HOW HUMANS ADAPT LATERAL STEPPING REGULATION

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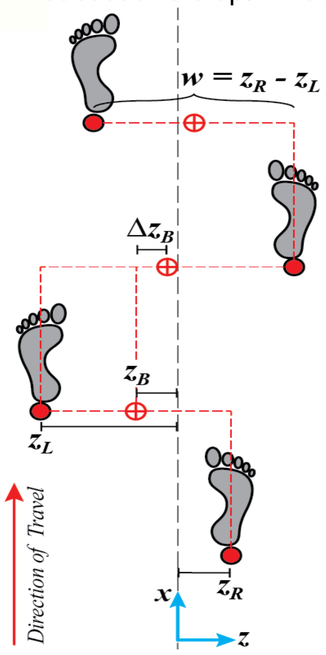
INTRODUCTION

- Humans are more unstable laterally when walking [1,2] and sideways falls can be detrimental[3].
- If humans regulate foot placement over consecutive steps to achieve task goals while walking [4,5] , and our day-to-day environment is complex[6]—walking requires flexibility in how we regulate stepping.
- **How do humans alter their lateral stepping regulation given different task goals?**

THEORY

Lateral Stepping Regulation

- There are *infinite* choices for each successive step. What might we regulate?



Proposed Variables

Left/Right Foot Placements: $\{z_L, z_R\}$

Step Width (w): $w = z_R - z_L$

Position (z_B): $z_B = (z_L + z_R)/2$

Heading (Δz_B): $\Delta z_B = z_B + z_{Bn-1}$

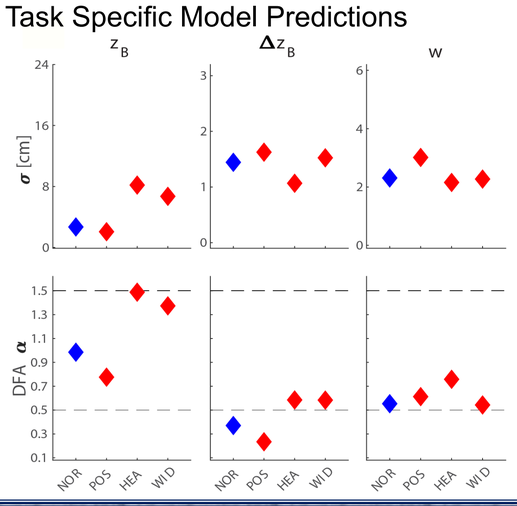
Multi-Objective Model Results

$$\mathbf{F} = \begin{bmatrix} q_{1n} - q_1^* \\ q_{2n} - q_2^* \end{bmatrix} \rightarrow q_{1,2} \in \{z_B, \Delta z_B, w\}$$

- ~85-95% w / ~15-5% z_B control replicates human stepping dynamics

To What Extent Can We Modify This Regulation?

- Task Specific Model Predictions



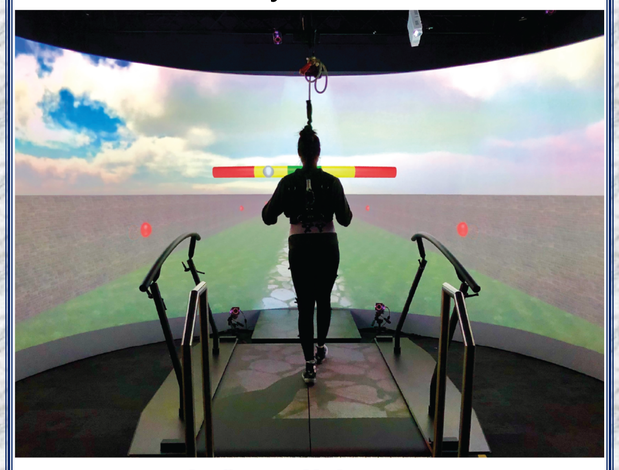
METHODS

Participants

- 12 Male / 12 Female
- 23 ± 3 years old

Treadmill Walking Trials

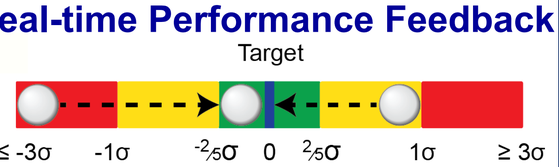
- Virtual reality environment



3 Conditions

- **NOR** – Normal walking
- **POS** – Maintain position ($q = z_B$)
- **WID** – Maintain step width ($q = w$)

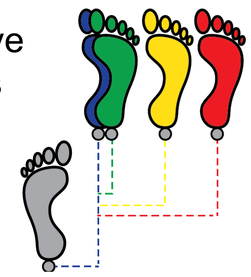
Real-time Performance Feedback



- minimize errors wrt:

$$F_n = q_n - q^* = 0$$

- Bead position = $f(q_n - q^*)$
- Positive/Negative auditory queues
  Green = chime
  Yellow = flute
  Red = buzzer

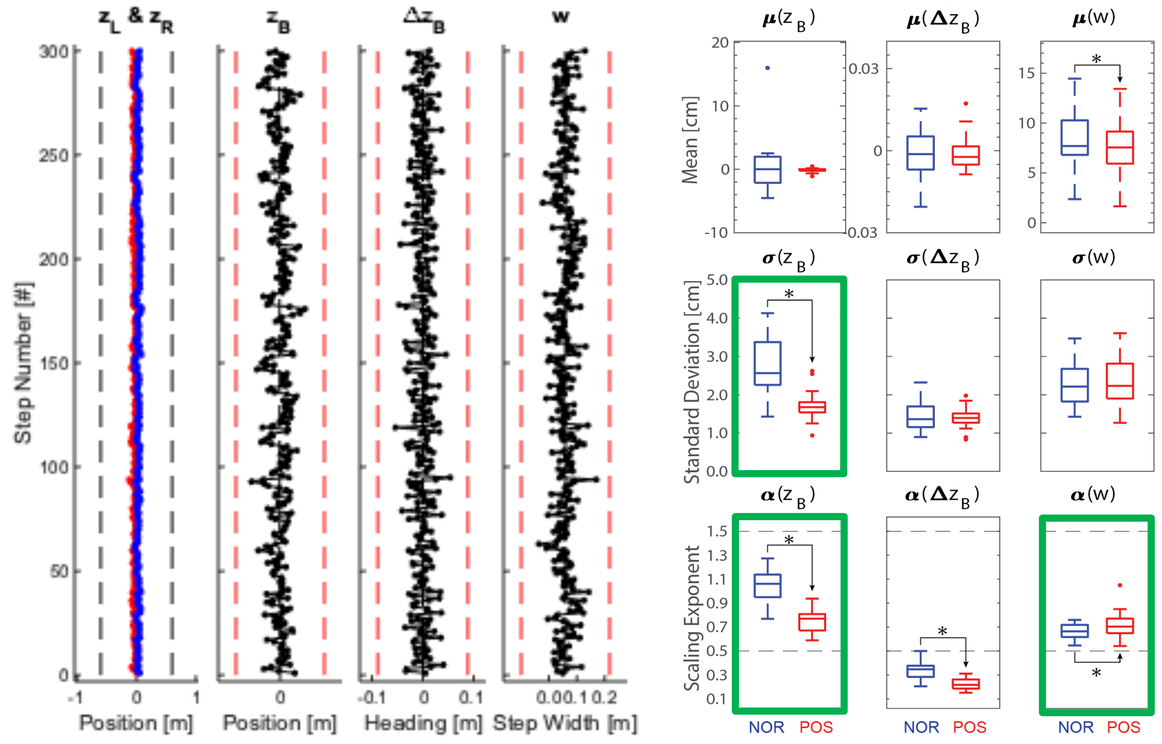


Step-to-Step Analyses

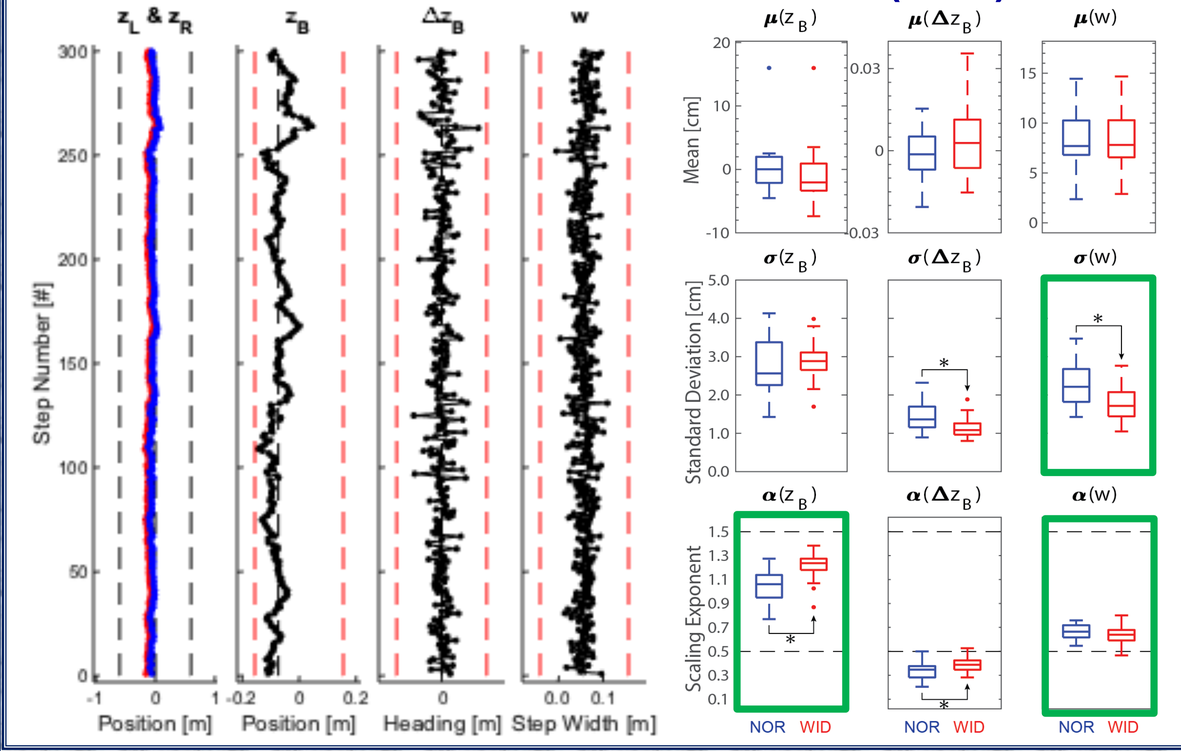
- Time series of z_{Bn} , Δz_{Bn} & w_n
- Variability (σ)
- Statistical persistence (DFA α; step-to-step regulation)

RESULTS

MAINTAINING POSITION (POS)



MAINTAINING STEP WIDTH (WID)



DISCUSSION

- **POS**: decreased variability of z_B, tighter step-to-step regulation of z_B, and weaker step-to-step regulation of w.
- **WID**: decreased variability of w, continued tight step-to-step regulation of w, and weaker step-to-step regulation of z_B.

task-specific tradeoffs between w and z_B

- People modified stepping consistent with model predictions.
- Humans tradeoff regulation between w and z_B to adapt lateral foot placement dependent on task goals.

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