Monitoring attentional state using functional near infrared spectroscopy

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fNIRS Symposium
Center for Human Growth and Development
5/4/2012

Monitoring attentional state using fNIRS: Motivation

funded by NASA's Aviation Safety Program

- Attentional lapses during safety-critical tasks such as piloting are a source of risk.
- In-task detection allows error-prone states to be avoided before off-nominal events occur, reducing accidents.

Monitoring attentional state using fNIRS: Aims

- To determine the accuracy with which attentional state can be discriminated *during task performance* using:
  - pattern classification with training based on behavior
  - and the detection of functionally-connected attentional (ATN) and default mode (DMN) networks with fNIRS.

Monitoring attentional state using fNIRS: Default Mode Network

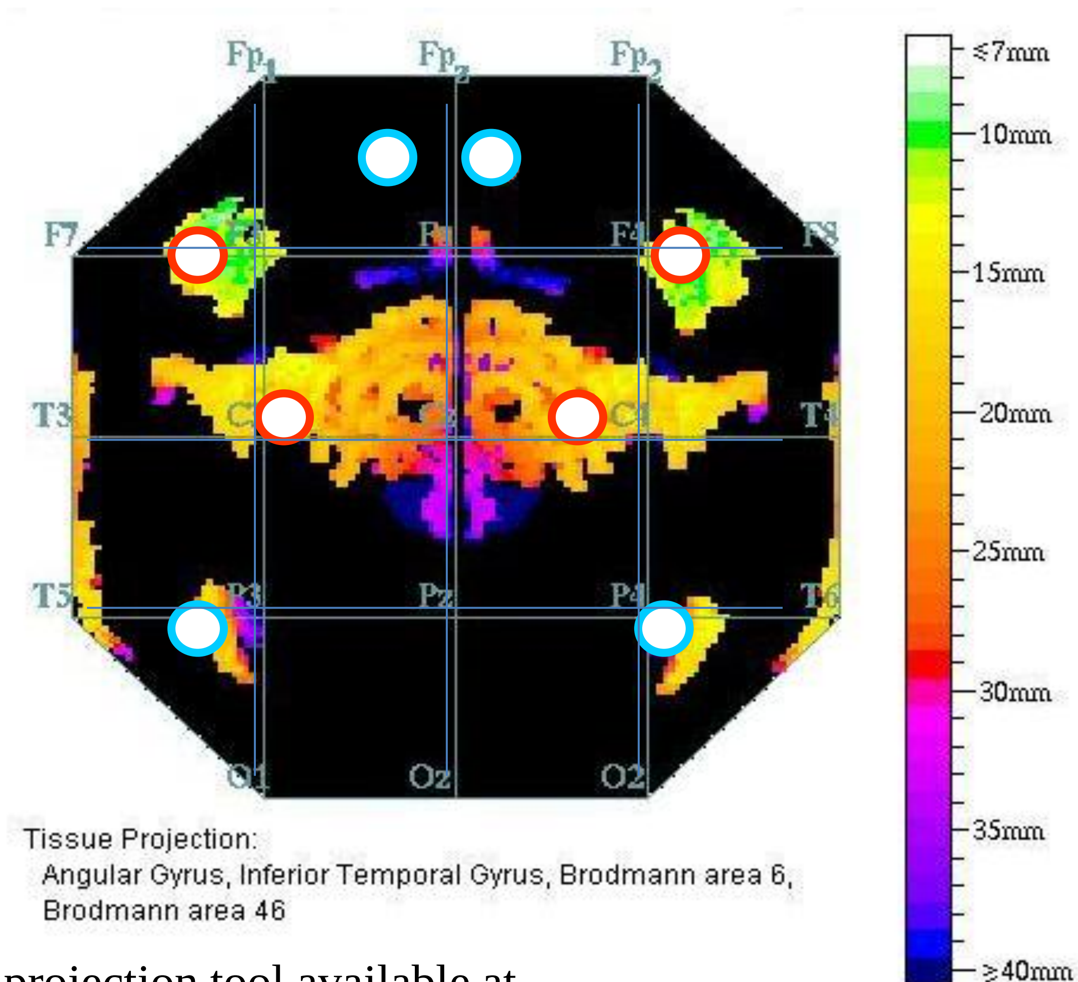
- The default mode network, one of many resting state functional networks:
  - deactivates with goal-oriented behavior.
    (Greicius, 2003; Raichle, 2001)
  - has been shown to reveal attentional lapses (Weissmann, 2006)
  - and to be associated with poor performance due to sleep deprivation. (Drummond, 2005)

- DMN measurement may allow improved specificity of state prediction by differentiating forehead-only measures.

  Frontal oxygenation as measured by fNIRS has been show to be sensitive to workload during a complex task, but not necessarily predictive of performance decrement. (Izzetoglu, 2004)

Monitoring attentional state using fNIRS: Head Probe Locations

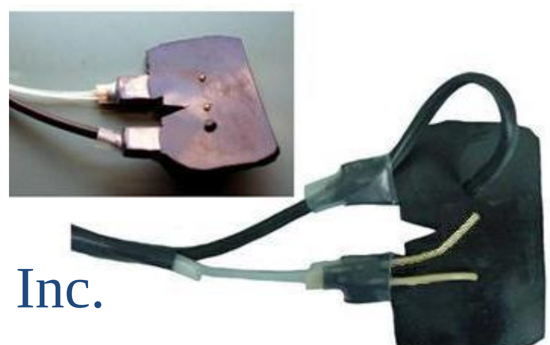
- anti-correlated ATN and DMN (task-positive and task-negative) activations are expected (Kelly, 2008; Fox, 2005)
- for example, 8 locations as shown
- functional connectivity can be used as a check on probe placement or as a classifier input feature



tissue projection tool available at
http://wwwneuro03.uni-muenster.de/ger/t2tconv/conv3d.html
[Steinstrater, Knecht, 2001]

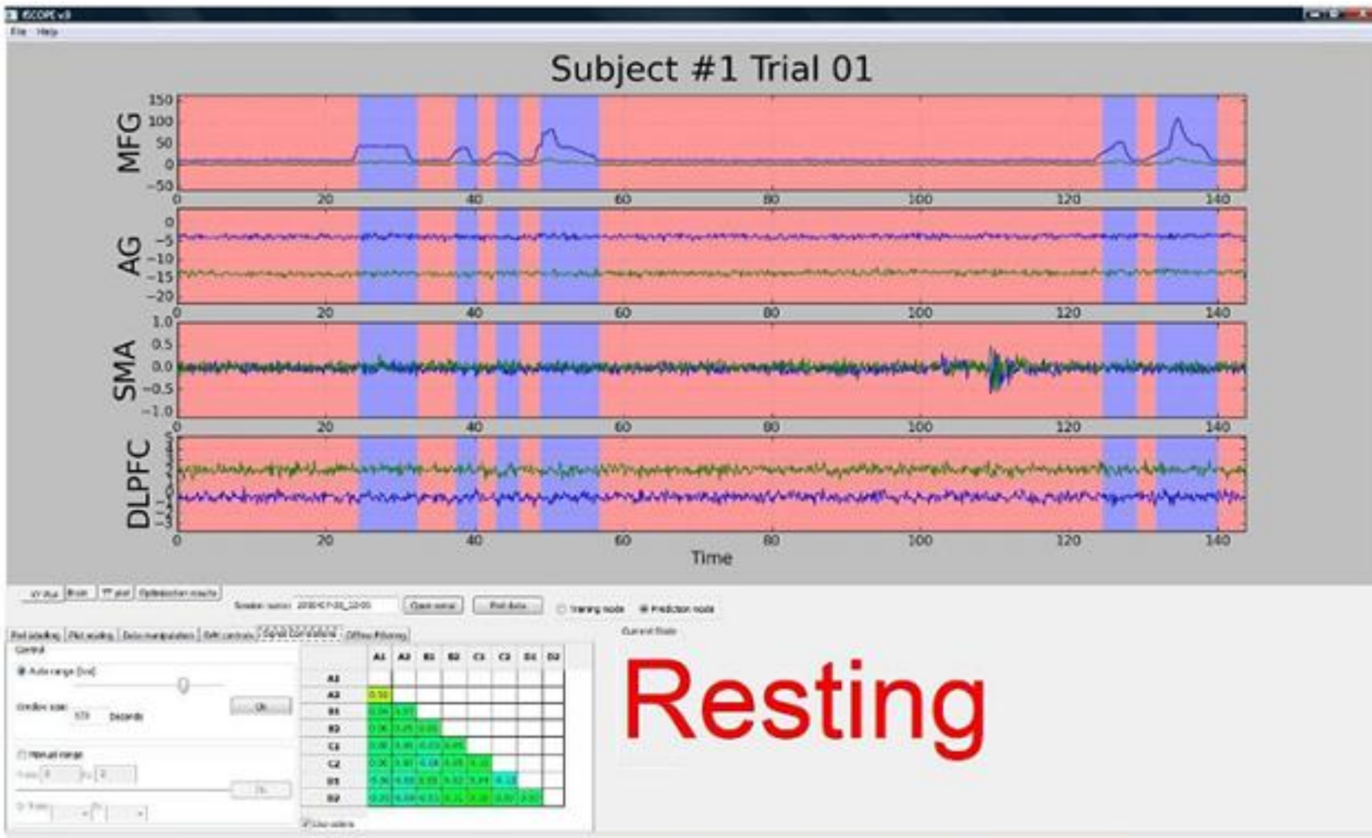
Monitoring attentional state using fNIRS: fNIRS-fMRI Study

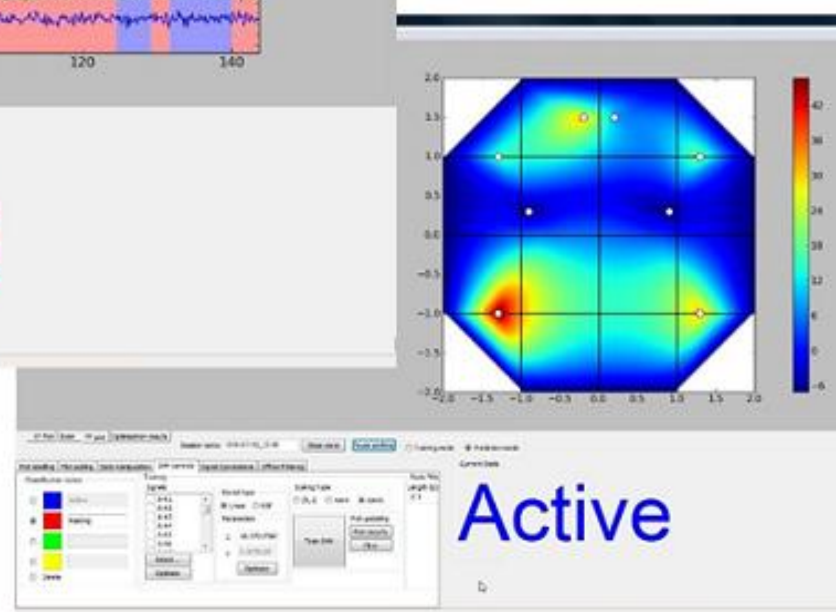
- We plan to use pilot fMRI studies to verify and inform probe locations
- Protocol: one 8min rest plus
  5 x { 4min continuous performance task
  followed by one minute of rest }
- We will assess cross-network correlation and classification accuracy
  for various input features
- Each of the four probe locations has both
  a main and a shallow physiological source
- Using the Imagent by ISS, Inc.



probes from ISS, Inc. and fMRI-compatible headgear

fSCOPE: real time plotting, classification and correlation software





written by Dr. Tristan Hearn, GRC co-op
in Python using Lib SVM (Chang, 2001)

We are still adding motion artifact and physiology removal.

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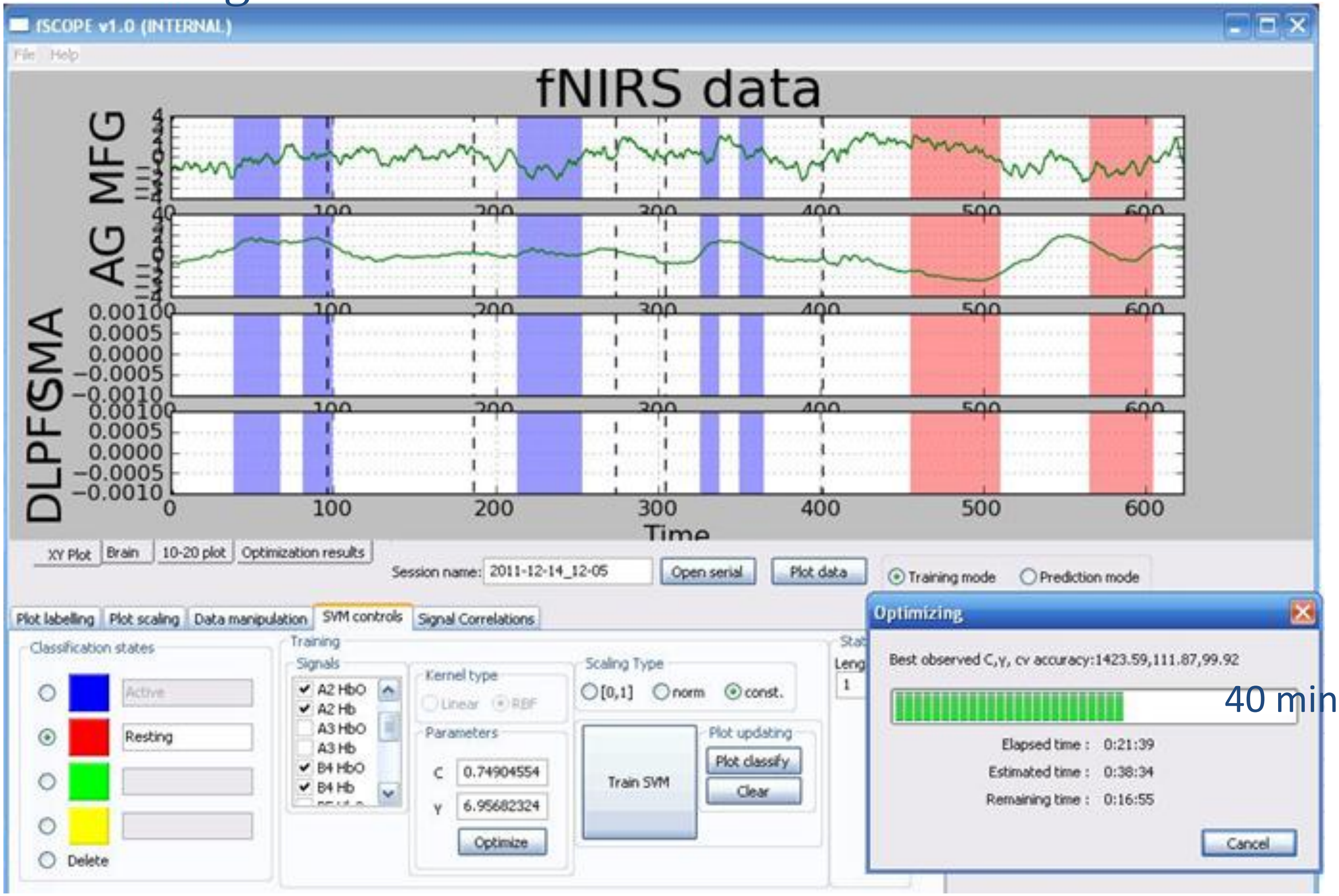
Classification Optimization

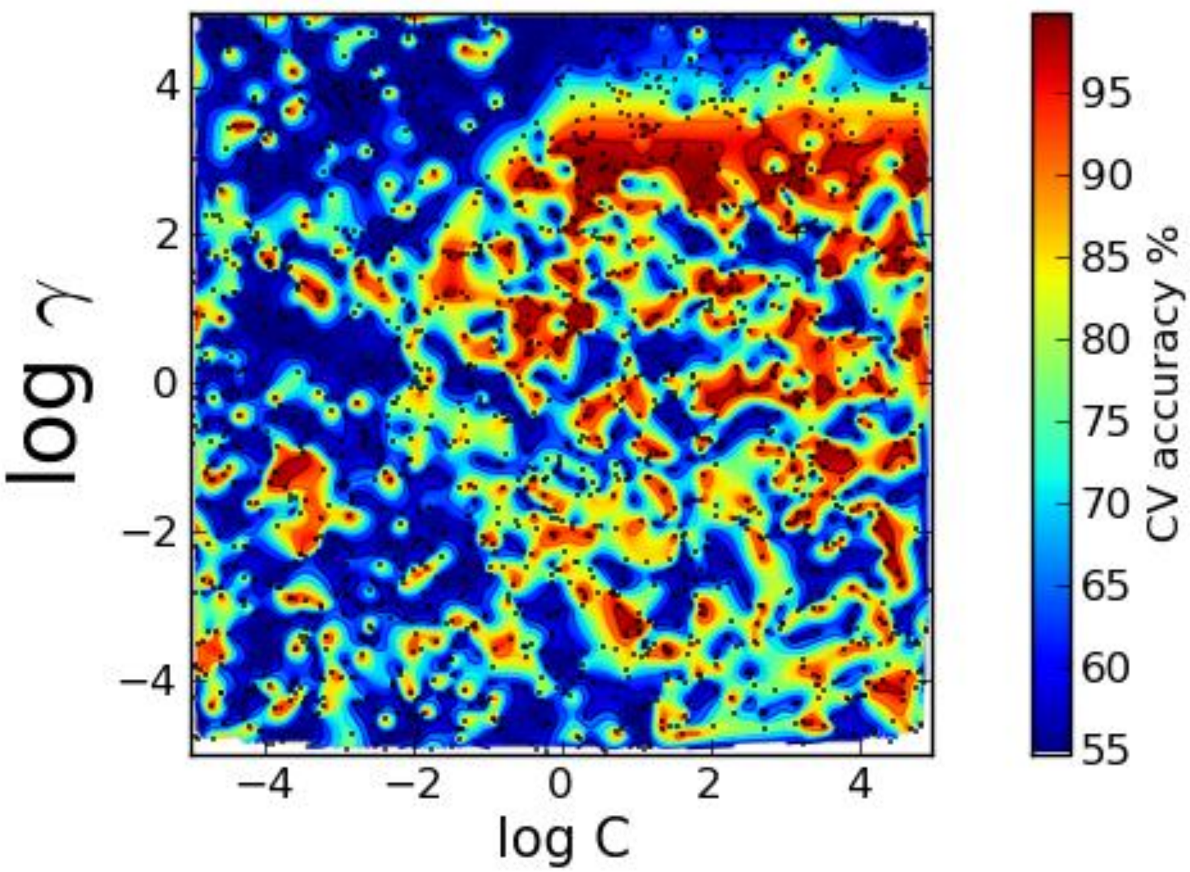
- Add training labels to the time series from session one based on behavioral measures, avoiding artifact
- Rest began at 400s



40 min

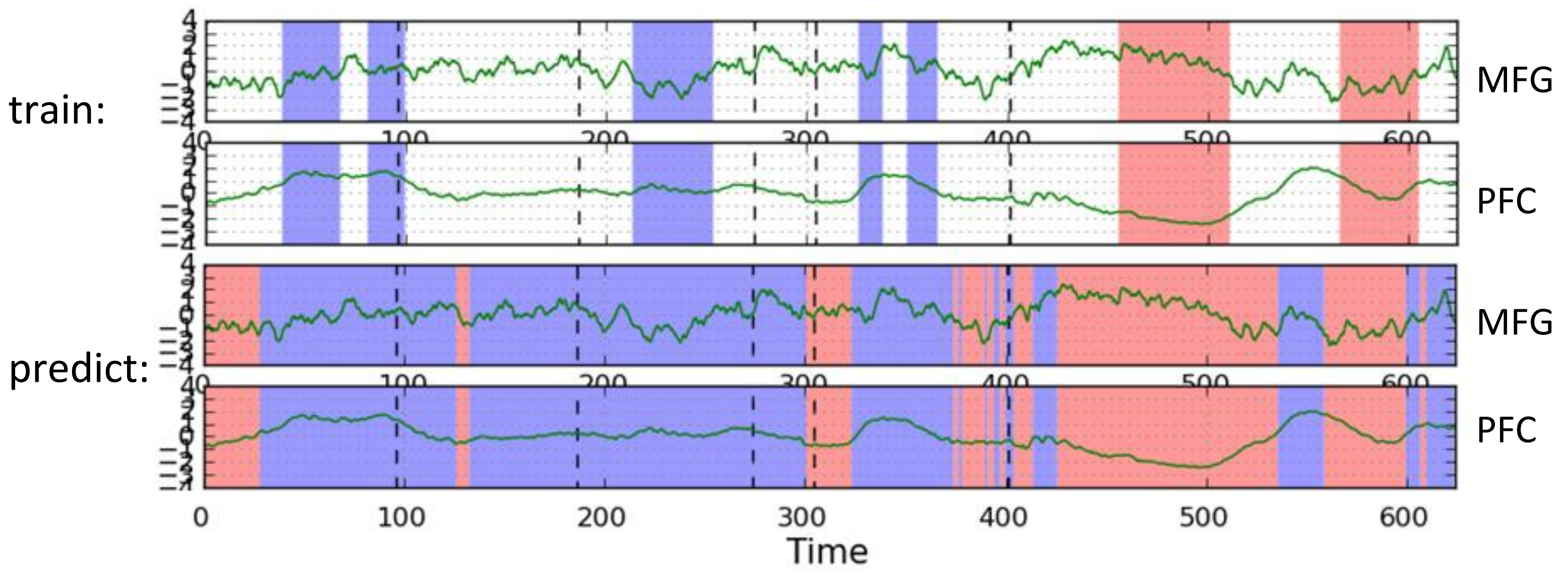
Classification Optimization

- optimize the Support Vector Machine parameters
- select c, gamma based on 4-fold cross validation accuracy



Real time classification process: session one

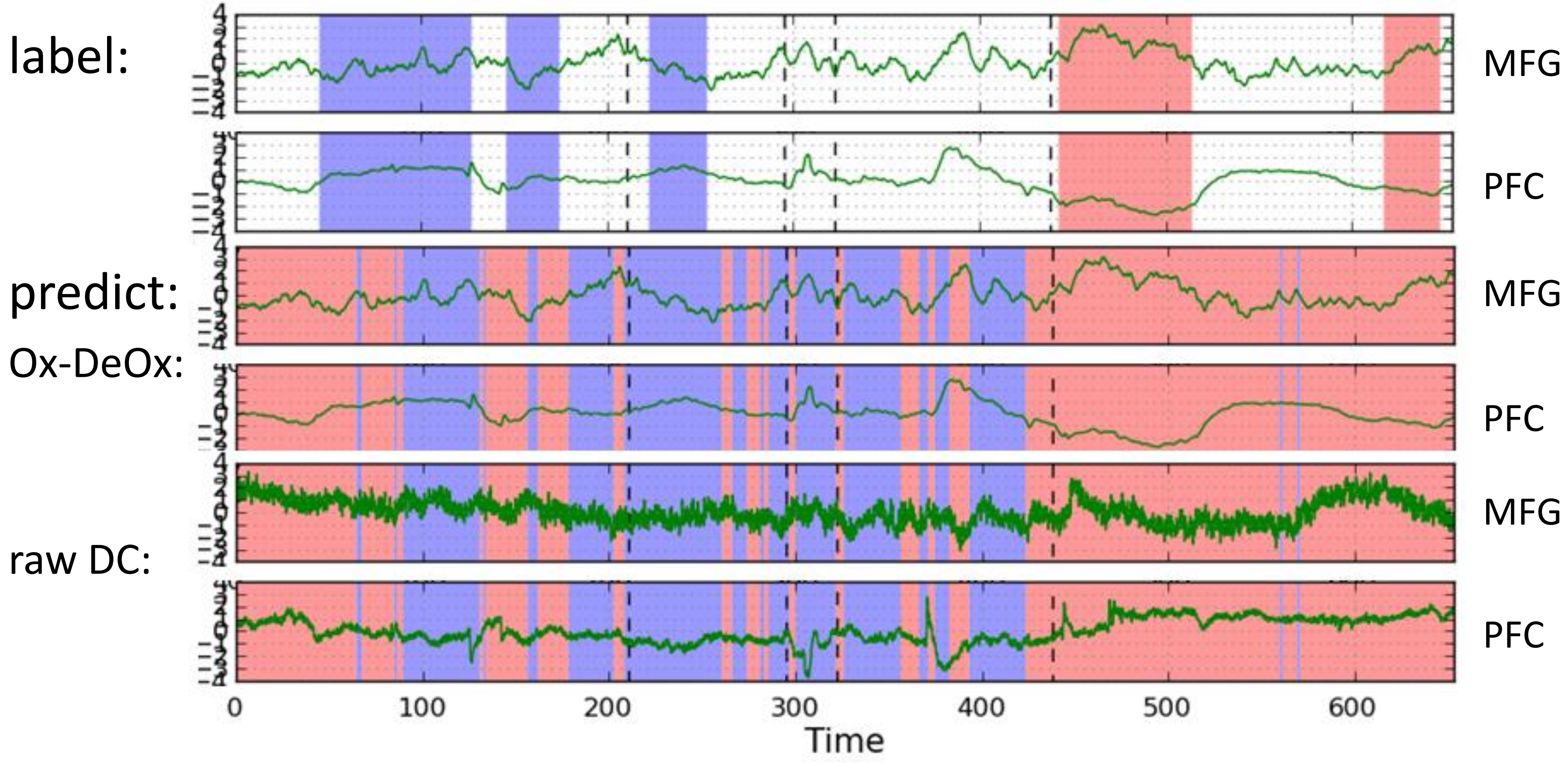
- train with time series from two probes during session one
- predict all of session one with the selected c and gamma
- obtain 97% cross validation accuracy
- save the SVM model



normalized to the mean, relative [HbOx-HbDeOx], 0.01 Hz to 0.5 Hz band pass

Real time classification process: session two

- open session two and predict with that SVM model
- obtain 74% accuracy
  with respect to the labels shown at the top



Acknowledgements

This work is performed in the fMRI Laboratory at the University of Michigan, where Ms. Harrivel is a PhD candidate.
Co-advisors: Prof. Douglas Noll and Dr. Scott Peltier.
Committee members: Prof. Luis Hernandez, Prof. Daniel Weissman, and Prof. Theodore Huppert.

It is supported by the NASA Aviation Safety Program. All subjects consented to take part in this human subject study as approved by the NASA Committee for the Protection of Human Subjects. We gratefully acknowledge colleagues at the NASA Glenn Research Center.

Questions?

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Existing commercial EEG product

B-Alert Cognitive State software
with proprietary metrics to classify data from
B-Alert Wirless EEG systems
by Biopac Systems, Inc.

Existing commercial EEG product

Emotiv EPOC
Brain Activity Map

real-time map of:

Delta (0.5-4Hz) - indicating deep sleep, restfulness, and conversely excitement or agitation when delta waves are suppressed

Theta (4-8Hz) - indicating deep meditative states, daydreaming and automatic tasks

Alpha (8-15Hz) - indicating relaxed alertness, restful and meditative states

Beta (15-30Hz) - indicating wakefulness, alertness, mental engagement and conscious processing of information.