Recognition of Sleep Dependent Memory Consolidation with Multi-modal Sensor Data

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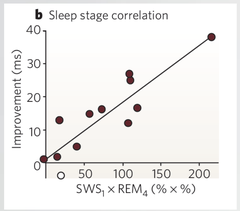
Motivation

Sleep dependent memory consolidation?

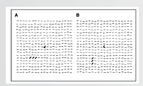
Significant performance improvement on a Visual Discrimination Task (VDT) becomes proportional to the amount of sleep in excess of six hours

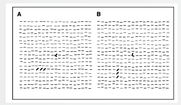
Correlation in performance to the sleep stages:
1Q: SWS (Slow Wave Sleep)
4Q:REM (Rapid Eye Movements)

Can we predict whether sleep-dependent memory consolidation occurred by using automated analysis of sensor data during sleep?

Data Collection

24 healthy university students (ages 18-22, 16 males)
3 nights of measurements





VDT(PM) → Sleep → VDT(AM)

Measurements

1)Electroencephalogram (EEG, C3, C4, O1 and O2) for the nights in the sleep labs

2)Sleep stage

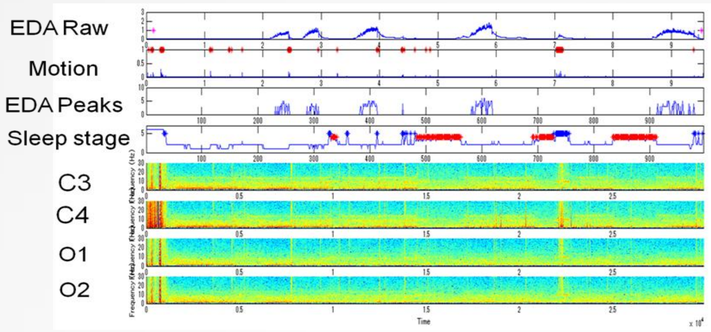


3) Electrodermal activity (EDA, a measure of sympathetic nervous system activity)

4)Actigraphy (3-axis accelerometer, ACC) from the wrist

5)Task performance improvement on VDT (PM-AM)

Feature Extraction and Classification



	Features
EEG	Power spectrum density of the frequency band (delta, theta, alpha, beta) of the quarters of the night for electrode locations C3, C4 and the average C3 and C4
EDA	Mean, standard deviation, median of normalized EDA amplitude and EDA peaks before sleep, during sleep and during each sleep stage % of epochs with EDA peaks for each sleep stage
ACC	Sleep latency, sleep duration % of wake in each quarter of the night mean ,standard deviation, and median of the motion level.
Sleep stage	% of each sleep stage over the night Sleep efficiency derived from the EEG (the percentage except wake and others during sleep) Time to first deep sleep % of each sleep stage for each quarter of the night

Raw Data


EEG

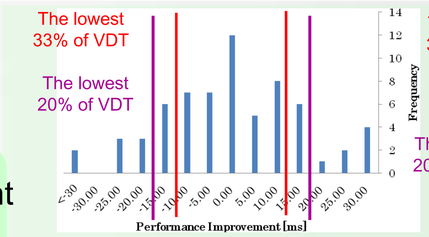

EDA
ACC


Sleep stages

Features
a) ALL
b) EDA
c) ACC
d) EDA+ACC
e) EEG
f) Sleep stage
g) EEG+EDA+ACC

Classification

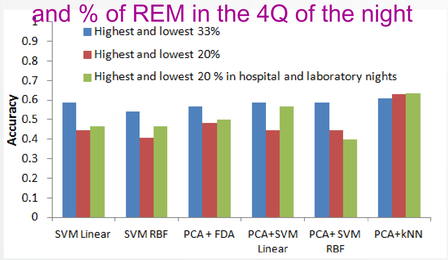
Training Model → Task Improvement or not?
Test Data
10-fold cross validation



A) Support vector machine with linear kernal
B) Support vector machine with Gaussian kernel
C) PCA and linear discriminant analysis
D) PCA and support vector machine with linear kernal
E) PCA and support vector machine with Gaussian kernel
F) PCA and k nearest neighbors (k=1-5)

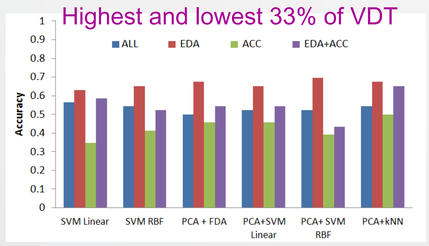
Results

Baseline with the % of SWS in the 1Q and % of REM in the 4Q of the night



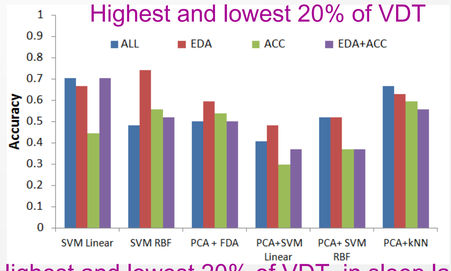
~60% or below it.

Highest and lowest 33% of VDT



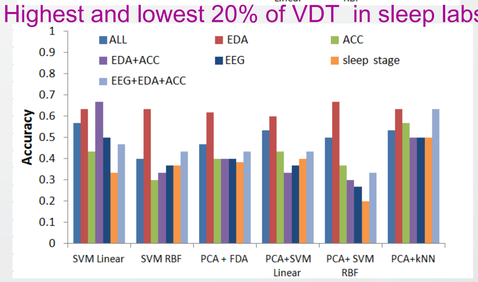
EDA alone showed the highest accuracy, around 60-70%

Highest and lowest 20% of VDT



The features from EDA again showed the highest accuracy, 74%, followed by EDA+ACC

Highest and lowest 20% of VDT in sleep labs



The features from EDA solo or EDA+ACC showed the highest accuracy, 67%, followed by EEG +EDA +ACC.

Conclusions

In all the comparisons here, overall, either solo EDA features or EDA +ACC features improved the classification accuracy compared to use of sleep stages and to use of only EEG.