100 years of EEG for brain and behaviour research

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Standfirst (360 characters): On the centenary of the first human EEG recording more than 500 experts reflect on the impact this discovery has had on our understanding of brain and behaviour. We document their priorities and call for collective action focusing on validity, democratization and responsibility, to realise the potential of EEG in science and society over the next 100 years.

On 6 July 1924, psychiatrist Hans Berger found himself in an operating room in Jena, Germany, with the neurosurgeon Nikolai Guleke. Here, Berger made the first recording of spontaneous electrical activity from a human brain, which would lead to the development of modern electroencephalography (EEG; see Box 1). One hundred years later, we surveyed over 500 experts from over 50 countries (https://www.eeg100.org/survey), asking them to reflect on the impact of EEG on our understanding of brain function and dysfunction and where the community should prioritise efforts to maximise the impact of EEG. We also prompted them to speculate on EEG's evolving role in neuroscience and society for the next 100 years. Our commentary draws upon these responses and ends with a call to action, pushing for collective action to realise EEG's full potential.

History & Impact

In an era where physiologists worked at the level of cells and fibres, placing two electrodes on the brain's surface seemed an absurd endeavour. Berger, engaged in a lifelong search for biomarkers of "mental energy", was undeterred and, after years of toil, he made his breakthrough.

While 1924 marked the year of discovery, a self-doubting Berger did not publicly reveal it to the world until 1929[1]. In the intervening period, he undertook hundreds of experiments, extending his observations from direct recordings from the brain to the scalp. While the scientific community hesitated to embrace the discovery, the popular press wasted no time, coining the term "brain script" ("Hirnschrift") to describe the waveforms captured by Berger's galvanometer. Public discourse in the Weimar Republic reflected their excitement, with fantastical ideas on its potential—from telepathy to judging a horse's temperament[2]. Perhaps, above all, the discovery brought an expectation that this unprecedented empirical access to a living human brain might help unravel the mysteries of the mind.

It was, however, left for Lord Adrian, Nobel laureate and physiologist extraordinaire, to turn the scientific doubters into believers. Together with B.H.C. Matthews, Adrian replicated Berger's experiments in 1934[2], lighting the torch for a new field of study. Soon after, new laboratories started pushing boundaries. The neural characteristics of sleep were quickly defined, with Einstein as a famous subject in these early studies[2]. Similarly, epilepsy, previously seen as a personality trait, was repositioned as a disorder of electrophysiological brain activity. This work, pioneered by William Lennox, and Erna and Frederic Gibbs, was a considerable success for developing biomarkers of neurological disorders[3]. Quantitative analysis of EEG (qEEG) was born when Mary Brazier and Norbert Wiener modelled the EEG as a stochastic process using analogue computers[3]. These approaches were quickly superseded by digital computers, which opened the way for evoked potentials, (time-)frequency analysis, artifact rejection, and progress on topics currently popular such as brain age and normative modelling.

Reflecting on its history, our survey respondents reported that clinical diagnosis is where EEG has had its most significant impact. Today, EEG is supported by well-established scientific and professional societies that foster its use across the globe[4]. Indeed, it is often the only neuroimaging modality available in resource-limited clinical settings and remains the only imaging modality shown to be successful for mass screening of brain dysfunction[5].

Figure 1: An EEG recording in 2024.
An illustration of a young participant wearing a modern wireless headset recording EEG outside of the laboratory in a school classroom setting. The signal displayed on the screen, repeated across rows, is an adaptation of an early recording taken by Hans Berger from his son Klaus[1], showing a sinusoidal 10-Hz activity, which he referred to as the “alpha rhythm”.

Box 1. What is EEG?

Electroencephalography (EEG) is a non-invasive neuroimaging technique used to record electrical activity of the brain via electrodes placed on the scalp. The recorded signal, the electroencephalogram (which shares the acronym EEG), is the product of synchronized synaptic activity in populations of cortical neurons (pyramidal cells organized along cortical columns). Voltage fluctuations at each electrode site reflect a differential measurement between the active and reference electrodes that is amplified and recorded as an EEG trace. These electrical changes can be captured with high temporal resolution, offering a window into the time course of brain activity in the submillisecond range.

EEG has proven particularly useful in a clinical setting because certain cases of abnormal brain function evoke relatively consistent EEG patterns that can be detected. Such applications have been facilitated by quantitative EEG (qEEG), the application of mathematical techniques to extract numerical features of the EEG trace to support signal interpretation. EEG traces provide a canonical test for epilepsy and can be used to identify sleep problems, determine whether the brain is alive or dead, or probe certain disorders of consciousness. Visual evoked potentials have been used in diagnosing multiple sclerosis, a disorder that leads to demyelination, and auditory evoked potentials detect abnormalities in the hearing of newborns.

By time-locking the signal to a response or an external stimulus and averaging the signal over many trials, the neural activity that is specifically related to the sensory, motor, or cognitive event that evoked it can be extracted. This technique is regularly applied in studies monitoring brain maturation across development, in mental ill health and examining neural change following behavioural and pharmacological treatments. In academic research, EEG, through averaging the signal, and more recently, single trial analysis, has been used extensively to explore fundamental questions related to cognitive processing, including in the study of attention, emotion, memory, and decision-making.

With its portability and low cost, EEG is increasingly being used in real-world settings, with communities and in environments where other neuroimaging tools are either too expensive or logistically impractical. Commercial applications leveraging EEG are also on the rise, making brain monitoring accessible to the public. Its integration with other technologies including artificial intelligence and virtual and augmented reality is creating new possibilities to interact with the digital and physical world. Advances in brain-computer interfaces (BCIs) show EEG can be used to control prosthetics and communication devices, to deliver neurofeedback training and promote physical rehabilitation.

The Future

To predict EEG's impact over the next century, we generated a list of potential developments, breakthroughs, and achievements, covering what we assumed to be critical to progress through to the highly improbable. Our respondents gave an estimate of when (if at all) each statement would be fulfilled.

Responses suggest that most predictions will be realised within the next couple of generations **(Figure 2)**. Some near-term ambitions have already been fulfilled within specific quarters. For example, EEG contributes to the diagnosis of sleep disorders and there are established standards and automatic analysis approaches for some clinical applications[3].

Other predictions seem only a few years away. The idea that consumer-grade hardware will become common, and that EEG could be used for reliable detection of brain abnormalities and pharmacological interventions are ostensibly within reach. Personalised neuromodulation therapies also seem a promising avenue for improving brain function in disease and accelerating learning and skill acquisition in healthy individuals. Moreover, there is an expectation that progressive diseases including neurodegenerative dementias, which initially manifest at the synaptic level, will find in advanced EEG techniques a tool for early detection.

As expected, the two boldest predictions, deciphering the contents of dreams and reading the contents of our long-term memory from EEG, elicited the most pessimistic responses.

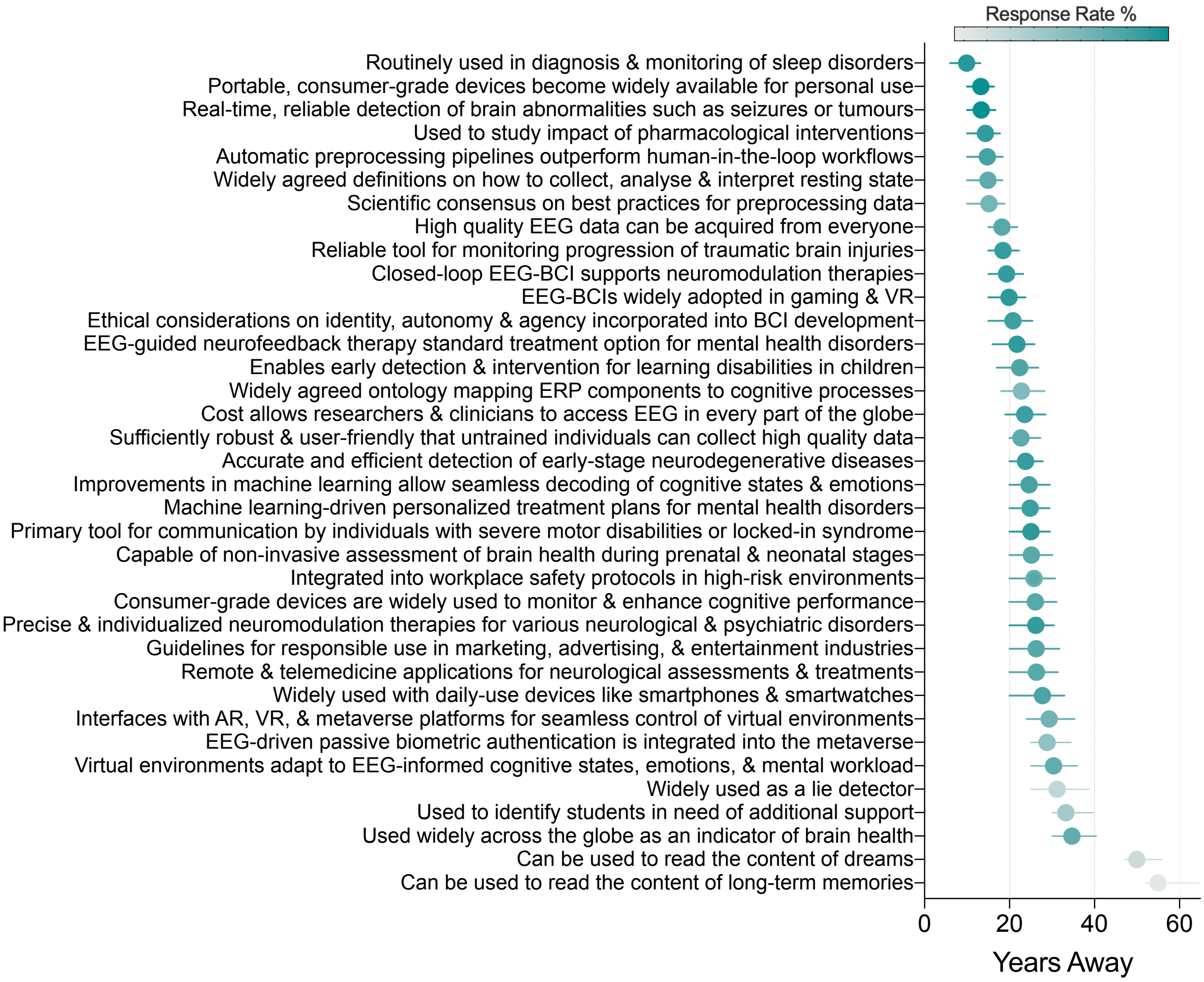

Figure 2: Predicting Future Milestones of EEG

Survey respondents (n = 515, from 51 countries) with 6,685 years of collective experience rated when the EEG community might widely accept the listed statements as being achieved. Here we present rank-ordered median averages of all responses (error bars represent 95% confidence intervals of the mean). Statement labels are shortened for presentation (see[6]). Participants could opt out of making predictions if their uncertainty was too high. The percentage of response per statement is indicated by colour, ranging from teal (88%) to light grey (37%). Stratification of predictions by respondent characteristics is available through our web application (https://www.eeg100.org/survey/).

Priorities

Another objective of the survey was to identify the priorities of the EEG community for guiding future efforts.

All our proposed priorities reached a median rating of at least moderately important (**Figure 3**). Of these, improvements in qEEG tools (artifact cleaning, recording hardware, and analysis software) ranked highest. Standardisation emerged as another urgent priority, with a need for consensus on the protocols used for data acquisition as well as for signal processing and data analysis in basic and clinical science. Hardware manufacturers and software developers have an important role to play here, with interoperability across devices and packages needed to support the adoption of standards.

We propose that these priorities, together with the above predictions, should form a roadmap for the coming decades: technological advances will need to go hand in hand with community-agreed standards to optimise the future of EEG.

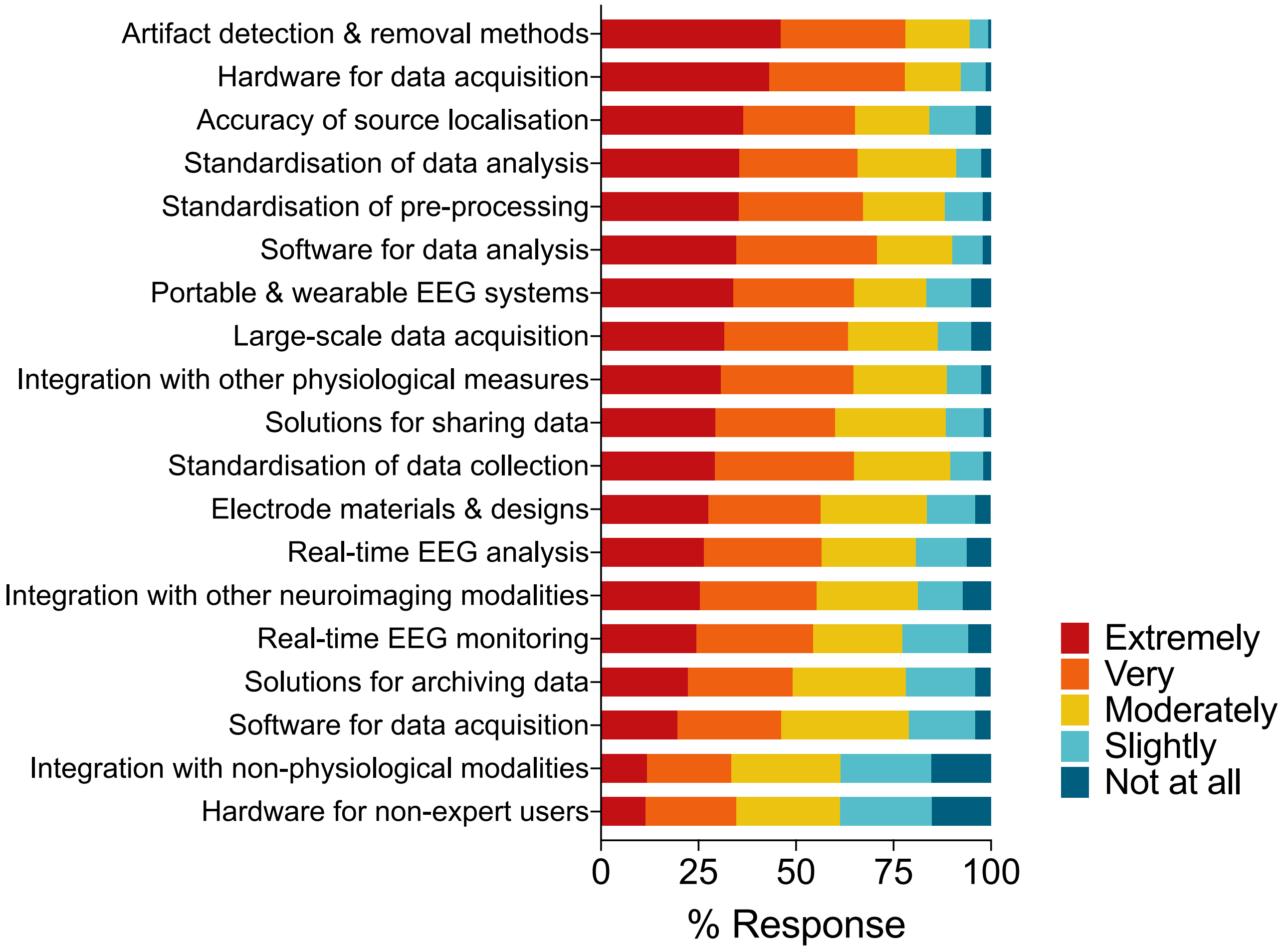

Figure 3: Priorities for Progressing EEG.
Participants rated how important major developments and advancements in various domains of EEG research would be to their work. The priority list is ordered by the frequency of "Extremely Important" ratings.

A Call to Action

In addition to rating priorities and estimating predictions, we also invited survey respondents to offer their insights through free-text responses. Their comments indicate a degree of optimism that emerging technologies are opening exciting new possibilities for EEG. Increasingly affordable hardware, coupled with advances in AI, virtual reality, and brain-computer interfacing, holds immense potential for advancing our understanding of brain-behaviour relationships. These technologies could also fundamentally transform our interactions with the physical and digital world and contribute to addressing the global burden of brain disorders[7]. However, there was also a sense of frustration with slow progress. Although our respondents were generally confident that EEG's low cost, non- invasive nature, portability, and temporal resolution will secure its long-term future, it is striking that the development of EEG-based biomarkers for global brain health was seen as a more distant possibility. From the free-text responses, we also heard concerns—ranging from a lack of adherence to agreed standards and protocols for clinical and scientific practice to ethical questions created by novel commercial applications and the lure of 'neuroenhancement'.

We propose that for EEG to survive and thrive deep into the 22nd century and beyond, right now we must focus on the following aspects:

(i) **Validity**, established by ensuring our work is robust, reliable, replicable, and as reproducible as possible in both basic research and clinical settings;

(ii) **Democratization**, delivered through recognizing the importance of diversity of data to advance fundamental neuroscience and automation of processes to support the development of inclusive health policies;

(iii) **Responsibility**, considering issues of equity in access, privacy, and sustainability.

We elaborate on this manifesto below.

Validity

EEG has already proven its worth in several clinical settings. However, the lack of large open datasets annotated by experts has hindered the development and validation of new automated techniques and splintered the consolidation of research findings (but see[8]). In other fields such datasets have provided a foundation for machine learning and the application of AI—developments only starting in EEG. In research, large-scale investigations of EEG phenomena are underway[9]. Clinically oriented efforts, hampered by the progressive loss of clinician-academics specialising in EEG, are needed to generate large reproducible datasets that will be central to improving the diagnostic accuracy of new methods to address some of the highest priority items identified by our respondents. As such, it is surprising to see mixed perspectives towards open science practices. Solutions for sharing and archiving data ranked low but such efforts will be central to realising the most urgent priorities of improving methods and developing standards that are widely adopted.

We recommend:

- Pooling resources to generate large annotated open data repositories to facilitate discovery science and improve diagnostic applications.
- Continuing and accelerating community-driven efforts to implement standardised protocols for data collection, processing, and analysis to support reproducibility and improve replicability.

Democratization

Despite EEG being the most widely used direct measure of brain function, it is still not accessible to most of the world[4] and much of the scientific data come from a small number of countries and a small section of the population from therein. The EEG community, as elsewhere in science and society, is beginning to recognise the limitations that this lack of diversity brings. Recognizing the potential for bias, we sought to distribute the survey as widely as possible by extending beyond our personal networks, asking societies and device manufacturers to distribute the survey to their mailing lists to ensure broad and diverse participation. Despite this, the demographic of our final sample is noteworthy: most respondents work in universities in North America or Europe while lower and middle-income countries are poorly represented, participants in senior positions are generally male and only few participants are clinical workers or hard- and software engineers. If our sample is a reasonable reflection of the demographics of the EEG community, then such underrepresentation could have potentially negative consequences for the scientific and clinical importance of EEG, from understanding fundamental processes to interventions and evidence-based health-related policies[10].

The good news is that the field is well-positioned to tackle these challenges. Devices are becoming cheaper, more portable, and user-friendly. This is allowing scientists and clinicians to engage with communities traditionally excluded from EEG research. AI-driven automation, based on large representative datasets, could also help overcome the substantial barriers to accessing training and expertise to support interpretation in clinical settings. We believe these innovations will be important drivers in the acceptability and inclusivity of future applications of EEG and are excited by their potential to support our understanding of mechanisms of brain function in health and disease that represent all of society. The time is ripe for growing a more inclusive and diversified field of neuroscience.

We recommend:

- Leveraging the affordability and portability of new EEG devices to work with minoritised communities.
- Supporting international collaborations, networks and initiatives that can facilitate the global expansion of clinical and research activity; foster training programs, and resource sharing to build local expertise and infrastructure.

Responsibility

Ongoing and potential future developments also raise new ethical questions that resonate with pressing societal challenges. EEG has significant promise as a tool for supporting the delivery of population brain health for all[5]. Moreover, our collective predictions suggest that EEG may become embedded in everyday commercial technology within a generation. Concerns around cognitive freedom and mental privacy must be addressed through regulation that prioritises protection from harm without limiting the benefits of open data[11].

With the expected proliferation of large-scale data that new low-cost and easily accessible consumer-oriented devices will bring, we must also consider the environmental costs of large-scale data acquisition (including waste management) and computing resources required for storing and processing those data and arrive at an approach that supports the long-term sustainability of our planet.

We recommend:

- Funders, institutes and individuals advocate for the development and use of environmentally friendly technologies and methods for data acquisition, storage, and processing, as well as for sharing and reuse of already recorded data to minimise EEG's ecological footprint.
- The development of ethical guidelines and regulations to support equitable access to brain data as well as the protection of sensitive personal information.

Next Steps

While it is unlikely that any of the current authors will be around to evaluate the success of our predictions in one hundred years, we trust that the present work and accompanying survey data will serve as a time capsule in the scientific record. At the same time, we recognise that these results capture only a partial picture of perspectives. We welcome more: as a homage to the years between the discovery and public release, the survey will remain open for the next 5 years and responses will be made publicly available. As we move through this fourth industrial revolution, we hope this will provide an outlet for new and seldom-heard voices to share their hopes, concerns, and priorities.

More immediately, we invite the full spectrum of the neuroscience community—from academic, clinical and industry settings—to take up our call for action and commit to promoting robust, ethical, inclusive, and sustainable practices that will help realise a century of potential for EEG in science and society.

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References

1. Berger, H. Über das Elektrenkephalogramm des Menschen. *Arch. Für Psychiatr. Nervenkrankh.* **87**, 527–570 (1929).
2. Borck, C. *Brainwaves: A Cultural History of Electroencephalography*. (Routledge, Abingdon, 2018).
3. *Niedermeyer's Electroencephalography: Basic Principles, Clinical Applications, and Related Fields: Sixth Edition*. (Wolters Kluwer Health, 2012).
4. Bringas-Vega, M. L., Michel, C. M., Saxena, S., White, T. & Valdes-Sosa, P. A. Neuroimaging and global health. *NeuroImage* **260**, 119458 (2022).
5. World Health Organization. *Measures of Early-Life Brain Health at Population Level*. https://www.who.int/publications-detail-redirect/9789240084797 (2023).
6. Welke, D., Mushtaq, F. & van den Bosch, J. #EEG100: Supplementary Materials. osf.io/qv38p (2024).
7. Steinmetz, J. D. *et al.* Global, regional, and national burden of disorders affecting the nervous system, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet Neurol.* **23**, 344–381 (2024).
8. Beniczky, S. *et al.* Standardized computer-based organized reporting of EEG: SCORE – Second version. *Clin. Neurophysiol.* **128**, 2334–2346 (2017).
9. Pavlov, Y. G. *et al.* #EEGManyLabs: Investigating the replicability of influential EEG experiments. *Cortex* **144**, 213–229 (2021).
10. Webb, E. K., Etter, J. A. & Kwasa, J. A. Addressing racial and phenotypic bias in human neuroscience methods. *Nat. Neurosci.* **25**, 410–414 (2022).
11. Jwa, A. S. & Poldrack, R. A. Addressing privacy risk in neuroscience data: from data protection to harm prevention. *J. Law Biosci.* **9**, lsac025 (2022).