Evoked EEG Signatures Index Cognitive Workload in Human-Machine Interaction
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Introduction
Superior human performance in complex tasks such as piloting a jet fighter or driving a formula one race-car requires optimal utilization of cognitive resources. This usually involves a balancing act of maximizing task engagement and cognitive workload while keeping autonomic stress response in check; failure to do so can result in catastrophic accidents.

Case-study: Pilot-induced oscillations (PIOs) are rare but dangerous flight characteristic that can develop due to non-optimal human-machine coupling. Research into cognitive factors underlying PIOs remains sparse but a popular hypothesis in the flight community implicates cognitive overload as a strong contributor [1]. In this work we investigate possible neural correlates underlying PIOs.

Experimental Design

- Boundary avoidance task (BAT): Navigation of an aircraft through equidistant waypoints that defined a complex undulating trajectory in a 3D virtual environment NEDE [2].
- Waypoint boundaries were safety critical and were reduced at regular intervals (Large, Medium, and Small); boundary size impacts cognitive workload [1].
- Aircraft heading controlled using a joystick; aircraft response to input had a small delay (200-300ms) with damped oscillatory dynamics (wobble).

PIO Behavior
- Full-fledged PIOs are rare; therefore surrogate measures were developed.
- Higher workload led to
  - Quicker failure
  - More frequent and large inputs
  - Phase divergence b/w input and output

Workload classification of 64-channel motor-locked EEG signals using Hierarchical Discriminant Component Analysis (HDCA)
Training Data: EEG signals occurring 100-700ms after onset of joystick movements. Classify Large vs Medium+Small boundary epoch.

Conclusions: We show that response-locked EEG signals can be used to identify neural correlates of workload buildup in complex tasks involving precise man-machine interaction. Future work will investigate how these signals can be used in a closed-loop HBCI system for optimizing man-machine coupling in high performance tasks.

References

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