Using Virtual Reality to Assess Sensory Integration for Navigation and Balance Control

Peter Fino , PhD
Health & Kinesiology

Sarah Creem-Regehr, PhD
Psychology

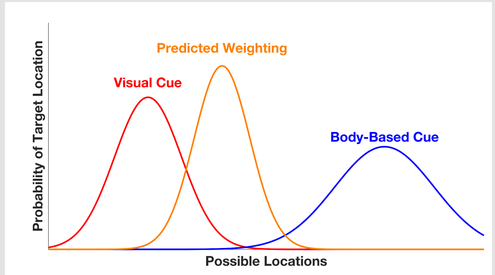
Colby Hansen, MD
School of Medicine

1U4U Innovation Funding

Funded Project Amount: $30,000

Introduction

- Balance impairment is a common symptom following concussion
- Recent work attributes balance disruption to impaired sensory integration - the ability to combine visual, vestibular, and proprioceptive information
- Sensory integration supports balance and navigation, but our knowledge of sensory integration following concussion is limited to static balance tasks
- When navigating, healthy participants show optimal integration as reliable sensory cues are upweighted



- Currently, the effects of concussion on sensory integration for navigation remains unclear

The Current Study

- Here, we investigate the impact of concussion on sensory integration for navigation and balance in a virtual reality (VR) Homing Task that reflects daily mobility
- We explore sensory integration by manipulating the availability of sensory feedback and recording the impact on navigation and balance
- During this 1U4U project, we have:
  1. Programmed two tasks in VR to evaluate both static and dynamic balance and sensory integration
  2. Collected pilot data with both concussion patients and healthy controls
  3. Received an R21 grant from the National Institutes of Health

Methodology

- **Participants:** 8 healthy controls and 7 people with concussion (3-12 weeks post injury)
- Participants completed two tasks in VR using the HTC Vive Pro Eye head-mounted display

- **VR sensory organization task (SOT):** Developed during 1U4U to measure static balance across two surfaces (firm or foam) in four sensory conditions:
  1. Normal visual feedback
  2. Fixed visual feedback
  3. No visual feedback
  4. Sound only

Fig 1. The virtual environment developed for the SOT

- **VR homing task:** Measures spatial navigation performance with gait & balance tracking
  - Participants walk three legs of a triangle and then walk back to a previous location under four sensory conditions:
    1. Vision only (participants spun in chair)
    2. Self-motion only (landmarks removed)
    3. Consistent cues (no manipulation)
    4. Conflicting cues (landmarks shifted 15°)

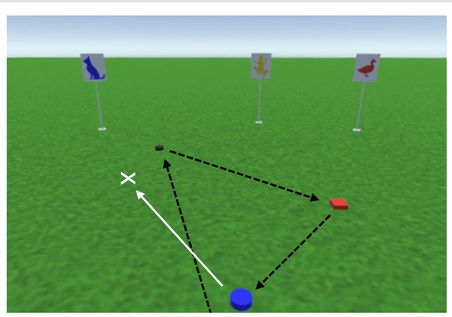
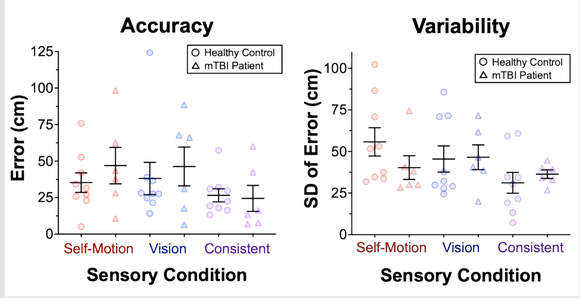


Fig 2. An example trial of the homing task with the three segments (black dashed lines) and the participant's response phase (white solid line)

Results

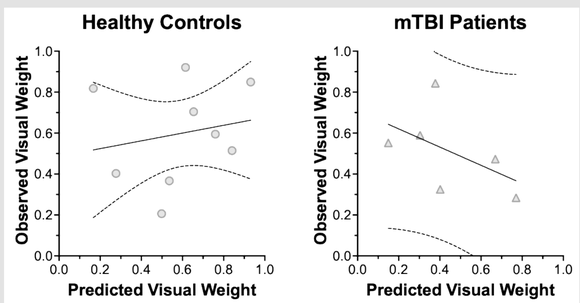
- Healthy controls seem to be more accurate and less variable in single-cue conditions compared to people with concussion
- All participants saw an improvement in performance when multiple cues are available



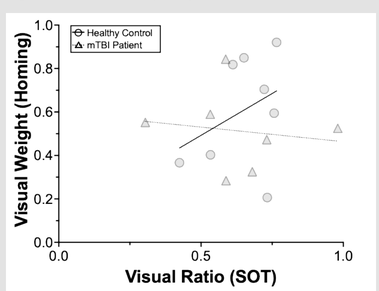
- Predicted weights are calculated using the relative variance of single cue performance:

$$\text{Predicted Vision Weight} = \frac{1/\sigma^2_v}{1/\sigma^2_v + 1/\sigma^2_{sm}} = \frac{\sigma^2_{sm}}{\sigma^2_{sm} + \sigma^2_v}$$

- Predicted weights are related to observed weighting (derived from conflict condition) for healthy controls but not for people with concussion



- In healthy controls, reliance on vision for static balance (SOT) is associated with reliance on vision for navigation (homing), but not for people with concussion



Conclusion

- After concussion, people did not efficiently navigate when only provided a single sensory cue
- People with concussion also showed sub-optimal sensory integration through a negative relationship between predicted and observed visual weightings
- Inconsistent visual weightings between the SOT and homing task in those with concussion shows different integration processes for static balance and navigation
- Sub-optimal sensory integration following concussion disrupts navigation performance as well as balance control

Future directions

- Investigate how concussion affects sensory integration for dynamic balance control in the homing task by exploring: step width and length, velocity, and margin of stability
- Investigate differences in homing path between those with and without concussion.
- Assess dual-task interference between sensory integration for navigation and dynamic balance control
- Explore the relationship between static balance and dynamic balance by comparing balance between the SOT and homing task.

Acknowledgements

This work was largely conducted by graduate students (Corey Shayman and Maggie McCracken), postdocs (Sam Beech), and research coordinators (Christina Geisler).
Funding was supported by the 1U4U Innovation Funding.
Additional funding was secured and provided by National Center for Medical Rehabilitation Research (NCMRR) within NICHD/NIH (R21HD110713; MPIs: Fino | Creem-Regehr)