Decoding of Event-Related Potentials Through Steering Wheel Movements

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Introduction

Corrective Sub-Movements Reflect Neural activity

- EEG is the most efficient method for monitoring cognitive states[1]. However, it is impractical for driver monitoring in real-life scenarios
- Error-related EEG potentials (ErrPs) are modulated by cognitive impairments such as cognitive load and intoxication[2]
- ErrPs are coupled with corrective sub-movements[3]

Thus, we use error-related steering sub-movements to monitor drivers' cognitive states

Objectives

- Identify error-related potentials during driving
- Identify driver's cognitive state such as intoxication and cognitive distraction based on corrective sub-movements in steering kinematics

Methods

- **Vehicle driving – Intoxication**

  Participants (N=127; 59 women, age 24-64 years), drove in seven different vehicle models on six closed tracks. The steering wheel angle was sampled at 100 Hz with a resolution of 0.1 degrees, obtained from the vehicle CAN bus. BAC was manipulated within subjects by drinking 40% alcohol 15 minutes before driving. Alcohol levels of 0, 0.05, and 0.08 BAC were verified by Breathalyzers.

Methods

- **Simulator driving – Cognitive load**

  Participants (N=79, 34 women, age 20-62), drove in a highway simulation for 15 minutes: 5min practice, 5min no load, 5min during a WM load task: Backward spelling of full sentences while driving. The order of load/no load was counterbalanced across participants. Participants were instructed to keep the central lane. The steering wheel angle was sampled at 100 Hz with a resolution of 0.1 degrees. EEG was recorded using a 12-channel cap with 10-20 design, digitized at 512 Hz.

Model: We used TSFRESH and TSFEL for automated feature extraction from time series data, complemented by kinematic and methodological feature engineering. XGBoost is then employed as the classifier for detecting the impairment in question (e.g., intoxication, cognitive load)

Results

- **Steering kinematics represent level of intoxication**

Identification of BAC at three thresholds

Track	BAC	True Positives	False Positives
1	0.1	81%	0%
2	0.1	80%	0%
3	0.08	100%	0%
4	0.05	100%	0%
5	0.05	90%	0%
6	0.05	75%	0%
Across tracks	0.08	82%	1.29%

Results

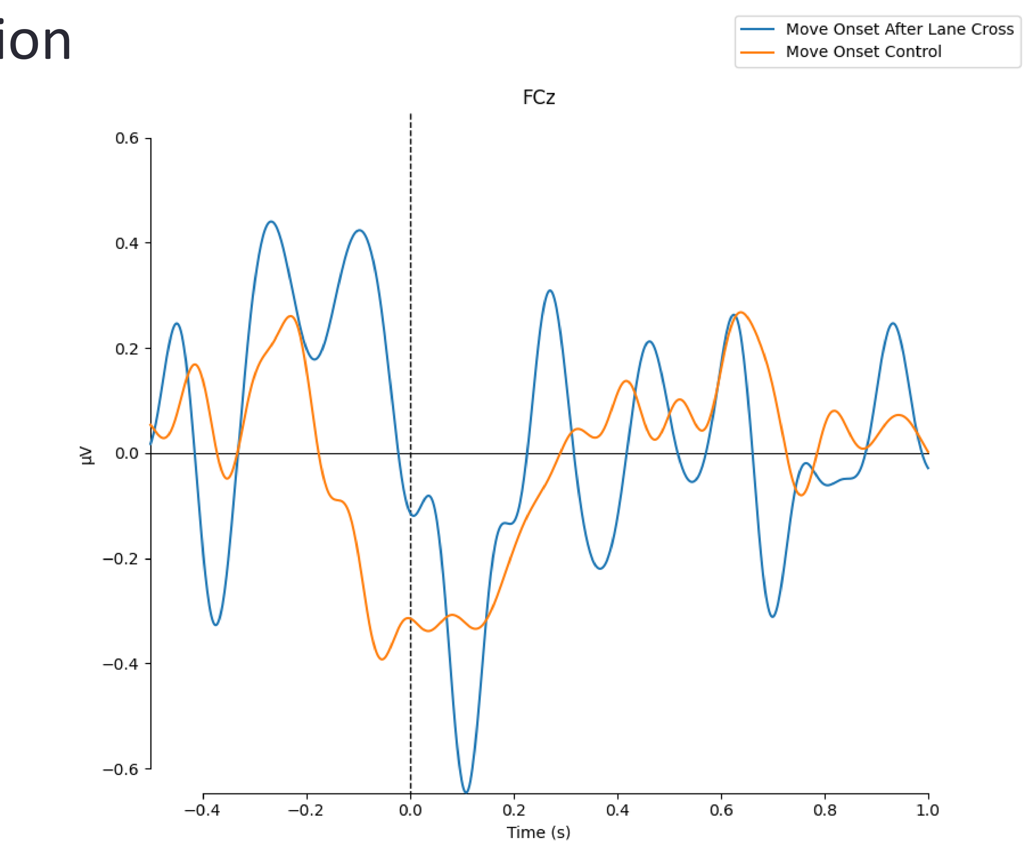
- **Modulation of steering kinematics under cognitive load**

Identification of load vs. non-load driving

Accuracy	True Positives	False Positives
89%	84%	5.5%

- **Preliminary EEG results:**

  ErrPs are found for errors locked to movement initiation



Conclusions

- Corrective movement onset is coupled with ErrPs during driving
- Corrective sub-movements in steering kinematics indicate the level of intoxication and cognitive load

Acknowledgement

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References

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