Development of an At-Home Wireless Electroencephalogram (EEG) Device

Eric Chen, Shifra Narasimhan, Aaron Rodrigues, Jeremiah Ukwela, Lauren Zukowski
Department of Biomedical Engineering, Case Western Reserve University, Cleveland Ohio 44106

Introduction

- EEG is the most common clinical measure of electrical activity in the brain
  - EEGs are extensively used for neurological diagnoses [1]
  - Clinical trials use EEGs to assess *participant eligibility*
- Limitations of Existing EEG Devices:
  - EEG preparation consists of an iterative application of gel under each electrode; this process takes 30-60 minutes
  - The patient is often left uncomfortable due to gel residue in their hair

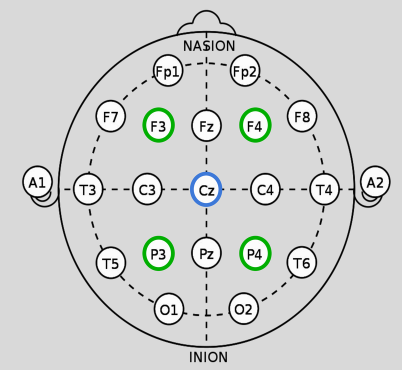

Figure 1: Standard EEG 10-20 electrode designations

Figure 2: Common gel (wet) electrode setup

Objective

Our device aims to simplify EEG recordings used to determine clinical trial eligibility. It enables users with different hair types to self-administer EEG with comfort and ease.

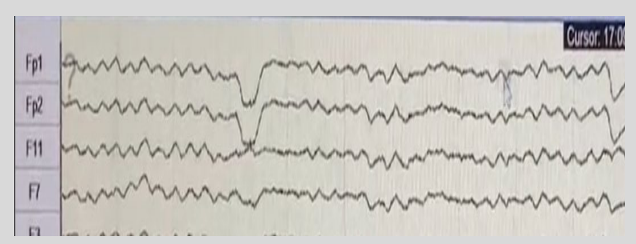

Figure 3: Sample EEG recording from 10-20 System EEG locations.

Results

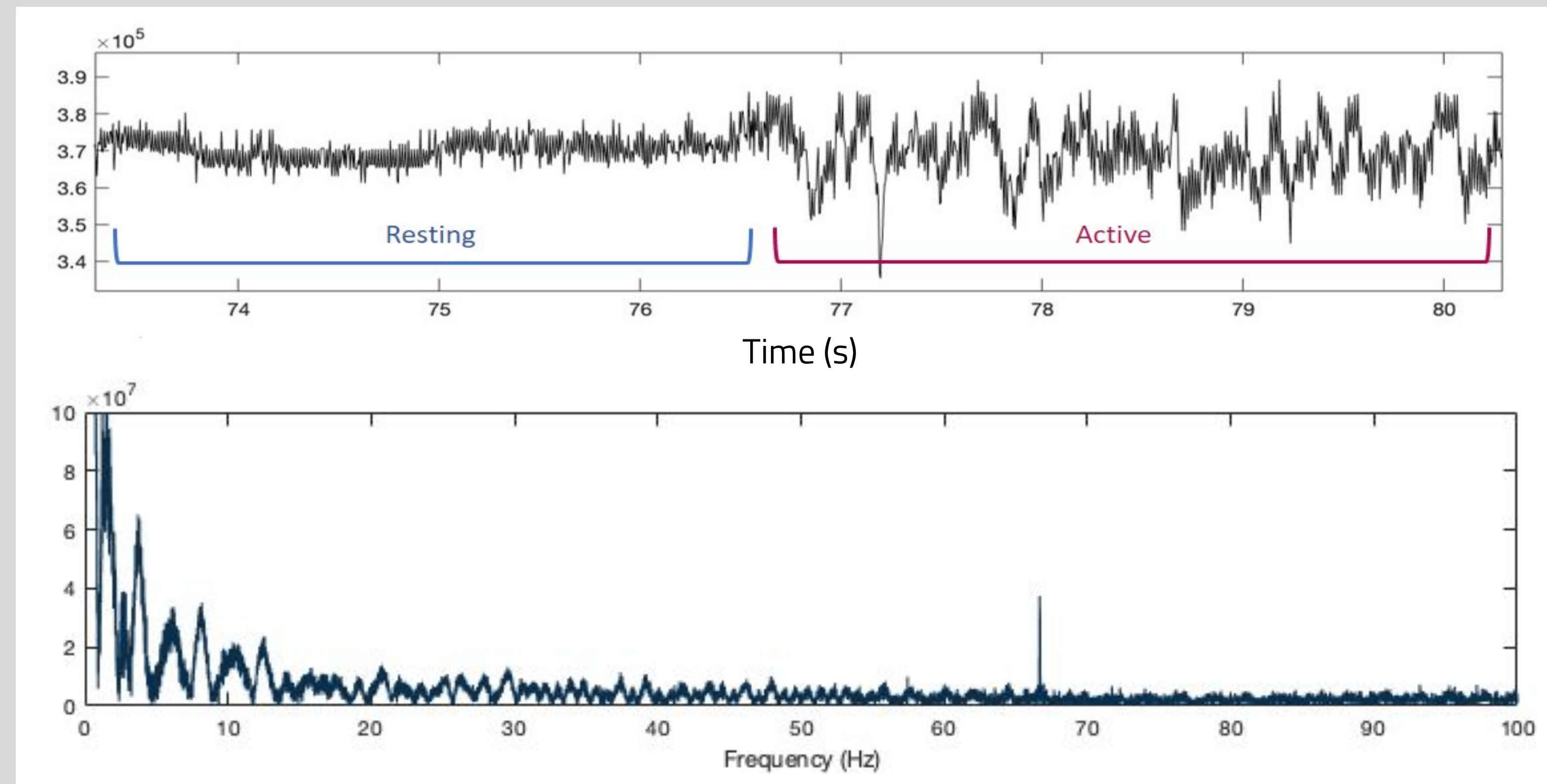

Figure 9:

Top: Raw EEG data from the NOHAmini with resting and active neural activity. The "resting state" is characterized by passive focus and relaxation; the "active state" is characterized by focused thinking and intent to speak.

Bottom: Graph of the frequency components extracted from the raw neural data. We see theta, alpha, and beta waves.

Neural Oscillation Frequency Spectra (Hz):
- **Delta δ (0.1 - 4 Hz):** Non-REM sleep, unconscious state
- **Theta Θ (4 - 7 Hz):** Deep relaxation, meditative state,
- **Alpha α (7.5 - 12 Hz):** Awake, normal, conscious state
- **Beta β (12 - 30 Hz):** Focused, excited, alert state
- **Gamma γ (30 - 100 Hz):** Deep concentration, higher level processing

Verification/Validation

- Data of meaningful reading (alpha, beta, theta waves)
- Comfortability & wearability tests for all head types
- Ability to detect "resting" and "active" brain states (Fig. 9)
- Electrode pressure tested and versatility (different hair types and head shapes). Electrode placement follows 10-20 International System (Fig. 1), specifically F/C locations
- Accuracy (+/- 10%) of EEG signal collected by the device will be tested by comparing signal power with reference data

Future Work

- *Acquire easy, efficient, and accurate* EEG recordings for the detection of neurological risks
- *Integrate a self-guiding phone application* - Associated phone app can guide end user for correct EEG placement (Fig. 8)

Design

- Our design contains a set of 5 dry electrodes [2], a data port, and a mobile device application
- Comb electrodes accommodate different hair styles, and blunt tips promote comfort and wearability [3]
- Mechanisms for noise filtering are built into electrical (Fig. 5) and programming subsystems
  - Instrumentation amplifiers and digital filters are used to pass frequencies between 1 to 100 Hz [4]
  - Audio data from a mobile device is used to identify noise artifacts that may compromise signal integrity
- Data is collected, stored, and prepared for processing and determining clinical trial eligibility

We present the NOHAmini!

NOHAmini

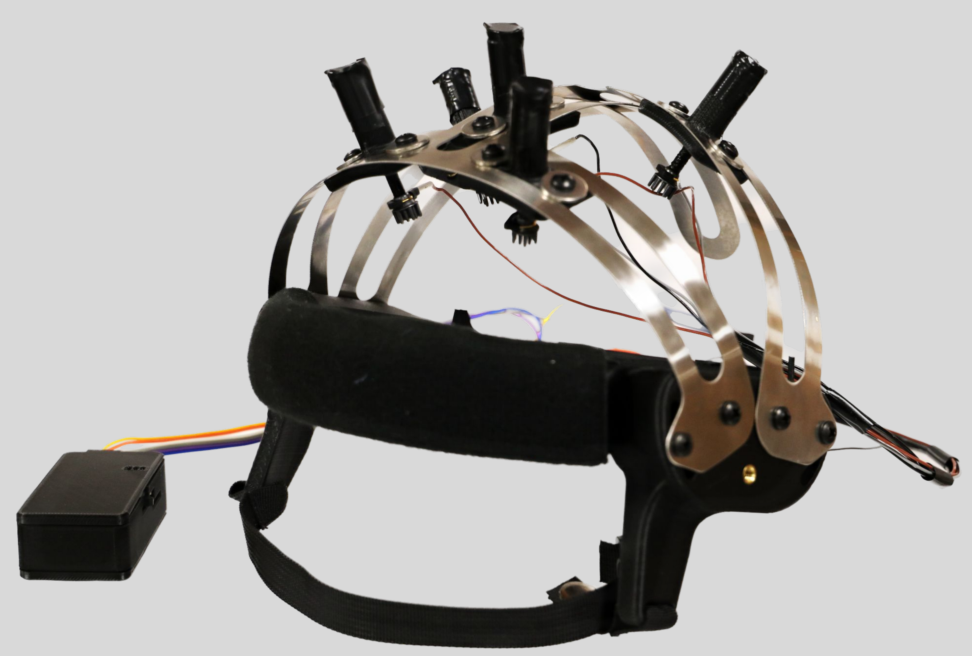

Figure 4: Internals of EEG Headset

Figure 6: Spring electrode design implementation

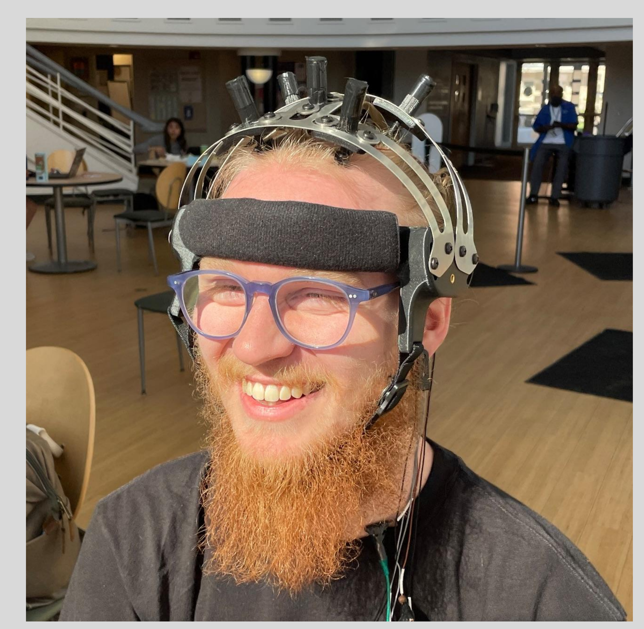

Figure 7: Participant with NOHAmini

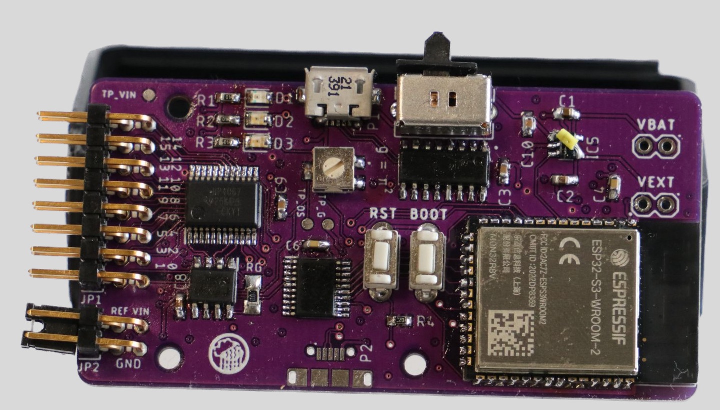

Figure 5: Current iteration of the EEG device (2.72in x 1.38in)

Figure 8: Proposed self-guided application. Instructions for users to put on the cap are provided (A). Electrode alignment is verified (B). Recording is performed (C) before completion (D).

Significance

- Our adjustable bike helmet-inspired cap and spring-loaded dry comb electrodes ensures comfortable at-home usage
- With our signal fidelity, we are able to distinguish between and identify different brain states.

References

[1] Sanei, S. et al. (2007). EEG signal processing. John Wiley & Sons.
[2] Shah, V. et al. (2017). Optimizing Channel selection for seizure detection. *2017 IEEE Signal Processing in Medicine and Biology Symposium (SPMB).*
[3] Hinrichs, H.et al. (2020, March 23). *Comparison between a wireless dry electrode EEG system with a conventional wired wet electrode EEG system for clinical applications.* Nature News.
[4] Arroyo, S. et al. (1992). High-frequency EEG activity at the start of seizures. Journal of Clinical Neurophysiology, 9(3), 441–448.

Acknowledgements

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