# EEG and the quest for an inclusive and global neuroscience

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## Abstract

The current lack of diversity in neuroimaging datasets limits the potential generalisability of research findings. This situation is also likely to have a downstream impact on our ability to translate fundamental research into effective interventions and treatments for the global population. We propose that electroencephalography (EEG) is viable for delivering truly inclusive and global neuroscience. Over the past two decades, advances in portability, affordability, and computational sophistication have created a tool that can readily reach underrepresented communities and scale across low-resource contexts—advantages that surpass those of other neuroimaging modalities. However, skepticism persists within the neuroscience community regarding the feasibility of realizing EEG's full potential for studying the brain on a global scale shortly. We highlight several challenges impeding progress, including the need to amalgamate large-scale, harmonized datasets to provide the statistical power and robust computational frameworks necessary for examining subtle differences between populations; the advancement of EEG technology to ensure high-quality data acquisition from all individuals—irrespective of hair type—and operable by non-specialists; and the importance of engaging directly with communities to co-create culturally sensitive and ethically appropriate research methodologies. By tackling these technical and social challenges and building on initiatives dedicated to inclusivity and collaboration, we can harness EEG's potential to deliver neuroscience genuinely representative of the global population.

**Keywords:** Electroencephalography (EEG), Inclusive Neuroscience, Global Neuroimaging, Data Harmonisation, Community Engagement

Much has been written in the social psychological sciences on the problems that emerge from only sampling from WEIRD populations. The fact that most of our understanding of brain structure and function comes from a small segment of the global population is a major cause for concern in neuroscience and brain health research too (Greene *et al.* , 2022). There are clear downstream impacts on translating basic human neuroimaging research into effective interventions and treatments. We propose that scalp-recorded EEG, having recentlt celebrated its centenary (Mushtaq *et al.* , 2024), is one of the most viable tools for delivering a genuinely inclusive and global neuroscience.

The last two decades have seen significant advances in the portability and affordability of EEG, creating new opportunities to reach under-represented communities and to scale across low-resource contexts. For instance, brain clocks from diverse populations, modulated by physical exposome, gender and disease disparities, socioeconomic inequality, and dementia, can be similar—or even more robustly assessed—with EEG than with fMRI (Moguilner *et al.* , 2024). Its non-invasive nature also makes it suitable for a wide range of populations. Yet, despite its potential, the neuroscience community appears skeptical: A recent community survey revealed that many believe we are decades away from EEG being used as a tool across the globe (Mushtaq *et al.* , 2024).

Here, we highlight challenges and suggestions for overcoming the main barriers. We propose a multifaceted approach focusing on (i) the amalgamation of large-scale harmonized datasets; (ii) advances in the technical capabilities of EEG; and (iii) engaging directly with the communities we aim to study and serve.

Many EEG datasets are already available from different parts of the world. But such datasets are nothing if not fragmented. Standardization, e.g., through BIDS, while increasingly common, is far from universal. Indeed, even when the same tasks are being employed to examine the same purported constructs, there can be substantial variation in task parameters. We appreciate the recent efforts in developing benchmark datasets to provide a helpful starting point for comparison and serve as a standard for others to follow (Kappenman *et al.* , 2021). Extending those beyond individual laboratories and across diverse settings will help progress the field.

On the signal processing side, advances in data harmonization can help increase the interoperability and utility of shared data. The HarMNqEEG algorithm (Li *et al.* , 2022) developed by members of the Global Brain Consortium (GBC) provides an example of such an effort. They introduced a Riemannian approach to harmonizing cross-spectral tensor data and demonstrated its utility by connecting 1564 datasets from 14 sites collected over 50 years. Advances in computational methods are also helping to tackle the challenges associated with data diversity- which can accounted for through data augmentation and deep learning techniques incorporating perturbations, biological noise, and multimodal prior information (Ibanez *et al.* , 2024). The use of synthetic datasets can also increase representation of groups, enhancing sensitivity and generalizability (Moguilner *et al.* , 2024). The application of generative biophysical models of EEG can account for heterogeneity and incorporate multiple priors, making the models more robust to individual differences (Coronel-Oliveros *et al.* , 2024). More broadly, probabilistic frameworks including Bayesian and Markov models enable continuous updating of predictions as new individual data becomes available (Ibanez *et al.* , 2024). These frameworks pave the way for large-scale, harmonized databases that can significantly enhance statistical and computational power to understand population differences.

Hardware limitations present another significant barrier. Although EEG technology has become portable, challenges persist in obtaining high-quality recordings from individuals with specific hair types (Bradford *et al.* , 2024). Standard EEG cap designs often struggle to maintain good electrode contact, leading to lower signal quality and frequent participant exclusion. Innovative solutions include comb-shaped "fingered" electrodes that show promise in improving signal quality by better adapting to textured hair (see Choy *et al.* , 2022 for a review of possible solutions).

While progress in hardware is a critical driver in making EEG viable for global reach, affordable, high-density systems suitable for widespread deployment are still lacking. Open-source initiatives and commercially available low-cost devices are positive, but balancing cost, channel number and data quality remains a significant challenge. Similarly, the complexity of operating the equipment, which requires specialized training, must be reduced. The feasibility of conducting EEG studies will be limited in low-resource contexts or environments where trained technicians are not readily available. We need platforms that simplify setup procedures, automate calibration processes, and provide intuitive interfaces facilitating data collection with minimal training.

Engaging directly with under represented communities is crucial. Much of the work in the global north has been collected through convenience sampling – most highly educated individuals from affluent backgrounds. We now have the opportunity and privilege to take EEG out to historically under-represented communities. By involving community members as partners, we can better understand their priorities and inform targeted interventions. Culturally sensitive research practices (e.g., how will you collect data from a Muslim woman wearing a hijab?) and community engagement strategies (e.g., how will you encourage participants to take part in studies when they have much more pressing priorities affecting their daily lives?) will be essential.

Work is already underway to address some of the issues highlighted here. While the present authors perspective may be biased by the projects we are personally vested in, efforts such as the GBC, ReDLat, the Global Brain Health Institute (GBHI), EuroLad EEG, and #EEGManyLabs (Pavlov*et al.* , 2021) provide examples of how international collaboration can promote a more inclusive future for neuroscience. The GBC has been building networks focusing on the unique challenges faced by the global south. ReDLAT, EuroLad EEG, and GBHI have been illustrating the impact of macrosocial factors on brain health (Moguilner *et al.* , 2024). The #EEGManyLabs initiative is demonstrating the power of multi-site collaboration, providing a model for achieving the scale necessary to explore complex questions about brain function. We must build on these foundations and expand them. This will necessitate investing in training, building infrastructure, and making multi-site international collaboration the norm rather than the exception.



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