EZwakeup: A Sleep Environment Design For Sleep Quality Improvement

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Introduction

Sleep quality affects people's work performance, mood, safety, and quality of life. Poor sleep quality reduces short-term memory, cognitive abilities, and motor skills for all age groups. We introduce EZwakeup, a system that extracts sleep quality indicators with an e-textile-based sensing system and applies feedback-guided external stimuli to smoothly wake people up from deep sleep. It does not require people to wear any external devices and can be directly deployed in home environment.
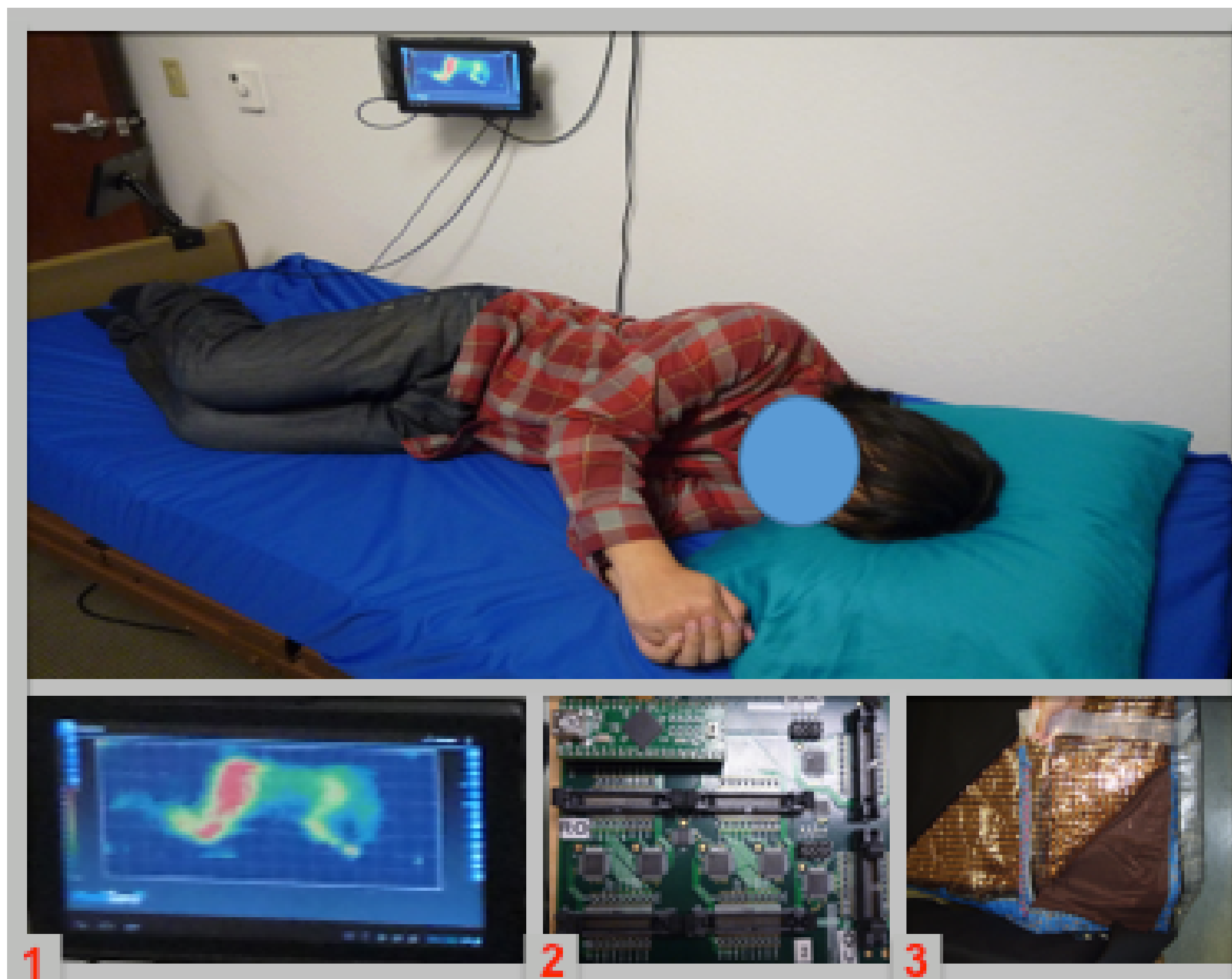

Figure 1: Hardware system overview. 1.Tablet display. 2.Motion sampler and aggregator. 3.High-density textile sensor array.

In experiments, participants reported that they felt well rested and energetic for the rest of the day when they were awakened by the guided stimuli. This result suggests that EZwakeup might be a viable option for improving personal sleep quality and have potential in treating common sleep disorders.
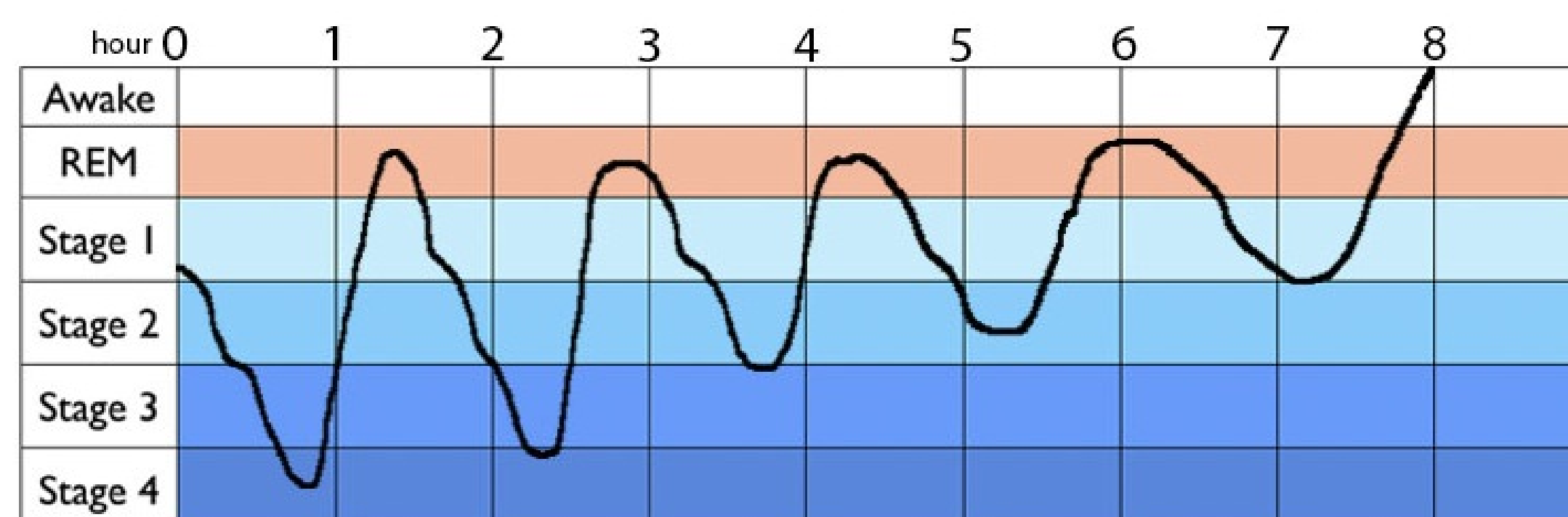
Sleep Stage Samples

Figure 2: A sample sleep cycle pattern which records sleep stage changes with time.

An ideal wake-up moment should be in shallow sleep stage (Stage1 preferred).
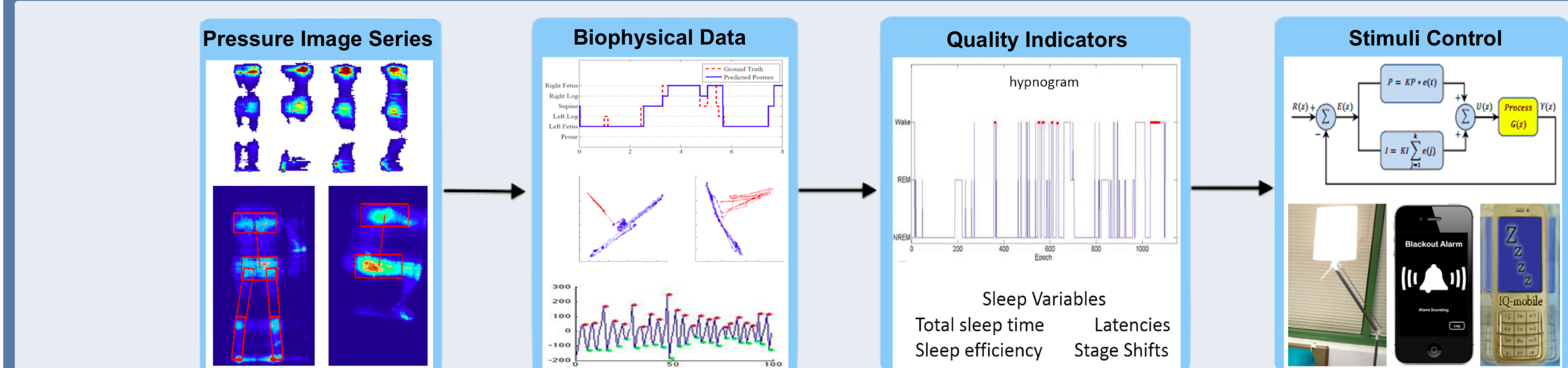
Algorithm Flow

Figure 3: EZwakeup algorithmic flowchart from sensing to controlling.

EZwakeup extracts biophysical signals from static and dynamic pressure image series.
Three biophysical sample signals are plotted with time: sleep posture changes, body movements, and respiration signals.
Sleep quality indicators such as total sleep time, latencies, sleep efficiency, and stage shifts can be derived from the hypnogram.
The stimuli controller has the ability to adjust the strength and frequency of the stimulus based on the feedback of sleep quality indicators.
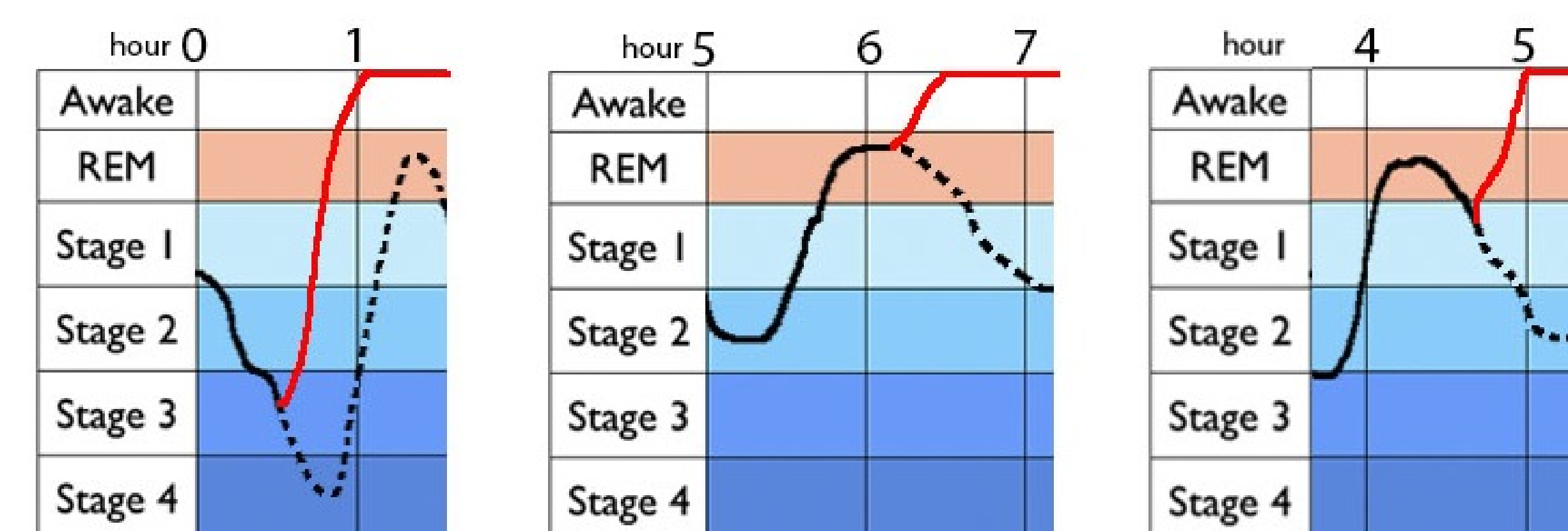
Wake-up Moment

Figure 4: Wake up a user from different stages. 1.Deep sleep stage. 2.REM stage. 3.Shallow sleep stage.

- If the user is detected in deep sleep stage, EZwakeup emits stimuli with a repeated gentle but high frequency signal. The repeating frequency was inverse to the time interval of the wake-up time and the current time.
- When the subject is detected in REM stage, EZwakeup emits a gentle stimulus with constant low frequency signal, which can slowly guide the sleep stage from REM to light sleep.
- When the set wake-up time came, if the sensed sleep stage is in the shallow sleep stage, the stimuli intervention emits a repeated high frequency and large strength signal (light, sound, or vibration).

Experiment

- Subjects: 6 graduate students
  - Age: 26-30
  - Gender: 4 female, 2 male
  - Weight: 110-180 pounds(within e-textile sensitivity range)

In the pilot study, each participant used EZwakeup for three non-consecutive nights. Three stimuli (light, sound, and vibration) were used respectively each night. We interviewed each participant to understand usability and effectiveness of the proposed system.

Evaluation

- Goals during evaluation
  - Sleep quality improvement with intervention
  - Sensitivity of stimuli among participants

Most participants reported that the unobtrusive sensing technology and stimuli intervention effectively improve their sleep quality.
The feedback from participants indicated that EZwakeup seamlessly integrated with their usual sleep environment and made them feel well rested and energetic.
This pilot study result indicates that waking from appropriate sleep stages could effectively improve sleep quality.