A Brain-Computer Interface for Walking

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Is it possible to determine whether a person is walking or not, using EEG?

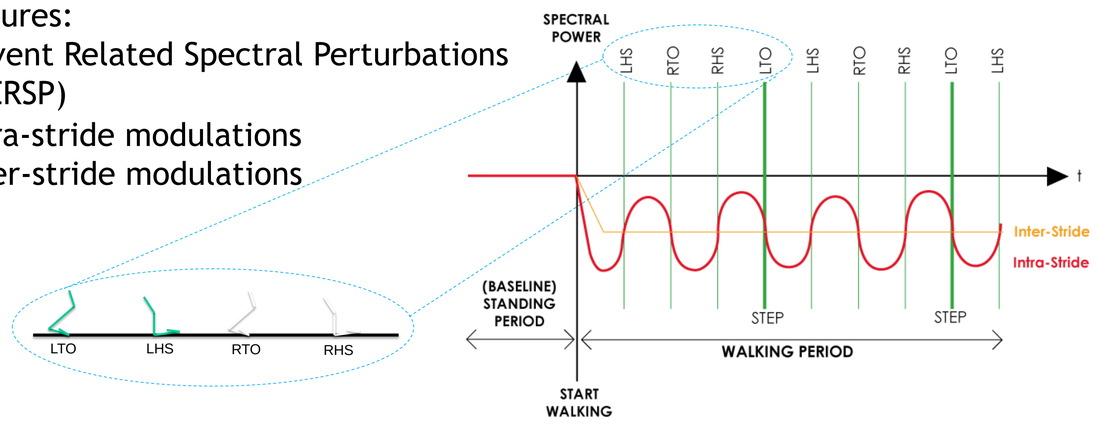
Introduction

- Online setup for actual walking and an online BCI for imaginary walking
- Two studies comparing simple forward walking and a less automatic walking:

1. Feasibility Study: Forward vs. Backward walking
2. Online setup: Simple walking vs. Walking at varying speeds

Which combination of tasks and features provides better performance?

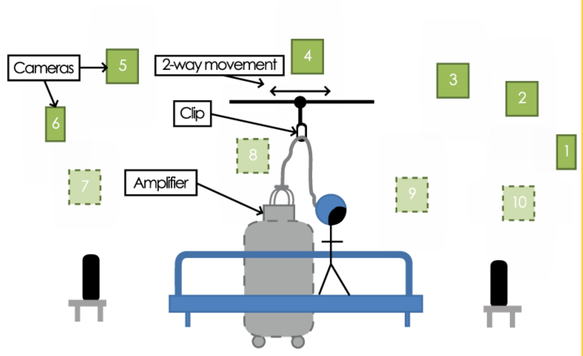
- Features:
  - Event Related Spectral Perturbations (ERSP)
- Intra-stride modulations
- Inter-stride modulations

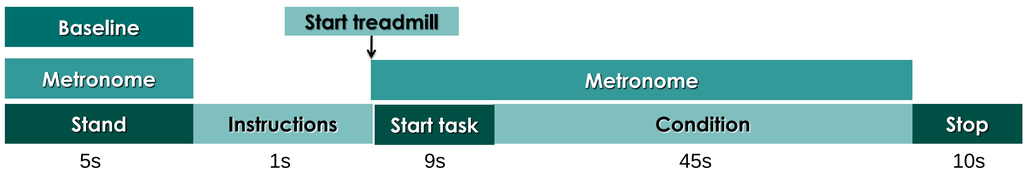


  - Mu (8-12Hz), Beta (12-25Hz) and Mubeta (8-25Hz) frequency bands
- Task: automatic walking and a less automatic walking
- Walking modality: actual walking and imaginary walking

Experiment design 1

- 12 healthy subjects
- 2 (*forward vs. backward walking*) x2 (*actual vs. imaginary walking*) within-subjects design
- EEG (64 electrodes, TMSI-REFA, 250Hz)
- 8 blocks. In every block, each condition occurred once, in random order
- Trial overview:





EEG Analysis

- No-walking ← baseline period
- Walking ← period after the instruction
- **Preprocessing:**
  1. Common-Average Reference (CAR)
  2. Detrending
  3. Bad channel/epoch detection
  4. Canonical Correlation Analysis to remove EMG artifacts [1]
  5. Surface Laplacian

Inter-stride modulations

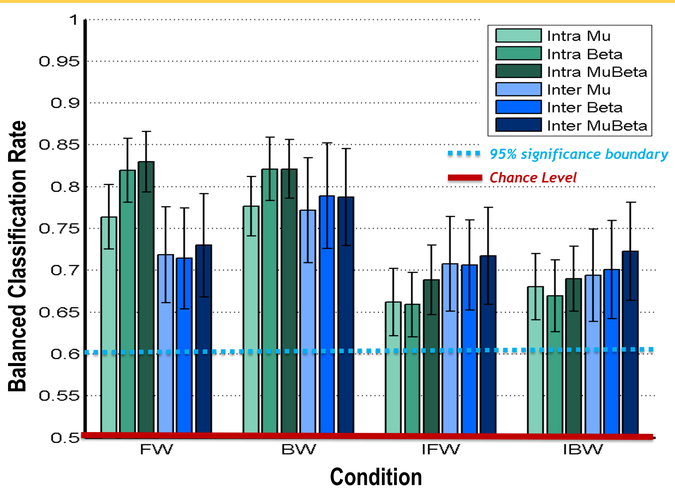
- 2,5 seconds windows
- Welch Power Spectral Density
- Leave-one-sequence-out classification: Logistic Regression

Intra-stride modulations

- 1 step (~1,33 seconds) windows
- Steps were rescaled and normalized
- Time varying spectral power (Short-Time Fourier Transform)
- Leave-one-sequence-out classification: Logistic Regression

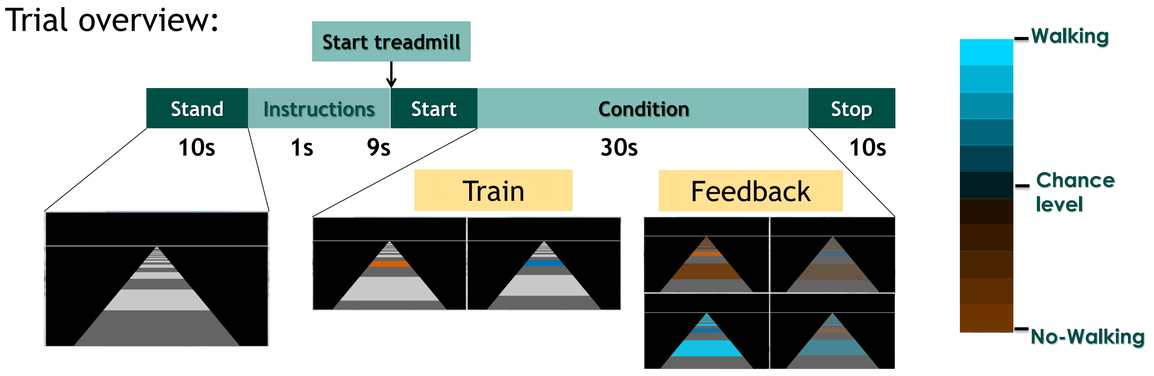
Classification Results 1

- Intra had better performance for actual walking and Inter for imaginary walking ($p<0.01$)
- Actual walking had better performance than imaginary walking ($p<0.5$)
- Mubeta band had better performance than the mu or beta bands separately ($p<0.5$)



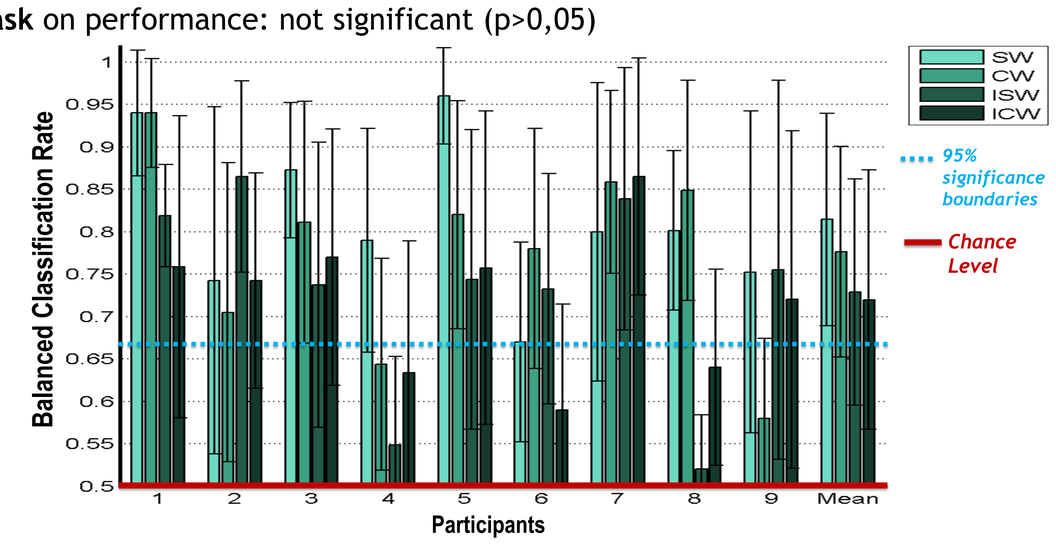
Experiment design 2

- 9 healthy subjects
- 2 (*simple walking vs. walking at varying speeds*) x 2 (*actual vs. imaginary walking*) within-subjects design
- Inter-stride classification only
- 16 blocks. In every block, each condition occurred once, in counterbalanced order
- First 8 blocks: training data, last 8 blocks: online test
- Trial overview:



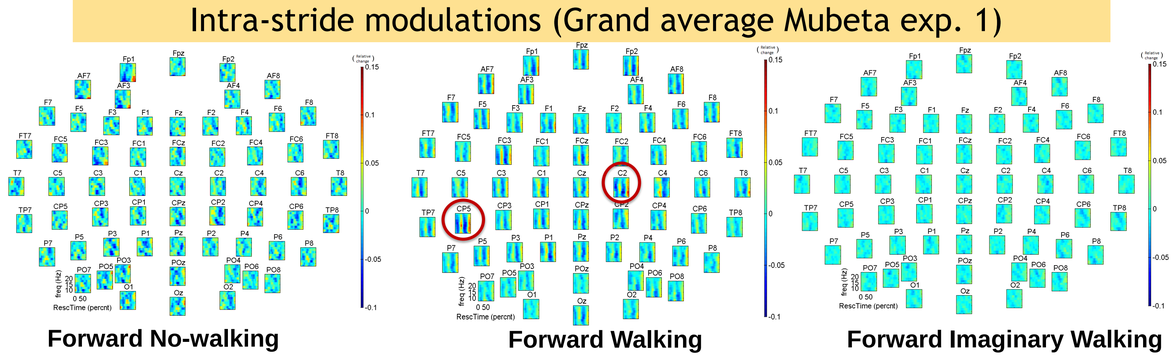
Classification Results 2

- **Best frequency band differed per subject:**
  - Mu (3 subjects), Beta (1 subject), Mubeta (5 subjects)
- **Walking modality** on performance: Actual walking better than Imaginary walking ($p<0,05$)
- **Task** on performance: not significant ($p>0,05$)

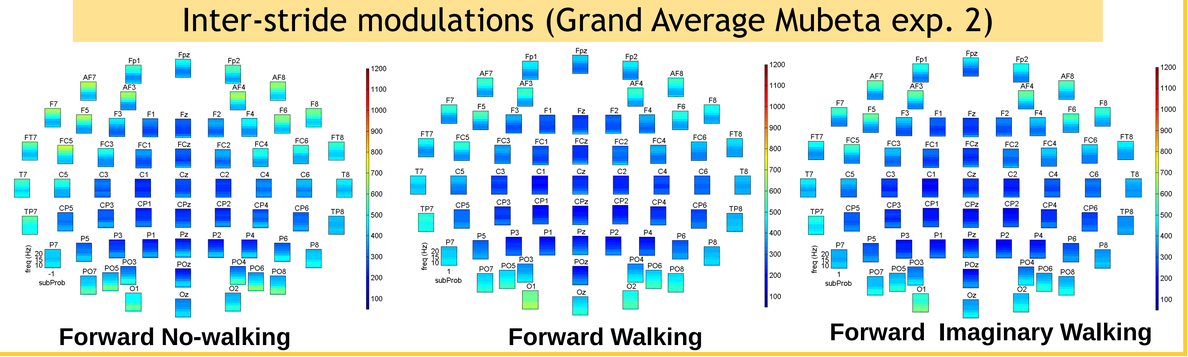


ERSP distribution

Intra-stride modulations (Grand average Mubeta exp. 1)



Inter-stride modulations (Grand Average Mubeta exp. 2)



Conclusions

- It is possible to differentiate walking from no walking using EEG
- Classification is robust for both offline and online setups and different walking tasks
- Automaticity of movement did not influence classification performance
- The Mubeta band increased performance

Reference

[1] Severens, M., Nienhuis, B., Desain, P., & Duysens, J. (2012). Feasibility of measuring Event Related Desynchronization with Electroencephalography during Walking. *In IEEE engineering in medicine & biology society*.

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