

Responses to locomotion commotion caused by translation perturbations

Motivation

How do humans navigate non-steady-state environments?

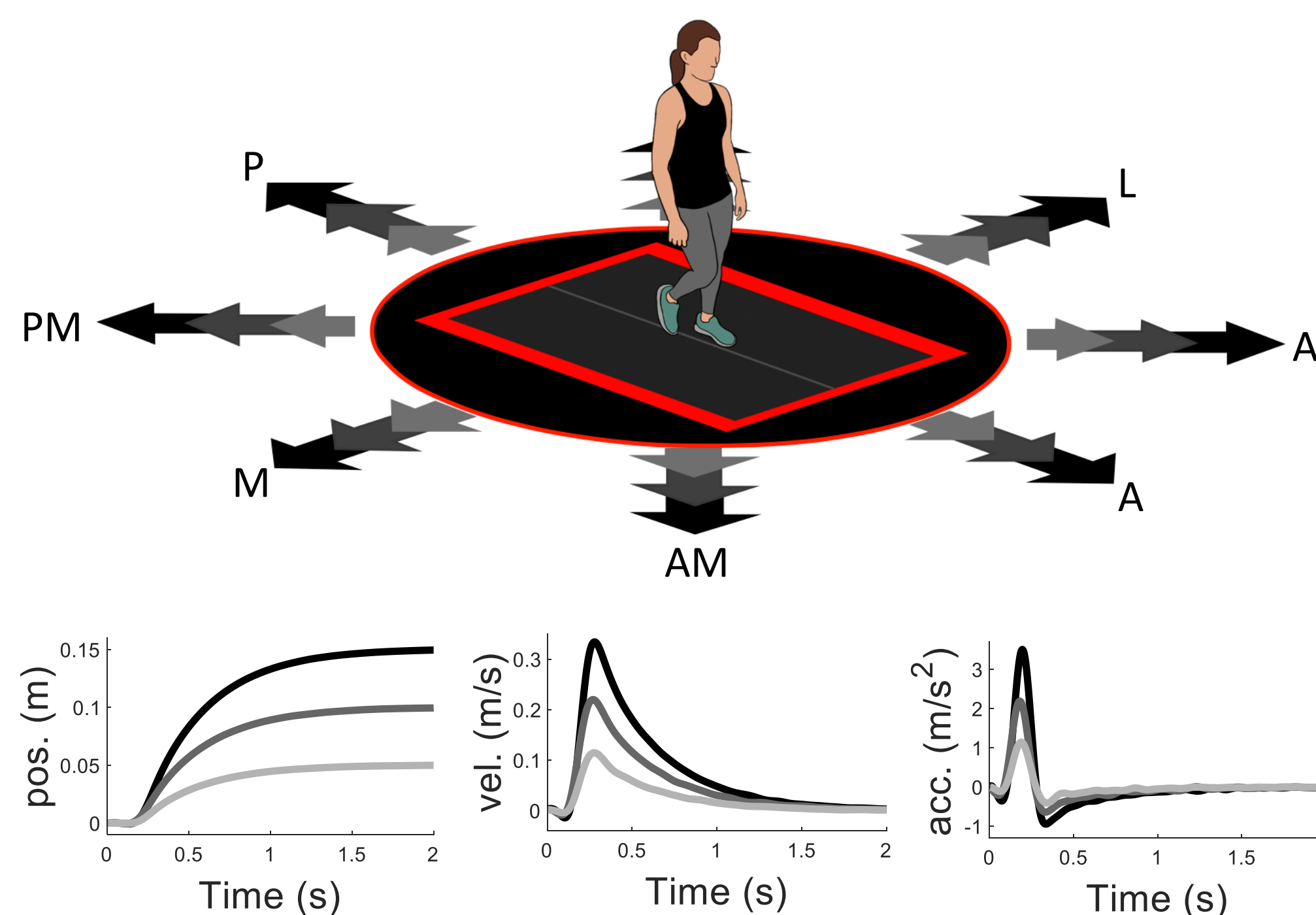
A thorough understanding of stability could aid in

- Assessing impaired populations and informing rehabilitation therapies [1]
- Creating assistive and augmentative devices [2]
- Informing methods for stable control of bipedal robots

Perturbation recovery strategy is indicated by:

- Step length (SL)
- Step width (SW)
- Step time (ST)

Methods



- N = 1
- Walking speed: 1.25 m/s
- Perturb subject by translating walking platform (24 conditions)
 - Magnitudes: 5, 10, 15 cm
 - Directions: 45° increments
 - (24 conditions) x (12 repetitions) = 288 perturbations
- Collected kinematics
- Identified gait events using kinematic coordinate method [3]
- Calculated step length (SL), step width (SW), and step time (ST) for the perturbed step (S_0) and subsequent steps (S_1 - S_5)

Hypotheses

Mediolateral perturbations will cause the most extreme changes in step width

Anteroposterior perturbations will cause the most extreme changes in step length

Discussion

Step length:

- Most affected on the S_1 step, trends last 1-2 steps
- Shorter steps with PL perturbations (up to -18%), longer steps with AM perturbations (up to +7%)

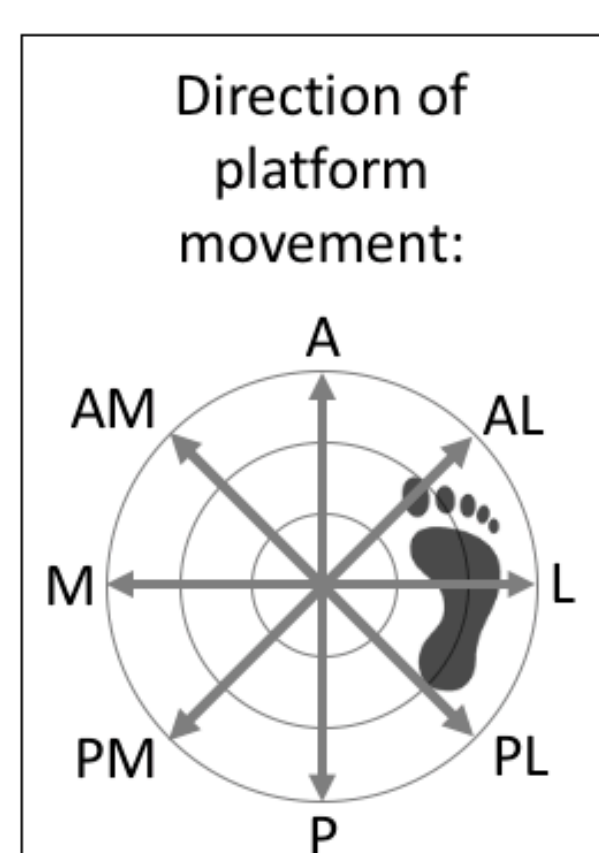
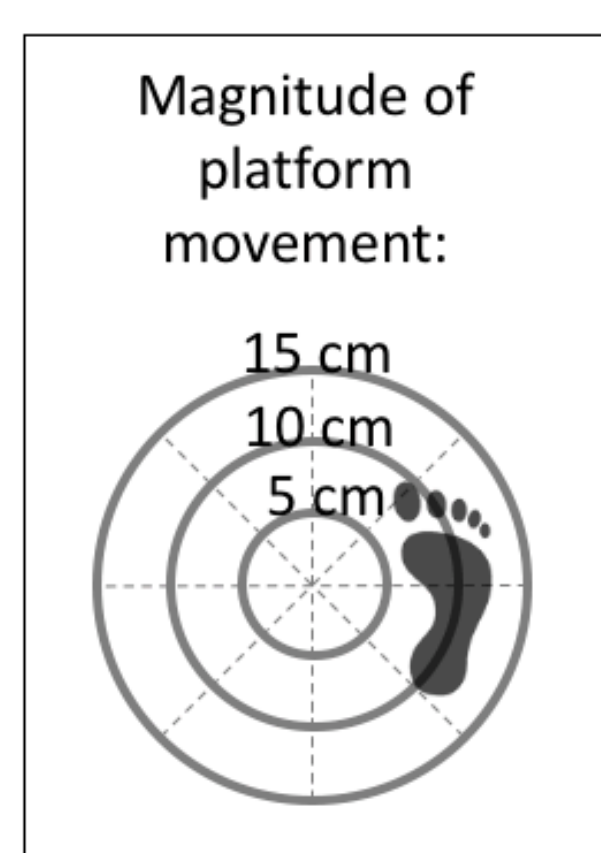
Step width:

- Most affected on the S_1 step, trends last 2-3 steps
- Narrower steps with M perturbations (up to -135%), wider steps with L perturbations (up to +129%)

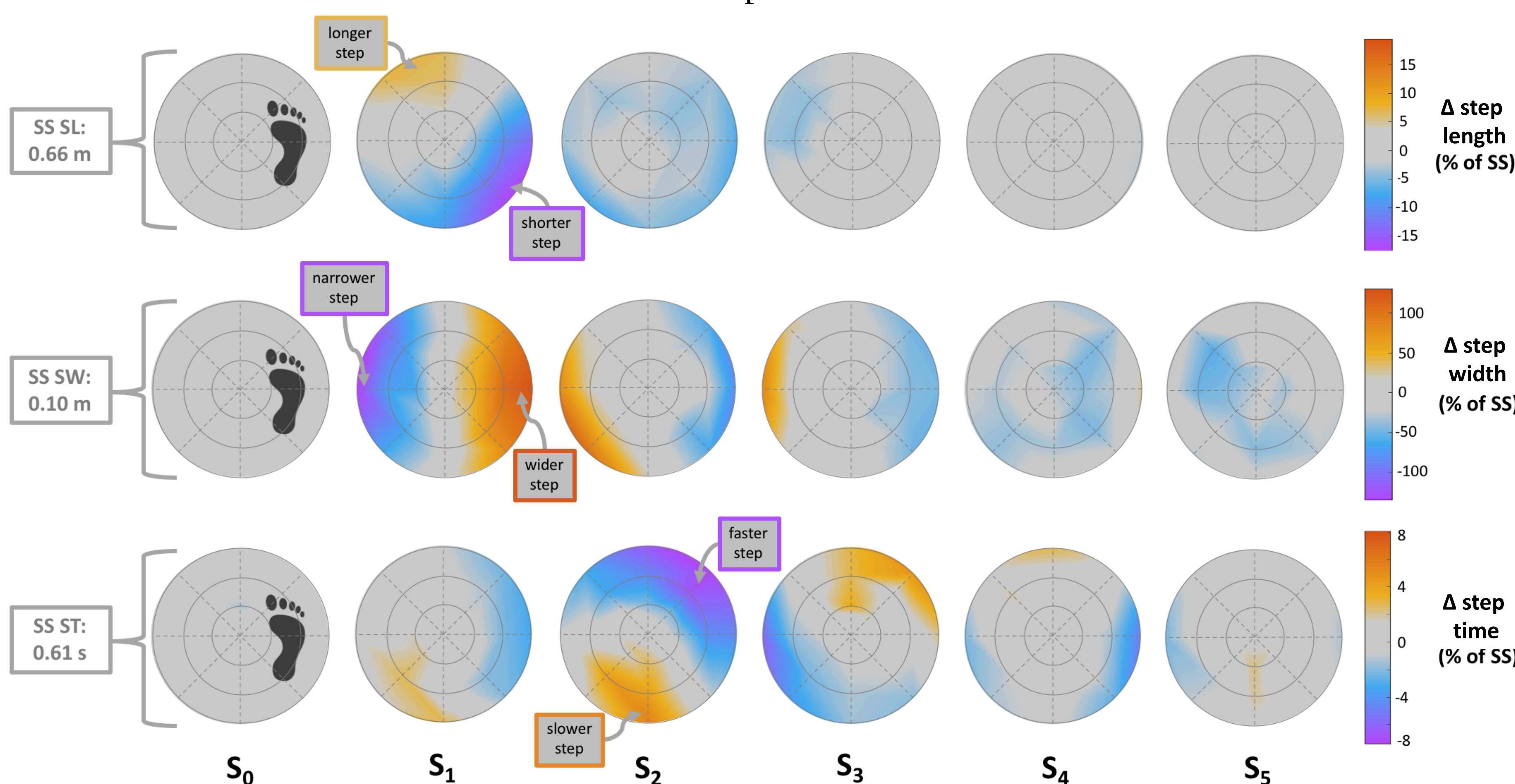
Step time:

- Most affected on the S_2 step, trends last 3-4 steps
- Faster steps with AL perturbations (up to -7%), slower steps with P perturbations (up to 6%)

Results



- Radial axis:** magnitude of platform movement
- Angular axis:** direction of platform movement relative to stance foot, all data displayed as right foot perturbed
- Columns:** perturbed step (S_0) and subsequent steps (S_1 - S_5)
- Rows:** change in SL, SW, and ST as a percent of steady-state (SS)
- In general, platform movement in one direction will cause center of mass (CoM) movement in the opposite direction
Ex: lateral (L) perturbation causes CoM movement to the medial side of the perturbed stance foot



Key Takeaways

- Humans modulate SL, SW, and ST in response to perturbations
- Largest changes to SL, SW, and ST are not elicited by the same perturbation conditions
- PL, a diagonal condition that is not often incorporated into experimental protocols, elicited the most extreme change in SL

Future Work

Experimental additions:

- We are including perturbation timing as a third independent variable in future experiments
- More subjects will be tested to expand on this pilot work

Future analyses:

- Role of stance and swing limb joint torques in balance response
- Lower limb muscle activity correlations with joint torques and recovery strategies

References

- S. M. Bruijn, et al., *J. R. Soc. Interface* 10, (2013)
- D. Tokur, et al., *Hum. Movement Sci.* 69, (2020)
- J. A. Zeni, et al., *Gait Posture* 27, (2008)

Acknowledgements

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