

Whole Night Sleep Monitoring With A Low-Cost In-Ear Wearable Device

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MOTIVATIONS

- Sleep is critical to help human body balance and regulate its vital system as well as human brain develop and restore.
- Quantifying sleep quality is significantly valuable to detect and diagnose sleep-related disorders that affect one's health by recording electrical activities of human brain, eyes, and muscles.
- Sleep monitoring requires patients to undergo an expensive, obtrusive, and uncomfortable sleep study in sleep labs.



Fig 1. Polysomnography as the current "Gold Standard" for sleep study with many wired sensors attached on the patient's body.

EXISTING HI-TECH SOLUTIONS



- Inaccurate
- Inconvenient
- Uncomfortable
- Easy to fall out during sleep
- Able to capture only a single signal (e.g. EEG)

OBJECTIVES

- Develop a *wearable bioelectrical sensing system* that is
- Significant to **reduce the number of wired electrodes**
 - Able to **measure all EEG, EOG, and facial EMG signals** at the same time
 - Potential for both **human computer interaction** and **self-care health applications**
 - Less obtrusive, comfortable, light-weight, and cost-effective

LIBS – AN IN-EAR BIO-SENSING SYSTEM

Challenges:

- Mixed signal** challenge: The biosignal captured by LIBS is composed of the original EEG, EOG, and EMG signals and noise, which
 - Overlap in both the amplitude and frequency domains
 - Vary across subjects and recording times
- Design** challenge:
 - Human ear canal is small and easily deformed by facial movements.
 - EEG, EOG, and EMG signals have low amplitude.

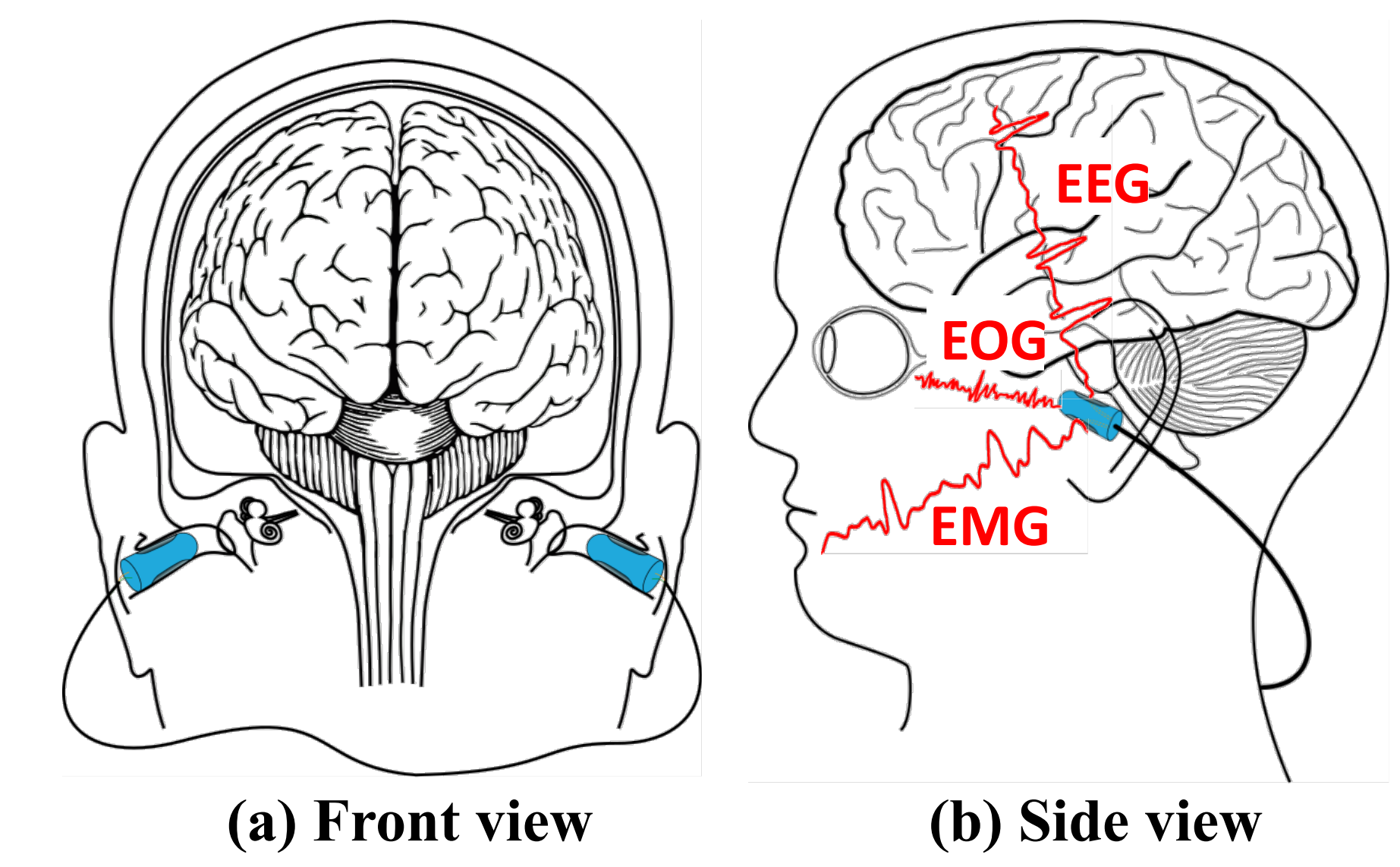


Fig 2. LIBS and its relative position to the sources of EEG, EOG, and EMG that we are interested in.

We introduce our system named LIBS. In LIBS,

- It takes the in-ear single-channel biosignal and adaptively decompose into EEG, EOG, and EMG signals without loss of their physiological information using a *supervised non-negative matrix factorization* technique.
- It guarantees a comfortable and safe feeling while being worn as it is made of a combination of *thin, soft, and highly conductive materials*.

System Design:

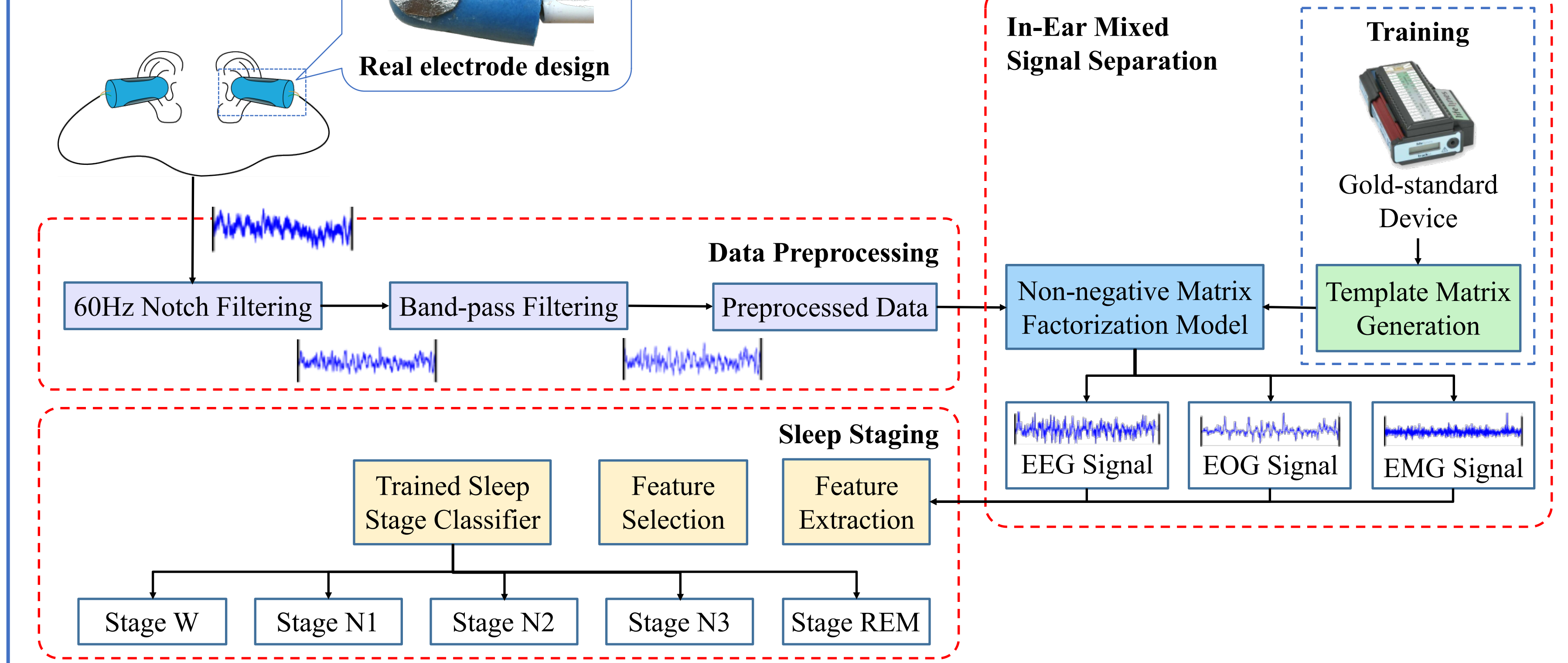


Fig 3. LIBS architecture and its sleep staging application

LIBS PERFORMANCE IN REALITY

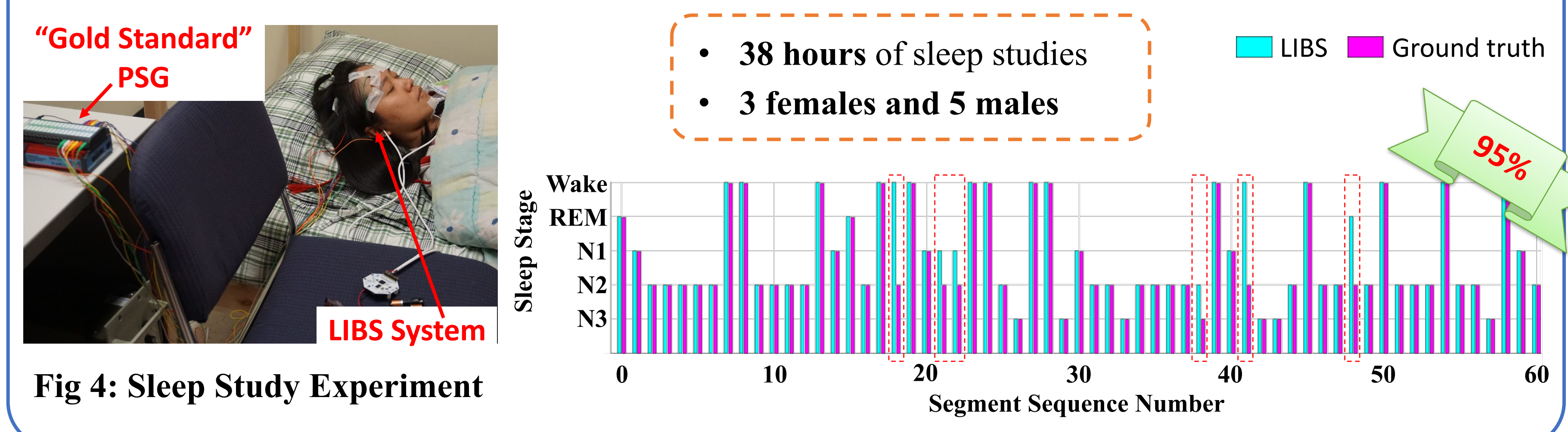


Fig 4: Sleep Study Experiment

IN-EAR SIGNAL ACQUISITION VALIDATION

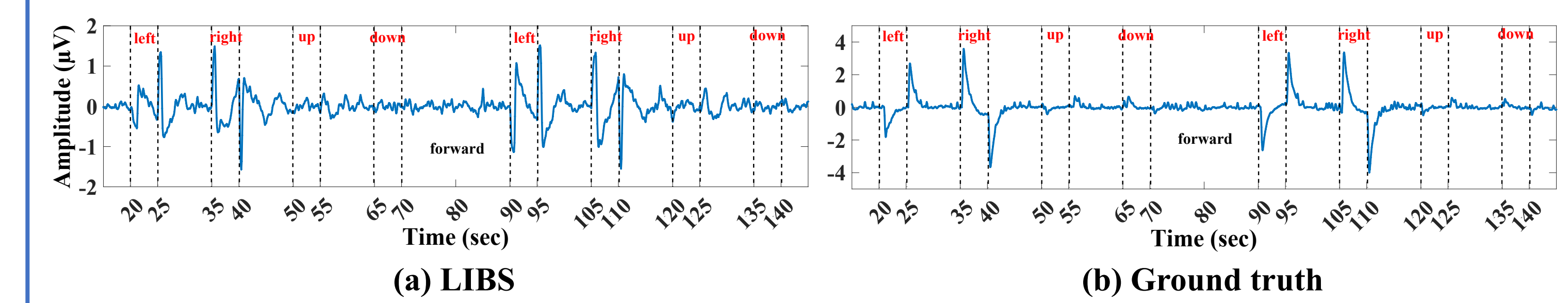


Fig 5. Eye movement detection

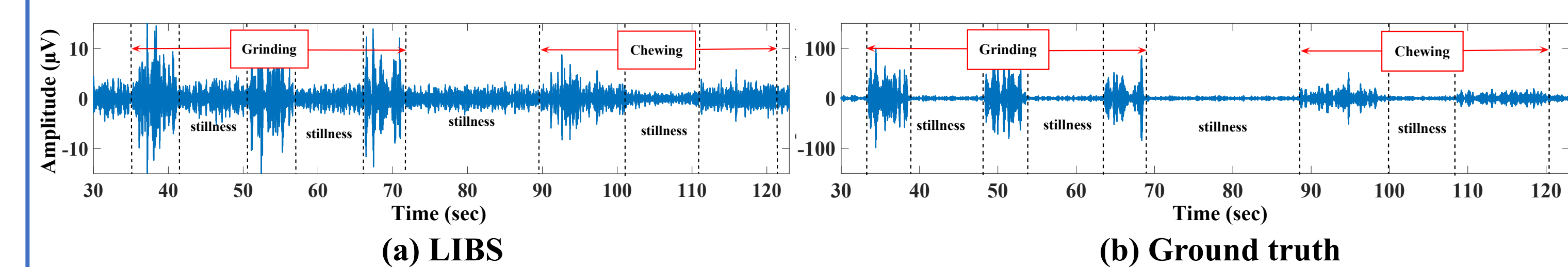


Fig 6. Facial muscle contraction detection

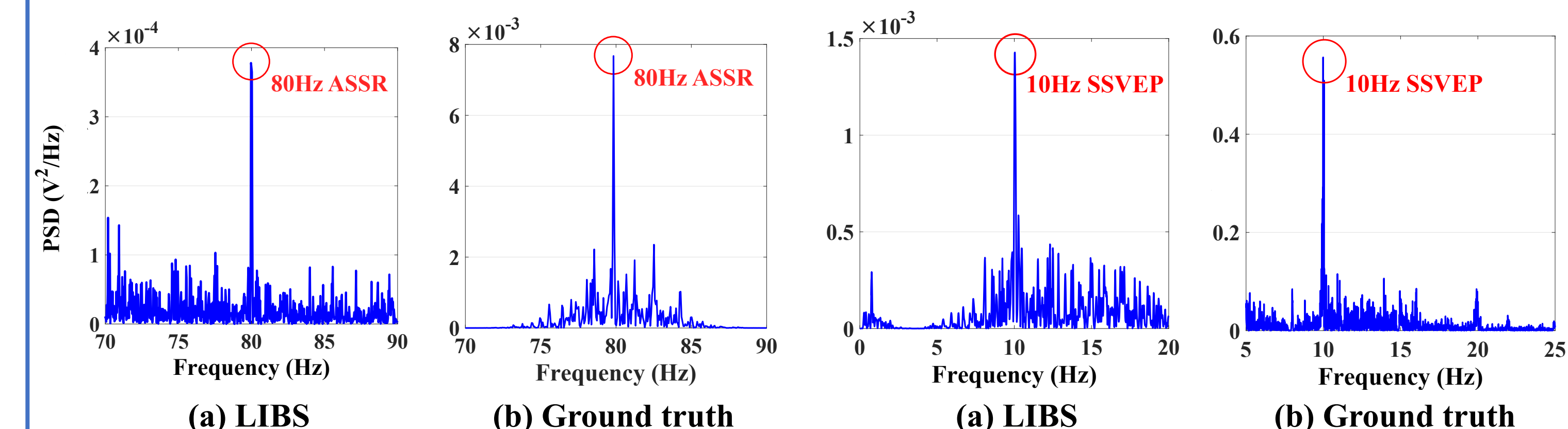


Fig 7. Audio steady-state response (ASSR)

Fig 8. Steady-state visually evoked Potential (SSVEP)

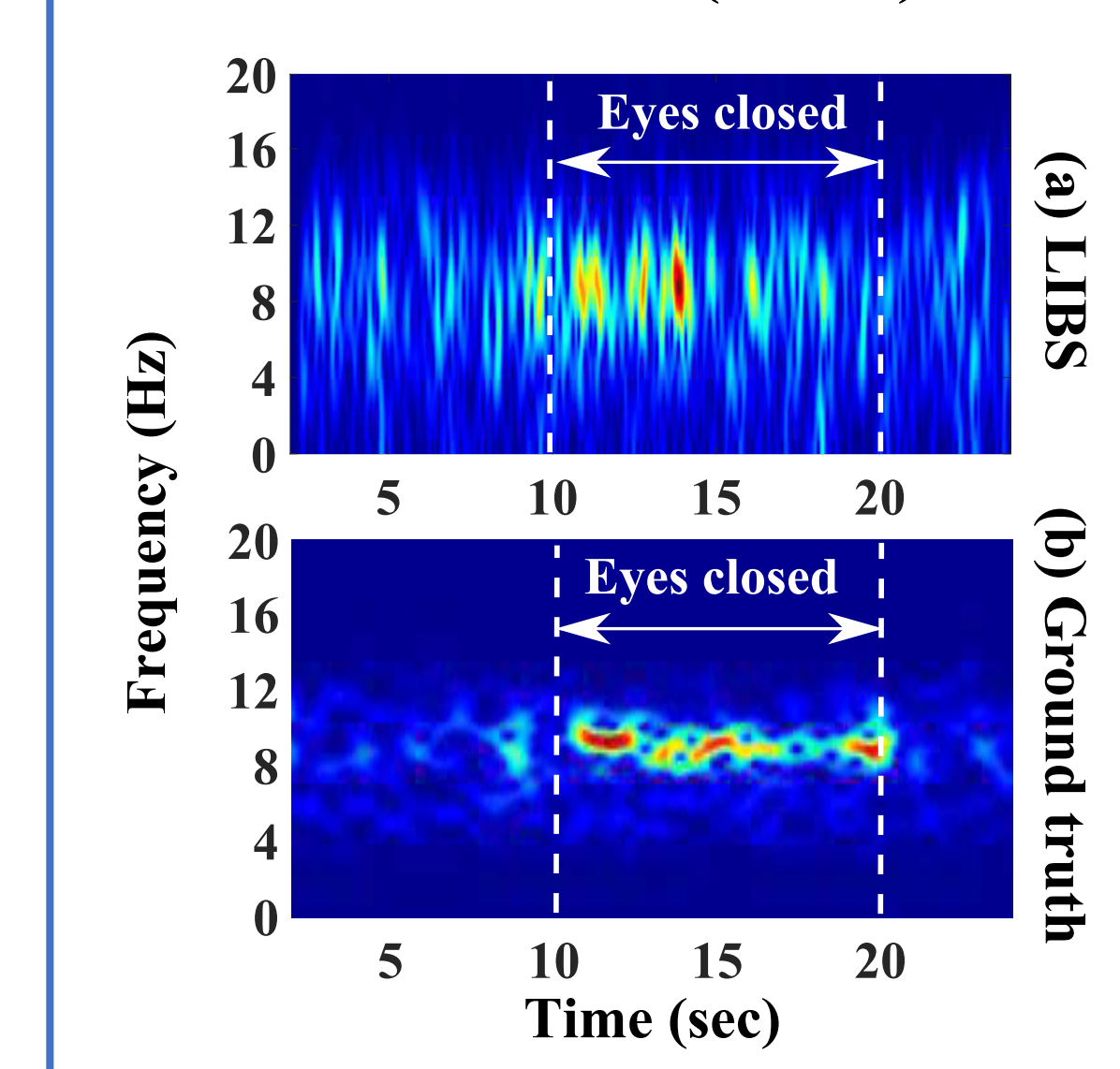


Fig 9. Alpha rhythm detection

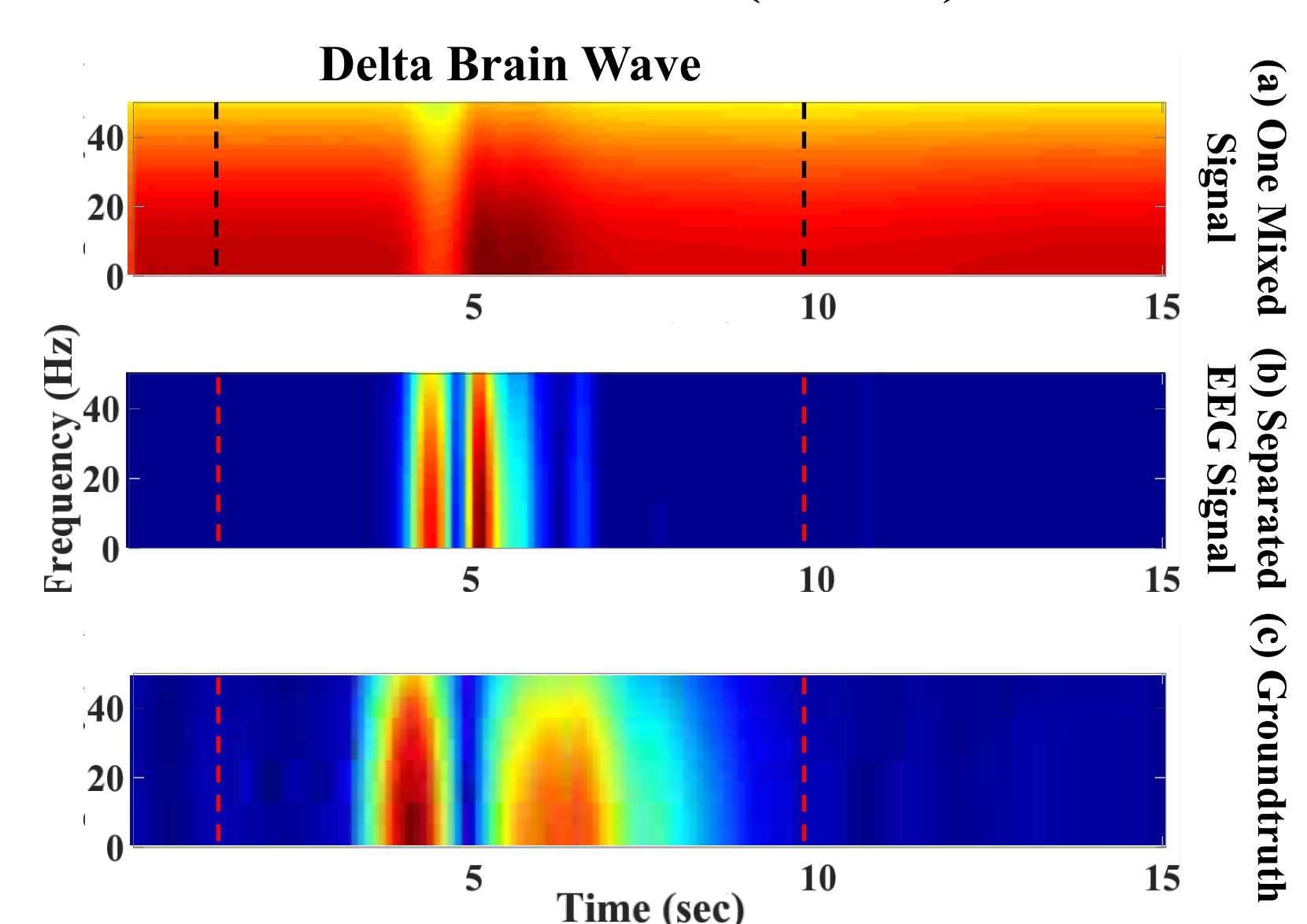
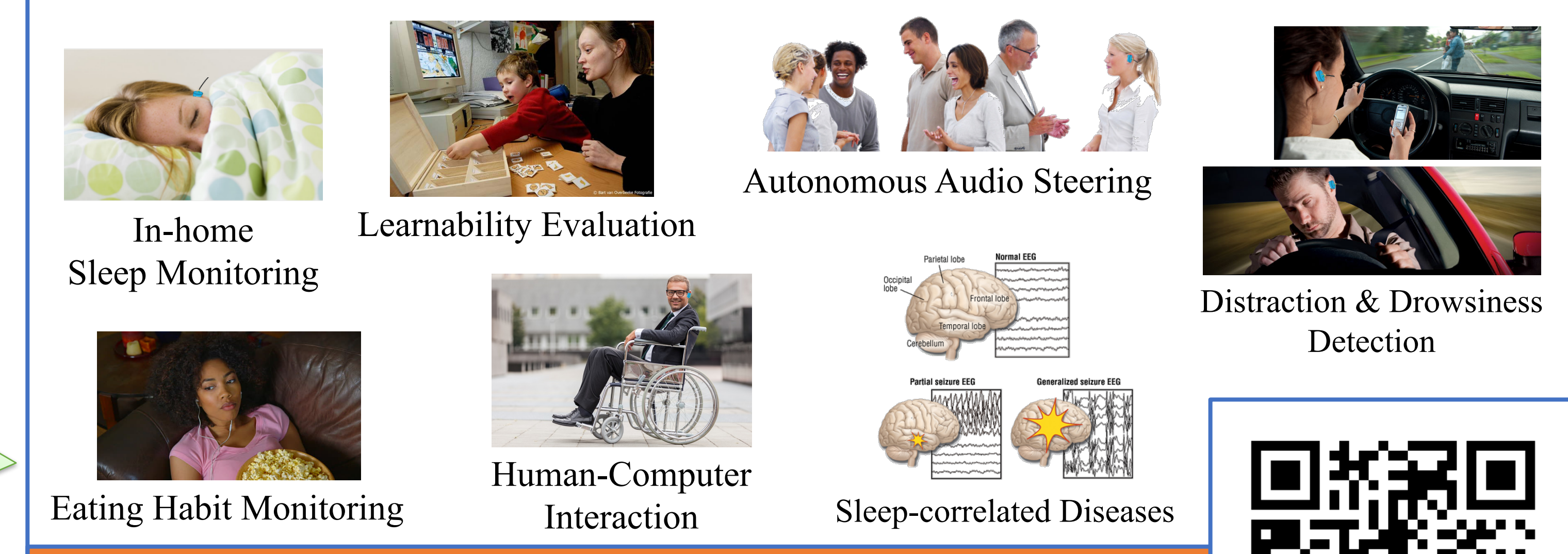


Fig 10. Signal separation performance by LIBS

FUTURE OF LIBS



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