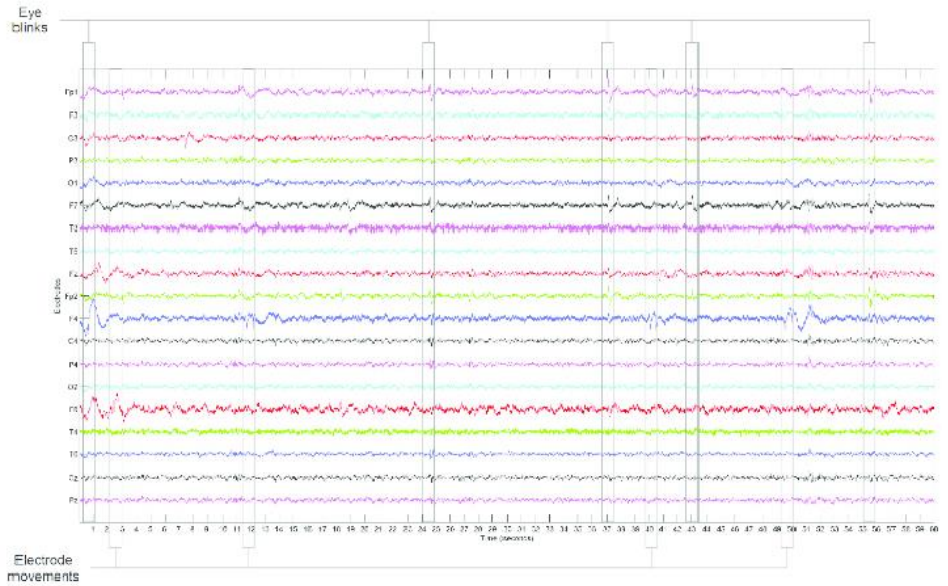


Participants

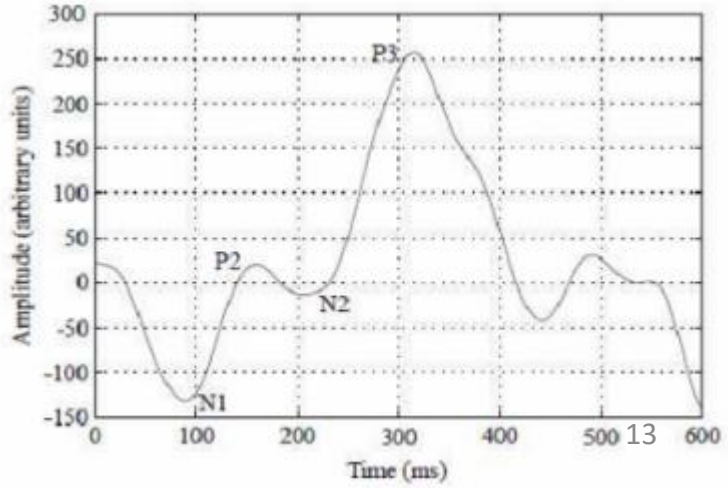
- Collegiate athletes with diagnosed SRC who had been cleared to return to play by a professional
- Collegiate athletes with diagnosed SRC who had sustained multiple SRCs
- Athletes were similar in single task, dual task, and neuroimaging outcomes, so they were combined into 1 group and compared to never-concussed athletes.
  - Multiple* SRC group
    - N = 10
    - Six male athletes, four female athletes
  - Never Concussed group
    - N = 10
    - Six male athletes, four female athletes

Testing the Model

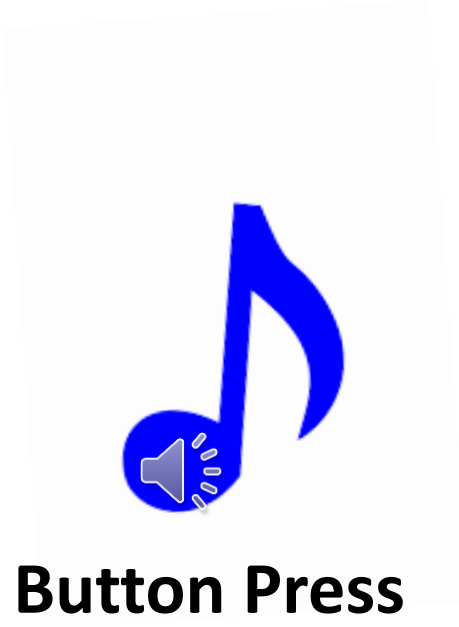
Electroencephalography (EEG) in Brainwaves Research Lab



Raw electrical signal is converted to event-related potentials (ERPs)



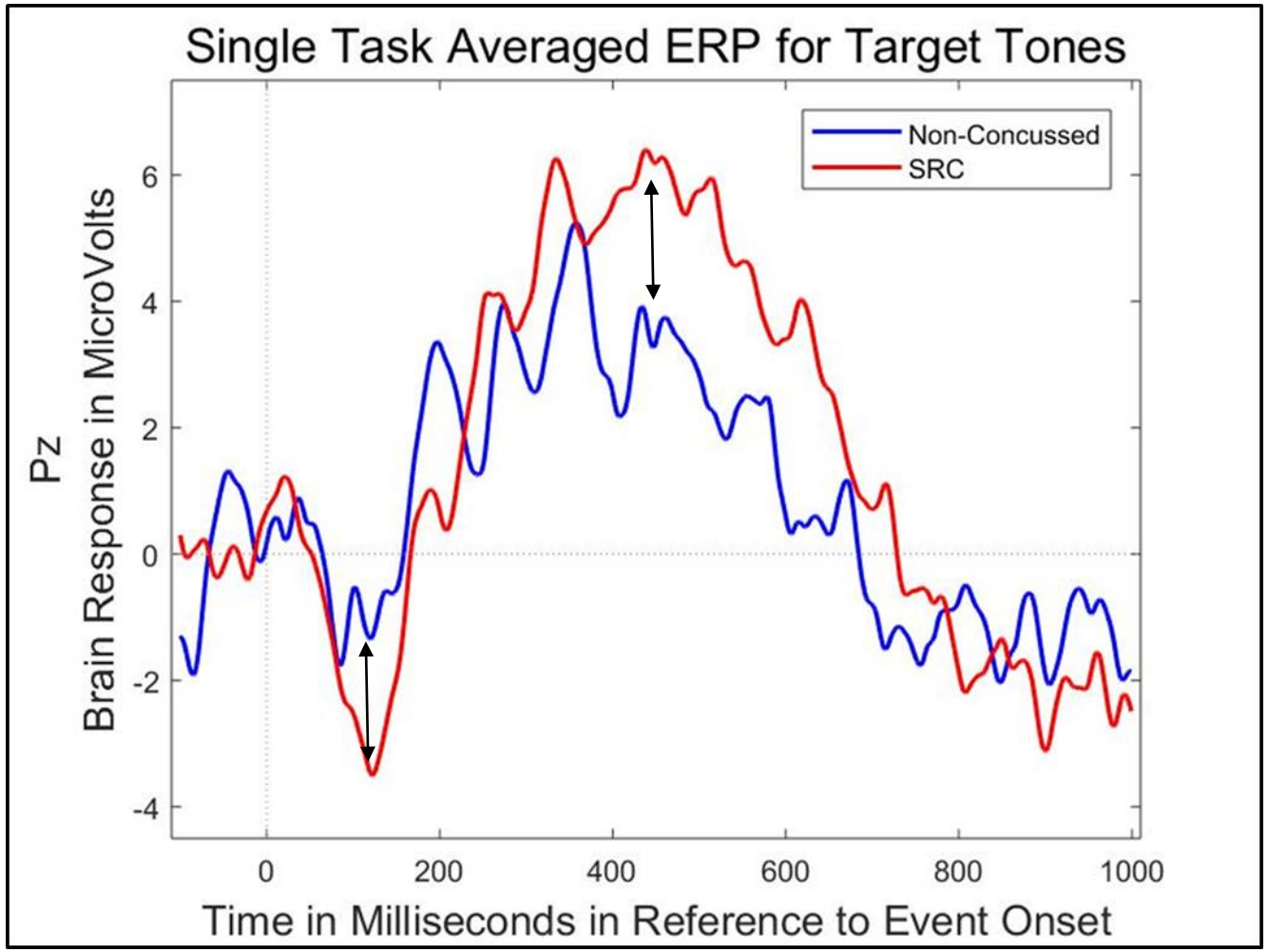
1st EEG Task – Novelty Oddball



Button Press

Sample Trial Sequence

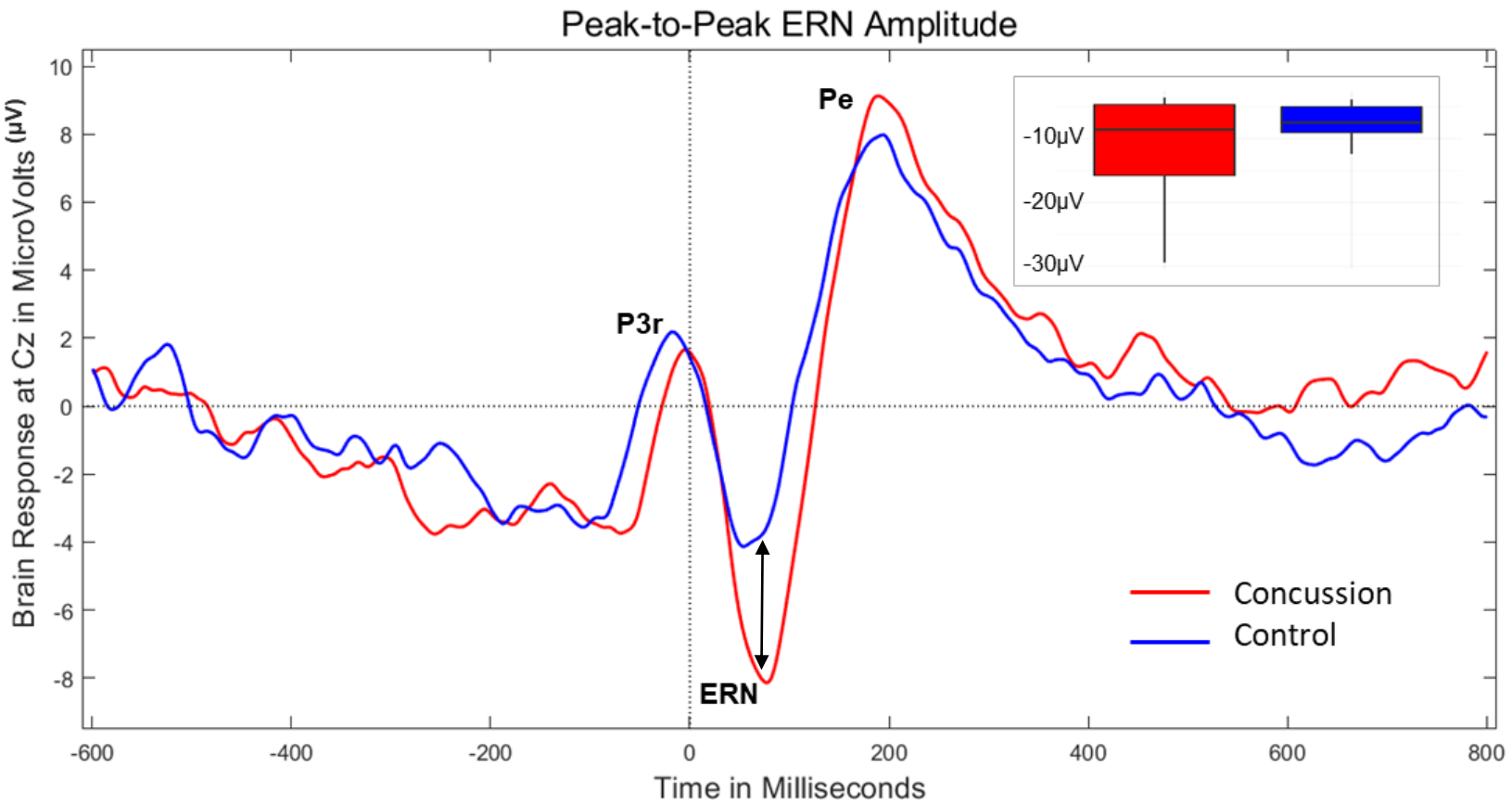
Preliminary EEG Findings



2nd EEG Task – Flanker Task

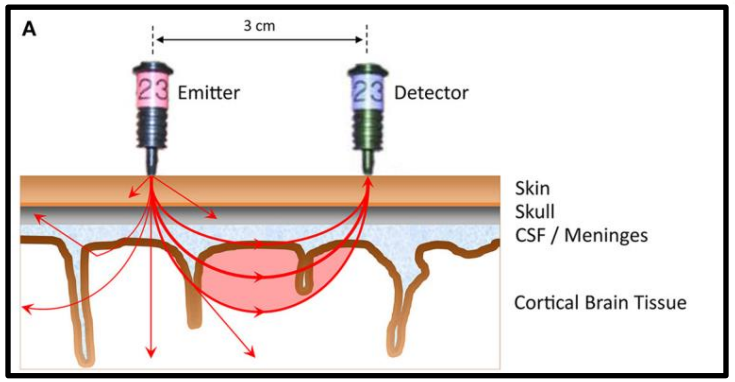
Instructions: *You will see 5 letters appear on the screen. Your task is to look at the middle letter. If the middle letter is an H, tap once with your left index finger. If the middle letter is an S, tap once with your right index finger. Ready?*

Preliminary EEG Findings

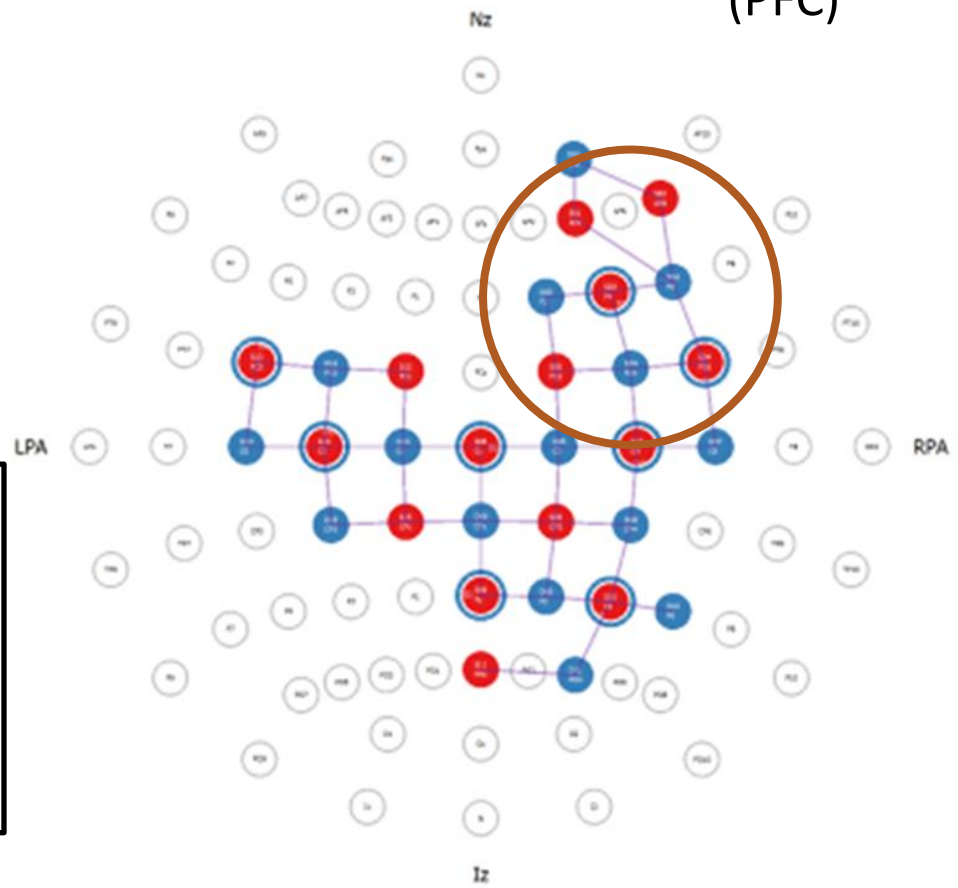


Testing the Model

Mobile Functional Near-Infrared Spectroscopy



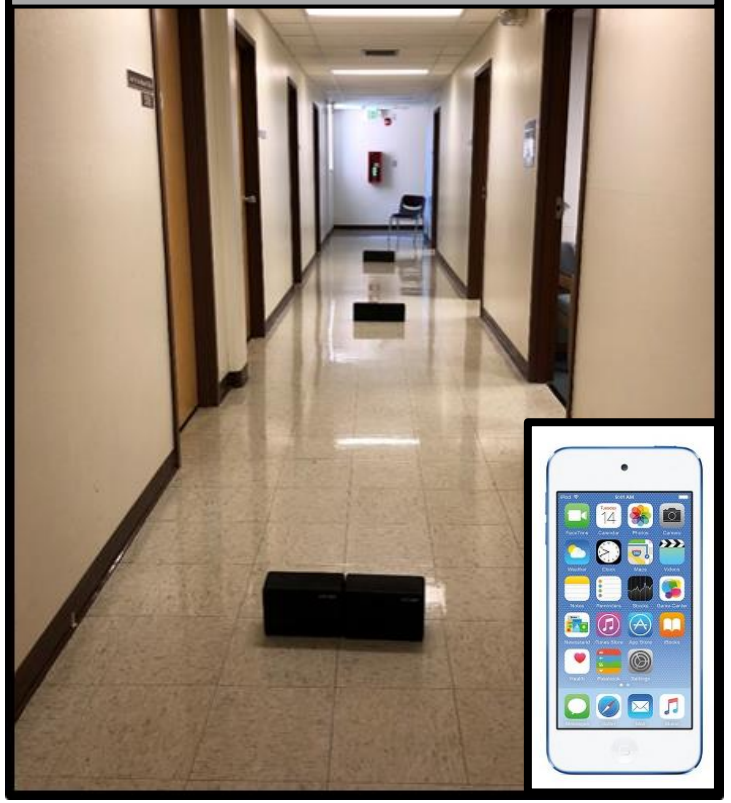
Focus on right prefrontal cortex (PFC)



fNIRS Task - Dual Task Screen

Hand-Eye Coordination Subtask

Obstacle Walk/Gait Subtask



Evaluating Task Performance

Single Task Performance

Straightforward comparison of performance using task outcome (e.g. gait speed)

Dual Task Effect:
(Dual Task – Single Task)/Single Task

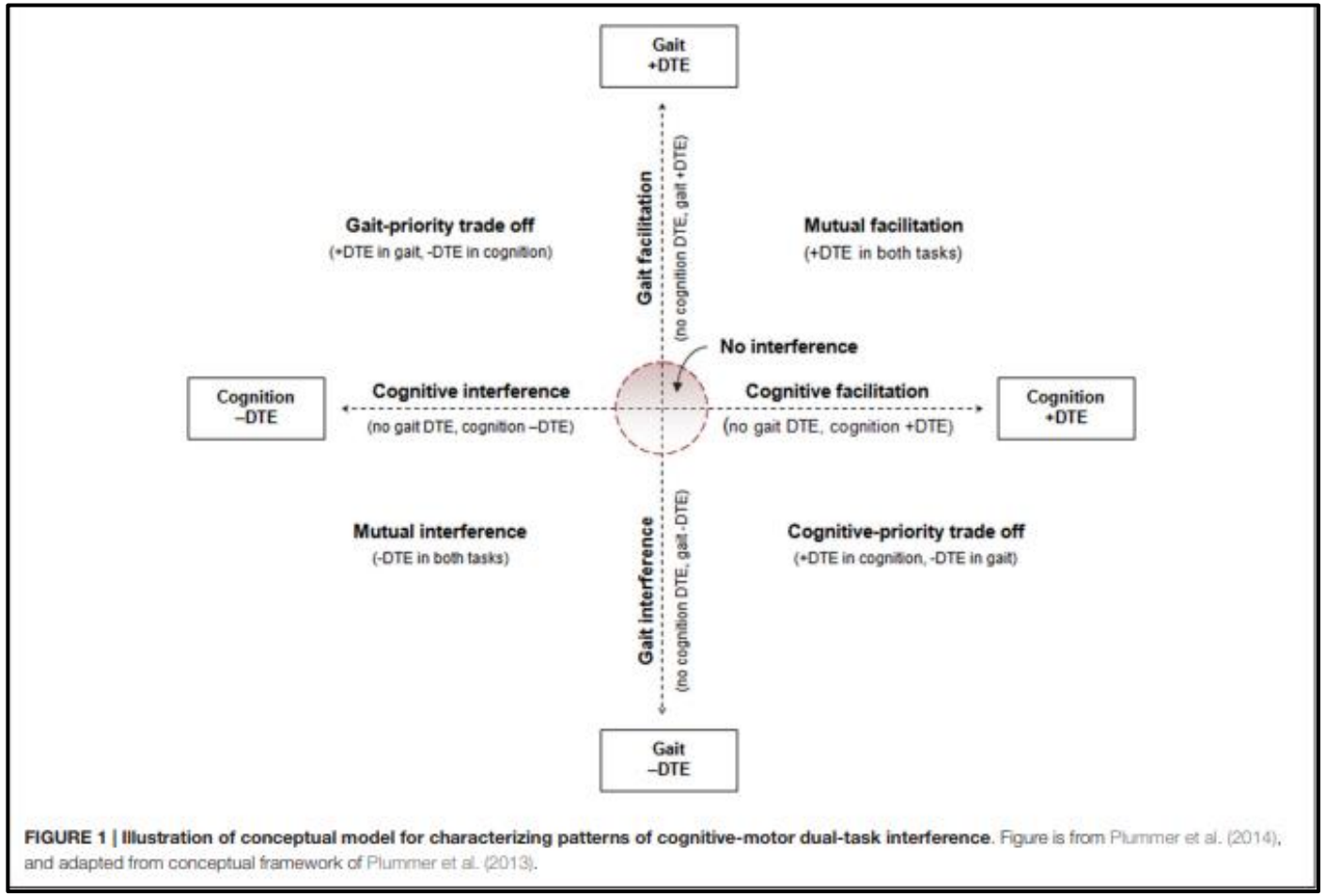


FIGURE 1 | Illustration of conceptual model for characterizing patterns of cognitive-motor dual-task interference. Figure is from Plummer et al. (2014), and adapted from conceptual framework of Plummer et al. (2013).

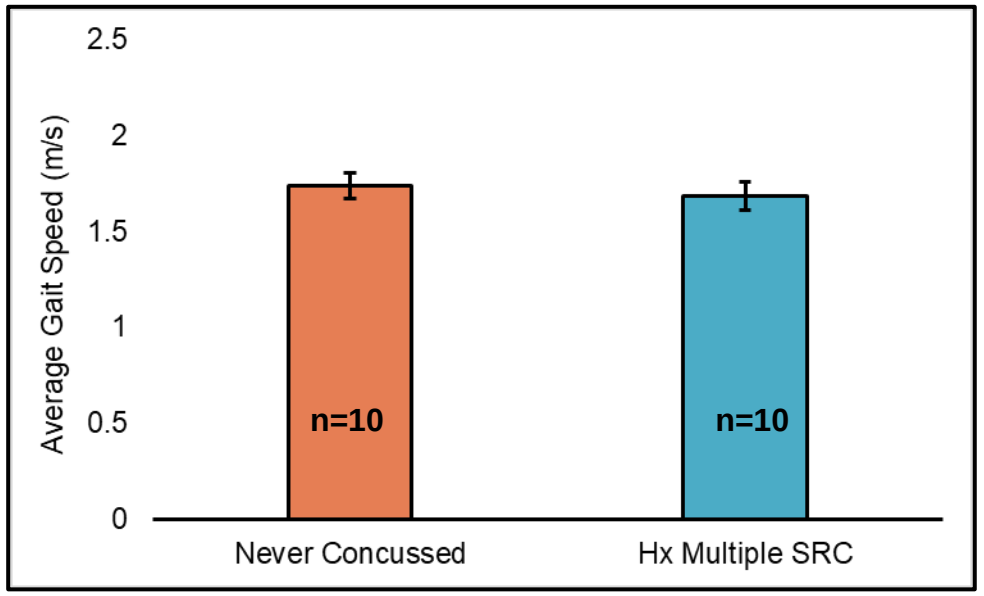
Prudence Plumber and Gail Eskes 2015 in *Frontiers in Human Neuroscience*

Multiple SRCs & Single Motor Tasks

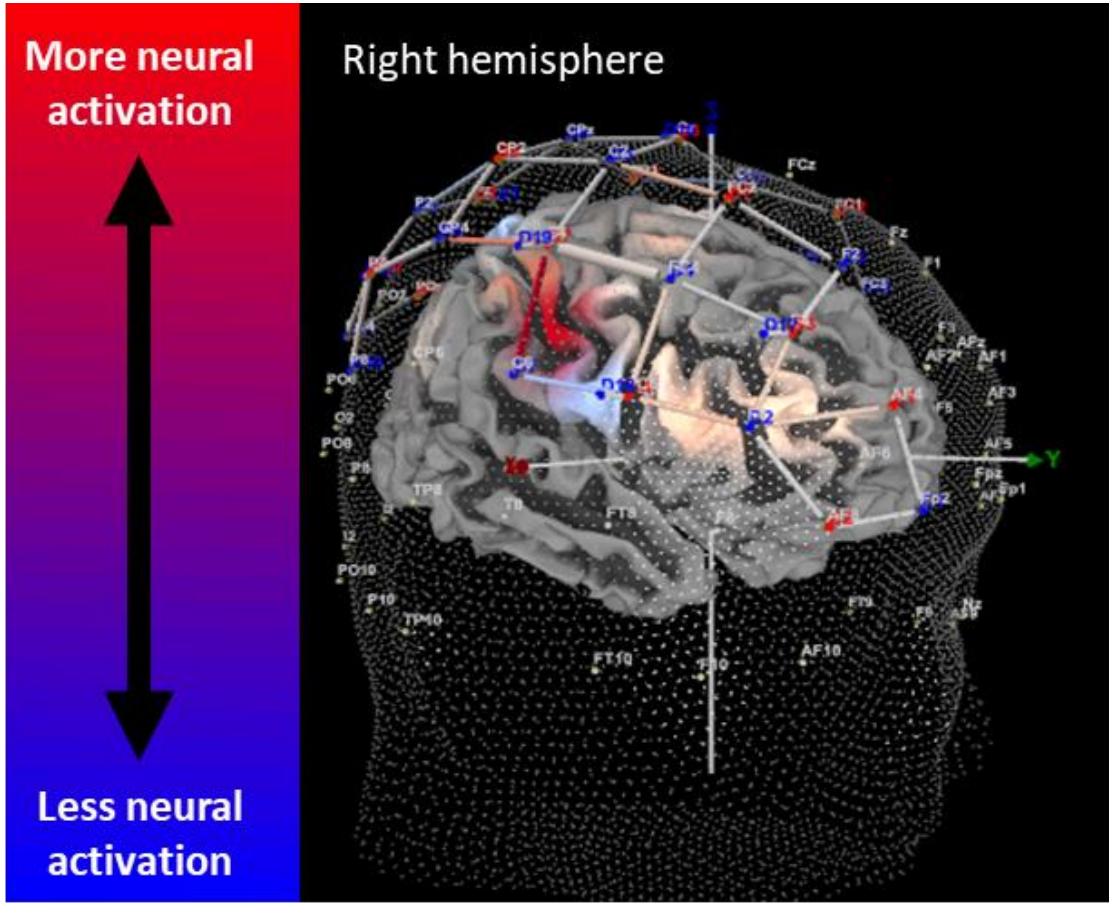
LE Subtask

Single Motor Task – Obstacle Walk:

- No differences in gait speed, p = .586



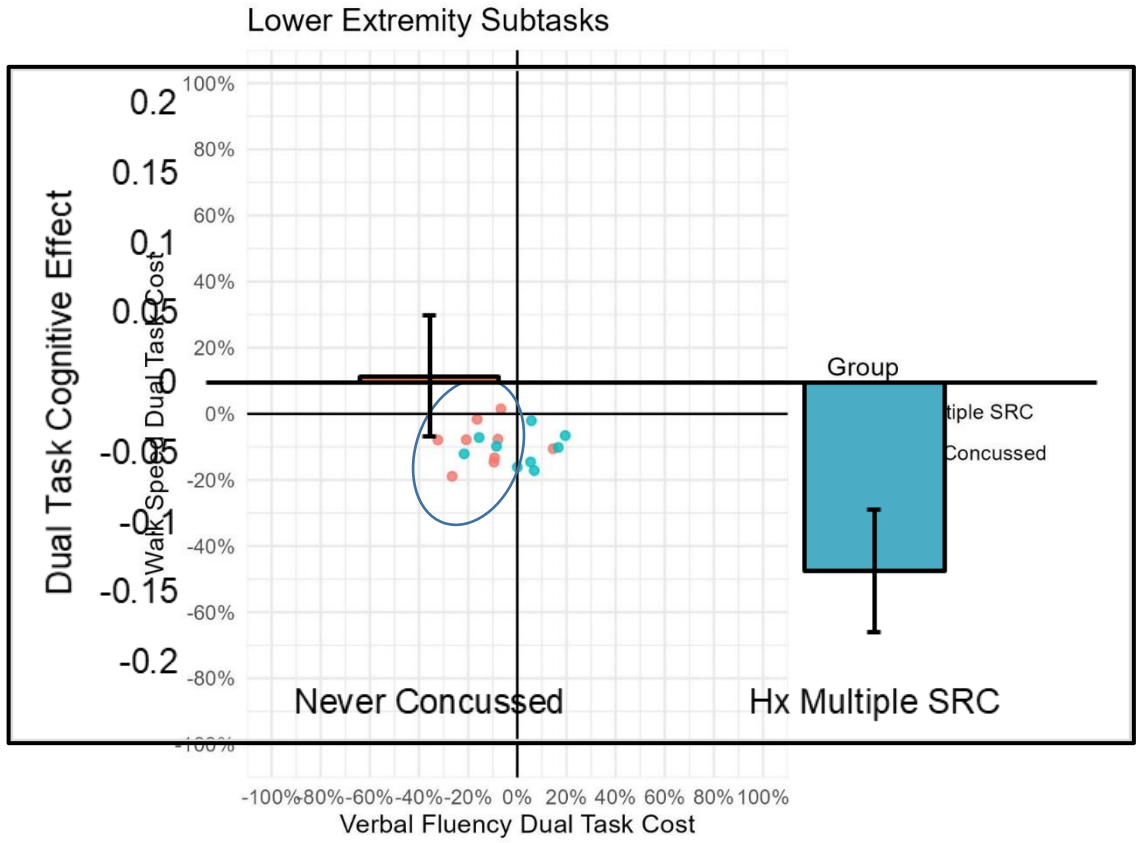
- But, participants with a history of multiple SRC had significantly greater neural activation across multiple brain regions.

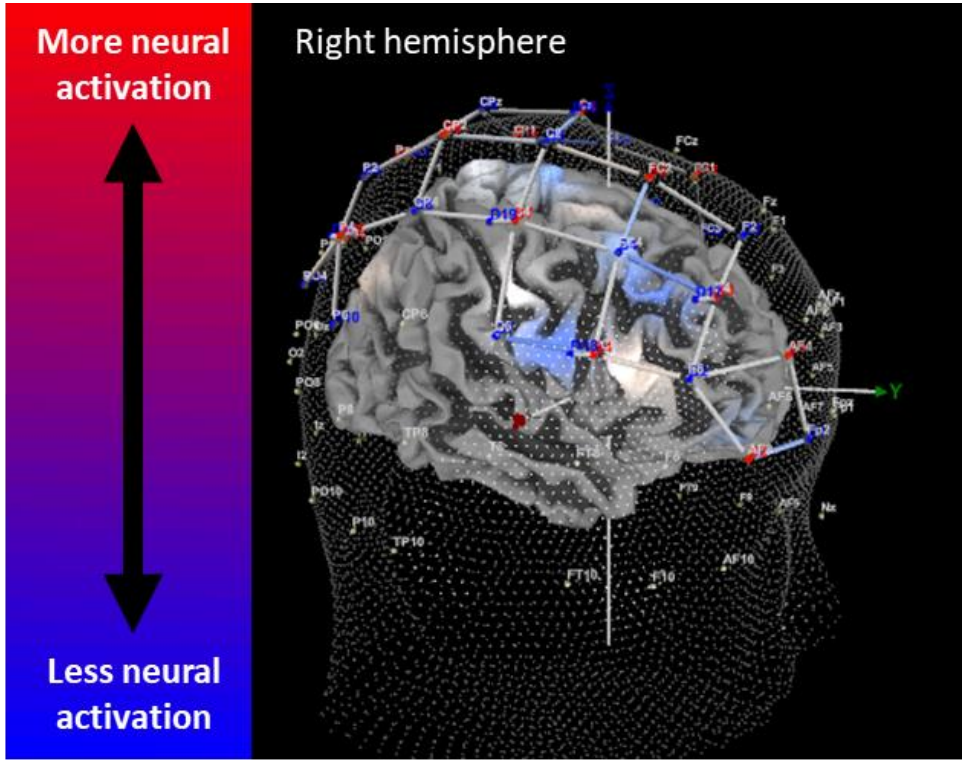


Multiple SRCs & Dual Tasks
LE Subtask

Dual Task – Obstacle Walk + Verbal Fluency

- Participants with a history of multiple SRC had a significantly larger dual task cognitive effect, p = .014





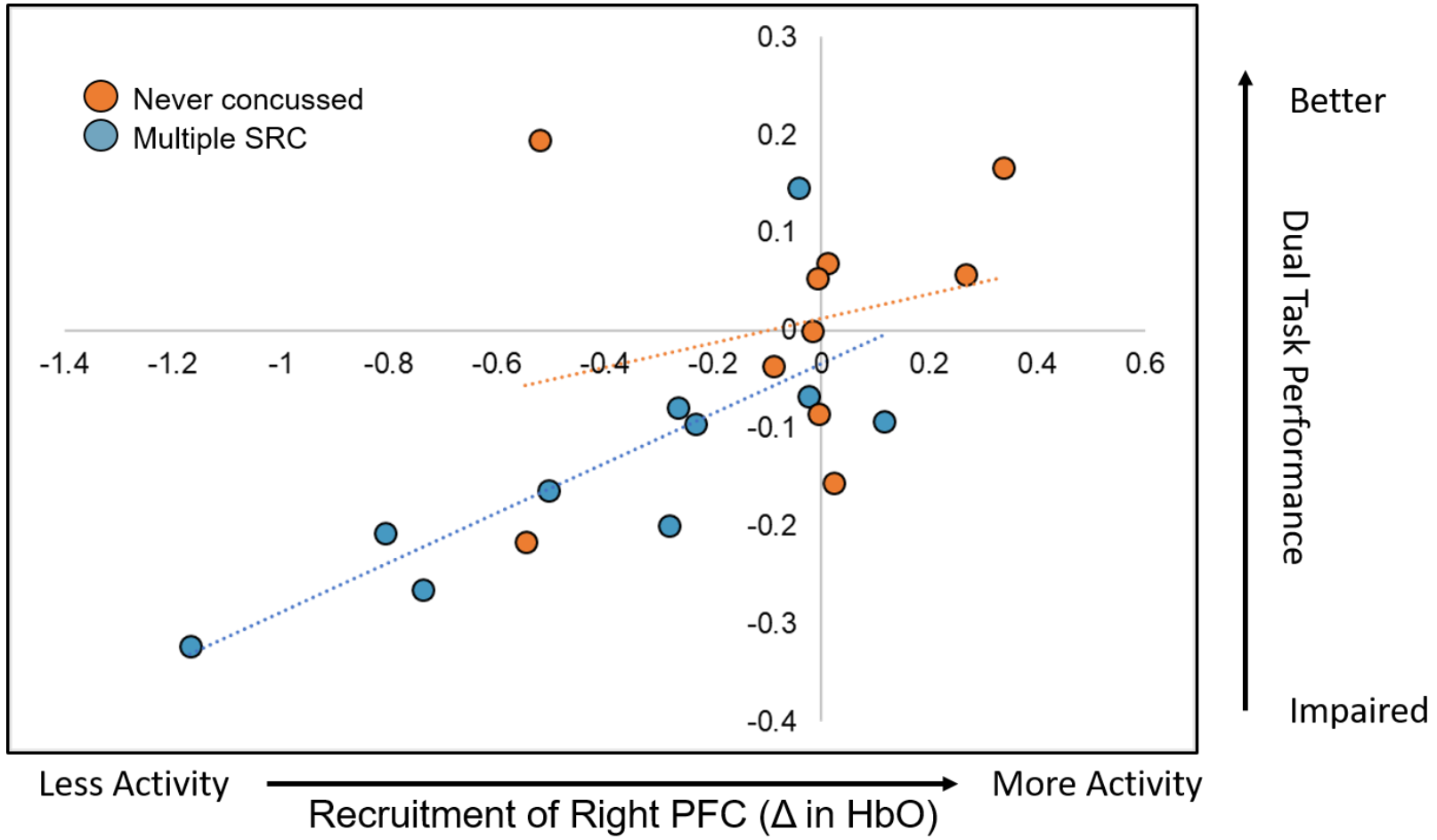
Participants with a history of multiple SRC had significantly lower neural activation in multiple brain regions.

Integration of Brain & Behavioral Findings

- Channel S3-S4, situated over the inferior frontal gyrus - part of prefrontal cortex (PFC) had robust group differences, even after strict correction for multiple comparisons.
- Is neural recruitment of this area associated with dual task costs?

Simple Answer: Yes

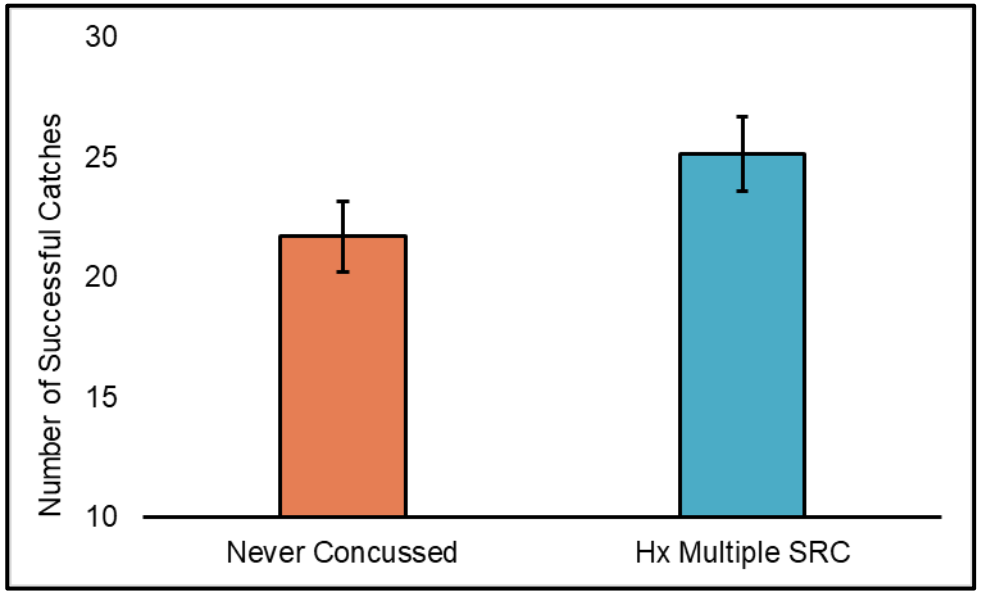
r = .662
p = .001



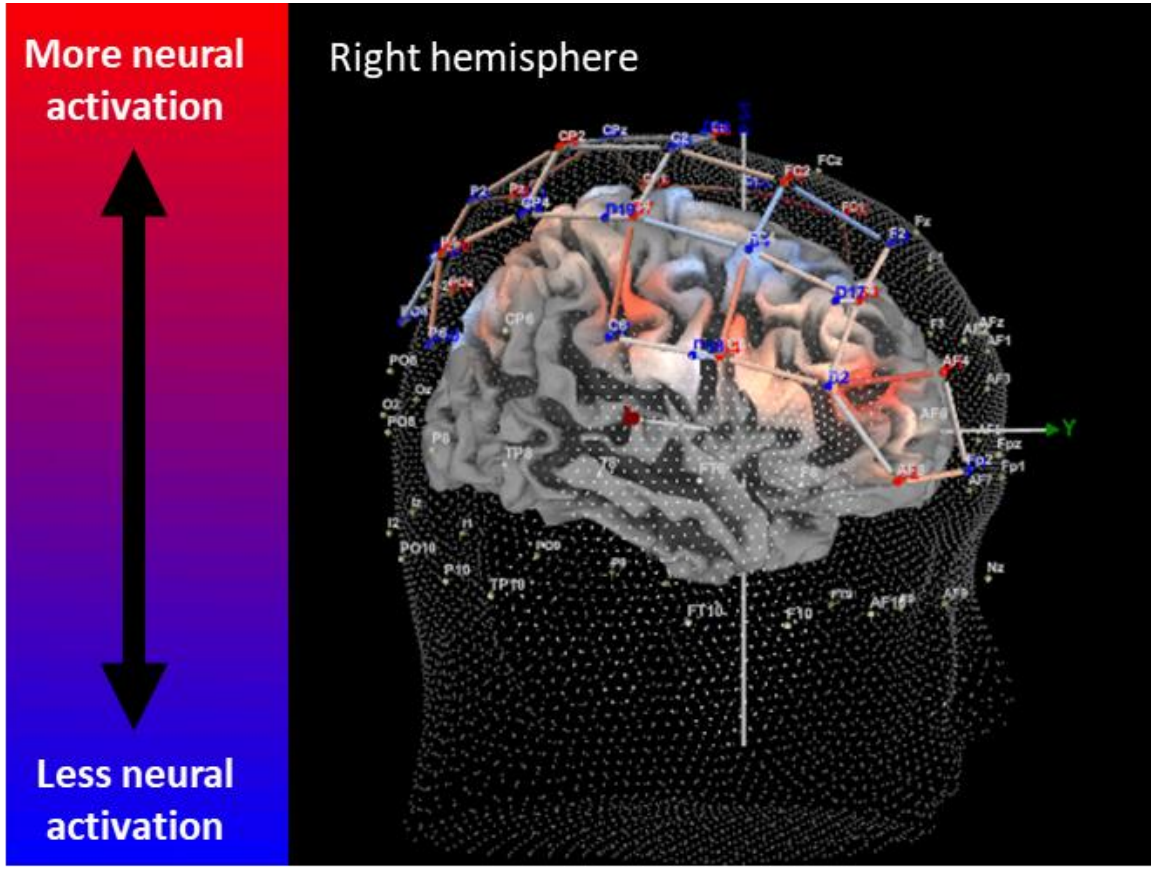
Multiple SRCs & Single Motor Task
UE Subtask

Single Motor Task – Wall Toss

- Participants with a history of multiple SRC have better single task performance, $p = .052$



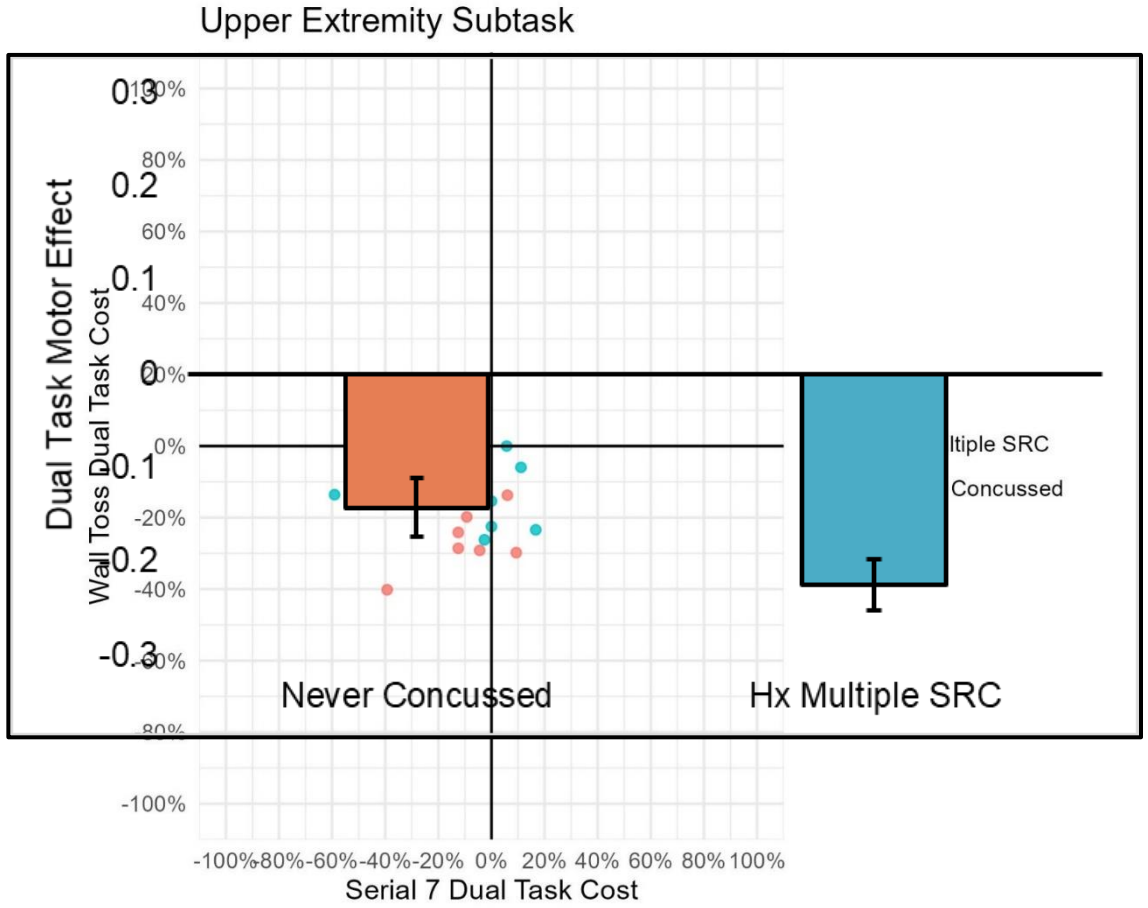
- Participants with a history of multiple SRC had significantly greater neural activation across multiple brain regions.

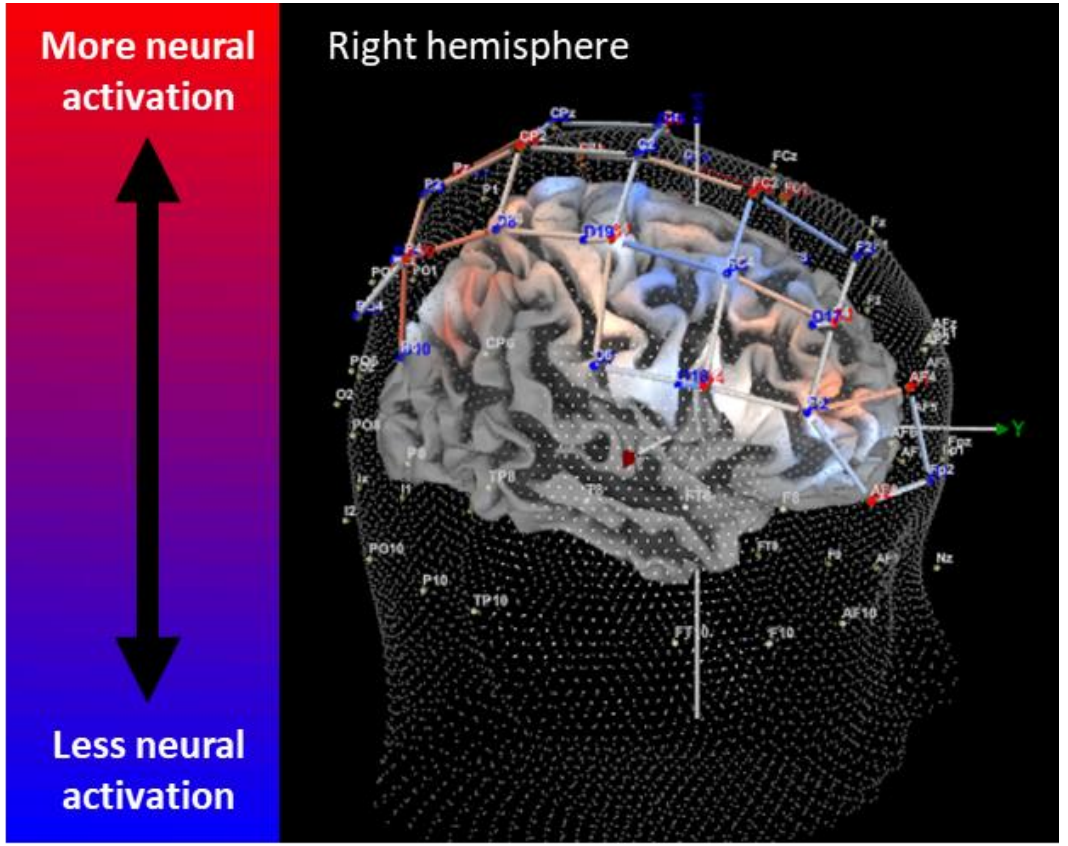


Multiple SRC & Dual Task
UE Subtask

Dual Task – Wall Toss + Serial 7's

- Participants with a history of multiple SRC had a significantly larger dual task motor effect, p = .024





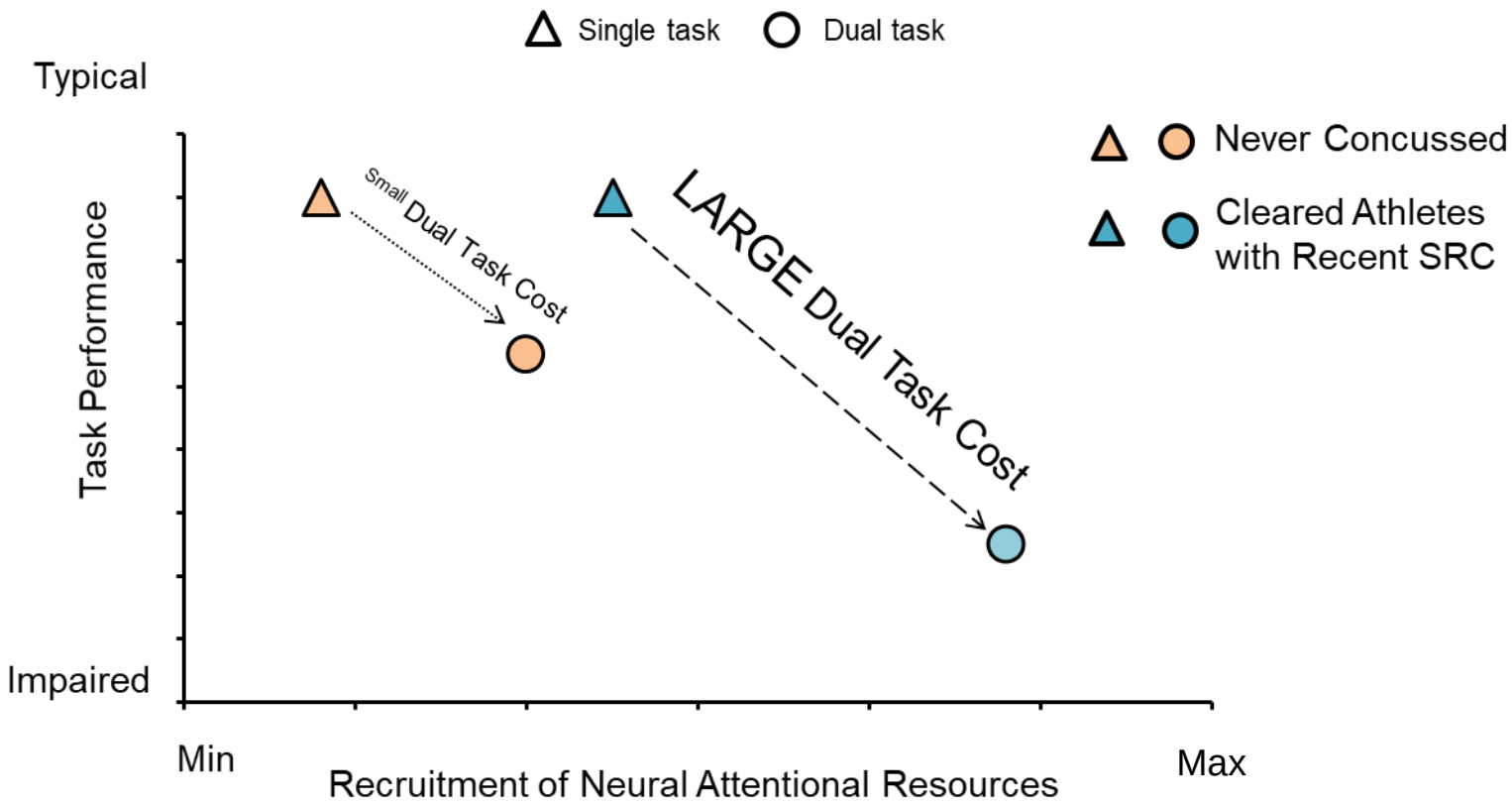
Participants with a history of multiple SRC had lower neural activation in multiple brain regions.

Integration of Brain & Behavior Findings

- Although there was a pattern of decreased activity during dual task on the UE subtask, the group differences were not robust.
- After correcting for multiple comparisons, no channels remained to evaluate potential relationships in neural recruitment and dual task motor cost.
- There are likely different mechanisms at play during dual task performance of a highly learned/automatic task (gait) and a more novel, less-automated task (wall toss).

Summary of Brain & Behavioral Findings

- In general, participants with recent or multiple SRC have increased brain activity during single tasks, but decreased brain activity during dual tasks.
- This pattern of activity supported single task performance on both subtasks, but failed to support dual task performance.



Possible Interpretation & Next Steps

- Inefficient neural activity during dual tasks is also observed in aging (Stojan et al., 2023)
- Individuals with multiple concussions are at a heightened risk for developing neurodegenerative diseases, like Alzheimer's (Schneider et al., 2021).
- Are young adults with multiple concussions showing signs of accelerated neurocognitive aging?
- If yes, what interventions could be used to prevent repeat SRC or to restore dual task performance and brain activity to 'age-appropriate' patterns?

Discussion – Your Ideas

Question 1

- Which of the following is **not** included in current goal standard approaches for determining return-to-play readiness after SRC?

a) Self-reported symptoms
b) Attention testing
c) Computed tomography (CT) scan in an emergency department
d) Balance testing

Question 2

- True or false – when gold standard assessments are used, athletes with recent SRC have no risk of repeat SRC at return-to-play?

Question 3

- Which of the following is included in the Dual Task Screen protocol?

a) Serial 7 subtractions
b) Electroencephalography (EEG)
c) Balance testing
d) Reaction time testing

Question 4

- How does functional near-infrared spectroscopy (fNIRS) measure brain activity?

a) Directly, by measuring activity of neurons at specific sites.
b) Indirectly, by measuring oxygen use of neurons at specific sites.
c) Directly, by measuring activity of neurons throughout the brain.
d) Indirectly, by measuring oxygen use of neurons throughout the brain.

Question 5

- Which of the following is a true statement?

a) Medical professionals and athletic trainers always use gold standard approaches when evaluating athletes with SRC.

b) The Dual Task Screen is ready for widespread use in clinical settings and athletic training rooms.

c) Neuroimaging should always be used to assess readiness to return-to-play after SRC.

d) Dual task assessments might be able to identify residual deficits of SRC and assist in return-to-play evaluations.


thank you