Project Proposal by (Student Name):

Validation of a Low-Cost Mobile EEG Device to Increase Diversity, Participation, and Opportunity in the field of EEG

Introduction

Electroencephalography, or EEG, is a technique that measures the electrical activity in the brain, using small metal discs, called electrodes, which are embedded in a cap or net and positioned on the scalp. EEG has been crucial in developing our understanding of the brain and its vast array of functions. Despite its usefulness, the conventional systems currently available to conduct EEG research come with several drawbacks. These include high costs, the need for extensive training, and usage restricted to labs equipped to utilize them (Casson, 2019). The time commitment required for travelling to a research lab and participating in an EEG study can be a barrier for individuals from low socioeconomic (SES) backgrounds who may have work or family obligations. Additionally, the design of electrode nets or caps can potentially exclude individuals with diverse hairstyles/textures as well as those who wear religious hair coverings (Choy et al., 2021; Ricard et al., 2022). These factors of portability, affordability, and accessibility can gatekeep research participation and ultimately hinder the potential of EEG research and application. This issue is especially pronounced in large-scale neurogenomic studies which combine genetic and EEG approaches. These studies require large sample sizes (>1000), yet often fall short in terms of diversity (Sterling et al., 2022). This underrepresentation can lead to biases in identifying genetic risk variants. Certain genetic variants, more common in non-European populations, may be overlooked, affecting our understanding of medication sensitivity and disease susceptibility. This lack of diversity can worsen health disparities and limit our understanding of human health and diseases.

Because of these hurdles, there is a growing concern about the lack of diversity and representation of different SES in EEG research (Penner et al., 2023; Webb et al., 2022). In recognition of these hurdles, there is a burgeoning interest in the field of EEG in portable, affordable, accessible alternatives (e.g., Niso et al., 2023). Some consumer grade EEG devices, such as InteraXon's Muse 2, have been shown to yield promising results for more traditional EEG research purposes (Cannard et al., 2021). This project is designed to address under representation in EEG research by focusing on these alternative EEG systems. It specifically aims at conducting a comprehensive comparison of the Muse 2 headset's performance with that of a research-grade EEG system. The goal is to determine whether this low-cost EEG headset can quickly measure EEG and yield results comparable to those produced by a high-grade EEG system in specific scenarios. This could potentially increase accessibility to EEG studies and diversify the sample population. Inclusion of diverse cohorts who reflect the full range of biologic and health considerations, racial and ethnic identities, and psychosocial and economic factors is not only the ethically appropriate approach but also holds greater potential to advance scientific understanding.

Background

Conventional EEG systems, such as the Geodesic Netstation currently used in my host lab, offer a host of benefits, such as high accuracy, reliability, and a variety of high-channel support. However, they are often expensive and require a controlled environment for accurate results (Casson, 2019). On the other hand, InteraXon's Muse 2 is a consumer-grade, portable EEG system that can record EEG data in various environments. The difference between these two EEG systems and their portability, affordability, and accessibility, could mean the difference in an individual getting to participate in EEG research. There is mounting research that reveals a bias in terms of those afforded the opportunity to participate in EEG research and those who are typically excluded from it. In their 2021 publication, Choy et al. stated, “Black American participants are often excluded in EEG research due to challenges adapting EEG methodology to account for the variations of African hair types of curly and tightly coiled hair” (pp. 16). Webb et al. mirrored this sentiment in their 2022 publication, stating, “Despite their premise of objectivity, neuroscience tools for physiological data collection, such as electroencephalography and functional near-infrared spectroscopy, introduce racial bias into studies by excluding individuals on the basis of phenotypic differences in hair type and skin pigmentation” (pp. 410). Penner et al. found evidence for similar biases in their EEG research on the maternal brain (2022). From specific studies to EEG research at large, it has become increasingly clear that there is a gap in EEG participation and opportunity.

Since January 2023, I have been acting as the lab manager of the Brain and Language Lab (a.k.a. BLL) directed by Dr. Magne. I have acquired the skills to operate the EEG system independently as well as administer several of the behavioral measures used in our research. My duties also include data management, scheduling participants and training new research assistants on the EEG (2 undergraduate and one graduate student so far). I have been actively involved in an NSF-funded neurogenomic research project that collects EEG resting-state and saliva samples for DNA extraction, along with administering various standardized cognitive and language measures. Since beginning my work in the BLL, I have conducted over 35 EEG experiments, and personally witnessed some of the previously mentioned challenges and limitations associated with conventional EEG systems. I have encountered several situations where the EEG net or the environment was not well-suited for the participant. These instances have sparked my interest in proposing an alternative to traditional EEG research. As I progress in my EEG research, my goal is to foster an inclusive environment for all participants, by providing comfortable and accessible EEG opportunities for all who wish to contribute to science.

Purpose

This research seeks to compare resting state EEG data, characterized by spontaneous neural activity when someone is awake but inactive, recorded using a high-grade EEG system (Electrical Geodesic Netamp 400) and a budget-friendly wireless EEG headset (InteraXon Muse 2). The analysis of EEG resting state has gained widespread acceptance and popularity in the neuroscience field because it helps see broad patterns that link biological (e.g., genes) and psychological states with specific types of brain activity (Smit et al., 2021). Resting state data can be recorded with as few as 2 electrodes. The Muse 2, with its portability, affordability, ease of use, and an expanding library of open-source research tools, could enhance the diversity of research subjects, by making EEG technology more adaptable to various hairstyles and accessible beyond the confines of a lab.

The present study is specifically designed to address the following research question: How does the quality of resting state EEG data, captured with the Muse EEG device, compare to the data recorded with the Geodesic system? Based on the previous literature (Cannard et al., 2021; Niso et al., 2023), It is anticipated that the Muse 2 device will yield resting state measurements comparable to those obtained with the Geodesic system. However, It is important to note that low-cost EEG devices may not offer the same data quality or precision as more expensive, research-grade equipment. Therefore, they may not be suitable for all types of studies. It is therefore crucial to understand the limitations and ensure the tool is appropriate for the research question at hand.

Methods

The study is already approved by the Institutional Review Board (IRB protocol 20-2021). Participants (N = 60, aged 18 to 40 years) will be recruited from the MTSU subject pool and the Murfreesboro community. Both EEG systems (Muse and Geodesics) will be employed simultaneously to capture a 10-minute snapshot of each participant's resting state. First, data from each EEG system will be analyzed separately to quantify brain markers typically used in resting state EEG research. These markers are separated by frequency bands: 2-4hz (delta), 4-8hz (theta) 8-12hz (alpha), and 12-30hz (beta). The recorded data will then be analyzed and compared between the two EEG systems using several quality and reliability measures. A resampling analysis approach will also be used to measure the proportion of significant statistical tests for 5000 random samples of the data with sample sizes ranging from 2 to 60 participants.

Collaboration with Faculty Mentor

Throughout the course of this project, I will be the primary investigator. However, I will be working in tandem with Dr. Cyrille Magne throughout every step of the process. This includes, but is not limited to, initial project design, data interpretation, and report creation. Dr. Magne will act as a source of advice, guidance, and direction as I continue my research with him. At the same time, I will continue contributing to his ongoing NSF-funded EEG research. To ensure that our collaboration is consistent, we will be having weekly meetings.

References

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Appendix

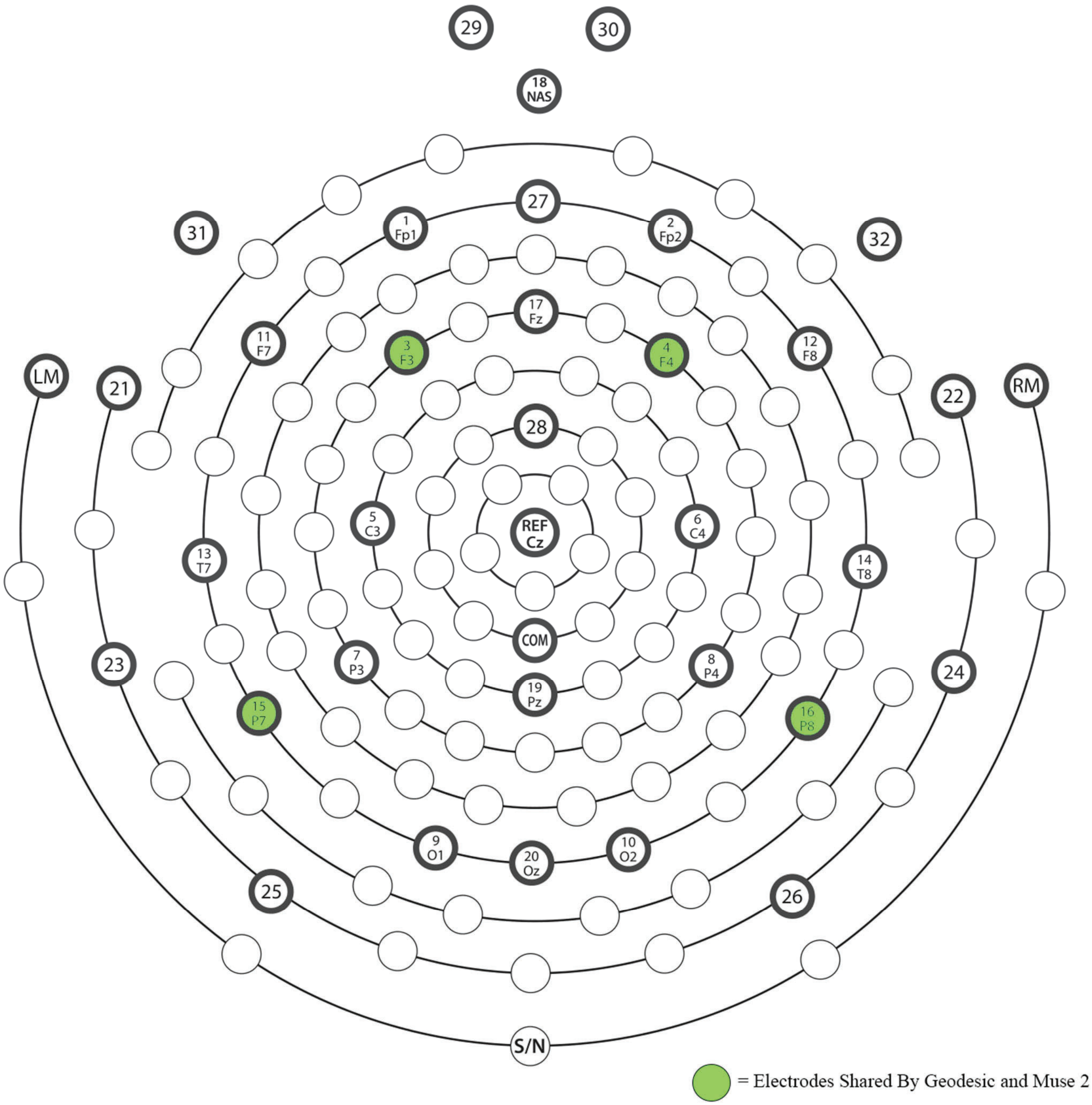
Pictures of the Electrical Geodesic Netamp 400 (All sourced from BLL)

Pictures of the InteraXon's Muse 2

(Source: https://mashable.com/article/muse-2-review)

(Source: https://nymag.com/strategist/article/muse-two-headset-review.html (originally from the retailer)

Electrode Comparison Between Electrical Geodesic Netamp 400 and InteraXon's Muse 2



Project Timeline

<u>January:</u>

Designing the Muse 2's integration into present research

Developing a research pool

Weekly Meetings with Dr. Magne and Bi-weekly Meetings with Research Lab

<u>February:</u>

Testing the newly integrated Muse 2 with numerous pilots

Scheduling participants

Weekly Meetings with Dr. Magne and Bi-weekly Meetings with Research Lab

<u>March:</u>

Initial data collection begins

Weekly Meetings with Dr. Magne and Bi-weekly Meetings with Research Lab

<u>April:</u>

Continued data collection

Weekly Meetings with Dr. Magne and Bi-weekly Meetings with Research Lab

<u>May:</u>

Continued data collection

Weekly Meetings with Dr. Magne and Bi-weekly Meetings with Research Lab

<u>June:</u>

Data interpretation and organization

Preparing for presentations

Weekly Meetings with Dr. Magne and Bi-weekly Meetings with Research Lab

<u>July:</u>

Continued data collection

Presenting my findings

Weekly Meetings with Dr. Magne and Bi-weekly Meetings with Research Lab

<u>August:</u>

Presenting my findings

Weekly Meetings with Dr. Magne and Bi-weekly Meetings with Research Lab