Brain Computer Interface (BCI) Based Smart Alarm and Sleep Classification

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Need

-About **70 Million** Americans suffer from chronic sleep problems[1]

-Sleep is a dynamic **neurophysiological process** characterized by **sleep stages (REM, N1, N2, N3)**[2] and wrist-based assessment → inconsistent accuracy

- Waking in light sleep results in: ↑wakeup feeling[3] and ↑cognitive function[4]

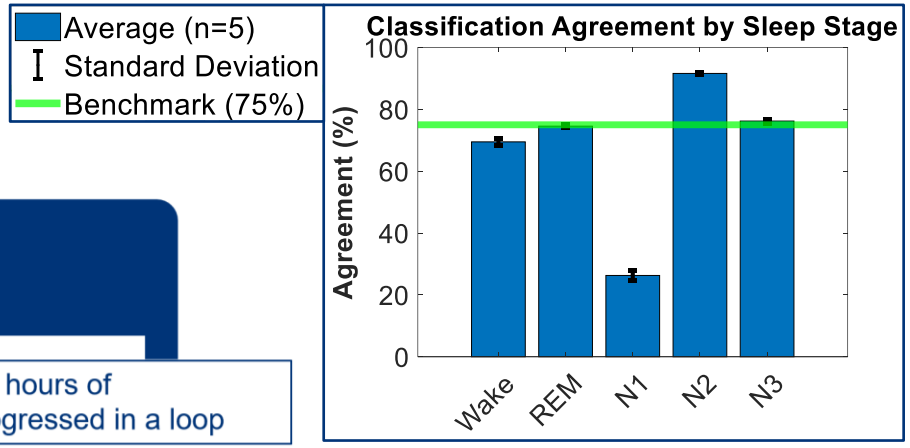
Project Objective:

Develop a near-real time BCI system that can determine sleep architecture (sleep stages throughout the night) and identify least disruptive wakeup time

Testing

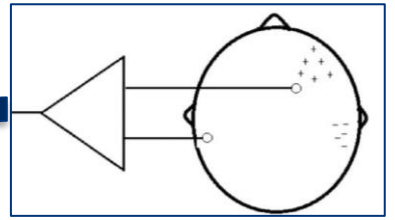
Requirement 1: 78.1 ± 0.2 % overall agreement > 75% compared to expert analysis[5]

Simulation Approach: 8-9 hours of chronological EEG data progressed in a loop



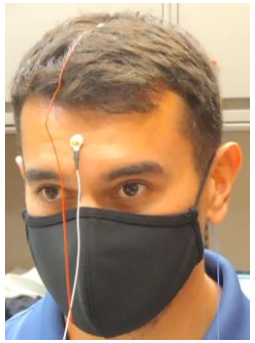
Requirement 2: Alarm activation must (and does) occur within user-defined wakeup time window and during stages N1 or N2. Processing Time: 0.46 ± 0.03 seconds / epoch.

Solution



Single Channel EEG

Wakeup Time Window



BCI Smart Alarm and Sleep Classification:

- Continuous Near Real-Time Processing
- Extraction of Frequency Based Features[6]
- Machine Learning Model Trained by Clinical Data[6]
- Time and Sleep Stage Dependent Alarm

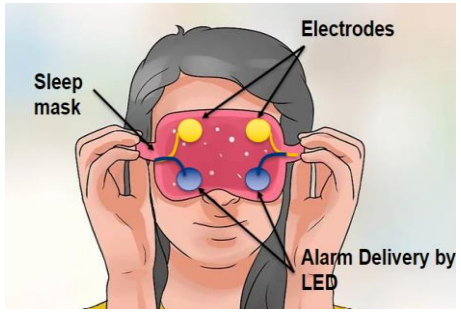
Alarm Activation Signal (on/off) with Light/Sound Options

-Signal processing, random forest classification, and GUI implemented in MATLAB

Impact and Next Steps

- Avoiding disruption of REM and deep (N3) sleep:
  ↑**learning,** ↑**memory,** ↑**mood,** ↓**sleep inertia**

- Accurate at-home sleep assessment with meaningful feedback:
  ↑**public health** ↑**workplace productivity,** ↑**further sleep/health monitoring innovations**



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[1] Department of Health and Human Services. Wake Up America: A National Sleep Alert. Report of the National Commission on Sleep Disorders Research. ASI 4008-130 1993.
[2] Miller et al. Chapter 4 - Methodology for the Assessment of Sleep. In Sleep and Affect, Elsevier Inc., 2015
[3] Peever, & Fuller, P. M. The Biology of REM Sleep. Current Biology, 2017. https://doi.org/10.1016/j.cub.2017.10.026
[4] Matchock, & Mordkoff, J. T. Visual attention, reaction time, and self-reported alertness upon awakening from sleep bouts of varying lengths. Experimental Brain Research, 2007. https://doi.org/10.1007/s00221-006-0726-x
[5] Ulysses J. Magalang, MD. Agreement in the Scoring of Respiratory Events and Sleep Among International Sleep Centers. Sleep. 2013.
[6] Fraiwan et al. Automated sleep stage identification system based on time–frequency analysis of a single EEG channel and random forest classifier. Computer Methods and Programs in Biomedicine, 2011
Orange EEG Waveform Adapted From:: www.macmillanhighered.com/BrainHoney/Resource/22292/digital_first_content/trunk/test/schacter3e/asset/img_ch5/c05_fig09.html
EEG Head Image: Lee-Chiong, et al. Fundamentals of Sleep Technology. 2019. LED Concept Art Adapted From: https://www.wikihow.com/Sleep-with-an-Eyemask-on