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Diversity and Inclusion in EEG protocol design and recruitment

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ABSTRACT

A recent review of the literature on diversity and inclusion in EEG experiments shows important areas for deepening and improving these trends in ways that are baseline to both protocol designs and subject recruitment. The following report discusses a range of issues relevant to this topic and provides suggestions for implementing diversity and inclusion in more profound ways in future EEG research.

Social psychologist Claude Steele and others have demonstrated repeatedly that stereotype threat – in which symbols and signals of exclusion create negative psychological efforts – measurably impairs learning.

H. Holden Thorp (*Science*, July 8, 2022, p. 129)

Duke University has been fortunate to host one of the Mellon Sawyer Lecture Series (MSLS) devoted to discrimination in fragile and precarious communities for the past 3 years. This series has brought together groundbreaking and inspiring presentations from faculty, scholars, and researchers across a wide variety of academic disciplines in the natural, social and quantitative sciences and humanities, as well as professional schools (medicine, law, public policy, engineering, environment) from over 20 universities and numerous K-12 school systems. While the Mellon Sawyer has endured unique challenges due to the COVID-19 pandemic and more recently endemic, the commitment of colleagues and fellows to the goals of the grant and series was quite astounding.

In the summer of 2022, as a result of a fascinating Mellon Sawyer lecture by Dr. Eric Miller on the importance of diversity and inclusion in neuroimaging research and a subsequent review of the existing published research focusing on this question and EEG, the Andrews Neuro Lab began expanding its research scope beyond structural and functional MRI studies to include experiments and data collection with EEG. The inclusion of electrophysiological techniques provides opportunities for greater "hands on" engagement for undergraduate and graduate students from the Duke FOCUS Program, Bass Connections *Brain & Society* team and Duke at large. The following report is an attempt to synthesize some of our realizations in the process of deepening the analysis of existing research, examine challenges and benefits, and provide suggestions for future directions in experimental and protocol design and subject recruitment.

I. Current Literature on Neuroimaging, Diversity and Inclusion

Our team did a review of the literature on the topic of diversity and inclusion in the design and subject pools in EEG studies, and we were surprised to find that there is relatively little on the subject. Our core findings include seven articles from the period 1993 to 2022 that address recruitment of diverse populations in both general neuroimaging research and EEG research. We discovered that the peer-reviewed journals publishing this research focus in five major areas: Engineering (Cuffin 1993, Etienne et al. 2020, Lehtinen et al. 1996), Public Health (George et al. 2014), Psychology (Habibi et al. 2015), Psychiatry (Losh et al. 2020), and Affective Science (Choy et al. 2022).

While not minimizing the potential and significant effects of implicit bias in research questions and design, we also would like to suggest that there may be some other reasons that impact this issue. First, it is important to acknowledge the central role that *communities of practice* (CofP) critical to cognitive neuroscience research, including neuroimaging, play in what is fundamental to reliable experimental design. McConnell-Ginet (2004) provides an excellent discussion of communities of practice:

> A community of practice (CofP) is a group of people brought together by some mutual endeavor, some common enterprise in which they are engaged and to which they bring a shared repertoire of resources, including linguistic resources, and for which they are mutually accountable ….Communities of practice are not free-floating but are linked to one another and to various institutions. They draw on resources with a more general history – languages as well as various kinds of technologies and artefacts.

Communities of Practice play a central role in how disciplines conduct research and present the core knowledge of the fields represented.

Second, another potential source is discouraging research questions that would seek to explain system-level **variation** across subjects (quite common in fMRI and EEG studies of bi- and multilingualism over the past 20 years). The extensive research data acquired by Dr. George Ojemann and his teams since the 1960s using Cortical Stimulation Mapping (CSM – an invasive form of EEG) show clearly that there is an extensive amount of variation from brain to brain in terms of language mappings (1993, 1991, Calvin & Ojemann 1994, Corina et al. 2010, Serafini et al. 2013). Examples of this avoidance arise in neuroimaging studies that focus on a "where" (not explanatory) instead of a "how" (an explanation) (see Poeppel 2008, Poeppel and Hickok 2004). The impact of a focus on "where" manifests itself at multiple levels -- in protocol design, hypotheses and interpretations of analyzed data (ibid.). Third, the incorporation of more full-brain studies that examine gray matter (fMRI, PET), white matter (cortical and subcortical structural MRI), as well as including imaging of subject groups that is both hemodynamic (fMRI, PET) and electrophysiological (EEG, MEG) will continue to move the field forward while improving reliability and repeatability of experimental outcomes. [For a brief view of different *dynamic recording* imaging technologies, see Andrews 2014: 17.]

Thus, one of the core issues emerging from the review is erroneous applications of *essentialism* and the *essentialization* of subjects (cf. Andrews 2014: 158-163, 203-204). For example, a checklist of gender, age, and handedness often takes precedence over a more nuanced approach determined by empirically rigorous data on what subjects can do. Those communities of practice represented by subjects who have mastered particular levels of skill and proficiency in areas including bi-/multilingualism, musicianship, and other high end sensory-motor activities also have access to behavioral data and tests that can be used in tandem with neuroimaging data.

Specifically, for bi-/multilingualism there exists batteries of proficiency testing that are internationally recognized and used frequently (e.g. CEFR [Common European Framework]). CEFR offers 6 different levels of proficiency across 5 skills for over 40 languages of the world. Rather than eliminating these common checklists, best practices would suggest that it is imperative to include additional behavioral data collected from reliable batteries like CEFR proficiency testing. This problem is not restricted to neuroimaging studies of bi-/multilingualism alone, but can be found across a spectrum of psycho-social-linguo-cultural research involving human subjects. See Andrews (2014: ibid.) for more discussion on these topics.

While we continue to make significant progress in the field of neuroimaging, we have not made comparable progress in incorporating the principles of diversity and inclusion in design and data collection in neuroimaging studies. The take-away message is simple – we need to include structural principles of diversity and inclusion into the experiments from the very inception of protocol development and design.

II. Making laboratory research more accessible to different populations: From students in the lab to research subjects

Ledwidge et al. (2018) suggests a series of best practices for training undergraduate students in laboratory settings. Their suggestions include (1) a realistic time frame for initial student training (between 20-40 hours), (2) clarity in the explanation of research goals, (3) the importance of ongoing training throughout the experience, (4) the writing of a lab manual that is continuously updated, and (5) how students can progress to lab managers after working in the lab for multiple years.

As the Andrews Neuro Lab continues to grow and accept new student trainees specifically in EEG data acquisition and analysis, we take seriously the suggestions given in Ledwidge et al. (2018) and also have developed a framework for training specifically for data acquisition and software analysis using *dry* EEG.

It is important to note the differences between dry and wet EEG, including what the advantages and disadvantages may be. In general, EEG is easily accessible and affordable and is an ideal method for training students interested in beginning their journey in neuroimaging. It is also less expensive than fMRI, PET and MEG. While a "dry" EEG may not provide the same robust "signal to noise ratio" responses compared to "wet" EEG, there are other problems that can arise with "wet" EEG, including signal loss as the gel dries out. Dry EEG electrodes provide better stability. Another big advantage of dry EEG is its portability, thus allowing greater mobility for the subject in between sessions. Finally, subjects with tattoos, metal in the body, or claustrophobia can participate in studies.

Habibi et al. (2015) suggest best practices for recruitment, including special attention to a broader outreach in advertising with community organizations (not just the university itself), clarity in all documentation about the studies, informed consent documents, and building trust between researchers and subjects.

In sum, by increasing the diversity of student, postdoc and faculty researchers trained and active, laboratories open themselves up to building robust *communities of practice* (CofP) that include expertise from different, but related, areas of the cognitive neurosciences, and provide important representation of and access to these CofPs.

III. Specifics of dry EEG hardware and software

Since Hans Berger's 1929 publication, the international neuroscience communities recognized the ongoing electrical charges throughout the brain (Berger 1929). The fields using electroencephalography (EEG) continue to deepen and expand in applications. As discussed above, dry EEG has emerged as a safe and convenient way to collect data with human subjects. Popescu et al. (2007) is one of the earliest studies using dry EEG. In our lab setting during the initial stages of development, we will begin by focusing on a resting state protocol. For data collection, we currently use a 16-channel dry cap with the OpenBCI's Ultracortex "Mark IV" EEG headset and the Cyton+Daisy board. OpenBCI GUI applications with a dongle or Bluetooth connection produces clear recordings. OpenBCI GUI application features also include the following: Accelerometer, FFT (Fast Fourier Transform) plot, the ability to check the signal/impedance within the app, visualizations of band power, EMG, spectrogram, pulse sensor, and the option to design one's own widgets.

We selected for our analysis software NeuroGuide by Applied Neuroscience, Inc. This software creates brain maps and charts that display information and performs a variety of statistical measures and comparisons of alpha, beta, delta, and theta bands both within and between hemispheres. NeuroGuide also removes artifacts, calculates FFT and Z-score analyses, and displays in a 3D cortical surface viewer. The portable, non-medical grade 16-channel dry EEG headset does present some challenges, but does produce reliable data. In the near future we intend to invest in a 64-channel medical-grade dry EEG as we improve student training and create new protocols. Figure 1 shows sample z-scored FFT information from resting state data from one subject.

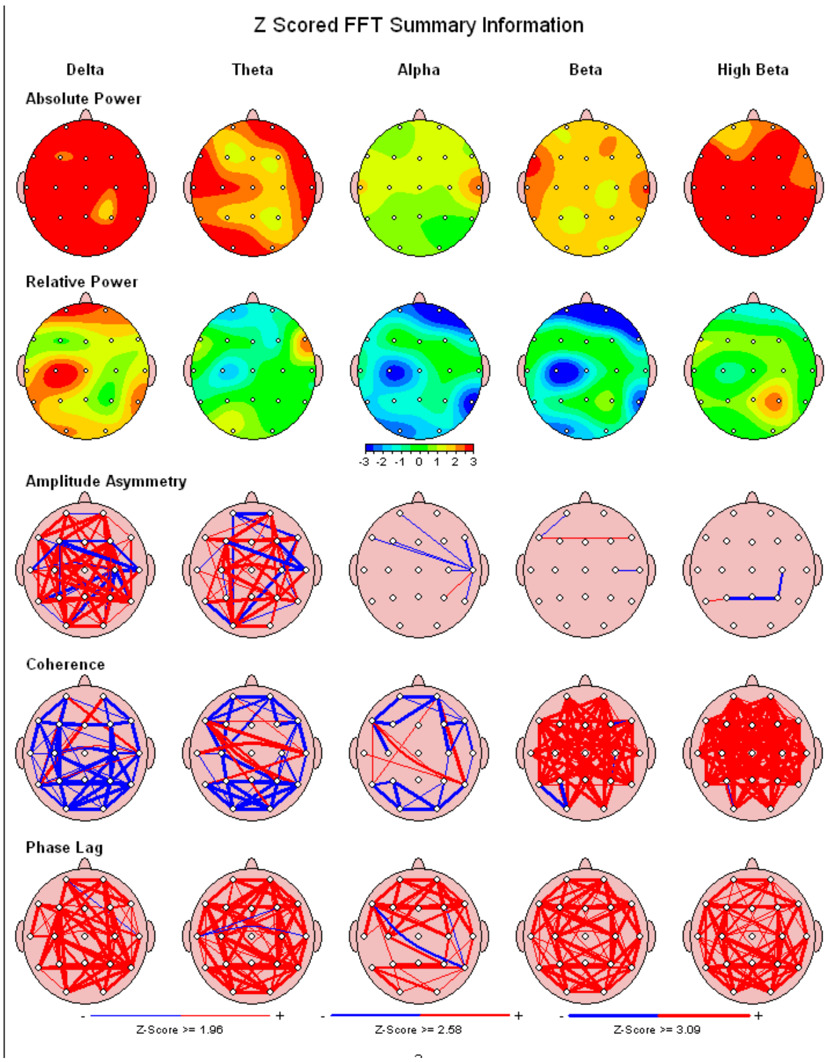

FIGURE 1

(Figure provided by Dr. Eric Miller)

IV. Future directions in protocol design and subject recruitment

As we move forward in our efforts with dry EEG, our lab team is committed to the principles articulated in this brief report. These principles are fundamental to all of our research initiatives and efforts to train new and upcoming scholars in the subfields of cognitive neuroscience and neuroimaging devoted to both multilingualism and musicianship.

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