Athletic Performance Predicted from Mental Motor Imagery of Source Localized EEG

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Introduction

- Mental Motor Imagery Improves Athletic Performance (Tennis, Volleyball, Archery, Basketball, Golf, Badminton, Rugby, High Jump, Football, Taekwondo, Long Distance Running). Deng et al, (2024); Jose et al., (2018); Parnabas et al., (2015).
- Mental Motor Imagery Activates Same Brain Regions Involved with Actual Execution of Task (e.g. Motor, Somatosensory, Planning, etc..) (Debamot et al, 2014).
- Brain Activity (EEG) during mental motor imagery of table tennis task correlates (R = 0.59) with world ranking (Wolf et al., 2015).
- The Goal of this Study is to Determine if Athletic Performance on a Skateboard Ramp task can be Predicted using Machine Learning Methods from EEG Source Localized Brain Activity during Mental Motor Imagery.

Skateboard Ramp Task

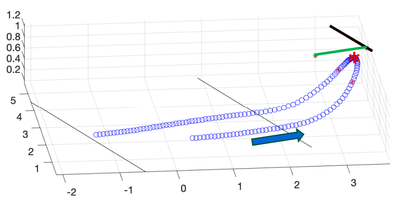
- LED turns on in a variable position within the center 1.5m (Red = Right Kickturn; Green = Left).
- Frontside and Backside Kickturns (Regular, Switch).

Subjects: 26 Amateur to Professional Level Ramp Skateboarders.

EEG Preprocessing

- Band pass filter: 3 to 100 Hz
- Cleanline (remove 60Hz)
- Remove Bad Channels
- ASR
- Interpolate Missing Channels
- Average Reference
- ICA (Infomax)
- ICLabel: Extract Brain Components

Trial Level Kickturn Performance: Distance to Target



Distance to target is measured by the closest point (*) the back foot is to the target light.

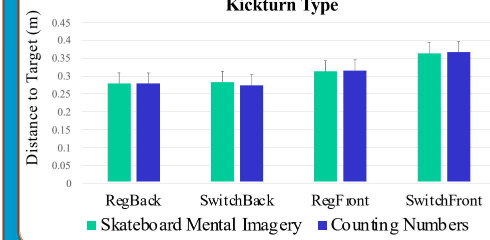
Mental Motor Imagery Task

- Each of the 3 sessions contains four ~90s ramp sets. Before each set is either a Mental Simulation of Skateboarding or Counting Numbers task for 60s. 6 of each for an experiment.
- 20s segments are taken from middle of 60s and subdivided into ten 2s trials for analysis.
- Cross Spectra on 2 Second Segments
  Alpha: 8-13Hz
  Sensorimotor Processing
  Beta1: 14-20Hz
  Dynamic postural control and movement preparation. (Nougaret et al., 2024).
  Beta2: 21-35Hz
  Attention, Planning (Nougaret et al., 2024).

- Cross Spectra to sLORETA
- Statistics on Mental Simulation vs Counting Numbers (Subject Level).
- Random Effects Group level annalysis of Results of Subject Level images.
- Group Level Correlation Analysis of Subject Level Skateboard Task Performance.

Behavioral Results

Skateboarding Task Performance by Kickturn Type

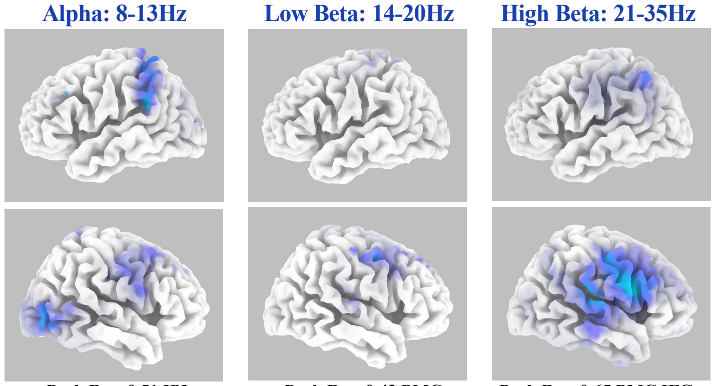


Correlation of Skateboard Ramp Performance with Subject Variables

	R
Age Start Skateboarding	-0.42*
Number of Years Skateboarding	0.04
How Often Skateboard	-0.01
Skateboard Self Skill Rating	0.19
Age	-0.35
Weight	-0.03
Height	0.07
Shoesize	-0.15
Number Trials	0.19
Number Channels Removed	-0.31

Correlation of Skateboarding Task Performance with Brain Activity

(Mental Motor Imagery Skateboarding Versus Counting Numbers)



Peak R = -0.51 IPL | Peak R = -0.43 PMC | Peak R = -0.65 PMC IFG p < 0.05 Corrected

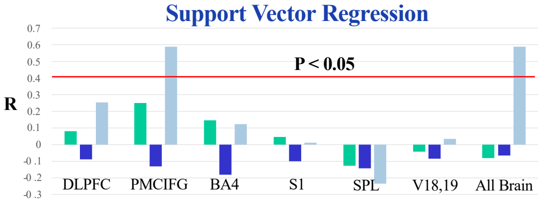
Machine Learning Prediction

Data:
- **X:** EEG data (26 subjects × N selected features from 6239 total voxels).
- **y:** Performance measurement (Mean Distance to Target).

Models:
- **Linear Support Vector Regression**
- **Sparse Regression (LSR ARD) 2023, Yuanhao Li, RIKEN AIP**

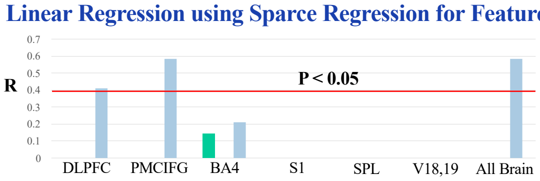
Methodology:
- Use leave-one-out cross-validation.
- Incorporate feature selection to reduce dimensionality.
- Validate model robustness via sensitivity analysis (random shuffling of labels, 5000 iterations).

Support Vector Regression



Feature Selection: Nested L1O Training Loop Using Features with Max Correlation. Number of Features Automatically Selected

Linear Regression using Sparce Regression for Feature Selection



Feature Selection: Nested L1O Training Loop Using Sparce Regression to Select Features that Occur for at least 30% of Training Trials.

Discussion

- No Difference in Task Performance After Mental Motor Imagery of Skateboarding Versus Counting Numbers so no Immediate Causal Relationship between Mental Motor Imagery and Performance.
- Utilizing SVR and Sparce Regression with Feature Selection can Reliably predict Subject Skateboarding Performance (Distance to Target) from Mental Motor Imagery Brain Data (PMC IFG). (R = 0.59, Large Effect Size).
- Prediction of Performance from PMC IFG region (R = 0.59) is Much Better than any Subject Related Variables (Age Start Street Skateboarding R = 0.43).
- Perhaps in the Future DecNef Could be utilized Together with Mental Motor Imagery to Improve Athletic Performance.