

## Background

- **Proprioception** is the sense of the body's movement and position. It is the least well-studied sensory modality. [1-2]
  - **Proprioceptive sensitivity** is the ability to detect the onset of imposed motion.
  - **Proprioceptive accuracy** is the ability to correctly identify a position.
- **Postural tone** is the background muscle activity necessary for opposing gravity. It needs to adapt so that we can appropriately resist or allow movements, depending on context. [3]
  - **Twister** is a custom device that can deliver passive motion to the body axis and measure resistance to assess postural tone. [4]
- **Mindfulness** is sustained somatic attention and is studied as a measure of movement sensitivity (the ability to detect the onset of motion). [5-6]
  - Typically assessed with self-report questionnaires. [7]

## Hypotheses/Predictions

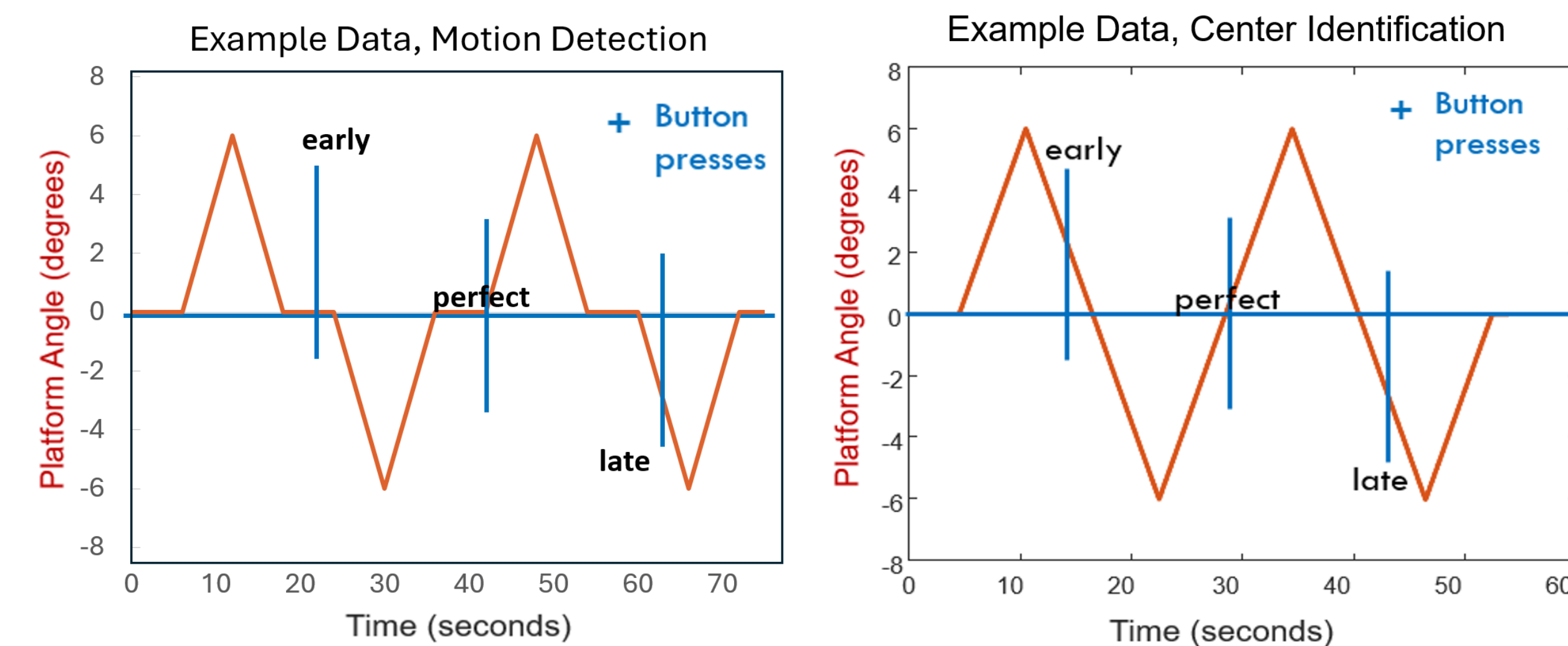
- We investigated potential **relationships** among:
  - Postural tone
  - Body awareness/mindfulness
  - Proprioception

## Methodology

- We tested 61 healthy young subjects (aged 18-36).
- We used **Twister** to test proprioceptive acuity and adaptivity of postural tone. Subjects stood on a slowly rotating (1 deg/s) platform and wore a harness attached to a torque sensor that measured their resistance to rotation. They wore goggles to obscure their vision.
  1. **Familiarity Trial** – Twister rotated 10 degrees in either direction. Subjects were asked not to interfere with the motion.
  2. **Center Identification Trial** – Twister rotated 8 degrees in each direction. Subjects pressed a button when they felt that they were facing exactly forward (zero degrees).
  3. **Motion Detection Trial** – Twister rotated 8 degrees in each direction, pausing for 8 seconds at zero degrees before continuing. Subjects pressed a button each time they felt movement start.
- **Surveys:** Mindful Attention Awareness Scale (**MAAS**) and Postural Awareness Scale (**PAS**) were distributed after the trials for mindfulness; Rapid Assessment of Physical Activity (**RAPA**) was distributed after the trials to assess general activity level. All surveys were self-report questionnaires.

## Data Analysis

- Subjects with fewer than 2 valid events were excluded from analysis.
- **Proprioceptive sensitivity** was defined by how close in time the button was pressed to when movement onset occurred.
- **Proprioceptive accuracy** was defined by how close in time the button was pressed to when the neutral crossing occurred.
- **Adaptivity of postural tone** was defined by how close to zero the peak torque was during Twister rotation in the familiarity trial.



**Left image:** Audrey Elg in Twister (with EEG cap).

**Right image:** Closeup of the backpack on the Twister.

## Conclusions

- The two proprioceptive trials were statistically independent.
- Our results support the hypothesis that these functions are governed by distinct central nervous system (CNS) mechanisms.
- Proprioceptive accuracy (center identification) was selectively and significantly impaired by increased axial stiffness.
- Proprioceptive sensitivity (motion detection latency) was selectively associated with higher mindfulness.
- Stiffness impacts accuracy while attention impacts sensitivity, causing distinct and separable effects on human proprioception.

## Results

- **Center Identification Trial:**
  - Accuracy in the center identification trial was significantly associated with lower stiffness ( $r=.40, p=.004$ ).
  - Marginally associated with lower RAPA score ( $r=.22, p=.12$ ).
  - In a combined model, stiffness remained significant ( $p=.01$ ).
- **Motion Identification Trial:**
  - Sensitivity in the motion identification trial was modestly correlated with higher MAAS, lower RAPA, and female sex ( $r$  between .25 and .29).
  - In the combined model, MAAS and RAPA remained marginally significant ( $p=.05$  and  $.08$ , respectively).
- The two proprioception measures did not correlate with one another.
- Higher body weight correlated with higher stiffness but not with proprioception.
- PAS correlated with MAAS but not with any other measure.
- Male sex was associated with higher stiffness.

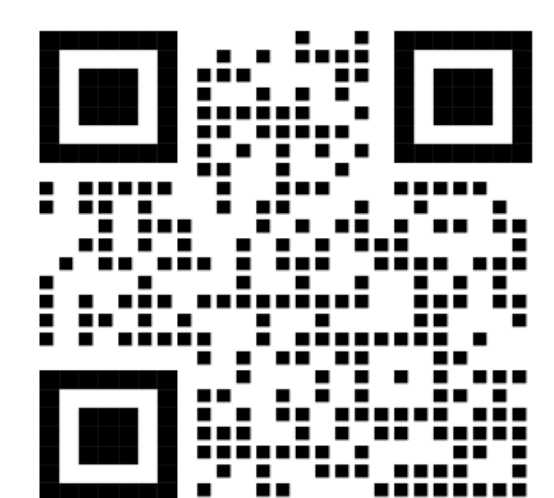
## Future Directions

- Different postural instructions
- Younger/older people/Parkinson's disease
- Incorporating EEG
- Additional surveys

## References

- [1] Han et al., 2016.
- [2] Kwon et al., 2013.
- [3] Ivanenko & Gurfinkel, 2018.
- [4] Gurfinkel et al, 2006.
- [5] Hospod et al, 2007
- [6] Brown & Ryan, 2003
- [7] Park et al, 2013

Learn more about our research at the Mind in Movement Lab website:



## Acknowledgements

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