Wearable Device For Long-Term Memory Enhancement

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Objective

Our goal is to develop and validate a non-invasive, sleep-based intervention that enhances memory retention through pink noise stimulation during NREM sleep. The closed-loop system combines a memory assessment app, wearable hardware, real-time sleep stage classification via machine learning, and a user-friendly patch design.

Background

- Alzheimer's disease affects approximately 55 million people globally, with 60-70% of dementia cases attributed to this condition, significantly disrupting sleep-dependent memory consolidation.
- Our study introduces a closed-loop wearable system that enhances memory retention by delivering synchronized pink noise stimulation during NREM sleep, providing an accessible, at-home solution for individuals experiencing early Alzheimer's-related memory loss.

Methods

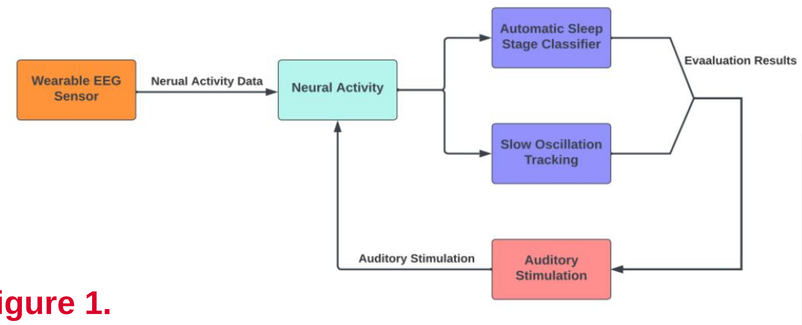

Figure 1.

- Design: A comfortable, biocompatible, user-friendly wearable device designed to ensure restful, uninterrupted sleep
- App: Assesses memory retention of user over a set period.
- Hardware: Records EEG data and shunts it to the cloud.
- ML Model: 30-second epochs into sleep stages using spectral features

Results

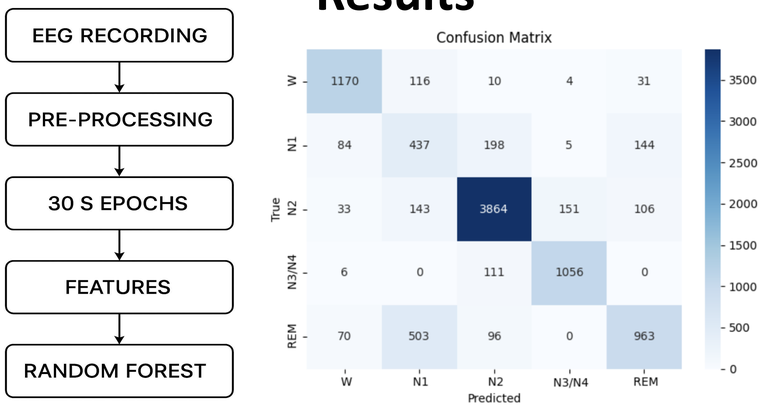

Figure 2. EEG classification pipeline with confusion matrix showing ~80% accuracy across sleep stages.

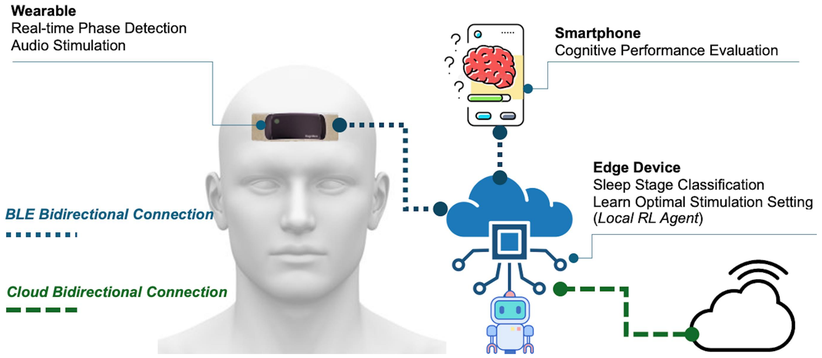

Figure 3. Our wearable device is designed to sit comfortably on the forehead

- Made with biocompatible TPU
- Secured with a TASA adhesive
- Utilizing a three EEG electrode system Fp1, Fpz, and a ground electrode to capture accurate brain activity data

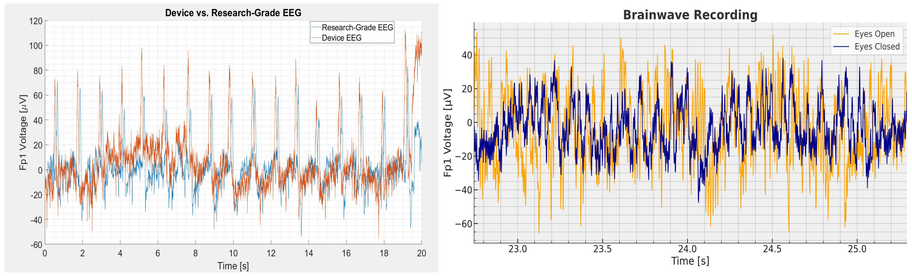

Figure 4. The left graph shows the device EEG closely follows the research-grade EEG signal in both timing and waveform shape, with minor deviations in amplitude and worse noise across a 20-second recording at the Fp1 electrode. The right graph shows the difference in the EEG signals in opening and closing the eyes. The alpha wave band is more pronounced, and the noise is lessened.

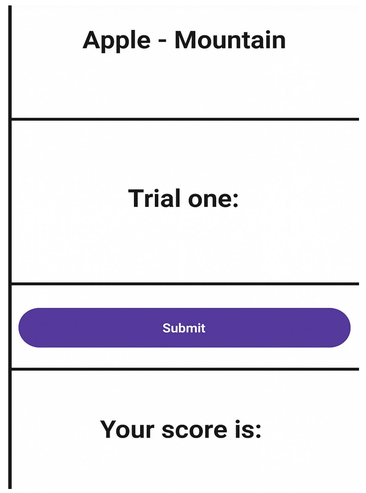

Figure 5. The app assigns word pair memory tasks that are tested on the subsequent morning.

Conclusion

- We developed a sleep stage classifier from scratch, achieving an overall accuracy of approximately 80%. While the results are promising, the model still requires improvement as feature extraction was not fully optimized
- We successfully designed and launched an Android app, with plans to better integrate cloud connectivity in the future.
- Our custom hardware is capable of acquiring EEG signals, though improvements in signal quality are needed.
- The device enclosure was successfully designed and assembled, but further refinement is required to enhance its aesthetic appeal.
- Continued development of both the analysis pipeline and hardware components will be essential for improving performance and usability.

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