Universität Marburg Postural Responses to Virtual Heights GRK RTG 2271 BREAKING EXPECTATIONS

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Research Question

- How does indoor VR height threat alter CoP mean position and MPF?
- Which anxiety dimension (cognitive, somatic, fear) best predicts:
 - CoP changes (mean, MPF) under Ground vs. Height?
 - Heart rate change (HRC) after height exposure?

Related Work

- VR height exposure shifts CoP mean and increases MPF [1, 2].
- Elevated MPF reflects a "stiffening" posture under threat [3].
- Somatic anxiety is strongly linked to increased sway and arousal in VR heights [4].

Materials and Methods

Participants: 29 adults (mean age 21.8 ± 1.5 y)

Apparatus:

Philipps

- CoP: Wii Balance Board (4 force sensors)
- VR & Eye-tracker: HTC Vive Pro + Pupil Labs
- ECG: Polar H10 chest strap

Protocol:

- 7 trials: 20 s exploration \rightarrow anxiety rating \rightarrow 60 s fixation
- Conditions: GC: ground plank ; HC: plank with 20 m drops front & back



Left: Participant on Wii Balance Board + HTC Vive setup. **Right:** VR room views: (A) ceiling, (B) front-plank, (C) fixation cross, (D) downward.

Data Analysis: Center of Pressure (CoP)

CoP Computation: *W_i*: force at sensor *i*, *X_i*: position

$$\mathbf{CoP}_{ML} = \frac{\sum W_i X_i}{F_{\text{total}}}, \quad \mathbf{CoP}_{AP} = \frac{\sum W_i Y_i}{F_{\text{total}}}$$

Mean Power Frequency (MPF): $MPF = \frac{\sum_{i=1}^{N}}{\sum_{i=1}^{N}}$

Psychophysiological Correlations

- MPF (HC) has the strongest positive link with somatic anxiety (r = 0.46).
- **CoP (HC)** is positively associated with *cognitive anxiety* (r = 0.14).
- **HRC (GC)** is negatively linked to cognitive anxiety (r = 0.23).



Heart Rate Change (HRC): Difference between consecutive trial averages.

Psychometrics: STICSA cognitive & somatic subscales; Fear-of-Height.

Mixed-Effects Modeling of CoP

CoP Mean Position (Fig. A):

- Height shifts AP mean anteriorly.
- ML mean moves slightly right under Height.

CoP Oscillation Frequency (MPF, Fig. B):

• MPF increases under Height in both axes.



Psychological Measures

Figure 2: Pearson correlations between STICSA/fear scores and CoP mean, MPF, HRC under Ground (GC) and Height (HC).

Summary and Discussion

Participants exposed to indoor VR heights showed a stiffening strategy:

- Reduced sway range
- Higher oscillation frequency (MPF)
- Anterior body shift likely due to front & back vertical drops

Unlike outdoor VR studies (which show increased sway), indoor minimalcue exposure triggered a more rigid and tightly regulated posture, likely due to heightened perceived threat from both directions. **Conclusion:** Postural threat responses are highly context-dependent.

Figure 1: CoP mean vs. CoP scatter + density for Ground (gray) vs. Height (orange). (A) ML vs. AP mean position. (B) ML vs. AP MPF. Dashed lines=condition means.

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- Use **inverse optimal control** to model fear-driven motor strategies
- Isolate directional threat effects (front-only vs. front+back)
- Develop adaptive VR training protocols for balance disorders

References

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