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One hundred years of EEG for brain and behaviour research

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On the centenary of the first human EEG recording, more than 500 experts reflect on the impact that this discovery has had on our understanding of the brain and behaviour. We document their priorities and call for collective action focusing on validity, democratization and responsibility to realize 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) (Fig. 1, Box 1). One hundred years later, we surveyed over 500 experts from over 50 countries and asked them to reflect on the role EEG has played in our understanding of brain function and dysfunction, and where the community should prioritize efforts to maximize the future impact of EEG. We also prompted them to speculate on the evolving role of EEG in neuroscience and society for the next 100 years. Our Comment draws upon these responses and ends with a call to action that pushes for collective action to realize the full potential of EEG.

History and impact

In an era in which 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.

Although 1924 marked the year of discovery, a self-doubting Berger did not publicly reveal it to the world until 1929 (ref. 1). In the intervening period, he undertook hundreds of experiments that extended his observations from direct recordings from the brain to the scalp. Although the scientific community hesitated to embrace the discovery, the popular press wasted no time and coined the term 'brain script' (*Hirnschrift*) to describe the waveforms that were 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 to unravel the mysteries of the mind.

However, it was 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 (ref. 2) and lit the torch for a new field of study. Soon after, new laboratories started pushing boundaries. The neural characteristics of sleep were quickly defined; Einstein was a famous participant in these early studies[2]. Similarly, epilepsy, which was previously seen as a personality trait, was repositioned as a

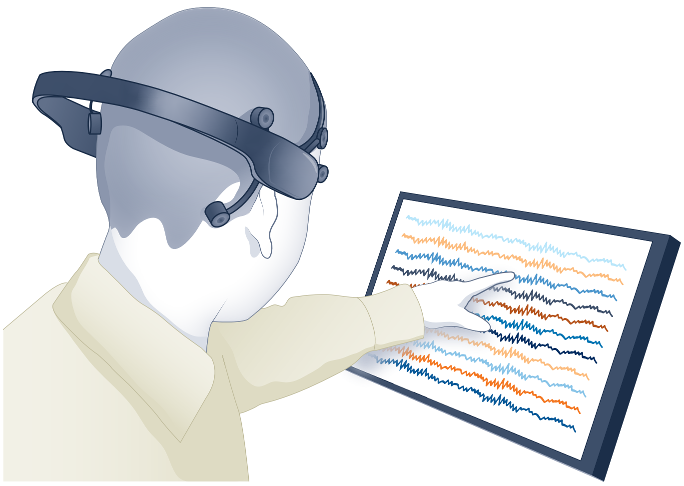

Fig. 1 | An EEG recording in 2024. An illustration of a young participant wearing a modern wireless headset recording EEG outside of the laboratory in a school classroom setting in Bradford, UK, in 2024. The signal displayed on the screen, repeated across rows, is an adaptation of an early recording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

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 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, spectral and time–frequency analysis, artefact rejection, and progress on topics that are 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 substantial impacts. 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 that has shown to be successful for mass screening of brain dysfunction[5].

The future

To predict the impact of EEG over the next century, we generated a list of potential developments, breakthroughs and achievements that covered 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 realized within the next couple of generations (Fig. 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

BOX 1

What is EEG?

EEG is a non-invasive neuroimaging technique used to record the 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 and offer 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, 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 that monitor brain maturation across development, in mental ill health and in examining neural changes following behavioural and pharmacological treatments. In academic research, EEG — through averaging the signal and 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 that leverage EEG are also on the rise and are making brain monitoring accessible to the public. Integration of EEG with other technologies, including AI and virtual and augmented reality, is creating new possibilities to interact with the digital and physical world. Advances in brain–computer interfaces show that EEG can be used to control prosthetics and communication devices, to deliver neurofeedback training and to promote physical rehabilitation.

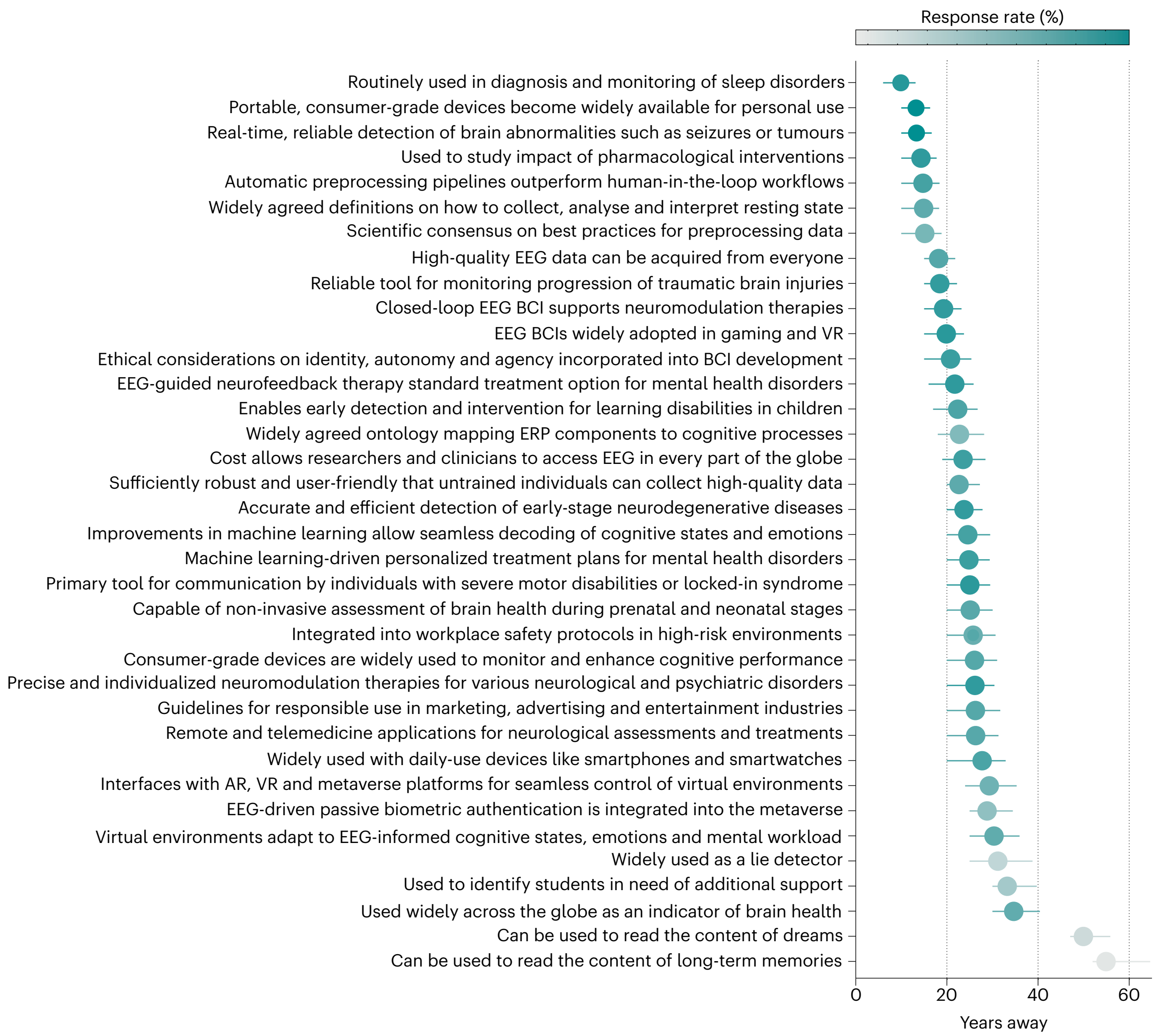

Fig. 2 | Predicting future milestones of EEG. Survey respondents ($n = 515$, from 51 countries) with 6,685 years of collective experience rated when the EEG community might widely accept the listed statements as being achieved. Here we present rank-ordered median averages of all responses (error bars represent 95% confidence intervals of the mean). Statement labels are shortened for presentation (see ref. 11 for full labels). 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. AR, augmented reality; BCI, brain–computer interface; ERP, event-related potential; VR, virtual reality.

interventions are ostensibly within reach. Personalized 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.

Priorities

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

All of our proposed priorities reached a median rating of at least moderately important (Fig. 3). Of these, improvements in tools for the quantitative analysis of EEG (artefact cleaning, recording hardware and analysis software) ranked the highest. Standardization 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 part to play here, as interoperability across devices and packages is 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 optimize the future of EEG.

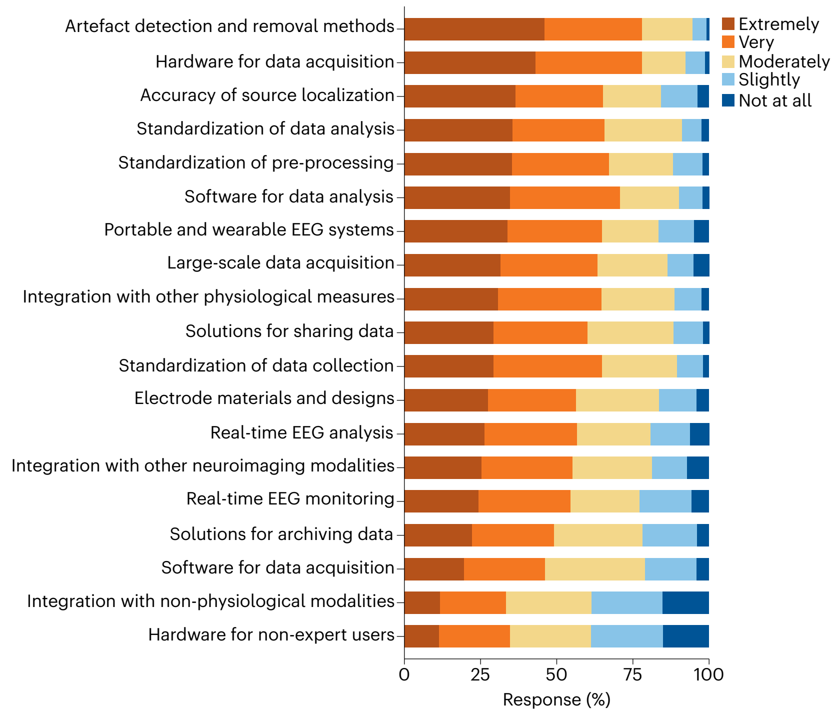

Fig. 3 | Priorities for progressing EEG. Participants rated how important major developments and advancements in various domains of EEG research would be to their work. The priority list is ordered by the frequency of 'extremely important' ratings.

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 up exciting new possibilities for EEG. Increasingly affordable hardware — coupled with advances in artificial intelligence (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[6]. However, there was also a sense of frustration with slow progress. Although our respondents were generally confident that the low cost, non-invasive nature, portability and temporal resolution of EEG will secure its long-term future, it is notable 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 that ranged 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:

(1) Validity, which will be established by ensuring our work is robust, reliable and replicable, and as reproducible as possible, in both basic research and clinical settings
(2) Democratization, which will be 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
(3) Responsibility, which will be achieved by 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 (see ref. 7 for a standardized terminology for reporting clinical EEG). In other fields, such datasets have provided a foundation for machine learning and the application of AI — developments that are only starting in EEG. In research, large-scale investigations of EEG phenomena are underway[8]. Clinically oriented efforts — hampered by the progressive loss of clinician–academics who specialize 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 realizing 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 standardized 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 in most of the world[4] and many of the scientific data come from a small number of countries and a small section of their populations. The EEG community, as elsewhere in science and society, is beginning to recognize 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, and 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, and lower and middle-income countries are poorly represented; participants in senior positions are generally male; and only few participants are clinical workers or hardware 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[9].

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 enabling scientists and clinicians to engage with communities who have traditionally been excluded from EEG research. AI-driven automation – based on large representative datasets – could also help to overcome the substantial barriers to accessing training and expertise to support interpretation in clinical settings. We believe that 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 minoritized communities
- Supporting international collaborations, networks and initiatives that can facilitate the global expansion of clinical and research activity, and foster training programmes 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 shows substantial 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 prioritizes protection from harm without limiting the benefits of open data[10].

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:

- That 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 the sharing and reuse of already recorded data to minimize the ecological footprint of EEG
- 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

Although 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 recognize 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 five 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 to realize a century of potential for EEG in science and society.

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References

1. Berger, H. *Archiv f. Psychiatrie* **87**, 527–570 (1929).
2. Borck, C. *Brainwaves: A Cultural History of Electroencephalography* (Routledge, 2018).
3. Schomer, D. L. & Lopes da Silva, F. (eds) *Niedermeyer's Electroencephalography: Basic Principles, Clinical Applications, and Related Fields*, 6th edn (Wolters Kluwer Health, 2012).
4. Bringas-Vega, M. L., Michel, C. M., Saxena, S., White, T. & Valdes-Sosa, P. A. *Neuroimage* **260**, 119458 (2022).
5. World Health Organization. Measures of early-life brain health at population level. *who.int* https://www.who.int/publications-detail-redirect/9789240084797 (2023).
6. GBD 2021 Nervous System Disorders Collaborators. *Lancet Neurol.* **23**, 344–381 (2024).
7. Beniczky, S. et al. *Clin. Neurophysiol.* **128**, 2334–2346 (2017).
8. Pavlov, Y. G. et al. *Cortex* **144**, 213–229 (2021).
9. Webb, E. K., Etter, J. A. & Kwasa, J. A. *Nat. Neurosci.* **25**, 410–414 (2022).
10. Jwa, A. S. & Poldrack, R. A. *J. Law Biosci.* **9**, lsac025 (2022).
11. Welke, D., Mushtaq, F. & van den Bosch, J. #EEG100: supplementary materials. *OSF* https://osf.io/qv38p (2024).

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Competing interests

M.G.M. is CEO of Xiberlinc Inc., a neurotechnology company. D. Coyle is founder and CEO of NeuroCONCISE Ltd, a wearable EEG company. R.K.M. is a shareholder in RBM Healthcare Ltd and an advisory shareholder for Opto Biosystems Ltd, a neurotechnology company. The remaining authors declare no competing interests.