Auditory closed-loop stimulation to manipulate slow-oscillations

A novel approach

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Interfaculty Research Cooperation:
Decoding Sleep

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Project Of The Interfaculty Research Cooperation "Decoding Sleep" (WP2: "Sleep & Brain")

Development Goals:

> Targeting and manipulating up- and down-states of slow-waves (SW) in slow-wave-sleep (SWS)

> Targeting different slow-waves based on their location and/or generators

> Creating a prediction algorithm for distinct states of the sleeping brain

Scientific background:

> SW generated in and traversing along many different cortical areas (Massimini et al., 2009)

> Closed-loop stimulation based on SW-amplitude (Ngo et al., 2013)

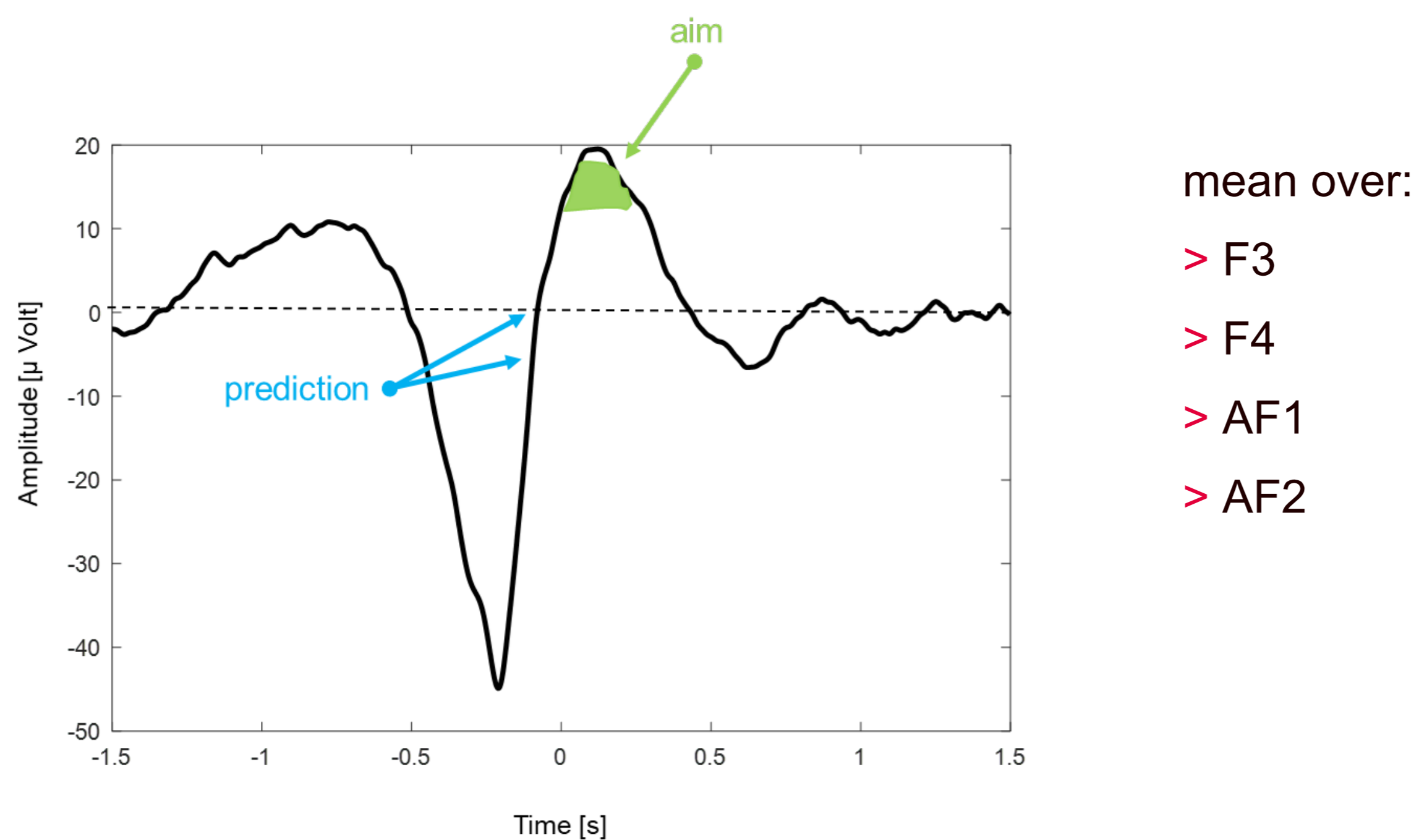> Closed-loop stimulation based on phase-synchorinsation (Santostasi et al., 2016)

Set-Up Closed-Loop Stimulation:

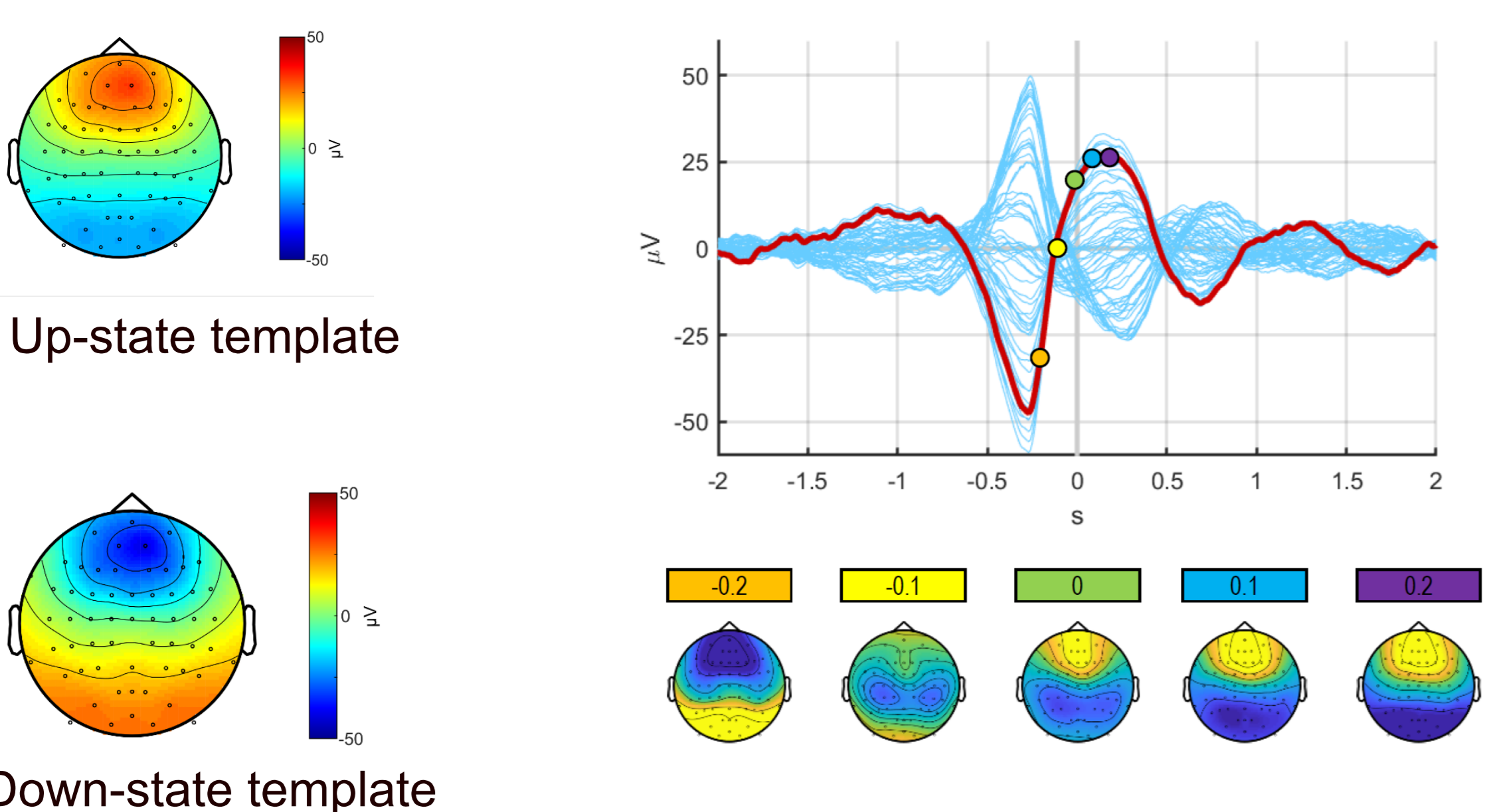Closed-loop set-up with Brainvision Recorder©, LabJack© and Matlab©
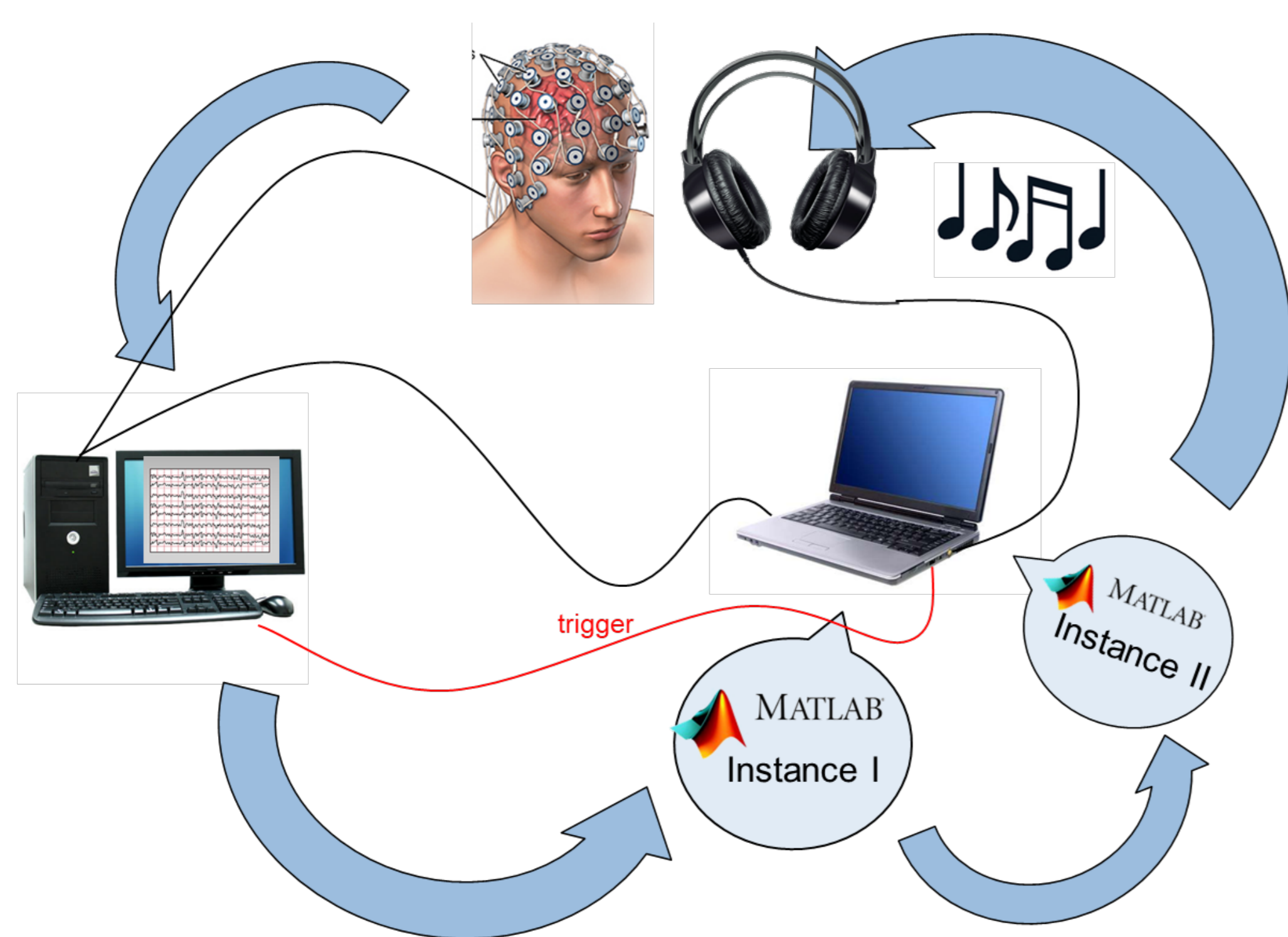
Prediction-Algorithm:

### Step 1: frontal electrodes and prediction zone

mean over:

> F3
> F4
> AF1
> AF2

Step 2: template correlation (topography)

Up-state template

Down-state template

Step 3: computation and thresholds

> Observing datapoints over last 120ms

> We computed for each timepoint the slope and the sign

> Once on the raw datapoints and once on the template correlation

> Thresholds are set to predict around zero-crossing [sign: 50 % and slope: 75%]
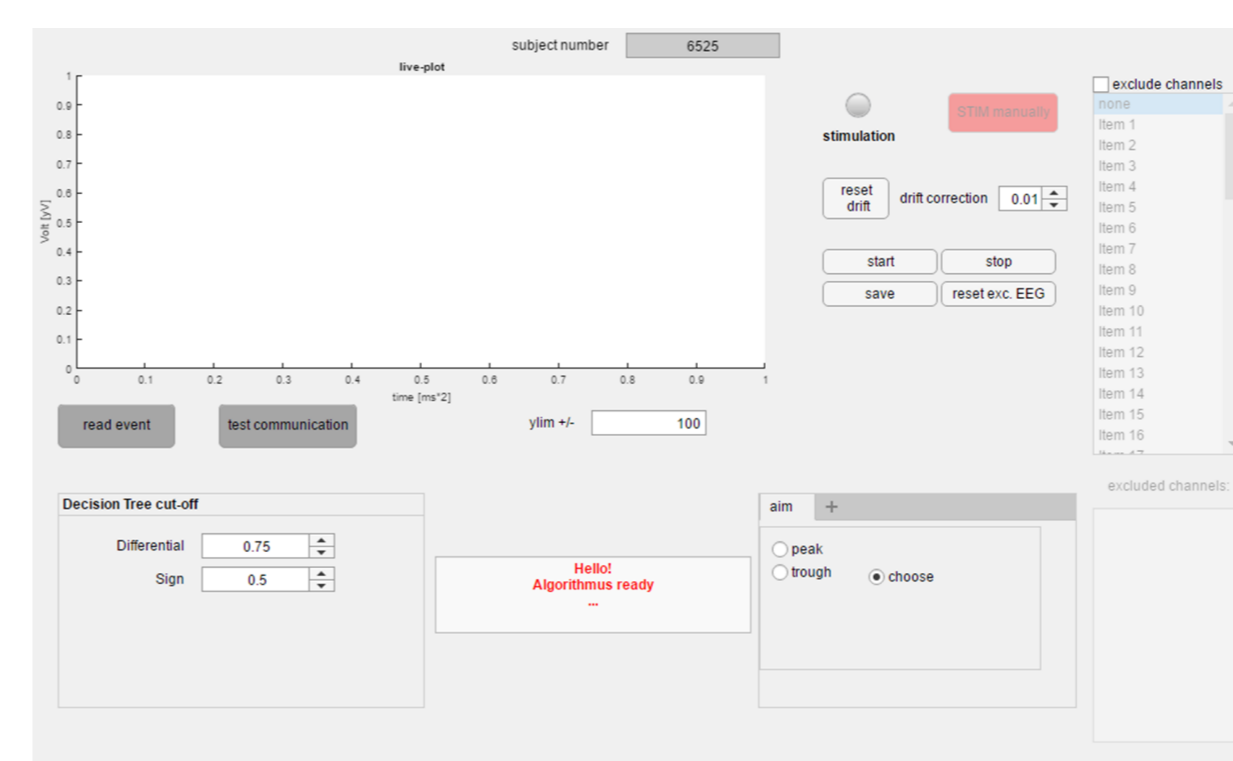
Up-state:

o Frontal voltage: increasing, but negative

o Template correlation: increasing, but negative

Down-state:

o Frontal voltage: decreasing, but positive
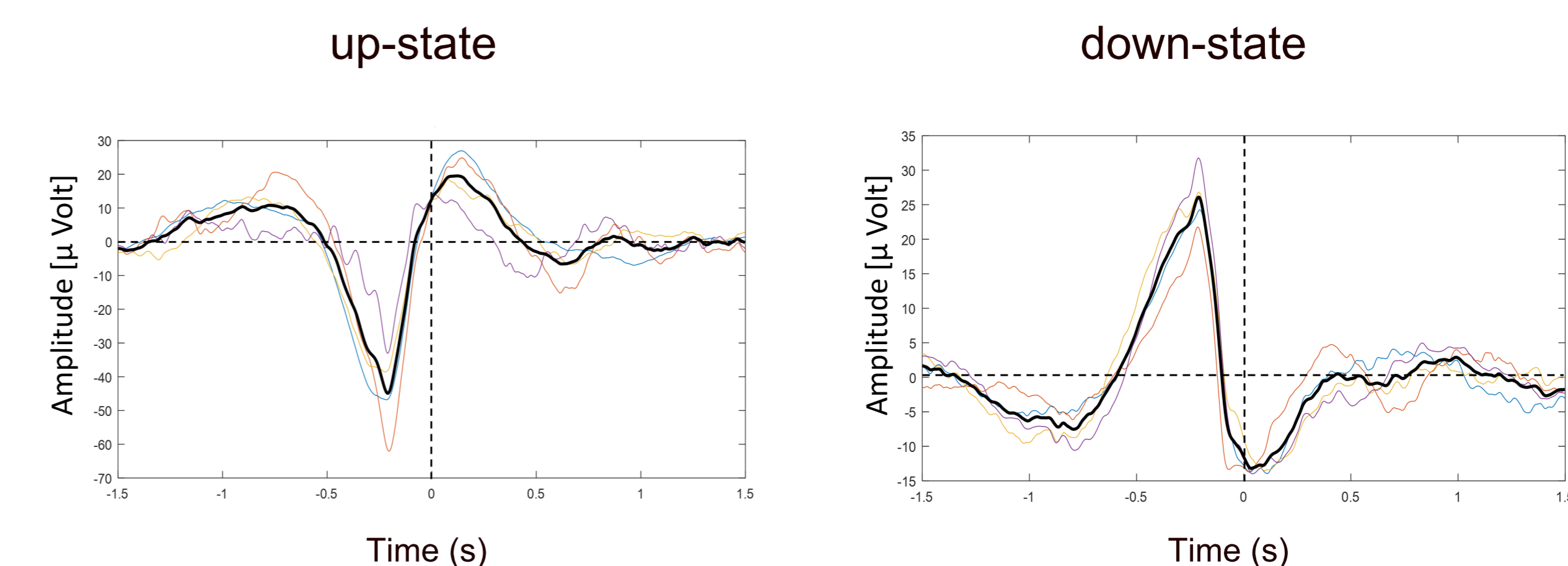
o Template correlation: increasing, but negative

Benefits and Reasons:

> Targets up- and down-states

> Less dependent on SW-frequency

> Allows to target specific SW-generators (frontal, parietal,...)
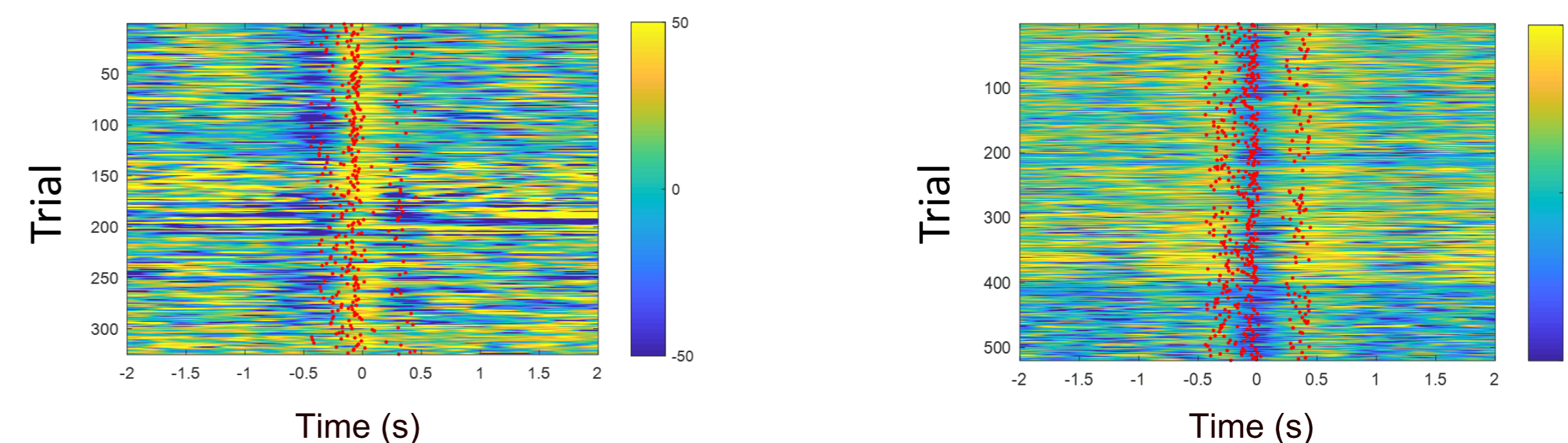
> Higher quality vs lower quantity of prediction

Prediction Accuracy:
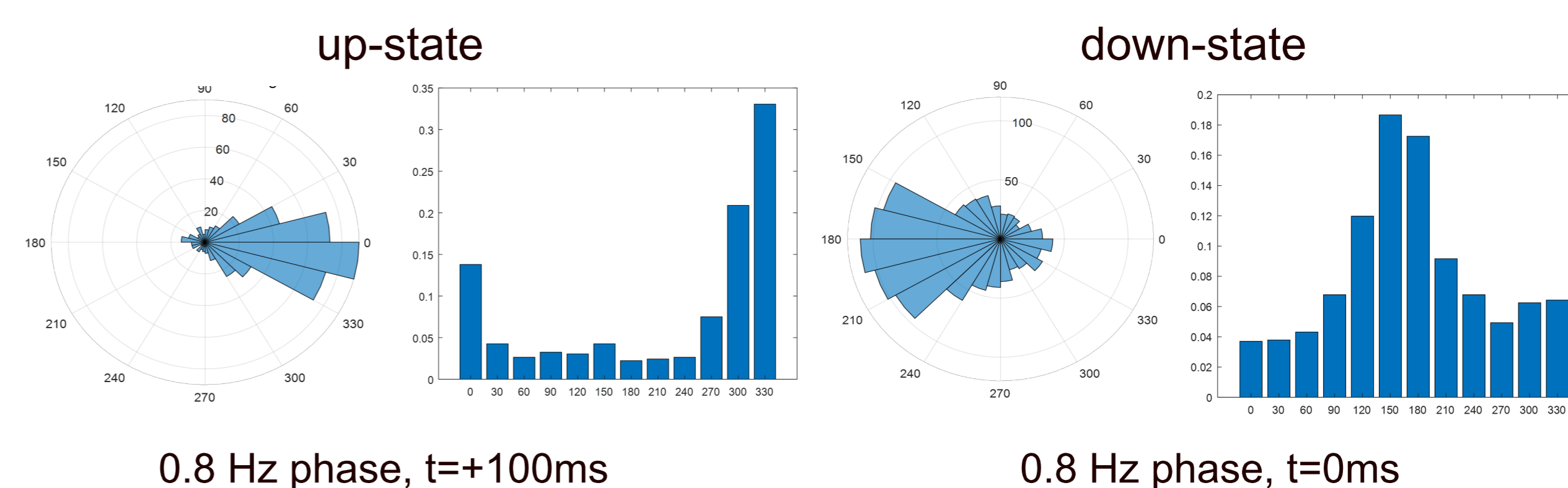
Data from 8 subjects (4 up-state and 4 down-state)

> Mean ERP

up-state   down-state

> ERP for each trial (sorted by time during sleep)

> Phase-accuracy as roseplot and timedifference from peak/trough

up-state   down-state

0.8 Hz phase, t=+100ms   0.8 Hz phase, t=0ms

References

Massimini, M., Huber, R., Ferrarelli, F., Hill, S., & Tononi, G. (2004). The sleep slow oscillation as a traveling wave. Journal of Neuroscience, 24(31), 6862-6870.

Ngo, H.-V. V., Martinetz, T., Born, J., & Mölle, M. (2013). Auditory Closed-Loop Stimulation of the Sleep Slow Oscillation Enhances Memory. Neuron, 78(3), 545–553. http://doi.org/10.1016/j.neuron.2013.03.006

Santostasi, G., Malkani, R., Riedner, B., Bellesi, M., Tononi, G., Paller, K. A., & Zee, P. C. (2016). Phase-locked loop for precisely timed acoustic stimulation during sleep. Journal of neuroscience methods, 259, 101-114.

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