



# Cognitive-motor integration (CMI) performance testing and symptom assessment reveals males and females respond differently to concussive injury

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## INTRODUCTION

Behavioural sex-related differences have been noted in multiple different aspects of cognition such as visual-spatial tasks<sup>1,2</sup>, verbal tasks<sup>1-3</sup>, perceptual speed<sup>3</sup>, and dexterity<sup>3</sup>. Recent imaging research has found sex-related differences in brain activation when performing a CMI task<sup>4</sup>. Despite finding differences in functional activity, there were no differences in behavioural performance, suggesting sex-related differences in the brain networks responsible for the successful performance of CMI tasks. These networks contain brain areas commonly affected by concussive injury.

Recently, research has also examined sex-related differences surrounding concussive injury in both symptoms<sup>5-7</sup> and recovery trajectory<sup>5,8</sup>. Males tended to report more cognitive symptoms including memory loss and confusion, and females tended to report more neurobehavioural and somatic symptoms including sensitivity to noise and fatigue<sup>6</sup>. There has been a mixture of results with sex-related differences in the recovery process from concussion in humans.<sup>9-11</sup> However, a recent study on mice observed sex-related differences in concussion recovery, whereby male mice experienced longer recovery of visuomotor skills, while female mice experienced longer recovery of emotion-related symptoms (but not visuomotor skills).<sup>12</sup>

It is becoming increasingly apparent that concussion affects males and females differently from risk to recovery; however, more research is required to understand the extent to which these differences exist in all aspects of concussion. In order to gain a better understanding of the underlying causes of concussion, and to improve the diagnostic and recovery standards surrounding concussive injury, it is important to investigate these sex-related differences.

Therefore, **the aim** of this study was *to examine the interaction between sex, concussion history, emotionality and visuomotor skill.*

## METHODS

**Participants:** York University Varsity athletes (n=333)

Concussion History (Hx) = 145 (78 female), No Concussion History (NoHx) = 188 (100 female)

\*All participants were asymptomatic at time of testing\*

All participants completed a SCAT3 or SCAT5, and a questionnaire.

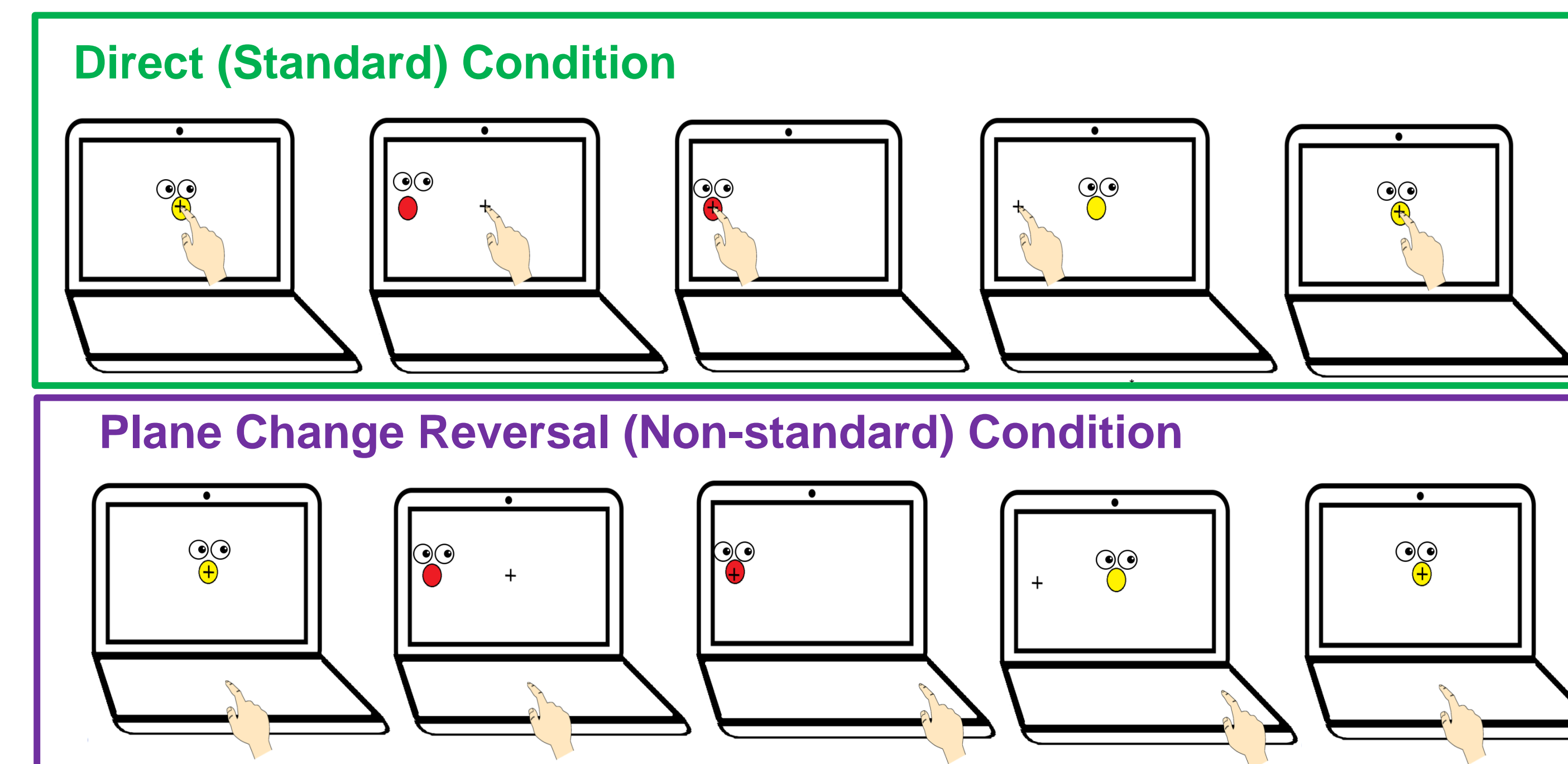
A subset of participants completed two computerized visuomotor tasks (**Brain Dysfunction Indicator - BrDI™**) one direct and one plane change reversal [see Figure 1],

**BrDI Task:** Slide a cursor from a central target to one of four peripheral targets (up, left, right, down) using their finger on a touch-screen tablet.

**Conditions:**

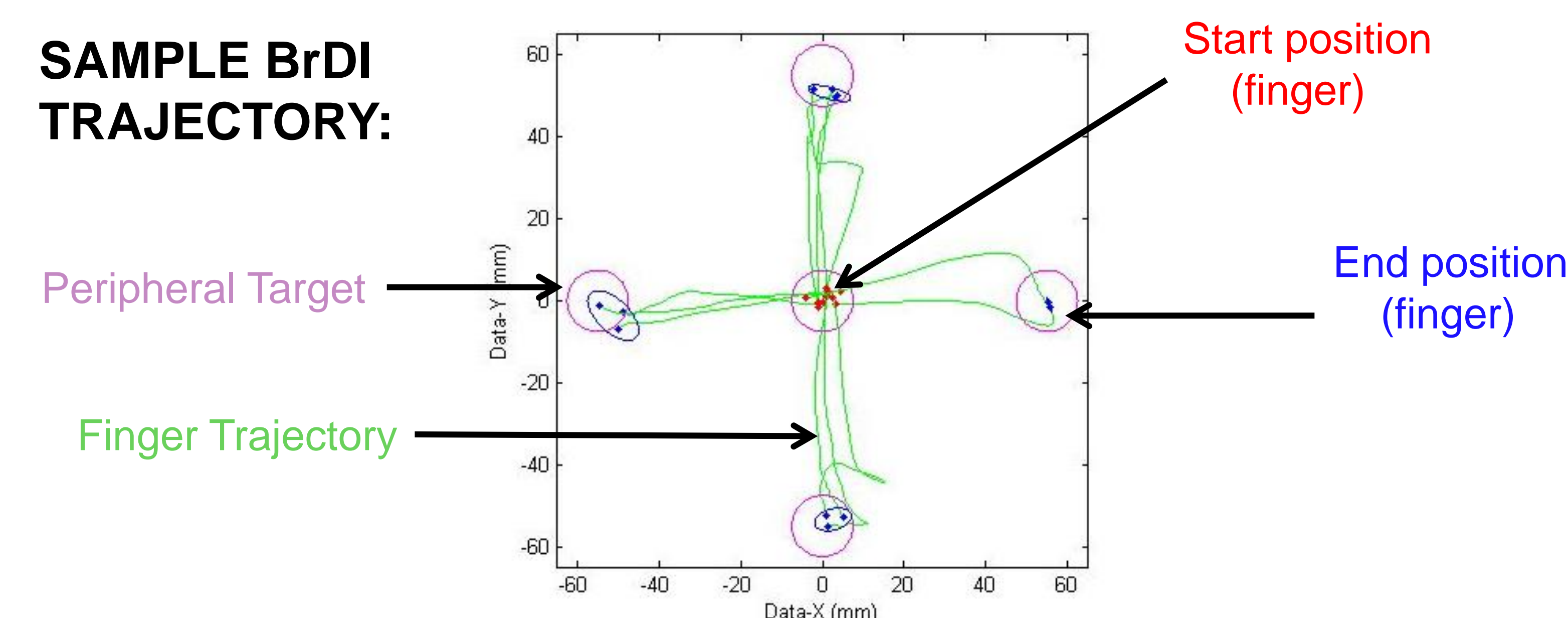
- Standard** – Target location and motor action are coupled
- Non-standard** (CMI task) –targets were viewed in a different plane than hand motion, and visual feedback was rotated 180°

## METHODS



**Figure 1.** Sequence of events during one trial. The yellow circle denotes the center, or home, target in which all movements begin. When the cursor enters the central target, it changes from yellow to green. After 4000ms a red target appears in one of four peripheral directions (90° to top, bottom, left or right of center) which serves as the 'Go' cue. The yellow center home target reappears after a target hold of 500 ms followed by an inter-trial interval of 2000ms, signaling the end of the trial. Top panels: Participant is looking at and moving on the screen where targets appear. Lower panels: Participant is looking at the vertical screen while sliding the finger on the horizontal screen. Visual feedback between cursor motion and finger movement is reversed 180 degrees.

### SAMPLE BrDI TRAJECTORY:



## ANALYSIS

### KINEMATIC OUTPUT VARIABLES:

|                                |                                    |
|--------------------------------|------------------------------------|
| Accuracy - Absolute Error (AE) | Trajectory - Full Pathlength (PLf) |
| Variable Error (VE)            | Peak Velocity (PV)                 |
| Timing - Reaction time (RT)    | Direction Reversals (DR)           |
| Full movement time (MTf)       |                                    |

### SCAT SYMPTOMS USED IN ANALYSIS:

|                |                    |
|----------------|--------------------|
| More emotional | Sadness            |
| Irritability   | Nervous or Anxious |

**BrDI Task Analysis:** For the seven of the kinematic output variables

Individual Mann-Whitney tests:

Hx males to the NoHx males

Hx females to the NoHx females.

Following this, a two-way ANOVA was run using sex and concussion history as covariates.

**Symptoms Analysis:** Binary presence of symptoms (1 if present, 0 if not)

Individual t-tests:

Hx males to the NoHx males

Hx females to the no Hx females.

NoHx females to NoHx males

Hx females to Hx males

## RESULTS

**BrDI Task:** Concussion history significantly impacted performance in males on accuracy (p=0.001) and precision (p=0.05) in condition two, peak velocity (p=0.026) in condition one, and full pathlength in both condition one (p=0.001) and two (p=0.001), which was **not seen in females**.

### Symptoms:

**Hx-NoHx males:** More emotional (P = 0.002), Irritability (p = 0.017), and Nervous or anxious (p = 0.0001). An increased number of males **with concussion** reported symptoms in all cases of significance

**Hx-NoHx females:** Sadness (p = 0.02) and Nervous or anxious (p = 0.002). An increased number of females **with concussion** reported symptoms in all cases of significance

**NoHx males to females:** More emotional (p = 0.005), Irritability (p = 0.0002), and Nervous or anxious (p = 0.0004). An increased number of **females** reported symptoms in all cases of significance

**Hx males to females:** Irritability (p = 0.025), Sadness (p = 0.07), and Nervous or anxious (p = 0.01). An increased number of **females** reported symptoms in all cases of significance

## CONCLUSIONS and FUTURE DIRECTIONS

- *Males and females respond differently to concussive injury*
- Males exhibit lingering difficulty with cognitive-motor integration performance when compared to females
- Males exhibit lingering emotionality symptoms when compared to males with no history of concussion
- Females exhibit higher emotionality symptoms when compared to males both with and without a history of concussion
- *These data suggest that females and males may require different tools for post-injury monitoring, outcome projections, and recovery assessment.*
- More research looking at sex-related differences in hormones, functional networks, and number of concussions is necessary

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