

SCIENCE, TECHNOLOGY AND CULTURE, 1700–1945



Brainwaves

A Cultural History of Electroencephalography



Cornelius Borck

Translated by Ann M. Hentschel

Brainwaves

In the history of brain research, the prospect of visualizing brain processes has continually awakened great expectations. In this study, Cornelius Borck focuses on a recording technique developed by the German physiologist Hans Berger to register electric brain currents; a technique that was expected to allow the brain to write in its own language, and which would reveal the way the brain worked. Borck traces the numerous contradictory interpretations of electroencephalography, from Berger's experiments and his publication of the first human EEG in 1929, to its international proliferation and consolidation as a clinical diagnostic method in the mid-twentieth century. Borck's thesis is that the language of the brain takes on specific contours depending on the local investigative cultures, from whose conflicting views emerged a new scientific object: the electric brain.

Cornelius Borck is Professor of History, Theory and Ethics of Medicine and Science and Director of the Institute of History of Medicine and Science Studies at the University of Lübeck, Germany.

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Brainwaves: A Cultural History of Electroencephalography

Cornelius Borck, translated by Ann M. Hentschel

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A Cultural History of Electroencephalography

Cornelius Borck

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Montreal, March 2005

Introduction to the English translation

Brainwaves then and now

Electroencephalography is a diagnostic technology: the recording of brainwaves, i.e. the rhythmic fluctuations in the electrical activity of the brain's neurons. As diagnostic practice, electroencephalography was quickly implemented for testing neuropsychiatric conditions. By the 1930s it had already proved tremendously important for characterizing and differentiating epileptic diseases. Before more advanced imaging technologies became available, the method was also helpful for localizing brain tumors and for investigating disturbances of consciousness. For some of these conditions, electroencephalography is still in use today, for example for the determination of brain death. An EEG, the record of the brain's electrical activity, is a medical and legal requirement for organ transplantation. For other conditions, such as the diagnosis of brain tumors, for example, it has been replaced by other technologies. What can and shall a cultural history of electroencephalography deliver in addition to understanding its use as a particular medical and diagnostic technology? Like other tools, the EEG went through various manifestations and transformations before it was tamed to a diagnostic tool of specified significance. From its very beginning electroencephalography revealed, for example, surprising relations between the physical characteristics of brain activity and mental conditions. The EEG appeared to be situated at the brink of mind and brain, providing promising access to their articulation. The recorded traces showed the undulations of electric activity, but their significance seemed to reach beyond the realm of mere physics into mental life: Intellectual activity replaced the regular oscillations of the idle brain with smaller and more irregular waves. In addition, the distribution of particular wave patterns appeared to correlate in initial findings with personality profiles. The EEG thus provides ample opportunities for a cultural history of brain and mind during much of the twentieth century. And this book shows how this came about.

The invention, construction, development and implementation of a piece of technology is always situated in a specific context of a large array of contributing factors—from the availability of materials and instruments to particularly pressing medical needs or promising research opportunities. In such networks of determining and enabling factors, a tool, a method, an

2 Introduction to the English translation

invention, or a new scientific idea emerges and takes shape along a specific trajectory that does not end with its arrival. Contextualizing science—and in this case a medical diagnostic technology—in such a web of ideas, questions, problems, local spaces, practices, and social relations thus allows to reconstruct how the technology was developed in a particular way, how it got used and adapted further by different practices, and how it pushed research, curiosity, medical practice, social institutions, or the health sector in new directions. Science is part of human culture as human culture informs how science is pursued. A cultural history of a scientific artifact must put its development and practice into context. It takes the science, and also the way it is done, seriously in order to explore how science interferes with, and alters, medical conditions, social life, the understanding of the human condition, and in this case, also the more philosophical question of the relation of mind to brain.

In Western societies the brain is a bodily organ with a very particular status. For some two hundred years, research has advanced the brain to the status of central organ for the control and execution of human activities. The American President George H. W. Bush expressed this specific status eloquently when he announced the final years of the twentieth century as the *Decade of Brain*: “The human brain, a 3-pound mass of interwoven nerve cells that controls our activity, is one of the most magnificent—and mysterious—wonders of creation. The seat of human intelligence, interpreter of senses, and controller of movement, this incredible organ continues to intrigue scientists and layman alike.”¹ In the meantime, more research efforts have been concentrated on the brain, of which the two flagship projects—the American *Brain Initiative* and the European *Brain Project*—are only the two largest and most recent. In a way, the trajectory of the scientific and public interest in electroencephalography has paved the way for the current role and activities of the neurosciences. The case of the EEG thus indicates that the brain attracted massive research interests already during the 1930s when electroencephalography was developed and introduced as a research technology. Because this technology delivered fascinating and unexpected findings, indicating imminent insights into the mechanism of mental processing, the EEG provides a rich case for studying the cultural investment in brain research in relation to scientific practice.

EEG research as part of scientific culture

The discovery of regular brain rhythms in the idle brain and their disruption by mental activity made headlines in the international press in the year 1930. Even the *New York Times* contacted the German neuropsychiatrist

1 George H. W. Bush, Presidential Proclamation 6158, 1990, www.loc.gov/loc/brain/proclaim.html.

Hans Berger to get first-hand information from the man who had worked so hard and long before he discovered the EEG.² The EEG provides a case where cutting-edge research and public interests intertwined heavily, thus opening an important nexus for a cultural history of science. In fact, brainwaves had not been cutting-edge research before their discovery. The technique of simply attaching two electrodes to the head for capturing some activity from the myriad nerve cells inside the brain had been regarded ridiculously naive in light of the then recent advances in neurophysiology. Back in the 1920s, neurophysiologists had just begun to dissect the signaling code among nerve fibers and nerve cells. Recording electricity from the brain as a whole using just two electrodes, regardless of the individually active nerve cells inside of it, was regarded utterly useless and far away from the meaningful biological signals, in particular when it was done with the electrodes attached to the outside of the head with the skull in between. Berger, however, searched almost desperately for bodily correlates of psychic activity and he had pursued this line of research by various means with little success. Electric potentials had shown promising data but he had encountered many obstacles and hesitated to publish, before, eventually, his second paper made headlines in 1930. After his publication of the EEG, prominent neurophysiologists such as Edgar D. Adrian repeated his experiments and wondered why they had not undertaken them in the first place, as they could have done this much more swiftly and easily than their German colleague who had pursued experiments along a rather outdated research program. Sometimes the most compelling research does not come from the most prominent research laboratories but from unexpected quarters and hitherto neglected corners. A cultural history of science is particularly suited for mapping and exploring such different temporalities of research trajectories and for evaluating the cultural differences among concurrent lines of research.

Berger's arrival at the EEG and its public recognition, however, was just the starting point for its implementation as a diagnostic technology as well as for the history of the electric brain. The second important question, dealt with here after the reconstruction of its emergence, is the path opened up by the EEG for further research. Here my research revolves particularly around the question of how the findings, shaped and formatted by the recording technology, transformed the culturally valid understanding of the brain's functional organization and of mental work. With the help of the EEG and the demonstration of electric brain activity, the brain started to be seen as an electric machine. In all likelihood, this idea would have hardly kindled much interest among researchers and the public alike had there not been contemporary developments leading to the construction of the first "electronic brain" at the end of WWII: the computer. The exchanges between these two arenas

2 Berger declined the request as he was going—once again—through a period of self-criticism and uncertainty about the validity of his findings (see p. 112).

4 *Introduction to the English translation*

flourished, although hardly any neurophysiological details served as a blueprint for the construction of these machines. Instead, the two camps both embraced quickly the revolutionary mindset of cybernetics as the new science of control and communication, and inspired the public to conceive of the brain as an electric machine in a world full of technological and scientific promises. Together with the computer, EEG research helped to push cybernetics as an interdisciplinary approach to its recognition as bridging between teleology and determinism, linking basic research with social studies and engineering.

The EEG traveled widely and in many different directions, but it did not do so on its own or simply by way of the powers of new scientific truths. The initial stir in the press about the EEG as a mind-reading device won the method recognition beyond the expert cultures of neurophysiology where it had been met, initially, with skeptical criticism because of its unclear neurophysiological basis and the crudeness of the approach. The tide turned after a Nobel Prize winner repeated and confirmed Berger's experiments, and Adrian did so with great fanfare in an experiment on himself. Now, many groups in many countries started with the new method, spreading the technology across the globe (though primarily among the global North), thereby moving the technology step by step closer to, and more into, their own research domains—an adaptation process that mirrored the attraction of initial results for very different audiences and scientific fields. From neurology and psychiatry to general medicine, from cybernetics to social relations, from educational pedagogy to personality studies, from esoteric hopes for rhythmic realities to marketing and branding activities, the EEG became an open research technology with great potential. The new and exciting technology produced more and more evidence about mind and brain, it promised insights into fundamental aspects of human life, intellectual ability, emotional content, and social performance—or simply kindled some more profane business ideas: Perhaps there was scientific evidence for the perfect relaxation that a new and comfortable chair offered, or for the psychophysiological effects of decaffeinated coffee?

In light of its many applications, the EEG remained a sophisticated piece of technology with a very specific window of research opportunities. The EEG is not a universal tool for writing the cultural history of the brain, as it provides a very specific focusing lens for an analysis of science in practice and culture. Here, everything is locally shaped and adapted but resonates with wider repercussions. Every detail is a specific research question and at the same time part of some more fundamental idea about mind and brain, human life and intellectual activity. The EEG is a very specific research and diagnostic technology, but as such, and in its specificity, it participated in unique ways in the history of the neurosciences during the twentieth century and thus helped to shape science in this period of increasing dominance of science and technology in society. Compared to the war efforts in technological research and the resulting period of “big science” in physics, the EEG remained a small craft where some specialists worked on their own and even

the larger groups comprised hardly more than a dozen researchers. Searching for the electric mechanisms underlying mind and brain, intelligence and personality turned this area into a much debated and highly visible field, preparing science and culture for the rise of brain research that was to come with the neurosciences. As an archeology of the present in Foucault's sense, this book aims at unearthing some of the pivotal constellations and conjunctions of how the brain moved to center stage of the research landscape for more than merely addressing neuropsychiatric conditions.

Writing and translating a cultural history of electroencephalography

Seeing one's own book translated a decade after its initial publication offers the doubled distance of the time passed and the foreign language. The translation has become possible with a prize that selected the book for publication in English and the invitation to include the book in this series, thus alleviating the burden of legitimizing the effort. Revisiting one's own work after more than a decade is always an ambivalent affair. Most of the research for this book was done at the then new Max Planck Institute for the History of Science in Berlin, a particularly exciting place at the time because the Institute had found its first rooms on three floors of the Czech Embassy on Wilhelmstrasse right in the middle of the emerging new capital. The new Mecca for history of science provided endless opportunities for meeting and interacting with scholars and colleagues right in the middle of the reunited and buzzing city; at one time, more than a hundred cranes surrounded the Institute, erecting the city's new center. The excitement about the vibrant developments in Berlin coincided with the thriving academic environment. Overcoming the agony of the cold war, Berlin started to remember its tumultuous past and the cultural exchanges during the interwar period. Discovering the open-mindedness of the first generation of cultural studies by Walter Benjamin, Aby Warburg, Siegfried Kracauer or Ludwik Fleck and connecting them with the French tradition of a phenomenology of concepts along the lines of Gaston Bachelard, George Canguilhem, and Michel Foucault was an intellectual adventure that still continues for me. The Max Planck Institute provided an ideal place to revisit these interdisciplinary reverberations and cross-cultural exchanges, from rationalization to Bauhaus, from the unity of science movement to the crisis of the European spirit, from the biomechanical theater to graphology—and in the midst (at least for me) the search for electric activity in the brain and its meaning.

Methodologically the book aims to weave three frames together, an interest in science as practice and culture based on my own experiences in neurophysiology and electrical recording, the historical epistemology of experimental systems and the specific role of visualizations in brain research, and finally, a media theoretical reflection on the wealth of available archival material in a microhistorical approach, taking the material constraints and

6 *Introduction to the English translation*

opportunities of instruments, preparations, techniques, etc. as the material “a priori” of scientific research—similarly to the way Foucault mobilized discourse as a historical a priori. Triangulating historical epistemology with media theory and archival scrutiny has remained the center of my research agenda. I regard it as a lucky coincidence that I was offered the chance to write this book in an environment of intellectual curiosity and ongoing discussions, while elsewhere the so-called science wars already threatened the playfulness and experimentalism in the still emerging field of cultural history of science. This book has been written in the context of the revived interest in Ludwik Fleck’s socio-cultural contextualization of philosophy of science, bringing the historical epistemology of George Canguilhem in close exchange with Hans-Jörg Rheinberger’s reflections about the material opportunities and intrinsic dynamics of experimental systems. Over the last ten years, scientific practices, technologies of visualization and the material articulation of objects, technologies, ideas, and practices have moved into the focus of historical studies of science. Bruno Latour’s actor-network theory functions as a widely used framework for science and technology studies and German media theory has gained recognition internationally. Also philosophy of science has opened up to practices, materialities, local contingencies, and systemic complexities—all buzzwords of historical studies of science.

The book’s publication coincided more or less with the peak of the renewed debate on mind and brain right after the Decade of the Brain—a debate particularly forceful and widespread in Germany where it spanned from the feuilletons of the newspapers to newly founded centers of excellence in brain research and back to a diversified general audience. This debate propelled scientists like Wolf Singer to the position of humanities editor with the well-respected Suhrkamp publishers, and kindled entire book series, preceding similar public debates in North America or Great Britain, thanks to the Wellcome Trust and the Dana Foundation, for example. In consequence of the emerging public interest in the topic, I was dragged into these debates and started to work on functional imaging, the new visualization techniques replacing electroencephalography and garnering even more public attention.³ Siding with the Critical Neuroscience group, I started to work on the more recent neurosciences and learned how this new work also revived EEG or kindled attempts to combine both methods.

On the occasion of this translation the question arose of how to address the gap between the original German and the new English version, namely: how to address the new developments in the scholarship on brainwaves, the visualization of mental activity, and on brain research in general and whether to contextualize these also in the newly intensified debate on the neurosciences. The history of electrophysiology and electroencephalography is a rather specialized area where historical scholarship can still be surveyed,

3 Cf. Borck 2016a, 2016b.

making it tempting to include at least some references to new literature, to add some new paragraphs or rewrite some passages. Equally tempting was to add a chapter or an appendix discussing the developments “since then,” focusing on neuroimaging and comparing its dynamics with my story on the EEG. This, however, quickly turned out to be an unruly and impossible undertaking as it confronted me with my way of writing from a decade ago and in a specific mode of argumentation which I realized I was unable to emulate again as I had moved on from the situation of pushing for a habilitation, for which the book had been written initially. Any attempt at rewriting the original text and adding new chapters would have resulted in a multiplicity of problems of which the increased terrain to cover would have been only the most obvious. In addition it would have resulted in having the original German and the English translation as two different books.

Discussing the situation with the series editors, we quickly decided to let the text stay and to opt for combining a faithful translation with this new introduction reflecting upon the different context. I want to thank Ernst Hamm and Robert Brain for their initiative and generosity to include this book in their series. Ann Hentschel has provided a translation that found expressions for my thoughts in the English language beyond my imagination. Staff and personnel at Taylor & Francis and Routledge guided me smoothly through the publication process. The new cover illustration shows the recording of an EEG in a photograph taken by Robert Doisneau in the year 1958 that captures in a nutshell the promises and complexities of the brain’s electric writings. I thank his agency for the permission to reproduce the photograph here. Unfortunately, there is no further information available regarding the circumstances of the recording or the persons involved. I would be most grateful for any hints and details.

The ongoing dynamics of brain research

The neurosciences are an incredibly productive field. There is massive investment in brain research. The advances in brain imaging are just the most prominent; equally important are new approaches from molecular biology, genetics, and the information sciences. The neurosciences were already a flourishing area when the book was originally published, though in retrospect, this was just the beginning. Meanwhile, the neurosciences rival molecular biology and genetics as dominant research fields in the life sciences and, in addition, there is a lot of cross-fertilization. Declaredly, the neurosciences now hold the “opportunity to unlock the mysteries of the brain” (Office of the White House, April 2, 2013) and to find the clue to crippling diseases such as Alzheimer’s. Research technologies in the neurosciences are malleable tools for finding in the brain persuasive answers to extremely heterogeneous questions on physiology or language, thinking and feeling, culture and biology, and even history or aesthetics. Brain research thus amounts to a collective effort to cultivate and animate the brain.

8 *Introduction to the English translation*

With the turn into the twenty-first century, the life sciences have arrived at the status of big science, hitherto reserved for physics or genetics. The American government and the European Union, respectively, have started the *Brain Initiative* and the *Human Brain Project*, competing mega projects to map entire brains in full detail. The size of these projects matches that of CERN in terms of personnel, complexity, and investment. Like the human genome project, however, these new initiatives coalesce around a common goal, not a singular research site. Instead, the new research is dispersed among a globally distributed network of research teams, each working locally on their parts of the shared project. The network is the new working model of brain research. The projects are organized in research networks, the brain itself is conceived as a densely woven network of active neurons (and many more participating cells), and the Internet serves as a live model of an interactive infrastructure processing information. Models and metaphors have guided brain research during all its different periods, and the models have evolved over time, reflecting changes in technology, as will be demonstrated here with some of the models instrumental for the electric brain. Models and metaphors thus point to the cultural fabric of which brain research forms an active part. These exchanges do not stop with scientific advances, as new technological developments provide new models. The rise of network theory together with the implementation of the Internet is just the most recent example.

This is hence a timely coincidence for the publication of the English translation. As an archeology of the electric brain, the book focuses on the local settings in which the new research technology emerged. It identifies the cultural resources and technological models on which this research drew and traces the wider resonances the new findings inspired in terms of the theorizing about mind and brain. If the English translation now helps to put more recent developments into historical perspective, more has been achieved than the author can hope for. Along this trajectory of the ongoing dynamics of brain research, one difference in the theorizing about the brain stands out by historical comparison: For the largest part of the twentieth century brain theory had conceived of the nervous system as a stable and hard wired structure once its development finished with adulthood—just like the computer. Learning and memory perfected the system but did not change the underlying structure. In fact, a whole series of technological objects was employed to explain the (relative) stability of memory mechanisms as the late Alison Winter has admirably shown.⁴ Today and in light of new evidence about ongoing plastic changes, however, neuronal theory conceives of the brain as a constantly evolving system—like the Internet. The concept of the plastic brain in a rapidly changing world is perhaps the most striking feature of the new neurosciences.⁵

4 Winter 2012.

5 Rees 2016.

While this co-evolution of the brain, contemporary (technoscientific) culture and brain theorizing is still so recent a process that any conclusions would be premature, other developments invite historical comparison: The advent of the new imaging technologies, for example, visualizing the brain at work and picturing differences in cultural patterns and social behavior, fostered the emergence of new branches within the neurosciences such as cultural and social neuroscience. In its beginnings, social neuroscience was harshly criticized as “neo-phrenology,” as a revival of ill-founded social diagnostics, linking behavior to localized characteristics of brain activity.⁶ Fascinatingly, advances in data analysis and display quickly allowed to visualize fiber connections and active networks instead of local centers, shifting the debate from localization to systems. Katja Guenther has recently put this quest for localization or the counter-paradigm of connectionism into sharp historical relief.⁷ The currently emerging debate on proper foundations for cultural neurosciences would certainly also benefit from such a more reflexive approach to the cultural history of the neurosciences.⁸

Such current developments are reminiscent of the repercussions that electroencephalography had once evoked. Back in the 1930s, this earlier visualization technique had also aroused enormous public as well as scientific attention, probably similar to the recent fascination. The role and position of the EEG in the discourse on localization, however, is much less clear. The method recorded integrated signals from the surface of the head, suggesting more abstract approaches to brain theory as exemplified in the concept of the electric brain. Like the social neurosciences today, electroencephalography kindled manifold attempts to apply the new technique to anthropological questions and social problems, because of the correlation with mental processing and because of the initial prospect to identify significant patterns like fingerprints (cf. chap. 5, p. 200). It would be cheap to argue that brain research has simply been there already, and such a cross-cultural statement ignores the historical specificities on both sides. Such similarities across the historical distance offer, however, a valuable opportunity for contextualizing these attempts, for tracing their trajectories and relations to other scientific practices and cultural concepts—and hence for a much more revealing picture. The time difference allows for critical distance, bringing the social significance of the EEG to the fore and unearthing the crucial role of other disciplines and scientific practices involved in this research. Looking at the interplay of physiological research and aesthetics in fin-de-siècle Europe, Robert Brain has recently provided a fine example for such a cultural history

6 Uttal 2001.

7 Guenther 2015.

8 Chiao 2009, Heinz et al. 2014.

of science.⁹ The social and cultural neurosciences are still to await such more careful evaluations.

An overarching feature of the research dynamics in the neurosciences, and the life sciences in general, is the new central role of information technology—pointing to larger shifts beyond technology-specific developments enabling particular scientific advances such as functional imaging or whole-genome sequencing. The new possibilities of data processing in terms of quanta, size, and speed have kindled a debate about a recent paradigm shift with the arrival of “Big Data” and the rise of inductive statistics.¹⁰ With new analytic algorithms, machine learning, and pattern recognition the new information sciences blur the differences between mapping, modeling, and simulation. The open but critical epistemological question is whether the concept of the experimental system (which has proven so productive in reconstructing research in the life science since the nineteenth century) approaches here its limit. In many labs, various robots already do much of the routine work, and software developments from filter algorithms to data visualization shape and format new scientific data. Still, however, only few scientists and philosophers would probably agree that robots do research. The open question is whether the epistemically new, beyond mere new data, still depends on material linkages, technical opportunities, and unforeseen couplings in experimental systems: Does science still rely on the attention of an observing investigator for recognizing potentially productive disturbances, caused by something not yet known, but already there?

The historical example of electroencephalography provides an extreme case at the opposite end: Hans Berger searched for physiological correlates of psychic activity and pursued this goal like an *idée fixe*. This kept him looking where most of his more advanced colleagues in neurophysiology did not expect anything valuable, but narrowed his focus of attention on something inexistent for more than a decade, until he was eventually ready to accept what he observed. Once he published the EEG, newspapers and the public readily embraced his discovery as “brainscript,” the meaningful language of the brain, and invested it immediately with far-fetched hopes. Such rhetoric continues. Recent findings in the neurosciences also attract much attention and appreciative elongation. From “mirror neurons” to the “reward system” or “memory pathways,” many of the most recent concepts fall in the category of mereological fallacy, attributing to a brain part the functions and efficacies of the faculties of an entire brain in a living person acting in social space. The notion of the experimental system anchored such concepts in the realm of material resistances and physical constraints. The new co-evolution of biological and technological information processing lessens perhaps the need for such linkages, blending real with virtual

9 Brain 2015.

10 Mayer-Schönberger and Cukier 2013, Leonelli 2016.

environments in a future of augmented realities. The cultural history of electroencephalography provides a case study of how brain research engages with new technology, inspires scientific experts, and engulfs public audiences and participates in the cultural investment in the neurosciences. Along these material, social, and intellectual linkages, the book opts for the ongoing dialogue, engaging with the neurosciences, society, and history.

1 Electrifying brain images

Dark room of the Psychiatric Clinic in Jena. Double doors shut out noises from the outside. A path-breaking discovery is about to be tested that Professor Dr. Hans Berger, director of the Psychiatric University Clinic in Jena, has successfully performed. It involves the recording of thoughts in the form of a jagged curve, the electric script of the human brain.¹

The brainwave graph—the recording of electrical activity by the human brain by means of the electroencephalogram—was a sensation. Technical progress in science had made possible a technique of downright marvelous qualities. It was neither an invention for everyday convenience, nor a new entertainment medium; one could not even foresee any medical use for it. The technique, rather, promised to provide a scientific explanation for a very special aspect of human life: thinking.

Imagine a person seated in a room, working out an arithmetical problem in his head; wires lead from his brain into another room to a recording apparatus. There one merely sees the zigzag course that an indicator traces on a strip of paper, and yet one knows exactly when the man in the adjoining room has begun to calculate, whether the work is taxing him very much, and when he is finished with the calculation.

The literally fantastic potential of this invention, which in 1930 evidently suited contemporary expectation horizons well, invited speculations that vied to outdo each other: “Today they are still secret signs, tomorrow they may perhaps reveal mental and brain illnesses, and the day after tomorrow, one may even be exchanging personal correspondence in brain script.” At the moment of its first description, the jagged curve was doing the rounds as “secret signs” in a new language whose decipherment seemed imminent—with far-reaching consequences for human self-understanding.

¹ *Stadt-Anzeiger* Düsseldorf, 6 August 1930. The following two quotes are also taken from this source.

This vision did not become reality. Thus far, Hans Berger probably has been one of the privileged few to have ever received a brainwave letter. His American colleague Herbert H. Jasper sent him such a message for Christmas 1938. Even a recipient with little practice in electroencephalography could discern from this rare specimen how the sender's brain initially produced comparatively slow waves, hence was surely in a resting state, before a brief phase of smaller fluctuations in the second row manifested clear activation with distinctly legible signs taking shape, before the activation waves eventually resumed slower oscillations in the last row (see Figure 1). Berger's brainwave curves were celebrated as "electric script" in 1930; however, research on those graphs obviously did not follow this direct path to inscription of a jagged pattern that contains substantial meaning. Generally speaking, some time had to elapse before Berger's fellow scientists began to take any serious interest in brainwaves and the new method for registering them. The, at times, quite fantastical newspaper reports incited skepticism among more critical readers, especially considering that similar sensational reports had always turned out to be quackery in the end. The central role played by electric current in how the nervous system operates had, of course, been known since the great successes of electrophysiology in the nineteenth century. But right after World War I, neurophysiology shifted in the direction of increasingly precise characterizations of the electrical activity of individual nerve fibers and nerve cells. What sense would there be in writing down the total activity of thousands of nerve cells inside the human brain, since very specific functions are ascribable to each area of the brain? Because Berger himself mentioned in his publications encountering problems and interferences, would it not much rather suggest the whole matter was an artifact?

For brainwaves to become an object of scientific experiment, they first had to become connectable to existing research cultures, to serve as their

Christmas Reverie

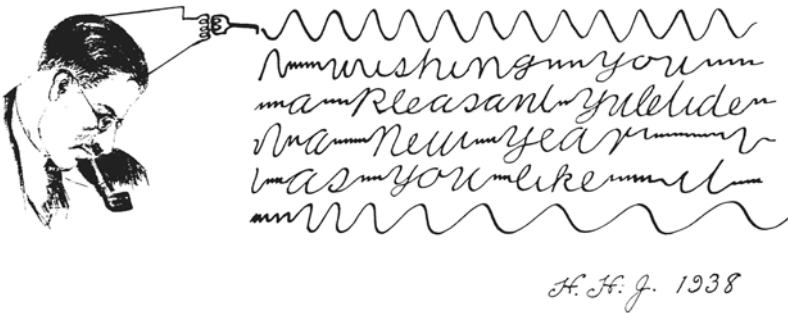


Figure 1 Season's greetings in brain script from Herbert H. Jasper to Hans Berger; card from 1938.

points of departure. The breakthrough for that was the confirmation of Berger's findings by the English Nobel Prize winner Edgar Douglas Adrian in 1934. The electroencephalogram (EEG), the brainwave curve, became recognized scientific fact.² From this moment on, EEG curves and brainwaves began to pose a series of serious questions, on one hand precisely because they fit so poorly in the knowledge about the electrical activity of individual nerve cells; on the other hand, because the curve pattern presented a noticeable correlation with processes of the psyche. Numerous research groups, above all in America, quickly began to specialize in the new method and produced EEG recordings by the meter, so to speak, as "brainwave factories." When clearly pathological curve patterns were also found a short while later, from which a series of brain diseases could be diagnosed with a precision hitherto unknown, this application of the new method grew further. But the more curves were drawn and the longer one labored on deciphering the spikes and waves in the EEGs, the more obstinately they resisted decipherment and insertion into physiological or psychological theories.

The history of brainwaves rather presents itself as a sequence of largely frustrated decoding attempts. Berger failed in his endeavor to pinpoint specific signs of mental exertion. The cartography of the "natural oscillations" (*Eigenströme*) of individual regions of the cerebral cortex done at the Kaiser Wilhelm Institute for Brain Research, in Buch on the outskirts of Berlin, was a stable project only as long as it strictly followed the guidelines of Oskar Vogt's cytoarchitectonic research program. When Adrian found, by electroencephalography, rhythms in the brain that were so idiosyncratic that they threatened to undermine the established theories of neurophysiology, he decided to change his field of research again as a precaution. Jasper maneuvered his experimental system, which had just generated those fine Christmas greetings, into a dead end in the attempt to orient the EEG curves exactly according to electrophysical and cellular processes. Grey Walter hoped to cope with the complexity of EEGs by increasingly refined visualization techniques, and ended up amid machinery instead of coming up with an electrical brain code. After World War II ended, cybernetics funneled research into EEGs for a few years more and it seemed as though a break-through was imminent from designs of electrical brains and psychic automatons. Nevertheless the neurophysiological genesis and psychophysiological significance of brainwaves that the EEG registered so regularly remained controversial.

Nowadays, the key to the brain's operation is scarcely being sought in the conventional EEG that Berger introduced to the public. The "decade of the brain," the closing decade of the twentieth century, impelled an already

2 For a reconstruction of this gradual acknowledgment of electroencephalography, Ludwik Fleck's "doctrine of thought style and a thought collective" (Fleck 1980) still offers a good grid seventy years later; although, the analysis of material cultures of individual experimental systems does leave the scope of his sociology of science.

existing trend toward other visualization strategies. The continually improving performance of computers then made them not only capable of defeating human world champions at chess, but also of filtering out individual intermediary steps of specific signal-analytical processes from EEG curves. The identification of gating mechanisms of individual ion channels advanced neurophysiology ever deeper down into molecular dimensions. Brain research probably celebrated its greatest triumph during these years with the revival of the morphological topographic model, long declared obsolete in the intervening period. New visualization techniques constructed images of the “mind at work,”³ in which the functionally active regions of the brain no longer traced curves but lit up as activity zones. The turn away from paradigms of electrical brain script and the revival of the localization doctrine also left their mark in the naming policy of professional associations and congresses, which dropped EEG in their founding names in this decade so as not to lose touch with more up-to-date research orientations.⁴ The new title widely chosen, “Clinical Neurophysiology,” documents more than just the growing distance from basic research. Rejecting the EEG or electroencephalography was supposed to subsume the old curve inscription under an encompassing context of interdisciplinary research methods; but at the same time it secretly also bolstered expectations legitimately attached to such an enterprise: Nowadays no writing from the human brain is being recorded; there is no prospect here anymore for any authentic script, only for physiology. The name alterations document something of a retraction of an unbacked promissory note that had long been relying on electroencephalography unlocking the mind’s secret by technically objective means.

Thus the EEG has almost become a closed object of research, even though it remains a standard process of neurological diagnostics. Research on the EEG does obviously continue, but something has ceased which is not easily circumscribed. This gap is perhaps the shortest formula for the subject of the present work. The history of brainwaves, constructed along the guiding thread of the development of electroencephalography, localizes the “inscription systems” (Friedrich Kittler’s *Aufschreibsysteme*) of electrical brain script within their material contexts, in order to expose the dynamics and effects of these researches in the interplay between scientific research and culturally determined knowledge production. Scientific research on the human brain as a form of self-enlightenment might have often proceeded historically in an indigenous way but is itself not a naturally given process. Brainwaves were materialized as EEG curves from a complex web of presuppositions,

3 Hagner 1996.

4 In 1995 the American Electroencephalography Society changed its name to American Clinical Neurophysiology Society; since 2001 the international federation convenes as International Congress of Clinical Neurophysiology; the German society went a step further by adding imaging to its name in 1996, as *Deutsche Gesellschaft für Klinische Neurophysiologie und funktionelle Bildgebung*.

groping preliminary trials, and adjustments of experimental arrangements. The nodal points, at which the EEG became an “epistemic thing” (Hans-Jörg Rheinberger) that posed plausible and graspable questions, formed within a broadly spanned net of technical preconditions, apparatus set-ups, and parallel modelings. Research on the curves finally generated phenomena that allowed a space of knowledge to crystallize around the EEG that stimulated new effects. The present cultural history of electroencephalography aims at a precise analysis of the shapability and adaptability of an electrotechnical inscription process in local research contexts, at the knowledge produced there, and at its effects.

A reconstruction of this forming process can thus reveal the historical conditionality of an apparently natural scientific object. The EEG shaped brainwaves into an *electrical brain* that could only partly be brought to coincide with the subjects of other branches of brain research. One important characteristic of this electrical brain was its medial and mediatory position between anatomical findings and psychological observations. Unlike neuroanatomical, electrophysiological, and psychological research, electroencephalography allowed observation of the brain “at work.” The experimental setup seemed to guarantee the feasibility of studying in an EEG mental and psychological phenomena at the site of the event; and thus electroencephalography put the mediation between the brain and the intellect on the research agenda in a new way. One of the reasons why the EEG was lastingly productive for decades, without any consensus being reached on the way the electrical brain functioned, is presumably that the technical circuitry between brain, mind, and machine made technical advancement virtually built-in within this science. More and more feedback loops stimulated the search for technical models which, in turn, gave new impulses to this research on the EEG. From the first electron brains up to the designing of *brain-computer interfaces*, the history of the electrical brain points beyond the period of electroencephalographic research examined here.

Electroencephalography is a case study of the complex history of visualization procedures in brain research. In the last few years the influence of visualization and measurement techniques on the development of the biosciences has become an important area of research analysis in the history of medicine and science.⁵ Numerous case studies have shown how new experimental and instrumental practices formed in specific socio-cultural contexts and how these local cultures, for instance, on the establishment of representational and interpretational conventions, crucially affected the formation and stabilization of new objects of science. Accordingly, representations of scientific knowledge—be they pictorial representations or theories—not only bear superficial traces of their genesis; they themselves are testimonials

5 Lynch and Woolgar 1990, Rabinbach 1990, Rheinberger and Hagner 1993, Howell 1995, Hess 1997, Galison 1997, Gugerli and Orland 2002.

to and products of their developmental contexts. In addition, these contexts of scientific developments, such as new recording procedures, are epistemologically relevant: A substantial part of the reality and validity of scientific theories and objects is explained by their history.

According to Eduard Jan Dijksterhuis, history of the sciences constitutes not only their memory but their epistemological laboratory.⁶ Dijksterhuis was aiming at a rehabilitation of the *context of discovery* as opposed to the *context of justification* (Hans Reichenbach 1938) that had been drawn into the focus of philosophy of science. Only a detailed analysis of the research process within its historical context could provide information about the way scientific rationality operates. *Science in the making* has long since advanced to a central object of study in the history of science with its various thematic and methodological orientations. In this sense this study understands the electrotechnical exploration of the brain and the psyche as a site at which an electrical brain was shaped out of brainwaves. As a historical epistemology of these researches, this study must form its own connection with the epistemological program of the field of expertise; for, brain research already stakes its own claim as an epistemic laboratory. During the nineteenth century, neuroanatomy and neurophysiology were already working on naturalizing the Kantian *a priori* and claimed far-reaching philosophical implications for their research because it was a matter of figuring out the biological conditions of human thought and action. During the 1940s, Warren S. McCulloch coined the unwieldy term “experimental epistemology” for his variant of this project.⁷ McCulloch’s experimental epistemology aimed to explain human thought and action through empirical experiment by a combination of electroencephalography, neurophysiology, neuroanatomy, and mathematical logic. This project could not, however, secure for electroencephalography the role of a *leading science* for the postwar period. It remained attractive only as long as cybernetics could hold the convoked sciences together. Now, fifty years later, a new alliance has formed between cognitive science, philosophy of the mind, and the neurosciences, poised to become the leading science of the mind in the twenty-first century. “Naturalizing the mind” is its program.⁸ Neurophysiological descriptions of the correlates of mental phenomena are supposed to be differentiated enough to attain the status of philosophically sufficient statements. Entirely in the sense of McCulloch’s experimental epistemology, the physiology of human brain functions would thus become a new *Mechanik des Geisteslebens*,

6 Dijksterhuis 1969, p. 182.

7 See McCulloch’s biographical remark in 1948 at the Hixon Symposium (Jeffress 1951, pp. 32f.) and McCulloch 1964.

8 This formulation adopts the title of Dretske 1995; similar titles indicate a trend (Kornblith 1985, Churchland 1989, Petitot 1999).

in which “the laws of thought would reappear in the laws of the world.”⁹ Such a self-enlightenment of the human mind then marked an “epistemic break,” by which the historical relativity of scientific theories, subsumed under this term by Gaston Bachelard, would be alleviated again.

By contrast, this study insists that history cannot be cheated in the epistemic laboratory of brain research, as the lab does not necessarily operate solely within historical time but is itself a product of history. Brain research might well produce fascinating scientific objects and theories according to the modern model of scientific objectivity without having a historically indicated claim to validity; nevertheless, multiple factors outside of the neuroscientific laboratory still decide the adoption or rejection of its background theories.¹⁰ Canguilhem’s historical epistemology sets out from this tense relationship when it, itself, looks at the historicity of scientific rationality:

The word “epistemology” denotes today the estate, not to say the residual stock of that traditional branch of philosophy which the theory of cognition represented. Ever since the relations of cognition to its objects have been increasingly persuasively demonstrated by scientific methods, epistemology has broken away from the philosophical preconditions and has redefined itself; it no longer derives the criteria of scientificity from the a priori categories of reason but from the history of victorious rationality.¹¹

A historical epistemology that inherits the philosophy of a critique of knowledge in this way simultaneously defines anew in what way the history of science is its epistemic laboratory. For, the “history of victorious rationality” is not a series of ever more perfect theories of the world measured against timeless objectivity. *Science studies* have shown how scientific development is embedded in local research cultures, is medially relayed, and intersected by multiple rationalities.¹² From this perspective the results of modern science are no less true than their own claims of offering solutions. But the claim to validity of neuroscientific experimental epistemology itself will become decipherable as the outcome of particular lines of development in research on the brain. In this sense, this *cultural history of electroencephalography* intends to expose the cognitive-critical implications of a historical epistemology of brainwaves. Thus it does not aim at criticism of the neurosciences held up against the scale of an alternative model of the

9 Bachelard 1988, p. 7. Max Verworn named this project “Mechanik des Geistesleben” (the “mechanics of intellectual life”) already in 1907.

10 On this now see Hagner 2004.

11 Canguilhem 1989, p. 88.

12 Representative of a few lines followed in this debate are: Longino 1990, Pickering 1992, T. Porter 1995, Daston 1999. Mario Biagioli (1999) has compiled a collection of guiding papers.

brain. The aim is certainly rather a critique of the hegemonic discourse in the neurosciences. While brain researchers occasionally muse about whether the brain is in a position at all to figure itself out, because presumably a more complex system would be required for that, this study trusts that the cultural context of brain research has always been richer than all the theories of the mind and brain models generated within it.

Throughout the past two centuries, the brain advanced to a central site of scientific human self-examination. This study analyzes the development and dissemination of procedures for the registration of electrical activity in the human brain during the first half of the twentieth century. It centers on the double question of how knowledge about the brain was produced and what effects the answers, concepts, and new questions elicited in this direction of research. Even now the most important persons and stations from the history of electroencephalography form a solid component of a discipline's memory. Yet a history of the knowledge produced there is lacking.¹³ Why would it happen to have been a German psychiatrist, in particular, who published the first EEG? How did this relate to the contemporary fascination with the mysterious effects of novel media techniques? Which coalitions and what constellation could produce out of Berger's observation of brainwaves one of the most active areas of mid-century brain research? How did the constituting of the "normal," or the "pathological" curve patterns intervene in the existing orders of knowledge about humans? In what way, finally, did the electrical brain contribute toward the present trend in the neurosciences or influence their research orientations?

The present analysis starts with a detailed reconstruction of the experimental system¹⁴ in Jena (Chapter 2: *Hans Berger's long path to the EEG*). Berger's publication of the EEG in 1929 was neither the product of a chance discovery nor the result of a research program on brainwaves headed straight for success. It was, rather, situated within the context of Berger's decade-long endeavor to demonstrate processes of the psyche by physiological methods. Since the turn of the century, he repeatedly conducted experiments to prove the existence of his supposed "cortex currents" (*Rindenströme*) whenever his work on other processes, such as the registration of brain volume oscillations or intracerebral thermometry, failed to lead to the hoped-for proof of a special "psychic energy" (*psychische Energie*). Berger set out from philosophical considerations and psychophysiological issues that were essentially determined by nineteenth-century research on the brain.

13 The most important papers on the history of the EEG even now originate from actors, who later became the historians of their field, such as Richard Jung (1963, 1992), Mary Brazier (1961, 1988), or Pierre Gloor (1969, 1974). Exceptions include Breidbach 1997 and Millett 2001a. The comprehensive bibliography on the EEG published by Mary Brazier in 1950 offers an excellent tool for that; Collura (1993) has described the instrumental development.

14 I borrow the term from Rheinberger 1992 and thereby propose its transferability onto another field of scientific laboratory research.

The microhistorical analysis of this experimental system shows how, in a complex and arduous shaping process, Berger's research program gradually had to be adapted to the phenomena recordable by an electroencephalographic experimental setup. In a certain respect, Berger achieved with the EEG the sought-after fame but not the goal of his researches, as—despite its conspicuous psychophysiological regularities—the EEG was not the detector of the psychic energy he was seeking. A consequence of this sobering result was that at the end of his life Berger continued to plan new research projects on the margins of the neurosciences.

The special fascination attached to those EEG researches can only become plausible against the backdrop of contemporary notions about the connection between the brain and electricity. Berger's research on cerebral currents, which could be described as almost solipsistic, contrasted sharply with the multifarious contexts of public controversy over electricity and the psyche, in which the research was embedded despite every attempt to isolate it (see Chapter 3: *Electrotechniques of the live mind*). For that reason the interest Berger encountered upon publication of his curves is significant, not just with respect to the history of its reception. Behind the enthusiasm about Berger's apparatus there appears a participation by the public in scientific debates that contributed decisively to brainwave observation; albeit in the history of science with its focus on academic research it is often neglected. A closer analysis of the contemporary representational methods of psychic things, of modelings of the psychic apparatus as an electric machine, of projects for targeted electrical manipulation of the human being, and of speculations about electrical communication from brain to brain; such an analysis draws our attention to how the electrical brain first took shape as a possible form in the public space. Long before the electrical activity of the brain was graphically registered and scientifically analyzed, the brain had been conceptualized and represented as an electrotechnical installation. In a cultural history of brainwaves, the public space itself appears as a kind of laboratory in which concepts on brain electricity were presented, discussed, and evaluated.

Electroencephalography took shape *alongside* university neurophysiology. The definitely improved technical capabilities to register the minutest bio-electrical signals in discharge-tube technology since the end of World War I would have easily permitted the recording of an EEG. But it was not something "in the air," as a kind of natural extension to and transferral of existing neurophysiological experimental strategies onto the brain. In order for brainwaves to be able to become the object of brain research, the EEG that had been produced in the Jena laboratory first had to be made connectable to already existing research contexts (see Chapter 4: *Terra nova: contexts of electroencephalographic explorations*). This applied to all locations where work on the EEG commenced, albeit each specifically in connection with local research programs. The young physiologist Alois Kornmüller was the first at the Kaiser Wilhelm Institute for Brain Research

in Buch near Berlin to take up Berger's researches. But he was committed to Oskar Vogt's localizing cytoarchitectonic research on the brain. The uniform curve plot of brain activity that Berger was propagating on the grounds of his holistic convictions seemed to make little sense to him. Instead Kornmüller looked for electrical activity in individual regions of the brain, which were supposed to complete the neuroanatomical cartography of the brain by physiological findings. The British neurophysiologist Douglas Adrian, in turn, was neither interested in psychic energy nor in cytoarchitectonic parameters. The challenge that he perceived as posed by the EEG curves was the inability to make them agree with the universal code of short, abrupt signals in the nervous system which Adrian had notably defined. Within a short time following Adrian's reproduction of Berger's curves, numerous other laboratories began to devote themselves to the EEG plots in the middle of the 1930s. Obviously the research conducted by these laboratories was also guided by the research issues they had been pursuing up to then. But the more researchers and groups began to experiment with EEGs, and the more voluminous the published findings became, the farther away electroencephalography removed itself from already established research contexts and the more independently it conformed itself to the observations made by this method.

Perhaps the most striking event in the history of electroencephalography—after the first observation of this curve—was the more or less chance registration of a strongly conspicuous curve pattern from an epileptic patient. The EEG showed a conspicuous distortion in the electrical functioning of her brain. This finding was to develop into the most important area of clinical applications of encephalography. The EEG curves of epileptic seizures afforded, at the same time, a method to objectivize diagnostics—and in more than one respect, at that (see Chapter 5: *Set to and survey much!*). The observed interference in the cerebral electric system totally reshaped the clinical picture of epileptic disorders. A mental disorder that fell within the purview of psychiatry turned into a neurological brain illness. This success set off various biopolitical imperatives. For instance, it motivated healthy family members of epilepsy sufferers as well as many other groups to search for conspicuous EEG patterns. The biopolitical dimension of the new knowledge space gained by electroencephalography manifested itself more drastically in the search for pathological curve patterns from people with personality disorders and likewise from children and juveniles exhibiting abnormal behaviors. Electroencephalography promised to lend a firmer basis to mechanisms of social discrimination by means of neurophysiologically “objective” findings and thus serve to pathologize those groups biologically. Such projects did not always yield the success that their defenders had hoped for; but they did promote the notion that the brain operated as an electrical apparatus that would soon be tackled from an entirely different aspect. The introduction of psychiatric shock therapy to short-circuit the head was the concrete therapeutic outcome of the conception of the electrical brain.

As the ‘knowledge space’ of an electrical brain increasingly assumed concrete form in the area of clinical therapy, the question of what an EEG was actually registering remained open, along with how to interpret it. Projects with novel methods to visualize electrical brain activity were successively launched to solve the puzzle of brainwaves (see Chapter 6: *Designing, tinkering, thinking*). The psychologist Hubert Rohracher, for example, looked for representations of mental processes in particularly rapid oscillations. Alois Kornmüller found in particularly slow oscillations an indicator that the brain was about to shut down; and he planned to turn the EEG into a monitoring device to alert pilots to oxygen deficiency during combat. Norbert Wiener, on the other hand, wanted to regard particularly regular oscillations as the beat of a human’s central computer in operation. Richard Jung surmised that brainwave resonance held the secret to the brain’s self-regulation. Experimental epistemology of research on the brain, with its goal of deciphering the way the human mind functioned out of the findings of neurophysiological brain research, made its first successes in the form of cybernetic theories of the brain that reduced human thought to mathematical functions. Grey Walter designed a kind of “brain television” out of the EEG that sought to visualize the complexity of cerebral processes. The designing and tinkering going on in EEG research produced brain theories by the dozen. This raises the question of whether models made in brain research are not fleeting in principle, because they allow ways of “self-misconception” (*Sich-selbst-Verkennen*, Käthe Meyer-Drawe) to become manifest.

Electroencephalography had fixated on brainwaves as a script and thus related back to a long tradition of graphic procedures in physiology. Visual representations have been propagated in the sciences since the nineteenth century with the rhetoric of representing Nature herself without any disturbing intervention by human actions, ranging from her own self-portraiture in photography to her self-inscription in the curve plots of instrumental physiology.¹⁵ Étienne-Jules Marey offered his well-known argument that his *méthode graphique* was a direct rendition in Nature’s own idiom.¹⁶ At the same time, it was beyond question that such a “self-representation” by Nature could only happen via technical media. Although constructed by human manipulation, they—unlike the act of drawing—functioned without any dependence on the human hand. Technical media, because of their

15 See Daston and Galison 1992, Chadarevian 1993, Brain 2015, Geimer 2001.

16 “Science is confronted by two obstacles that impede its progress: The deficiency of our senses to uncover truths, and the inadequacy of our speech to express and communicate what we have recognized. It is the goal of scientific method to overcome these obstacles. The *graphic method* achieves this double goal better than all others. For, firstly, in difficult analyses it can apprehend the most minute nuances that would escape other methods of observation; and secondly, it involves expressing the course of a phenomenon: This method reproduces the phases of a phenomenon with a clarity not accessible to our speech.” Marey 1878, p. i (translated from C. Borck’s German, original emphasis).

artificial inscribing mechanisms, seemed to be in a position to produce signs by Nature external to human writing and depiction conventions. This trend toward canceling out the technology is supported nowadays by a convergence between the eye and the computer, in that the image on the computer screen appeals to the morphology of a brain and thereby makes the new scientific object into a fellow inhabitant of our world. Beyond their novelty, present-day visualization procedures are superior apparently above all because they directly convey conventional images of the brain. They do not show the functional data as cryptic curves but as topological demarcations in the “real” brain.¹⁷ Whereas in the EEG the brain seemed to draw the trace of its own activity, computers today constitute a complex spatially differentiated reality of the brain. Possibly for this reason a hybridization with new visualization techniques such as in functional magnetic resonance imaging will lead to a renaissance of electroencephalography; since it still is valid that an analysis of electric potentials in real time alone delivers data on the working brain.¹⁸

In medicine modern visualization techniques, mostly referred to as “imaging processes,” are called *bildgebende Verfahren* in German—literally “picture-giving processes,” and their applications, *Bildgebung*—literally, “picture-bestowal”—, as if they were techniques by some demiurge handing out divine gifts. This way of speaking refers more precisely to the shift in the center of activity, as, such images are the creative products of computers. The gift that is bestowed upon researchers of the brain by computers is pictorially so perfect that those images represent new modelings of reality. The trends of the successive research methods used in the neurosciences, without the hopes once attached to them ever becoming reality, continually reiterate the figure of a prolepsis.¹⁹ The neurosciences are constantly opening up new and fascinating spaces of knowledge, yet they basically occupy themselves with similar problems. The central issues of brain research had been formulated from the nineteenth century on, yet the most current brain theories were always scarcely capable of being more than mere thetic solutions in anticipation of a presumably imminent breakthrough. This horizon of expectation, in chronic anticipation of a solution “behind the curve” (Gilles Deleuze), seems to form a not-negligible part of the fascinating attraction of the brain-research enterprise. Reduced to a common denominator,

17 One young Berlin company, for example, has been advertising its software for the visualization of EEG data as brain images with the slogan: “Images not curves! Visualization of EEG plots” (*Bilder statt Kurven! Visualisierung von EEG-Kurven.*) See www.eemagine.com (1 December 2004; the slogan is no longer in use).

18 In his *Berger lecture*, Pierre Gloor (1994) lauded the new visualization techniques in combination with new EEG procedures as fulfillment of Berger’s vision of a scientific glimpse into the workings of the mind. On the convergence between EEGs and new visualization techniques, see, e.g., Erwin and Rao 2000.

19 On the following, see Hagner and Borck 1999.

it is less the theoretical assumptions and approaches, and certainly not the philosophical branch of brain research, that determine the dynamics, than the practical insights and interventions made possible by new technologies.

Recently a Berlin group of researchers reported a curious interim result of their work on systems that was supposed to make it possible for physically impaired patients to control a computer solely by means of EEG signals.²⁰ In search of a suitable guiding signal from the sum of brainwaves, the group filtered out all concomitant currents until a localized so-called “readiness potential” of an impending motor action emerged sufficiently distinctly. The computer technique could be optimized to the point that it could be predicted with high reliability whether an experimental subject was about to move his or her right or left hand. However, the control had strangely shifted. The computer anticipated a decision about to be made by the subject in accordance with his or her own consciousness, because the readiness potential of conscious processes precedes it by some fractions of a second. The subject sitting in front of the screen, which depicted the computer’s calculations as a movement by the cursor toward the right or left, regularly felt the urge to perform that particular motion which the computer had just indicated. A module for individual control of a machine had evidently turned into a communication between brain and machine in which the subject’s ego could literally watch the actions of his or her brain. The startled reaction that one of the subjects reported was soon tempered by curiosity about what was actually being observed there.

The stream in history of science has swept up almost all endeavors to fix brainwaves. The characteristic trait of the history of brainwaves seems to be not so much positive knowledge, with ever-attendant, often doubtful effects, as scientific productivity. Attached to this productivity is the irritation provoked when EEG investigations became self-reflective. This demonstrates how science first poses new, unanticipated questions by answering some. If the neurosciences now propose to become a leading science of the twenty-first century, this is perhaps where their special potential lies. Instead of solving one of the “last puzzles of humankind,” they rather see to it that the human brain remains puzzling. A historical epistemology of the electrical brain becomes an appeal against a narrowing down of perspectives on the currently dominant forms and therefore, a *plea for an open epistemology* (see Conclusion).

20 Blankertz et al. 2004.

2 Hans Berger's long path to the EEG

Current in the head

In July 1929 there appeared in *Archiv für Psychiatrie und Nervenkrankheiten* the paper “Über das Elektrenkephalogramm des Menschen” by Hans Berger, who was a member of the editorial board of this leading German journal for psychiatry founded by Wilhelm Griesinger, in addition to being director of the Psychiatric Clinic at the University of Jena. In this paper Berger reported about a long series of trials on animals and humans to record electric currents in the brain. The end result was a typical curve graph of continuously rhythmic current fluctuations in the brain, for which he wanted to propose the name “*Elektrenkephalogramm*.” This observation and graphic recording of brainwaves had been his main project for quite a while, to which he had continually reverted as soon as other investigations were completed. The first time was in 1902, right after earning his habilitation degree; then in 1907, after completing research on the correlates of psychic states in volume curve plots of the brain; and in 1910, after working on temperature changes in the brain in relation to exertions of the psyche. All these trials on different kinds of animals had yielded only doubtful results, however. So Berger had redirected his research toward attainable goals. Only after he had assumed the management of the Jena *Nervenlinik* in 1919 did Berger again begin to occupy himself with the registration of electrical brain activity, this time in experiments not on animals but on humans. On 6 July 1924 he accomplished what to the end of his life he would acknowledge as the first successful EEG experiment. Nonetheless, Berger hesitated five more years before he believed he could finally be certain enough about the matter to submit a first publication. During those five years, he registered over a thousand brainwave plots in almost 200 experiments. These results were so unstable that, time and again, he doubted his observations. On 25 July 1929, shortly after the appearance of his paper, he wrote down in his lab journal, full of expectation: “The EEG is now in everyone’s hands!” (IV, p. 232).¹ Berger’s EEG was

1 Berger regularly maintained a laboratory journal. These journals were carefully preserved by his family after Berger’s death and initially handed over to Heinrich Boening and Richard

hence anything but a chance observation; it was the product of a tough struggle lasting almost three decades, with a preset fixed goal in view—namely: the registration of electrical brain activity in humans.

This repeatedly reinitiated effort to obtain a curve that at first existed only as a wish cannot be reconstructed simply as an overcoming of defined technical difficulties or as a gradual acquisition of sufficient skills in experimentation. It was rather marked by a very much more basic struggle about what it was at all that should be conceived as the object of observation. Paradoxically, at the beginning of his experiments it remained unclear what should count as the effect and what as the artifact, because Berger had very specific notions about the EEG, which could not easily be brought into conformity with the experimentally generated phenomena. Berger repeatedly failed to obtain the EEG because the electric signals of the brain that his registering apparatus detected were, in Gaston Bachelard's words, "messages from an unknown world."² Berger was confronted by an "epistemological obstacle" whose resistance always only in retrospect turns out to be a past of errors and false findings, as Bachelard argues:

Never is what is real "what one could imagine," it is rather always what one ought to have imagined. Empirical thinking is clear *retrospectively*, if the instrumentation of the grounds is correctly set. [...] In fact one cognizes *against* an earlier cognition by destroying false cognitions and superseding what becomes an obstacle to cognition in the mind itself.³

In a lengthy process of continual modifications, the expectations, observations, instrumental arrangements, conditions of analysis, and the various partial steps of the experiments, first had to be fine-tuned to one another so that they could together yield an experimental system in which the more-or-less stable curves could be recorded that only gradually came to be revealed as brainwave plots.

Jung for a planned edition that never came to be, however, owing to Boening's unexpected death. Jung studied these journals thoroughly, excerpting and publishing parts (Jung 1963, Jung and Berger 1979). The family gave the journals on loan to the University of Jena, where they are preserved in the Haeckel-Haus. I follow Jung's proposed enumeration of the journals and cite them with the date, volume, and page number according to the copies and excerpts preserved among the Berger papers at the Neurologische Universitätsklinik in Freiburg [now at the Archives of the Deutsches Museum in Munich]. Besides this material, Berger also wrote so-called "*Reflexionen*" about the EEG, which have survived mainly from the years 1928 until 1930. This material consists of many thousands of loose, mostly dated sheets, and the great majority of them are likewise preserved among the Berger papers at the Neurological Universitätsklinik in Freiburg [now also at the Archives of the Deutsches Museum in Munich]. My citations of these reflections are labelled "R.," with the date.

2 Bachelard 1974, p. 17.

3 Bachelard 1978, p. 46, translated here from the German translation by Henriette Beese (Bachelard 1974, p. 171).

A detailed reconstruction of the events in the Jena laboratory seems to me to be instructive in epistemological respects precisely because in this case of a “pure culture,” so to speak, of research work pursued largely in isolation, the interactions between expectations, disruptions, and observations, or the chain of theoretical and experimentally practical modifications resulting out of it, can be studied. Berger’s experimental rooms in the Jena Psychiatric Clinic, which were isolated in more than one respect, were the breeding site of an “epistemic thing” (Hans-Jörg Rheinberger) of an as yet unobserved and ill-understood, initially only concretely imagined object. “How, above all, to imagine that feeling of a labyrinth without an exit, that incessant search for a solution, without making reference to what has meanwhile been demonstrated to be *the* solution—without letting oneself be dazzled by its existence?”⁴—as the French molecular biologist François Jacob aptly identified this historiographic problem in need of mastery, even before the study of research cultures became an issue in the history of science.⁵ In the following, Berger’s “investigative pathway” (Frederick Holmes) up to the publication of his first notice about the EEG will be reconstructed in this sense, without projecting back onto anterior research situations the success of a particular experimental apparatus that would only be ascertained as such in future, hence, without ordering the concrete rejections and bifurcations in Berger’s experimental system teleologically, cast in the light of electroencephalography as it was ultimately realized. In his first communication about the EEG in 1929, Berger portrayed his preliminary trials and problems in unusual detail. Nevertheless, such a retrospective account can only provide first indications toward an identification of the decisive nodes and pivotal points of this project, because it necessarily establishes the problems from the point of view of an attained state of the research. That is why an analysis of unpublished recordings is the way to broach a constructive history of Berger’s electroencephalography. In doing so, I shall gradually move in on Berger’s experimental practice in a number of recursive loops before finally examining in detail a few episodes on the basis of preserved lab journal entries, his recording notes, and reflections.

In his first publication about the human EEG, Berger described how he registered continuous and regular current oscillations every time he connected a sensitive current-measuring device by means of suitable electrodes to the head of a relaxed prostrate test subject. Berger observed two

4 Jacob 1988, here quoted from Rheinberger 2001, p. 76.

5 In the wake of more recent writings on the genesis of scientific objects, practices, and research cultures, experimentation has been elevated in historiography and the philosophy of science from a mere instance of verification of theories, concepts, or models, to a central site of scientific activity, whence not only presuppositions or theories are tested but whence expectations and manipulation skills with scientific objects and materialities interact in unforeseen ways. See i.a. Latour and Woolgar 1979, Shapin and Schaffer 1985, Holmes 1992, Hacking 1996, Rheinberger 1992 and 2001.

basic rhythms of oscillations: the “waves of first order” with relatively large, regular amplitudes and a frequency of approximately 11 per second (hence 90 σ , as Berger wrote with the symbol used at that time for milliseconds) and a smaller, often more irregular and weaker oscillatory shape, the “waves of second order” of about 30 per second. These continuous electric oscillations proved not to be entirely independent of activity by the heart, respiration, the pulse, or muscles. However, they were clearly delimitable as an independent type of electrical activity whose source had to be in the head, and in particular, in the brain, as Berger reassured himself in a comprehensive series of control experiments. Berger finally formulated scrupulously at length on the forty-first page of his paper the quintessence of his contribution:

I thus do, in fact, believe to have found the Elektrenkephalogramm of humans and to have published it for the first time here. The Elektrenkephalogramm represents a continuous curve with continual oscillations, of which, as has already been repeatedly emphasized, one can distinguish the larger waves of first order with an average period of 90 σ from the smaller waves of second order of on average 35 σ . The larger deflections have a maximum value of 0.00015–0.0002 Volts.⁶

The detection, in principle, of electric currents in the brain was by no means what was spectacular about Berger's report. Richard Caton had reported in the *British Medical Journal* about brainwaves in animals as early as 1875; and the priority dispute about the first description of spontaneous electrical activity of the brain had drawn renewed attention to the topic at the end of the nineteenth century.⁷ In 1913 Wladimir W. Práwdicz-Neminski finally published curves of such currents conducted directly from the brain as “electrocerebrograms.”⁸ All the same, nobody prior to Berger had conducted the only seemingly so obvious experiment of connecting a galvanometer to a person's head. One explanation was presumably the development of increasingly efficient recording instruments. The level of analysis in neurophysiology since the end of World War I was thereby

6 Berger 1929, p. 567.

7 The Viennese physiologist Ernst Fleischl von Marxow fought this battle against his professional colleague from Cracow, Adolf Beck, in the *Centralblatt für Physiologie* in 1890/91. It primarily revolved around whether the deposition of a sealed note at the Viennese Academy of Sciences could count as publication, until Caton cut the dispute short with a reference to his earlier publication; see Borck 2000.

8 Práwdicz-Neminski 1913a, 1913b, 1925a, 1925b; see Brazier 1961. Berger's decision in 1929 not to adopt the already existing term but to propose instead the hardly pronounceable *Elektrenkephalogramm* was not so much a gesture of self-importance, as it was a consequence of his humanistic schooling, which forbade him from accepting mixed Greco-Latin terminology; see Berger 1929, p. 567.

tipping increasingly in the direction of communications between individual cells and fibers. The idea of conducting current from the brain as a whole, with its billions of neural cells, not only lay beyond the bounds of such a program, those investigations made the idea appear simply absurd. Berger's anchorage in clinical psychiatry and his associated lack of neurophysiological laboratory experience might have implied some technical difficulties in his materialization of the EEG. Against the backdrop of these contemporaneous developments in neurophysiology, however, that deficiency would even seem to have been a prerequisite.⁹

The spectacular thing about Berger's experiments was that, notwithstanding the evidenced complexity of the human brain's structure, their technically comparatively simple experimental arrangement was capable of registering a regular and uniform curve of electrical cerebral activity. Berger's experimental system for the registration of potential oscillations between the fore and back parts of the head neglected the enormous functional differentiation of the various brain regions situated between the contact points and produced a curve of astonishing stringency. This contrast between the complexity of the brain and the simple form of the traced curves blocked the way to immediate reception of Berger's *Elektronkephalogramm*. In 1929 the EEG of a human being was not a plausible object of research in neurophysiology. It was an epistemic thing in potential form that could become an object of neurophysiology only haltingly by adaptive intermediary steps.

Research strategies of a conservative psychiatrist

When Berger published the EEG from a human being in 1929, he had been director of a large neuropsychiatric university clinic for ten years, and at 56 years of age he already had far more than half of his professional life behind him. Since his first years of clinical work in Jena, Berger had specialized in the graphical registration of psychophysiological phenomena and had become a master at interpreting the curves long before he conducted successful experiments with electroencephalography.¹⁰

Born in 1873 in Neuses near Coburg as the son of the physician Paul Friedrich Berger, and grandson of the poet and orientalist Friedrich Rückert,

9 That is how the Canadian neurophysiologist Pierre Gloor once put it to Douglas Adrian: "I am personally convinced that Berger's success and the secret for his tenacity in pursuing this aim was partly due to the lack of appreciation he must have had as a non-physiologist for the enormity of the task he was about to undertake." I thank David Millett for this reference from the Adrian papers in Cambridge (Gloor to Adrian, 26 March 1969).

10 Among a total of about one hundred publications by Berger, sixty-five had already appeared by 1929, which treated many of the conventional neuropsychiatric topics of the time. The experimental papers indicate a clear emphasis on psychophysiological analyses by graphical methods, however. See the complete listing of his publications in Kreuter 1996, vol. 1, pp. 96–98.



Figure 2 Hans Berger at his desk, 1927.

whom he revered,¹¹ Hans Berger completed medical studies at Jena in 1897 and joined the local psychiatric clinic as assistant where he earned his doctorate that same year on a histological thesis. At that time, Jena with its 700 students could be described as a smaller university town of barely 20,000 inhabitants, where Carl Zeiss's and Ernst Abbe's factory of optical instruments was just initiating an industrial upswing.¹² Ernst Haeckel was certainly the most famous figure among Jena's intelligentsia at the turn of the century. This preacher of evolutionary theory in Germany introduced broad circles to the monistic view of the world, as a "tie between religion and science," with his popular book *Die Welträthsel*.¹³ Besides Haeckel, Berger's sponsor and predecessor as director of the clinic, Otto Binswanger, numbered among Jena's prominent figures. Binswanger was one of the most renowned

11 Hans Berger never had the opportunity to meet his grandfather but he recited his poetry to the end of his days. His mother Anna, born in 1839, was the youngest child of Friedrich Rückert, who died in 1866, hence seven years before Hans was born; Hans Berger's father was the treating physician. On Friedrich Rückert and his family, see the exhibition catalog for the bicentennial of his birth, Erdmann 1988.

12 See Walter 2000, Stolz and Wittig 1993.

13 *Die Welträthsel, gemeinverständliche Studien über monistische Philosophie*, appeared in various editions. The so-called *Volkausgabe* in 1908 attained a print run of 231,000–240,000 (Haeckel 1908, 1924). On the German reception of Darwin's ideas, see Engels 1995; on Haeckel's monism, Ziche 2000.

psychiatrists of his time. Patients from all over Europe came to consult him; these included Friedrich Nietzsche, Johannes R. Becher, and Harry Graf Kessler. Later, under Berger's directorship, few foreign patients were attracted to the private station anymore, which was surely due to the changed social circumstances of the Weimar Republic as much as to Berger's personality. His assistants and pupils unanimously described him as rather timid and reserved.¹⁴

Theodor Ziehen, who had supervised his dissertation,¹⁵ influenced Berger's research even more than Binswanger. Ziehen, himself a border crosser between psychiatry, physiology, and psychology, had introduced graphical registration of physiological parameters to Jena.¹⁶ The major impetus on instrumental physiology from graphical methods had raised hopes of helping psychiatry onto a new scientific foundation by the aid of these procedures.¹⁷ In his habilitation thesis Ziehen had pursued the question of whether typical alterations in pulse waves could be associated with mental illnesses. Although Ziehen had to answer his "main question with a decided no," he did not dismiss this research approach, rather encouraging his assistants to conduct more studies. In addition to registering pulse waves, by sphygmography, he wanted to establish volume recordings (by plethysmography). Ziehen had Berger examine the effects of the psychiatric pharmaceuticals then commonly in use on cerebral blood flow, while his colleague Korbinian Brodmann was supposed to conduct psychophysiological experiments while monitoring arm volume.¹⁸

14 His assistant Raphael Ginzberg, who later emigrated to New York, drew the sharpest character profile of him: "He was shy, reticent, and inhibited" (1949, p. 365). Kurt Kolle (1956, p. 3) testified to his "downright pedantic sense of order," and Heinrich Boening chose this roundabout formulation for his obituary: "The kindly distance that he maintained in routine official communications has been mistaken as coldness by superficial observers" (1941, p. 20).

15 Berger (1897) wrote his thesis on the histology of spinal-cord alterations from paralysis.

16 Theodor Ziehen (1862–1950) first worked with Munk on electrostimulation, completed his habilitation thesis in 1887 under Binswanger on "Sphygmographic analyses of the mentally ill" and was head physician there until 1896. After that he worked in an independent practice in Jena but seems to have coordinated the research at the Psychiatric Clinic until his departure for Utrecht in 1900. In 1904 Ziehen became director of the Nervenlinik at the Berlin Charité but left again to accept a university position in the philosophy faculty at Halle in 1917 (see Ziehen 1930).

17 Otto Wolff's "Beobachtungen über den Puls bei Geisteskrankheiten" (Wolff 1867–69) marked the beginning of a field of research that flourished up to the beginning of the twentieth century; see the historical sketch by Ziehen (1887, pp. 5–22) or Müller 1902, Bonser 1903. On the history of the graphical method, cf. Chadarevian 1993, Brain 2015.

18 Ziehen 1887, p. 63. The occasion of this study, Berger 1901a, was an observed rapid improvement in the semi-conscious state of one psychotic patient. The effect of a cocaine injection led Berger to suspect some regulation of the blood supply to her brain. Whereas Berger quickly completed his analyses despite predominantly negative results and earned his habilitation degree with it (just as Ziehen had before him), Brodmann did not go beyond studies on arm volume during sleep, which he only published in 1902, therefore after he

Berger's portion of the study rapidly developed into his first and groundbreaking project of plotting cerebral curves. In his method he closely relied on the procedure published by the Italian physiologist Angelo Mosso in 1881 for registering brain volume via a bone defect in the skull. Patients with gaps in the skull due to illness would remain preferred test subjects for Berger's later brain curves as well. Berger could try out Mosso's method on a patient at the Jena clinic. Because of a suspected tumor, a large piece of cranial bone had been removed, leaving the brain directly underneath the skin. Using a specially adapted cap, Berger recorded at this gap in the bone fluctuations in the brain volume, as pressure fluctuations in a closed pneumatic system that was connected by air tubes to a recording lever to cause the pointer to engrave the volume fluctuations of the brain onto a sooted kymograph drum. As previously described by Mosso and others, Berger's curves also exhibited regular fluctuations in the brain volume. The various influences due to cardiac activity, respiration, and vascular resistance could be distinguished by their frequency as waves of first, second, and third order. Berger's first work on brain curves thus revolved around waves and rhythmic oscillations; and he applied by far the largest part of his habilitation thesis to the establishment and characterization of the brain-volume curve as an objective parameter of physiological research. Already in this early paper Berger evaluated and optimized a brain-specific curve not with respect to any physiological processes participating in forming the curve, but solely within the chosen representational medium, namely, by comparison with other already known curve lines.

Berger's next major study, "On the bodily expressions of psychic states" (*Über die körperlichen Äußerungen psychischer Zustände*), which he published in 1904 and 1907 in two volumes, each with separately printed, oversized atlases, was a continuation of his investigations for his habilitation degree. The part of the study, which Ziehen had originally entrusted to Brodmann, who had not finished it because of critical considerations about the method, was supplemented here. However, radically different projects lay in the stage between Berger's habilitation and this continuation, such as his first experiments on cortex currents and even experiments on himself to test the contagiousness of acute mental illnesses by injection of blood samples from acutely psychotically ill female patients.¹⁹ The paper on cerebral volume curves in 1903 hence was a return to methodically familiar terrain after the failure of ambitious novel approaches. The occasion was evidently stimulated by one particularly sensible patient with a skull defect

had joined Oskar Vogt in Berlin, in the latter's journal (Brodmann 1902). It is unknown to me whether the misunderstandings with Ziehen that led to his decisive negative expert opinion on Brodmann's habilitation thesis originated from the Jena period. (On Brodmann and his academic career, see the dissertation by Markus Fix 1994.)

19 Berger 1903.

due to a revolver-shot accident and offered Berger the opportunity to execute exact volume recordings in relation to psychic processes and mental exertion. In addition, Berger read during this period Alfred Lehmann's *Die Körperlichen Äußerungen psychischer Zustände* (On bodily expressions of psychic states), which was to become a lasting model.²⁰ The next study even adopted the title of the Danish physiologist's book because Berger regarded it as formulating his very own research problem. Both were seeking the traces of mental activity in the two-dimensional representational space of graphical recordings. In addition to this interest in that specific form of psychophysiology, Lehmann and he also shared the assumption of a special psychic form of energy and additionally a belief in telepathy.²¹

In the first volume of his book "On bodily expressions of psychic states," Lehmann described arm plethysmography as one diagnosis of alien states of the mind. The plethysmograph, the registration of blood-volume fluctuations in the arm, was supposed to become a "psychoscope": "Once all these effects [states of consciousness] have been analyzed and their characteristic expressions ascertained, we shall have with a plethysmograph a real psychoscope by means of which a person's emotional state can be diagnosed with not little certainty."²²

"I must frankly admit that these words mainly motivated me toward these extensive plethysmographic examinations as well," Berger declared upon resuming volume recordings by which he transferred Lehmann's research program onto cerebral plethysmography.²³ With painstaking exactitude and in close adherence to Lehmann's psychological testing prescriptions, he began to record his patient's mental metabolism: the curves of a sense of desire (stimulated by sugar or a cash gift) or repulsion (stimulated by bad-tasting drops on the tongue), the curve of attentiveness (by physical contact) and alarm by a revolver shot (for this gun-shot cripple), as well as the curves of mental exertion while figuring out a mathematical problem. Berger interpreted the subtlest changes in the fluctuation pattern of the curves as the graphical trace of intellectual work, attention, shock, desire, or repulsion. Separated from questions about psychophysiological mechanisms, the trace in the kymograph soot became the tracks of psychical processes.

20 The first volume of this work to appear was *Plethysmographische Untersuchungen* (including an atlas) in 1899, followed by *Die physischen Äquivalente der Bewußtseinserscheinungen* in 1901, and finally, a third volume bearing the title *Elemente der Psychodynamik* in 1905.

21 Berger reviewed and thoroughly discussed Lehmann's texts even into advanced age, just as Lehmann, for his part, went into Berger's results and commentary in his subsequent publications; see, e.g., Lehmann 1914, pp. 62–73 and 166–168; or the many references to Lehmann in Berger's book on temperature (1910), his psychophysiology lectures (1921a), or his last work: *Psyche* (1940). Nonetheless, they seem never to have met personally; neither has any exchange of letters between them been preserved.

22 Alfred Lehmann 1899, p. 216.

23 Berger 1904, p. 42.

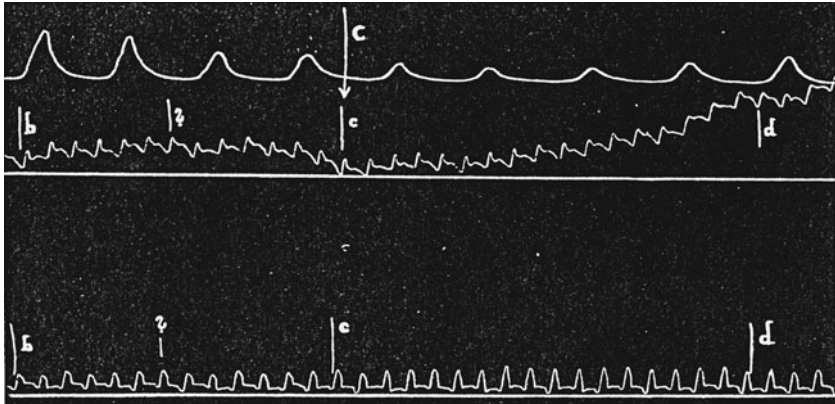


Figure 3 Plethysmographic curves. Top: breathing excursions; middle: volume fluctuations of the lower arm; bottom: blood-volume fluctuations in the head. Berger comments on the figure as follows: “Between b and c, probably at the spot labeled with a question mark (?), a ten-mark coin is given to the quite needy test person. One sees from the arm curve [. . .] the increase in volume, which starts at c and beyond d rises to such a degree that it reaches the respiration curve on the recording surface [. . .]. On the brain-volume curve recorded at c on a very insignificant decrease in volume [. . .] and an easily recognizable and clear increase in the height of the individual pulse beats of the brain, which suggests an expansion of the cerebral, specifically, the cortical vessels from a desire stimulus.”

The mediation rather constituted the instrumental coupling by the experimental setup, a reduction of the experimental system to the inscription of plethysmographic curves as a function of psychic stimuli. Berger found stable differences between various test stimuli, which he focused his experimental system on documenting (see Figure 3).

The recording of such “physiological attendant effects of psychic processes” (as he later put it) became Berger’s life-long project. This is already analyzable as a model case. A book review in *Journal für Psychologie und Neurologie* criticized Berger’s study *Körperliche Äußerungen psychischer Zustände* as “symptomatology of the emotions” lacking any physiological foundations.²⁴ Berger, on the contrary, considered the observed fluctuations in cerebral volume—in making Lehmann’s psychoscopy reality—as the counterpart to emotive states as defined by psychological testing, upon which he could erect a psychophysiological theory of the brain. He interpreted the observed rhythmic volume increases with desire and concentration as the graphical correlate to the fluctuations in attention already described by

24 Müller 1904. It is indicative that Berger saw no problem with that even in the next volume. He merely introduced new test subjects and added new curve analyses but entered into no discussion about which physiological mechanisms correlated the psychic processes with the cerebral vascular regulation.

Wilhelm Wundt and amalgamated this with Max Verworn's metabolism theory of psychic activity.²⁵ The inscribed lines of the curve were an expression of a psychogenic metabolic process in which the *biotonus* was rhythmically augmented until the neural stimuli reached the consciousness:

The periodic fluctuations in intensity of minimal psychic processes are hence determined by the vascular wave in the cortex. If I may avail myself of a metaphor, the torch, whose burning corresponds to the course of the psychophysical processes in the cerebral cortex, periodically blazes more brightly.²⁶

With this postulated correlation between fluctuation in attentiveness and vascular waves, Berger had reached the goal of his exegesis of the curves; he did not undertake any research into illuminating this connection experimentally. The graphical method endowed the psychic processes with their physiologically objective existence criterion, in the form of registered wave patterns; and the experimental arrangement supplied the physiological signs the dignity of exactly this expelling character. The metaphor of the blazing torch became such an effective image of the psychophysical processes that he repeatedly reverted to it in his researches on the EEG and even personally illustrated his last publication *Psyche* with a blazing torch on the title page (Figure 4).²⁷

The measure of psychic energy

How strongly Berger's experimentation, and particularly his research on brain curves was guided by speculations about brain theory and presuppositions from his view of the world is demonstrated by his conception of a special psychic form of energy, which he fully developed theoretically at the same time and from then on repeatedly elaborated experimentally.²⁸ In 1905, that is, exactly between the appearance of the two volumes of *Körperliche Äußerungen psychischer Zustände*, Berger began to deliver a lecture course on psychophysiology that Ziehen had been teaching in Jena

25 See Wundt 1893, pp. 255–302, and Verworn 1897, pp. 481–509.

26 Berger 1907, p. 196.

27 Berger probably developed this metaphor from a comparison that Eduard Pflüger had formulated thus in 1875: "This is how I imagine all living material, but very particularly so the gray matter of the brain. In the waking state its vibrations are the strongest, the humming of the flame is the loudest" (Pflüger 1875, p. 468; see Berger 1932a, pp. 25 f.)

28 Martin Schrenk has reconstructed the ideological horizon of "Berger's quest for psychic energy," (Schrenk 1970), in order to situate him along the same line of tradition as Wilhelm Griesinger and Robert Mayer. The central role of the concept of psychic energy in Berger's EEG research has also been emphasized by Richard Jung (1963), Pierre Gloor (1969, 1974), and David Millett (2001b).

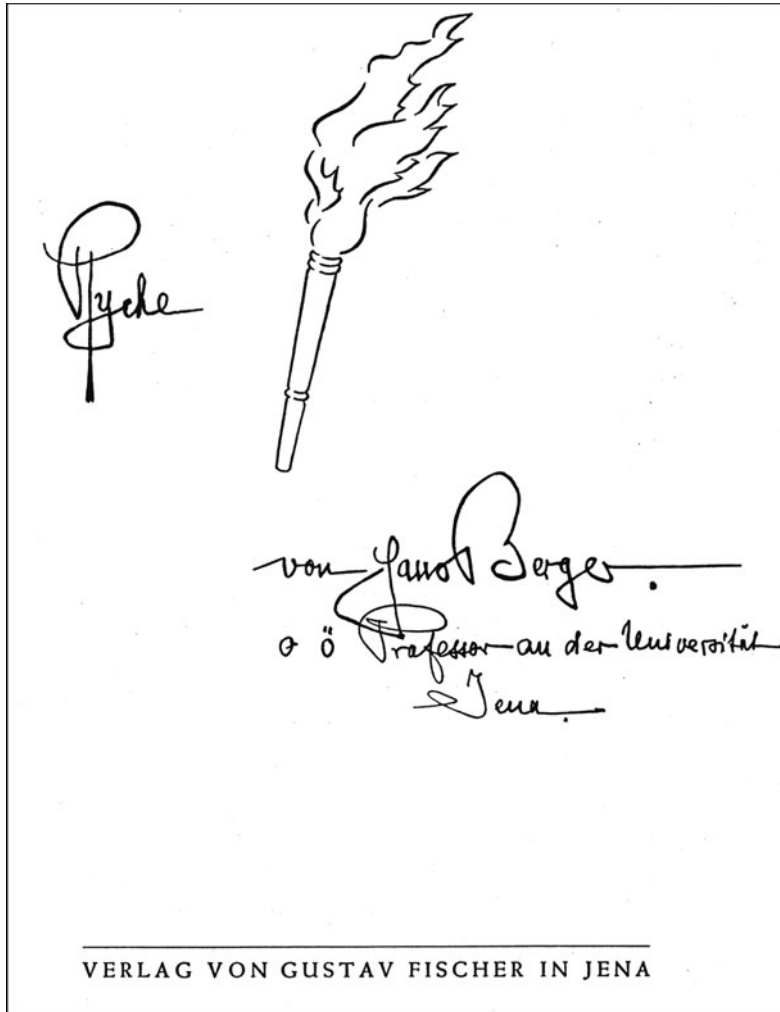


Figure 4 Title-page autograph sketch by Hans Berger for his last publication *Psyche*.

up to his departure in 1900.²⁹ Perhaps it was just coincidence, but Ernst Abbe died in Jena in that very year. Although Berger had already taken his habilitation degree but still awaited appointment as professor, he was medically treating Abbe and visited him almost daily up to his death.³⁰ To

29 Berger 1921a; Berger's lectures, like all his monographs, were published in only one edition. Ziehen's lectures, *Leitfaden der physiologischen Psychologie*, first appeared in 1891 and became his most successful book appearing in 12 editions up to 1924.

30 Information by Ursula Berger to Henri Fischgold, 1962, note among the Berger papers.

Berger psychophysiology was not so much a theory of the way the sensory organs function or the transition of sensorial stimuli into the consciousness. It was, rather, the name for experimental analyses on the relations between psychic and physiological processes, in acknowledgment of their ontological independence. This contrasted with the materialistically turned psychology of associations, such as his teacher Ziehen represented, for instance, in which all psychical matters were merely a manifestation of ultimately physiological phenomena. To Berger the reality and causal potential of psychic processes was beyond question. Psychological associations and their physiological substrates were to him “just the necessary substructure upon which the huge upper framework of thought itself rises.”³¹ As a brain researcher trained in the natural sciences, he at the same time acknowledged the energetic closure of all processes in the world, as Robert Mayer had formulated it in the law of the conservation of energy, whose writings he esteemed very much. To convey this tension Berger favored a special form of energy for processes of the psyche that should also be scientifically detectible.

Energetic descriptions of psychic processes can be found in the psychologies of Wilhelm Wundt and William James, ranging up to Sigmund Freud and Henri Bergson. Berger's conception differed from theirs by his particular interest in the transformation between different forms of energy and he sought models.³² Lehmann, Berger's authority on psychophysiological studies, was among those who hoped to make accessible to scientific research the assumption of an independent form of energy for psychic processes. Wilhelm Ostwald propagated in nearby Leipzig a “psychic energy” as a general transformation force within the framework of a natural-philosophical universal energetics that extended from physics and chemistry to psychology, linguistics, and the “fair and good.”³³ Although Berger was cautious about presenting such broad speculations, he similarly suspected that an energy

Berger's appointment as extraordinary professor (*a.o. Prof.*) occurred in 1906. By transforming the Zeiss company into a foundation dedicated to the common weal, the optician and entrepreneur Abbe contributed decisively toward the consolidation of the university in Jena. The foundation also financially supported Berger's analyses *Körperliche Äußerungen*. It may be presumed that it was only thanks to the support of the *Carl-Zeiss-Stiftung* that the costly atlas with the cerebral volume curves could be printed. Later the foundation funded Berger's purchases of electrophysiological apparatus in a number of instances. The city is also indebted to Abbe's socially reformistic ideas for many public facilities. On Abbe and the Carl Zeiss Foundation, see Stolz and Wittig (1993).

31 Berger 1921a, p. 96.

32 On the history of the concept of psychic energy, see Akert 1987, Ackerknecht 1984, and Glatzer 1976. Siegfried Bernfeld (1930) attempted sometime later to develop a scientifically quantitative psychophysiology, setting out from the concept of energy in Freud's drive dynamics.

33 *Zum “Schönen und Guten”* was the title of the last of his lectures delivered in the summer of 1901 before a large audience, *Vorlesungen über Naturphilosophie* (Ostwald 1902); see also Ostwald 1908.

existed as a “common tie” between all processes in the world that Haeckel had already spoken of. He eventually found under the label *psychophysische Energie*, that conception which endeavors to link the psychophysical conversion of energy with the consciousness: Its author, Kurd Laßwitz, the historical epistemologist of matter theory, was also the first German writer of science fiction.³⁴ Consequently, Berger shared the assumption of a special form of energy as a medium of psychophysical processes with a group of strongly metaphysically orientated scientists. It catered to an evidently widespread need at the beginning of the new century to harmonize science with the philosophy of life.

Berger's interest in “psychic energy” tapped another source as well—namely, an unusual experience during his student days, which had convinced him of the existence of telepathy.³⁵ An almost fatal accident during volunteer military service in 1893 had, in his opinion, made him into the emitter of telepathic signals because at that very moment, his sister, faraway at home, became so grievously worried about his fate that his father felt compelled without any further reason to send a telegram to inquire about him. With this background it is not surprising that the spectrum of works reviewed by Berger touched topics ranging from psychic energy far into occult literature. In 1908, for instance, he published in *Grenzfragen des Seelenlebens* a review of the treatise by Naum Kotik on the “radioactivity of the brain,” and in Max Dessoirs *Urkunden des Okkultismus* he reviewed Richard Baerwald's compilation, *Die intellektuellen Phänomene*. The assumption of a special psychophysical energy, or “P.E.” for short, quickly became a firm component of his world-view for the rest of his life. Time and again he considered presenting his views about psychic energy separately in a “P.E. book.” Only after his retirement did he finally publish a short text, *Psyche*, whose thirty-two pages were at least in partial fulfillment of the original plan. Its basic idea had already been laid down in a journal entry dated 10 March 1911 (II, p. 227): “P. E. is the most magnificent form of energy, which gains enormous influence on the course of all processes but is ephemeral as such, constantly revealing itself in other forms.”

Berger's psychoenergetics served a dual function as regards his research practice. “P.E.” was Berger's *idée fixe*, which continually led him to despair about the limited possibilities of physiological recording techniques, but it

34 Laßwitz 1895. Another (critical) reader of Laßwitz's energetics was the young George Herbert Mead, who wrote his first book reviews on it (Mead 1894a, 1894b). On Laßwitz as a writer, see Fischer 1984; Laßwitz's historical epistemology still awaits a critical reconstruction.

35 There have been many speculations about Berger's inclination for telepathetic phenomena, in greatest detail by Hans Bender (1962/63). As far as I can see, though, he only wrote about it in his last publication of 1940, a few months before his suicide (Berger 1940, pp. 5 f.), for which reason it is hardly likely that his inclination for telepathy had the negative repercussions on his reputation as a scientist that has often been suspected.

was at the same time the stable reference point of his experimental system and thus, in the end, became part of the preconditions for the feasibility of electroencephalography. On one hand, it legitimated his search for physiological detection methods for processes of the psyche, which only made any sense if it was possible to distinguish between physical and psychical processes, with psychical processes ultimately still belonging to the kingdom of natural phenomena and not just representing their epiphenomenon. On the other hand, psychoenergetics also offered Berger a new strategy in his search. Given the assumption of a really existing psychic energy but as yet not characterized scientifically more closely, the law for the conservation of energy became an objective principle of verification for psychophysical processes. Because of the strict validity of the conservation law of energy, an exact weighing of all the energetic transformation processes in the brain must allow that quantity of psychic energy to emerge as additional heat. In his next project on brain curves, Berger calculated with thermometric precision the energy of mental exertion. Now, instead of vascular waves, he registered temperature fluctuations in the brain. Berger might have changed the registration technique but he remained within the representational space of graphical methods.³⁶ Although the temperature measurements were undertaken sequentially by hand and the read-off values served as the basis of an arithmetical quantitative analysis, Berger did not dispense with their representation in the form of curve plots here as well.

Although Berger essentially performed the brain-volume recordings on his own, these new analyses could only take place in a broadly spanned web of cooperation. For example, the head of the *Präzisionstechnische Anstalten* in Illmenau supplied a thermometer according to Berger's specifications especially for those experiments. It had a particularly long and narrow probe that could reach deep inside the brain and a stretched-out precision scale in order to be able to read off temperatures up to 1/100°C. At first Berger tested the thermometer in some animal trials, on dogs and chimpanzees, whereupon a banana temporarily served the purpose that the cash gift had formerly performed as a desire stimulus. For these trials, which usually took place in the basement of the psychiatric clinic, up to six psychiatrists were needed in addition to the animal keepers, in order to be able to execute and coordinate the many simultaneous manipulations and observations required. Then his loyal patient with the shot injury to his skull again made himself available, for whom a brain puncture already happened to be planned. First the patient practiced the experimental procedure for a week with rectal temperature measurements; then they went into the operation room of Privy Councillor Bernhard Riedel's surgery clinic where Binswanger's head

36 Mosso provided the methodological impulse for this project, too. He had published temperature curves of the brain already in 1894; Berger followed him as scrupulously as before with the cerebral volume recordings. Mosso 1892, Berger 1910; cf. Borck 2002a.

physician Erwin Friedel performed the puncture. Right after the puncture, Berger inserted the thermometer into the puncture channel and began the psychophysiological experiments. Altogether five doctors and a number of other assistants were involved in conducting those experiments (which again consisted in the familiar combination of problem-solving, provoked feelings of desire and repulsion, and alarm from a revolver detonation), to observe the subject and the thermometer or record the results. Over the course of the study, such experiments were performed with six other test subjects between three and 53 years of age, for whom in each case a medical indication necessitated a cerebral puncture. His colleague Rudolf Straubel, a professor of physics, executed the complicated computations which first had to be gathered from the recorded temperature readings to lead to an assessment of the psychic energy portion in the brain's metabolism. The alliances Berger, an extraordinary professor since 1906, already had at his behest in Jena in 1909 are astonishing.³⁷

But despite this enormous gathering of forces, Berger lost touch with the problem he had originally posed for himself on the final pages of his cerebral temperature analyses *Untersuchungen über die Temperatur des Gehirns*. The test stimuli in the trials had clearly led to an isolated rise in temperature in the brain and Berger succeeded in calculating the triggered metabolic increase accurately out of those data. However, so long as they “merely” established physiological effects precisely, these figures were meaningless to Berger. He was looking for the *difference* between neural activity and mental expenditure, and precisely this had vanished in the established total sum. He gave his own verdict on this study in a poignant projection of his own philosophical ambitions onto the scientific community at the end of the book:

Can we now gather, even just approximately, out of our calculations of the cortical metabolic rate at intellectual exertion the equivalent figure for the P-energy, that *everyone is demanding*? To this question we can unreservedly respond with no. Of the additional consumption of 0.51 m. kg, or of 50,031,000 erg per minute, around 40% should be accounted to heat, the remaining 60% also contain, apart from the amount for processes purely involving the nerve cells, the portion that is transformed into P-energy.³⁸

37 Frederic Gibbs seems to me to have been projecting later personal impressions of a visit in Jena onto earlier years when he wrote: “During all those years [1902–1912] Berger's experiments were carried on in his spare time in utter secrecy. [...] As a diversionary measure he would give public discourses on telepathy [...]. Increasing inflexibility in his attitude toward his assistants went hand in hand with his increasing isolation, so that people began to shun him” (Gibbs 1970, p. 173). I could not find any indications of secretive experimentation or of public telepathy presentations.

38 Berger 1910, p. 130. Emphasis by the present author.

Consequently, Berger had not succeeded in differentially measuring any psychic energy. The calculations had merely led to an energetic limiting value indicating the sum of physiological and psychical work of the nerve cells.

This study signals, even more clearly than the researches on the brain-volume curves, an irresolvable ambivalence in Berger's psychophysiology, which was to return in his later EEG investigations. Berger's physiologically instrumentalized securing of traces of psychical processes focused solely on the plotted curve. Only the phenomena made visible on the surface of the recording sheet interested him and those representations' correlation with processes of the psyche. As graphical recordings, his curves documented temperature changes in the brain with a precision never before achieved. For Berger, however, this was just the first step. As evidence of the ontologically independent existence of psychical processes, it remained ambitious and unfinished. His notions about the calculation to use to distill psychic energy out of the measured physiological changes were nebulous, to say the least, not to mention how to solve the problem of body and soul. The *Untersuchungen über die Temperatur des Gehirns* were a setback in another aspect as well. They garnered him anything but the long yearned-for academic acknowledgment outside of Jena. He had not achieved the goal he had staked out for himself and his publication of the ascertained limiting value did not even yield any recognition: The "ref[eree], to whom the physical bases of the entire experiment and of the computational evaluation of the results are somewhat remote—which is not even requisite, of course—, would not like to delve further, in the author's own interest."³⁹ The Viennese physiologist Arnold Durig surmised, for instance, merely coincidental variations in the published temperature curves and suspected Berger of conducting "human vivisection," which deeply offended Berger and which he henceforth took as a warning example. All the same, in his eyes the *Untersuchungen über die Temperatur des Gehirns* remained "a bold & ingenious trial,"⁴⁰ which was why he had dedicated it to his teacher of experimental practice, Ziehen.

The course to current

After completing his analyses on brain temperature, Berger explored different directions to arrive at his great goal of establishing the "P.E.-equivalent," the psychical portion of the metabolic processes of nerve cells. But evidently all these attempts entered too difficult terrain to be published. In this connection he also conducted another series of brainwave trials that he would soon brush aside as "failed." His surviving notes and reflections not only allow

39 Durig 1910, pp. 944 f. The sentence in the original is grammatically incomplete.

40 Lab journal II, p. 161: 11 December 1910. Berger had dedicated his habilitation thesis to his father, the first volume of the *Körperliche Äußerungen* to his mother, and the second to Binswanger.

one to draw important conclusions about Berger's experimental course of action. Cast in the light of these journal entries and recording notes, the supposed adverse technical conditions which Berger believed were responsible for the "failed" cortex current trials of 1910–1911, rather appeared to be rationalizations of epistemologically low plausibility. These records allow the failure of those experiments to appear as an upheaval. Because the psychophysiological research program and the electrophysiological experimentation were not sufficiently tuned to each other, cortex currents could not become stabilized as an epistemic thing. Put in brief, effects were being sought that could not be produced in that experimental system. Consequently, potential oscillations definitely observed in 1910 remained noise and artifacts.

In the closing chapter to his temperature book, Berger already discussed electrical cerebral processes as portions of the energetic transformations, but he initially set them aside as "processes of surely but low intensity."⁴¹ After finishing the book he speculated about whether a direct measurement of electrical processes in the brain could lead to a determination of psychic energy. Current measurements in the brain were now supposed to prove exactly this local metabolic increase. Hence brainwaves advanced from a negligible factor in the sum of energetic transformations to a specific indicator of psychic energy. In summer 1910 Berger studied Albert Lehmann's *Element der Psychodynamik* and Max Planck's work on energy conservation, *Das Prinzip der Erhaltung der Energie*, in order to arrive at an exact determination of the "P.E.-equivalent" with a modified theory of psychophysiological energy transformation, after all.⁴² In the autumn he set out specifically in search of electrical cerebral processes on the basis of the recently spanned cooperative web for the temperature studies. Out of it emerged for a short while a very promising alliance between electrophysiology and psychophysiology when Berger was able to persuade Hans Stübel, a colleague from the Physiology Institute who had just written his habilitation thesis on an electrophysiological topic, to collaborate.⁴³ Stübel suggested first to conduct electric currents from the nervous systems of simpler organisms, such as frogs or snails, to which end a "small string galvanometer" was ordered from Edelmann. This detector was sensitive but required very

41 See Berger 1910, p. 121.

42 Lehmann 1905, Planck 1908; see the lab journal, 31 July 1910: "During t[he] trip I began to read *Max Planck, Das Prinzip der Erhaltung der Energie*, then only flipped through it. I do find all of this too specific & overly difficult. I should keep to the P-equivalent number & try tirelessly to approach the problem again and again" (II, p. 16).

43 When Berger returned one more time to cortical current experiments in 1924, Stübel was already teaching physiology and ethnology at the University of Shanghai. In Jena there was only his 72-year-old teacher Wilhelm Biedermann—a certified expert in electrophysiology, who had last published something on neural physiology in 1900—until Emil von Skramlik was appointed in 1927 as his successor, with whom Berger only seems to have become personally acquainted when they traveled together to a conference in 1937.

delicate handling and was ready for use in Jena in mid-September 1910. As a well versed electrophysiologist, Stübel made good progress with the instrument and within a few days could branch off the neural and cardiac currents in a frog, finally even the slight muscular currents of an earthworm.⁴⁴ Although the cooperation initially developed rapidly and constructively, according to Berger's information all ten of the trials on cortex currents in dogs that they jointly performed before the end of the year failed. This contradiction between Stübel's achievements and the failure of the directly following joint experiments is a clear indication of the special demands that Berger imposed on the findings. To him it was not a matter of describing brainwaves per se, but a targeted verification of special psychophysiological potentials. As Berger himself wrote in his first EEG notice of 1929, Stübel and he certainly had been able to observe electric currents in the dog trials. But those currents did not exhibit the psychophysical regularity that Berger required:

Although at rest again, i.e., without the influence of external stimuli, minutest string deflections were continually being seen, but this time as well, greater deflections occurred neither upon touch of the paw nor upon illumination of the eye, nor even upon activation of strong acoustical stimuli for any of the examined dogs, even though those animals were not under narcosis.⁴⁵

Therefore, the experiments did not fail because of technical problems but because they did not agree with Berger's expectations. Berger anticipated finding large potentials with large sensory stimuli. To him failure of his experiments meant, for example, that illumination of the retina did not lead to a deflection of the galvanometer, as he tersely noted in the lab journal in December 1910: "With relaxed filament & well-charged accumulators no deflection upon illumination [.]. Therefore, the 10th trial is also negative, thus this c[ortical]-cur[rent] affair ought to be at an end" (3 December 1910, II, p. 152). Ultimately, all of Berger's brain and current curves from the period around 1910 failed because they were too closely associated with the quantification of cerebral activity. In this series of experiments Berger gained

44 See Einthoven 1903, 1909. One major problem with the instrument was the fragility of the filament, which easily broke not only upon mechanical touch but also from random currents or switch impulses, see Garten 1911, pp. 428–437. Stübel's accomplishments in observing the smallest bioelectric signals thus illustrate his expertise in manipulating this device. 20 September 1910: "Collaboration with Stübel is assuming concrete forms: Stübel is recording nerve currents in a snail." 22 September 1910: "Dr. Stübel obtained good curves from snail heart & from the earthworms. Seems to be satisfied & gladly accepts my suggestions. Edelmann apparatus works very well. The idea of working together with a physiologist quite appeals to me" (II, p. 94).

45 Berger 1929, p. 531.

complete expertise in electrophysiological experimental arrangements, but his exclusive attention on psychic energy and psychophysiological transformations directly obstructed his access to the EEG, even though in those experiments of 1910 he very certainly did observe rhythmic potential oscillations.

In parallel with these experiments, Berger began to take an interest in an entirely different curve—namely, the fluctuations in the electric conductivity of the palm of the hand, known as galvanic skin response or the “psychogalvanic reflex phenomenon.”⁴⁶ In 1890 Ivan Tarchanoff had already reported in *Archiv für Physiologie* about similar skin-current fluctuations upon sensory stimuli and psychical activity. Tarchanoff detected weak, fluctuating galvanic currents in the palm when he touched the test person, assigned arithmetical problems, or simply had the person concentrate on the examination. Berger had already carefully excerpted this paper prior to his cooperation with Stübel. He was particularly interested that Tarchanoff had observed a correlation between the deflection of the galvanometer and the intensity of the psychic event, hence, for instance, the degree of difficulty of an arithmetical problem. Right after the failure of his cortex current analyses, Berger took up this experimental alternative because he hoped with these analyses to finally acquire a “measure of the cortical metabolic rate” (*corticalen Umsatz*, 29 September 1910; II, p. 95). One experimental record from this time described in detail the choreography of the prearranged intimate and restrained interaction with the test person, the technical assistant Ursula von Bülow, who had just recently joined the clinic:

Draft

Sit down next to Miss von B., don't converse, make no noises! After everything is in order, wait c. 15 minutes. Then notice the signal (suspended bell!)

a short time later (count c. 10 seconds)

1. Cautious touch of Miss v. B.'s l[eft] cheek with the glass rod & at the same time briefly press down the key (so that the instant of the contact is noted on the curve.)

NB. Miss von B. herself must not be touched, one mustn't even come close to the deck chair either

[...]

3. Assign Miss von B. the arithmetical problem 17×19 & briefly press down the key

Miss von B. gives the result, then the key is briefly pressed down again. Pause c. 2 minutes (per[haps] even somewhat longer)

[...]

46 That is how the Zurich neurophysiologist and spa physician Otto Veraguth titled his monograph from 1909. It seems not to have been known to Berger that Carl Gustav Jung had conducted similar experiments shortly before on healthy subjects and on psychiatric patients at Bleuler's clinic in Zurich (Peterson and Jung 1907).

End of experiment!

Therefore:

No touching of Miss von Bülow [. . .]

Do not speak, not even during the brief pauses.

don't make any noises

Throughout the entire time, stay seated in the same place.

Press the key down as silently as possible

Do not divulge the problem in advance. [R., 15 December 1910]

These experiments also initially developed very favorably. Thanks to the collaboration with Stübel, Berger had access to all the necessary apparatus, and the galvanometer reliably traced a current dependent on the psychical activity. Before Christmas 1910 he had already succeeded in obtaining “good” curves from the experiments with his assistant, so that he could already begin to draft first systematizations of the obtained curves.⁴⁷ When Berger read, the day after Christmas, in a report from the 4th Congress of Experimental Psychology that others before him had not only conducted such experiments but had already applied the same photographic recording procedure, he saw no room left for original research of his own: “I come too late.”⁴⁸ Berger’s resumé of the year 1910 could only be bleak:

The reception of the book on the temperature of t[he] brain—into which I had put all that I could afford & and had so much hope in, was partly a direct refutation. All the new experiments: thermal currents, cortex currents, have failed from technical difficulties & the initially enthusiastically welcomed glittering results proved to be gross experimental errors. Thus expensive apparatus which had been procured with my private funds have become superfluous and useless to me.—

The cortical measurements & Tarchanoff experiments did not yield what I had expected of them, or, got surpassed by other researchers.

[II, p. 178]

After half a year of intensive efforts in various directions, trying out everything available on the market, Berger lacked new theoretical and experimental initiatives. What remained was technical refinement by new methods of paths already taken. At the beginning of 1911 he resolved to optimize technically the graphical inscription of blood circulation in the

47 “Had a look at the retraced curves from yesterday. Dist[inct] deflection upon auditory stimuli at methodical work. I think I can also recognize in the electrical processes the attentiveness fluctuations at 3–9 sec. wavelength. This would be the first important finding.” “Afternoon experiments with Miss von B. Good deflections with Tarchanoff arrangement” (16 and 20 December 1910, II, pp. 166, 171).

48 Lab journal on 27 December 1910, II, p. 175. This was probably also the reason why Berger did not publish his skin resistance measurements, even though he performed such experimental series repeatedly.

brain using a hybrid plethysmograph-string galvanometer. He additionally considered trying out cardiac-current curves as indicators of psychical activity. Rather than pursuing this variety of vague plans, he decided first to return to skin currents. In a period of uncertainty about research strategy, this experimental arrangement with its stable curve plots offered something secure to fall back on—the experimental procedure documents, at the same time, new private potentials for development (25 March 1911, II, p. 242): “Ursel’s curve graphs: Magnitude o[f] deflections in relation to the mental expenditures? Deflection upon cheek-contact = – 3 mm, clock before t[he] ear = – 5 mm, arithmetical problem = – 6 mm.” Two months after this entry they were married, a year later their son Klaus was born. Berger did not see enough results for publication either right away or later on; thus experiments on skin conductance became a research alternative repeatedly resorted to during crisis situations, but Berger never published the results.

After those unsuccessful animal trials in cooperation with Stübel, further research on cerebral currents initially constituted thought experiments that went so far as to determine the “speed of energy production” intraoperatively by a repetitive electrical stimulation of the human cortex.⁴⁹ Although he hesitated to perform these “vivisections on a human,” Berger asked Fedor Krause nonetheless about the technical details of such experiments.⁵⁰ He even sent a copy of his *Untersuchungen über die Temperatur des Gehirns* to Harvey Cushing in Baltimore and suggested to him a series of experiments for determining the metabolic rate of the brain by cerebral stimulations similar to the ones Cushing had described in a paper in *Brain* in 1909.⁵¹ This

49 31 March 1911: “P.E.? Thought experiments: During operation: Stimulation at known current strength. Repeated stimulation then conditions that no more stimulus effects occur. Is calculation o[f] decay possible? No. As, apart f[rom] current strength, the lighter or heavier decay o[f] the] substance which is being passed through by the electr. current is definitive for the decomposition. I can also only gain temporal determinations, yet better than from t[he] fleeting lamings when the stimulation was being conducted under upheld consciousness in t[he] posterior central fold. Speed o[f] energy production could get determined. Acquisition of comparison figures?” (II, pp. 248f.)

50 Lab journal on 31 March 1911, II, p. 249: “I don’t want to do it: human vivisections! One must let others take the chestnut out of the fire.” Jung mentions a reply letter from Fedor Krause dated 7 May 1911, see Jung 1963, p. 35. Fedor Krause carried out electrical stimulus experiments on the human brain during neurosurgical operations in Berlin (Krause 1911, esp. pp. 177–205), but neither he nor Harvey Cushing in Baltimore nor Otfried Foerster in Breslau looked for intrinsic electric currents of the brain (Foerster 1923 and 1926a, 1926b). Berger’s publications were what prompted Foerster to record cerebral currents intraoperatively (Foerster 1935); see Devinsky 1993, Feindel 1998, Wieser 2000.

51 This is gathered from a reply by Cushing from 12 June 1911 among the Berger papers: “We have a great number of opportunities to follow out the suggestions which you have made, for hardly a day passes when a brain is not exposed for one purpose or another. I was fully aware that the strength of the current should have been accurately measured, and I shall use the galvanic current when we have another opportunity to stimulate the brain of a patient who is not under narcosis. I fully appreciate the significance of the investigations which you suggest.” See also Cushing 1909.

correspondence with internationally renowned experts at his own initiative—as he otherwise never did—shows the fervor with which Berger was searching for new methods to determine psychic energy after his local networks had only led to results of little use to him. The further away concrete research alternatives seemed to slip, the more tenaciously Berger tried to orientate himself by what had already been accomplished. A brief sketch (Figure 5), for instance, revealed how the but preliminary finding in the book on temperature might appear engraved on a brass plaque: “This purpose of my life, that grand goal of my life, is P.E. [. . .] P.E., time and again? Should really have this engraved! [. . .] But first inquire about price” (14 April 1911, II, pp. 245, 259 f.).

During the period that followed, his researches were interrupted by World War I, in which he participated as head of various reserve military hospitals in the occupied part of France. For this reason Berger supplemented his temperature studies by only two papers: During the idle periods of his medical service during World War I he began a series of precise observations of his own rectal temperature to $1/100^{\circ}\text{C}$, which he carried out scrupulously for months and found that psychic processes could clearly influence skin

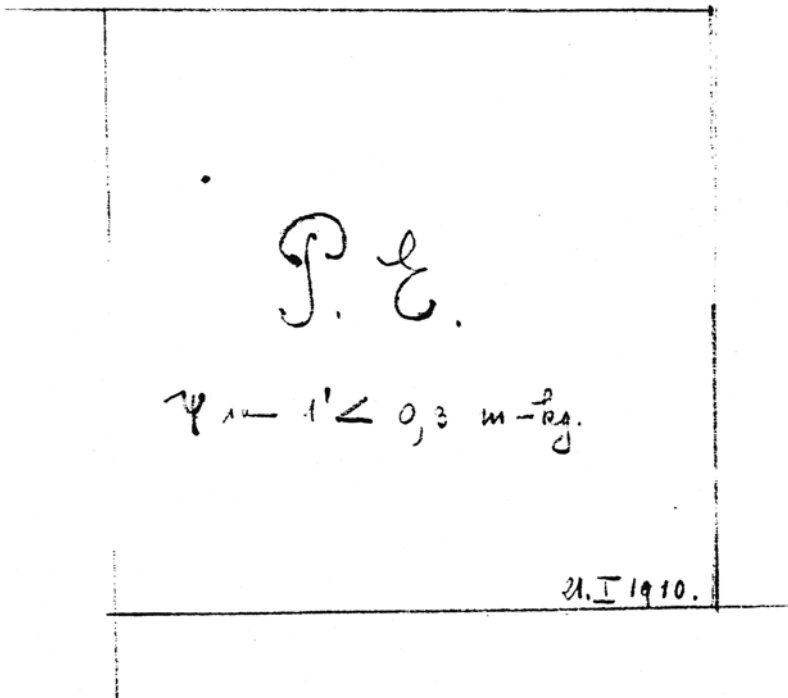


Figure 5 Berger’s sketch for an engraving of the psychic energy formula.

temperature.⁵² In the military hospital he likewise developed a new method for calculating the basal metabolic rate, which also only led to a definition of the upper limiting value, but this time suggested a transformation in psychic energy that was four times larger.⁵³ Berger's futile determinations of the exact magnitude of "P.E." finally got him to look for objective traces of intellectual work by other means but to continue to stay with the graphic method, that is, with new brain curves.

At the end of his academic career Berger published one more time about the physiological attendant effects of psychical processes, and condensed his experimental research into a contribution for the *Handbuch der Neurologie* by Oswald Bumke and Otfried Foerster under the heading *Physiologische Begleiterscheinungen psychischer Vorgänge*.⁵⁴ The great thematical arch that this retrospective casts over the studies ranging from blood circulation in the brain, to temperature measurements and his EEG research, reflected the conceptual continuity in Berger's research program, which from the *Körperliche Äußerungen* up to the EEG remained oriented toward graphical representation of those "attendant effects." However, the retrospectively construed continuity misses the transitions, breaks, and branchings between the different stations along this arch. Precisely the question of how the registration of electric currents, in particular, emerged as an option and supplanted methods that had been followed before is thus rather distorted. In Berger's experimental research there was no temporally distinctly determinable and clearly conceptualized transition from volume curves to temperature curves to EEG experiments. His occupation with electric current curve plots was obviously interspersed with series of transitional experiments, repetitions, and failures; its characteristic continuity was rather one of delays and disruptions. The cortex current experiments were a regularly recurrent alternative to experiments with volume and temperature curves, albeit one that was repeatedly rejected over the course of at least twenty years as not yielding any findings.

52 "That the central temperature rises under the influence of mood swings, I happened also to be able to record in an involuntary experiment on myself during the war period. I was interested at the time in roughly periodic, about 28-day-long fluctuations in air electricity, which in the view of prominent researchers correlated with fluctuations in mental efficiency, and I was looking for attendant corporeal effects in the pulse and body temperature. [...] I did not succeed in establishing any periodic fluctuations. But when one evening I received a letter from home that contained news about one of my dearest family members taking extremely seriously ill [...], the fluctuations in my morning temperature, which for months on end had only manifested an average of 0.15°, rose the next morning by about 0.3°." Berger 1922, pp. 216 f.

53 "Let us assume that upon mental exertion an amount of 1,198 m kg is converted into psychic energy in one hour [...]. Naturally, this calculation just now done is just very preliminary. [...] Despite that, though, I considered it already time to venture to do the calculation of the metabolic rate in the human brain one more time now" Berger 1919, pp. 95 f.

54 Berger 1937a. The contribution had already been agreed at the end of 1925 but was presumably not written before 1934 and finally appeared in 1937.

The intermediary phases of his psychophysiological studies comprised not only analyses of cortex currents but a whole range of other experiments in which Berger occupied himself increasingly with the electrophysiology of the cortex. Thus behind the chronology of failed cerebral current trials mentioned by Berger, a hidden continuity of electrophysiological experimentation becomes visible that extends from the first cortex current experiments in 1902 up to the celebrated experiment of 1924. By that time Berger had gathered enough experience with various electrophysiological experimental apparatus finally to be able to apply electrophysiology in pursuit of his own psychophysiological research goals. This quite heterogeneous series includes work from 1901 on electrically triggered eye movements, examinations from 1908 and 1913 on the so-called corneal or blink reflex, a paper from 1912 on electrically triggered epileptic fits, and a large two-part study published in 1926 on the electrophysiology of the motor cortex and on the nerve conduction velocity in the central nervous system. These experiments in particular require the attention of historians of science because they can be reconstructed as one context of electrotechnical experimental arrangements that gradually reshaped the method Berger used in his cortex current project, with the final outcome being the EEG experiments, which he viewed as successful.

The paper that appeared in 1901 on eye movements triggered by the visual center, *Über vom Sehzentrum ausgelöste Augenbewegungen*, described in detail how contractions of the ocular muscles can be provoked by electric stimuli to the exposed visual cortex of a locally anaesthetized dog. Purposeful variation of the stimulus can steer the eye movements in the given direction.⁵⁵ Thus even before Berger began his monumental two-volume study on *Körperliche Äußerungen*, he had already made the effects of electric currents in the brain the object of experimental analysis. These experiments were a sophisticated and technically demanding continuation of analyses of the brain of live test animals being performed everywhere in Europe at the time. One cortical region of the operatively exposed brain was electrically stimulated and, in most cases, the correlated motor effect was observed. Berger again seems to have acquired the experimental techniques autodidactically by intensive book study and his results document—contrary to his biographers' purportedly well-meant assessment⁵⁶—that by then he must have already been a skilled electrophysiological experimenter. Moreover, Berger established then an experimental arrangement in which brainwaves could also be observed without major modifications. For that, the current source used for the electric stimuli merely had to be exchanged for a current

55 Berger 1901b. In this paper Berger incidentally also argued that such movements could also be triggered by hallucinations, that is, by psychical events, not just purely electrophysiologically.

56 See, for example, Pierre Gloor (1969, p. 7): "From many points of view, Berger was ill-prepared for his new task [of recording EEGs]. He had only little electrophysiological experience [. . .]. His knowledge of physics and instrumentation was limited."

meter. That is why it is hardly surprising that Berger carried out his first cerebral current experiments directly after this series of experiments.

Berger's experimental research in the period from 1908 to 1913 demarcates intermediary steps by which the individual components of the experimental system of cortex current experiments gradually evolved out of various different studies. The experiments on the blink reflex from 1908 and 1913 completed the transition from animal testing to experiments on humans about questions of cortex physiology. Furthermore, Berger tested out new graphical inscription methods, such as the recording of movements of a blinking eyelid.⁵⁷ The *Experimentelle Untersuchungen* from 1912 employed animal experimentation to delve deeper than his earlier plethysmographic studies on blood circulation in the human brain.⁵⁸ It just so happened that electrophysiology and graphical recording first met there in a single experimental arrangement—namely, for the registration of effects of electrically triggered epileptic seizures.

For the phase from 1924, when Berger began a series of electrophysiological tests on patients with cranial defects, the connection between stimulation experiments and cerebral current tests can be understood as a seamless, smooth transition. The “cortical stimuli” and “time measurements” (*Rindenreizungen und Zeitmessungen*) as Berger called these experiments in his notes from 1924, formed the immediate context of the first successful EEG experiment. In these studies Berger transferred onto experiments on human subjects the stimulation experiments tested in the animal trials on the blink reflex and on artificial epileptic seizures. The fact that Berger was now reconsidering such experiments after having rejected them in 1911 as too risky, presumably has something to do with a demonstration of similar experiments by Otfried Foerster at the 13th annual convention of German psychiatrists hosted by the *Gesellschaft Deutscher Nervenärzte* in Halle in October 1922. There Foerster had shown an impressive film about electrostimulations of the human brain during surgery on an epileptic subject, which had received much attention in the professional press.⁵⁹ Compared to these spectacular experiments, Berger's series *Zur Physiologie der motorischen Region des Menschen* were just a small repetitive exercise.⁶⁰ But precisely

57 Berger 1908 and 1913a.

58 Berger 1912.

59 Foerster 1923, see, e.g., Spatz 1922. Two unusual things characterized Berger's cartography of the human motor cortex: First, he executed the stimulation through the closed scalp, at the site of the cranial defect, hence not under the risky conditions of an operation; second, he did not conduct these experiments within the framework of any therapeutic intervention.

60 Berger 1926, pp. 321–342, or 342–356. The second part “On the measurement of the propagation velocity of neural excitation in the central regions of the human nervous system” also rather gave the impression of being a belated repetition of the famous determination of nerve conduction velocity by Hermann von Helmholtz from 1850; cf. also Blasius 1964 and Lenoir 1986.

this repetition produced the difference, because in it the hitherto futile cortex current experiments could stabilize into the EEG.

The experimental arrangement of Berger's stimulation experiments basically consisted of two parts, a device for the application of the electric stimuli and a recording apparatus for the provoked effects. First the effects of the stimulations were mechanically recorded onto a kymograph as the scale of the motions of a finger, tongue, or eyelid; later Berger changed over to graphical inscription of the currents produced from muscular activity. Apart from the difference that here the electric current was conducted not from the head but from various muscles (usually the arm), this recording of currents from muscular activity demanded methodically and technically exactly the same interconnection between body, electrodes, electric wiring, galvanometer, and photographic registration as an EEG recording. The specific experimental setup for the "cortical stimuli and time measurements" furthermore particularly suggested this transition from muscular to cortical currents, as in these experiments Berger performed the stimulation not by the usual psychological tests (touch, taste, pain, mathematical problem-solving) but electrically on the head. In order to get from cortical excitation and time measurements to the EEG, one literally only needed to switch plugs and connect the galvanometer to the cable leading to the head instead of to the inductor. The stimulus electrodes thus became registering electrodes, the recording of currents of muscular activity became the registration of brainwaves, and the stimulus site in the cranial gap became the EEG registration site. Berger's laboratory journals and notes document this smooth transition from electric cortical stimulation to EEG registration within one and the same experimental system very precisely. On the basis of those recordings it can be dated to June–July 1924. The successful EEG test on 6 July 1924 was embedded in this series of trials and was technically suggested by the experimental system:

- | | |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 9 March 1924 | Yesterday I <u>successfully</u> performed a unipolar cortical stimulation on a human with a bone defect. |
| 2 June 1924 | T[he] idea to check for cortex currents in pall[iatively] trepaned persons. |
| 14 June 1924 | The idea occurred to me to redo the analyses of cortex currents on those people with cranial defects. I am preparing all the apparatus for that. |
| 6 July 1924 | Also did time-measurement experiments on Mrs. H[.]. Muscular currents o[f] flexors o[f] forearm also nicely positive with the small string galvanometer. Today trials with Z[.] on cortex currents! ⁶¹ |

61 The entries from 9 March, 14 June, and 6 July 1924 are from the lab journal (IV, pp. 156, 161, 162); the statement dated 2 June 1924 is an unbound note.

Thus, initially, Berger applied current to the brain repeatedly before he managed to record convincingly currents from the brain. Out of the concrete research practice of various electrophysiological experiments, there gradually and successively developed one variant of Berger's attempts to record electrical brainwaves that worked. Individual experimental arrangements, theoretical presuppositions, technical installations, and electrical laboratory practices from research partly dating back many years, merged in 1924 into an ensemble by which the potential oscillations of the brain could finally be registered in a way that let them become an epistemic thing.

Amplified oscillations

Five years lay between the "idea to check for cortex currents in pall[iatively] trepaned persons" that Berger had jotted down on 2 June 1924 and the appearance of the first communication, *Über das Elektrenkephalogramm des Menschen* in *Archiv für Psychiatrie* on 25 July 1929. This was even though just five weeks after that "idea" Berger managed to take what he regarded as his first successful EEG exposures. The preserved graphs and records of Berger's EEG experiments document that this tardy publication of the EEG was by no means due to a lack of trials and results.⁶² From 1925 on Berger executed quite regularly about fifty EEG trials per year, hence about one experiment per week, mostly on Sundays, when he could be sure that the clinic's electrical installations were switched off, above all the x-ray facilities.⁶³ This number of experiments rose only temporarily following the publication of his first notice on the EEG. After the eighth communication to appear out of a total of fourteen, under the stereotypical title *Über das Elektrenkephalogramm des Menschen*, his experimentation diminished to about 25 per year.⁶⁴ By the time the EEG was published in the summer

62 With reference to a first trial on 10 February 1925, that is, presumably at the beginning of the experiments with the large string galvanometer, Berger enumerated his EEG trials sequentially along with their recorded curves. It was only from 1930 on, though, when 1,100 curve graphs had already accumulated, that he began to note down the numbers directly on the graphs. Berger's last EEG trial took place in July 1938, hence ten weeks before he became emeritus, and produced graph nos. 3,576–3,580.

63 The electricity supply of the Nervenlinik in Jena was still based on direct current even in 1937, as can be gathered from a letter by Berger to Hubert Rohrer from 6 March 1937: "We only have alternating current, with a period of 50 Hertz as you suppose, in the x-ray facilities, which are located in a special building that is about 50 m away from the main building of the clinic in which I work. Prior to working with the oscillograph this alternating current is turned off each time." On the performance of these experiments, see Jung and Berger 1979, p. 284.

64 Berger considered these fourteen communications the core of his EEG publications, as regular reports on the progress of his investigations in *Archiv für Psychiatrie*. All the other publications on the EEG were summary or reiterative reports. The second communication

of 1929, over a quarter of all the EEG curves that Berger recorded already existed.

The many hundreds of pages of laboratory records, evaluations, and reflections from the period before the first announcement about the EEG document a permanent state of rearrangement in the experimental setup, because some irritating finding continually drove Berger to radically question his work yet again. A close analysis of these laboratory notes and reflections demonstrates that throughout those five years he did not manage to develop his experimental system into a stable production site of those phenomena Berger imagined to be cortex currents. Rather, the accumulation of data created an increasingly unsurveyable terrain in which each new finding could draw into question the foregoing work. Berger had gone astray in pursuit of private science more than once before.

Berger's special expectations of his first EEG experiment in 1924 can be seen in his decision not to have it performed on one of the test subjects for the cortex stimulation trials being conducted in parallel. He preferred to specially summon a long-trusted patient to the clinic for a weekend just for this experiment and to observe the cortex currents generated by his problem-solving on Sunday, 6 July 1924:⁶⁵ "Today, trials with Z[.] with doubtful cortex currents; clearly positive findings from intell[ectual] exertions but galvanometer not sensitive enough!" Just as before, in a similar culmination of experiments on dogs in 1910 that had been declared as failures, the positive outcome of the experiment was not the recording of continuous oscillations of current from the brain but solely the observation of a special electric potential that was supposed to be specifically correlated with the working psyche. This working hypothesis was the actual obstacle to the materialization of the EEG, which, however, only gradually became perceptible. Yet Berger suspected a technical weakness and immediately planned to increase his investment in machinery. The note about this first EEG trial continues:

Plan to purchase a large string galvanometer & disburse those 3,000 m[arks] thus? Not entirely along the lines of the information I had supplied & of my former plans. But yes! For the attendant effects on the

to appear in 1930, in *Journal für Psychologie und Neurologie*, was certainly not a substitute publication due to any reservations by *Archiv*, but Berger's contribution to a commemorative volume edited by Oskar Vogt for the Swedish brain researcher and specialist in internal medicine at the Karolinska Institutet Salomon E. Henschen (see below p. 73 f.).

65 The patient's acceptance of this appointment still exists among the preserved laboratory records, as if Berger had regarded it as a kind of talisman for the success of those experiments. Other similar documents still available there are parental permissions regarding the examinations Berger later conducted on infants, which document Berger's sensibility and care in questions of medical ethics.

bod[y] of processes of the psyche, part III: Cortex currents (circul. temp. [of] electr. processes!).

[R., 6 July 1924]

The large string galvanometer was ordered right away but over half a year elapsed before it arrived in Jena and could be put into operation. A new word appeared in Jena sooner than the apparatus. In connection with a note about the string galvanometer order, Berger first mentioned “action currents of the human cortex” as the goal of the planned analyses.⁶⁶ This word *Aktionsströme* marked exactly the intersecting region between the two parallel projects, the triggering of muscular activity currents from cortex stimulations and cerebral currents. From this waiting phase up to the arrival of the large string galvanometer, there are among the preserved written reflections some musings about brainwave trials that gave a new name to the planned graphical inscriptions:

May I succeed in realizing the plan coveted since 20 years already & create this way a sort of brain speculum, after all: the Electrenkephalogramm! The same must naturally also be conductible from an intact skull & become a diagnostic aid in recognizing cerebral & mental illnesses!

[16 November 1924, IV, p. 164]

While waiting for the better measuring instrument, Berger pictured for himself a field of research that sounded somewhat like Lehmann's psychoscope but was nevertheless aiming in a new direction, as the added clause about clinical diagnostics so astonishing to Berger evidences. In the elevated tone of the annual review, Berger noted this new name on two more occasions; on 29 December: “May that wish for an Electrenkephalogramm still be fulfilled!” And on 30 December 1924, programmatically: “I do just have one definite heartfelt ambition but the true one: aut sacram aut nihil!—truly lasting achievements!—brain speculum idea: ‘Electrenkephalogramm!’”⁶⁷

In February 1925, when the trials with the large string galvanometer began and, in full confidence, with them a running enumeration of those experiments, the *Electrenkephalogramm* idea soon proved to be premature. The new apparatus did not produce the hoped-for breakthrough. Instead, the improved sensitivity to electric currents led to even more noise because the differences between the anticipated and observed findings

66 “Besides that [the cortical stimulations], & as the major goal, the ‘action currents [of] the hum[an] cortex!’ The large Edelmann string galvanometer is ordered & paid for. In the Hufeld building everything is ready for its installation” (31 August 1924, IV, p. 163).

67 The quickly added quotation marks around “Electrenkephalogramm” probably illustrate Berger's initial uncertainty about employing this term.

became more obvious. The technical improvement in the experimental setup did not yield what had been the reason for it being done in the first place. Berger tersely noted in the lab journal on 22 February 1925: “Cerebral currents not yet detectible” and shortly afterward:

I have good action currents of the ext. dig. comm. [finger-stretching muscle] upon cortical stimulation from Z[.]. The cortex currents are too weak for them to be practically exploitable. Purely scientific interest & exposure only possible in exceptional cases.

[IV, pp. 165 f.]

Instead of acting like a brain speculum and tracing the “Electrenkephalogramm” as a curve of psychical activity, the new instrument did still perform good services throughout the summer of 1925 recording muscle-activity currents. It inscribed the electrically stimulated unconscious motor impulses for the “time measurements” upon cortex stimulation and Berger was able to complete the experiments in October and prepare them for publication.

On the side, Berger conducted a series of other attempts to register brain-waves, and not all those attempts proved unsuccessful. Particularly after the cortical stimuli ceased there were promising, albeit conflicting results. Yet again, technical variations, modifications in the conduction technique, the electrode material or their attachment, and finally an even better instrument were supposed to produce the breakthrough:

I have also been continuing to work on the Electrenkephalogramm & am modifying the electrodes again (new design of unpolarizable electrodes): I believe to be on the right track. Mr. Hilpert is helping me well. [. . .]—I intend to procure a Siemens moving-coil galvanometer on 1 IV 26 for Electrenkephalogramms?

[30 November 1925, IV, p. 173]

If Berger did in fact order that moving-coil galvanometer on 1 April 1926, its delivery apparently was delayed or else it took longer for the device to be customized according to the specifications required for the registration of cerebral current. The first preserved graphic exposure with the new instrument is dated 9 April 1927.⁶⁸ When the moving-coil galvanometer could finally be utilized after a waiting period of an entire year, a single day

68 The secondary literature often erroneously mentions 1926 as when the work using the moving-coil galvanometer started, even though Berger himself indicated in his EEG monograph that he received the double-coil galvanometer “in April 1927”; see Berger 1938b, p. 179.

of experimentation sufficed for Berger to question the status of his equipment all over again and look around for improvements:

If I do arrive at the result that the waves form inside the brain & I thus really do have the human Electrenkephalogramm before me, then it must become [possible?] to conduct them from all human skulls. But for that a corresponding [amplification?] would be necessary, so then t[he] oscillograph really would be needed.

[R., 10 April 1927]

Such reflections were not just toying with ideas; Berger actually managed to think up another possible way of perfecting the technical equipment. However, an oscillograph with vacuum-tube amplification lay far beyond Berger's financial means in 1927: "I heard from Siemens: 20,000 m[arks]! The grapes are dangling too high & I can also make do with the coil galvanometer for the time being" (R., 22 November 1927). It was only after 1931, when the publications of Berger's EEG had already attracted broader interest and he could gather new financial support as a result, that Berger had Siemens & Halske construct an oscillograph according to his specific requirements.⁶⁹ At each step of such technical modifications, there were high-strung expectations dashed by each concrete improvement in the detection capabilities. Along the course of the technological history of Berger's electroencephalography, the development of the method can be reconstructed negatively, so to speak. It mirrors the crises in his project.

The productive phases in the development of his experimental system occurred during the wait for supposedly better equipment. Phases of technological standstill compelled more intense confrontation with what had been achieved and turned out to be unexpectedly productive. By the end of April 1926, during that year of waiting for the moving-coil galvanometer, he had traced "105 good curves" and had become persuaded that he had found his special research topic: "I am glad that God let me find what I always wanted, an original scientific task of my own that fully occupies me and to which I want to dedicate all my energy.—(Electrenkephalogramm!)" (R., 11 April 1926). And the succinct remark in the note written one-and-a-half years later that he could "also make do with the coil galvanometer" conceals perhaps the decisive turning point in Berger's experimental system. In autumn 1927 Berger began to describe the recorded curves *before* deciding whether

⁶⁹ That he had thus hit upon a financial limit for improvements of his technical equipment for the next four years quite evidently remained a thorn in his side, because in the closing sentence of his first EEG paper he considered it necessary to justify his failure to record the EEG using an oscillograph with the cost as well as to mention his inquiry to Siemens & Halske in 1927; Berger 1929, p. 570.

or not to toss them out as insufficiently instructive. This time the curves came from his 15-year-old son Klaus, which might perhaps have contributed toward their not being rejected prematurely.

In connection with a successful series of experiments, Berger started in September 1927 a systematic survey of the EEG trials, in which he organized his results for the first time based on a description of the findings—instead of eliminating all that had already been gained by making selections among the findings on the basis of his expectations:

A survey of the curves taken of Klaus in 5 different arrangements has yielded bifrontal conduction as the best. There then appeared waves of 86–88 σ that are composed [?] of waves of 16–20 σ .—Therefore, from among the 80 σ waves there are 11–12 [to 1]; from among the 20 σ , 50 [to 1 sec.].

[R., 15 September 1927]

Εῦρηκα I have indeed found the Elektrenkephalogramm and can also conduct it from the unscathed skull.

[R., 21 October 1927]

Berger's "*Εῦρηκα!*" did not remain unchallenged in 1927 (and later continued to be plagued by new doubts) but the first useful description of what had hitherto hardly been more than vacillation between results and noise had now come alongside the *idée fixe* of a brain speculum. The distinction made here between two basic types of waves would prove to be a constructive orientation that in the longrun would become the crystallization point of Berger's EEG.

The recording of these wave forms as a gauge allowed different electrode arrangements to be compared pragmatically and thereby the experimental arrangement optimized. A phenomenon generated by the experimental system, the magnitude of the recorded wave became the evaluation gauge that permitted an assessment of the experimental production of data independently of the assumptions made in brain theory. The experimentation was still not a stable production of scientific objects. But Berger had acquired an experimental system that produced curves, provided concrete answers to questions, and generated new questions. The contest between technical improvements and disappointments about faulty data turned into research on curves. For example, as a consequence of his experiments on his son, Berger planned the next series to be intracerebral recordings of electric potentials from patients in order to prove the cerebral genesis of the curves. The experiments progressed with a purposefulness that had hitherto been impossible for lack of even a basic orientation among the recorded waves. One month after the *Εῦρηκα!*, intracerebral recordings likewise exhibited

currents in the brain.⁷⁰ A control experiment on Klaus a few days later confirmed those intracerebral recordings: "I am completely sure about the *eureka*: The curves from Klaus from 30th Nov. agree in all details with the intracerebrally recorded curves from W[.]. No more control analyses are therefore necessary" (R., 2 December 1927).

The technical leap from the string galvanometer to the moving-coil galvanometer did not have the effect on the recordings that Berger was hoping for. The cerebral currents did not "suddenly" appear out of the registrations. Rather, the augmented sensitivity emphasized the distance between working hypothesis and observed phenomena. The work with the moving-coil galvanometer nevertheless constituted the decisive phase primarily because of the new representational technique attached to the new signaling method (Figures 6 and 7). The string galvanometer's photographically negative curves traced a white shadow of the galvanometer filament on a blackened background. The curves drawn by the moving-coil galvanometer, however, produced the potential oscillations as a black trace of the light beam on white paper.⁷¹ Apart from the increase in sensitivity for the detection of electric potentials, the improved form of the recording, with its broad black lines on wide white photographic paper instead of the faint, white-on-gray oscillations in the murkiness of the narrow black strips, would have been the decisive factor motivating Berger to sharpen his reflections about the EEG by the object that his experimental system produced. Thus began a phase of adjustment of the experimental system,⁷² in which Berger gradually disengaged himself from his presuppositions and the EEG, in turn, gained

70 "Today intracerebral conductions [. . .] *Eureka* legitimately holds" (R., 26 November 1927). One year later he performed another series of such experiments, even though the first one had already produced good curves because in the interim he had become unsure about his observations again. In temporal proximity to these intraoperative conductions he then also performed a series of animal tests, which he had not done since the cooperation with Stübel in 1910.

71 The moving-coil galvanometer produced by Siemens & Halske was a further development of the string galvanometer, in which instead of the very fragile filament a tiny rotatable mirror was suspended in the magnetic field of a coil. Berger informed himself about the properties of the new device from the paper by Schrupf and Zöllich (1918). Siemens & Halske produced the coil galvanometer serially as a device for electrocardiography optionally with one or more measuring circuit loops. Berger's device was a customized version with two of them with specially sensitive "inserted parts" that allowed simultaneous and independent recordings of two weak electric currents, with two more recording channels for the markings of time and the signal. Judging from the photographs of Berger's experimental arrangement from that time published by Richard Jung (1963, p. 42) and Pierre Gloor (1969, p. 32), as well as from the illustrations in the company catalog, Berger's instrument is identifiable as an only slightly modified "Elektrokardiograph Type B" which apart from the special coils largely corresponded to the serial model by Siemens & Halske; see Siemens-Reiniger-Verfa 1926, pp. 5–14.

72 I borrow the meaning of the term "adjustment" (*Ausrichtung*) from Hans-Jörg Rheinberger 1992, esp. pp. 9 f.

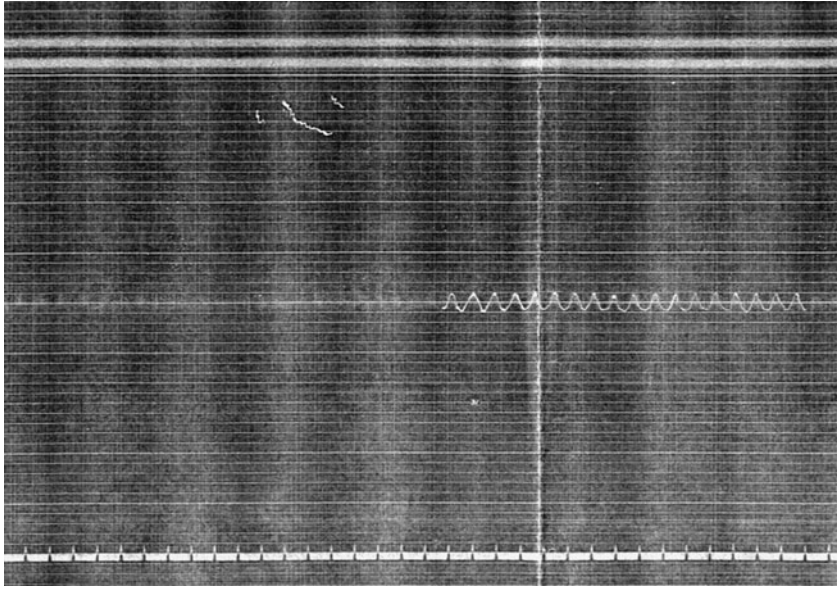


Figure 6 Cerebral current recording from 19 October 1925 generated by the string galvanometer. Bottom: the time signal; center: the brainwaves, redrawn by Berger in white ink on the right half of the image as a regular fluctuation.

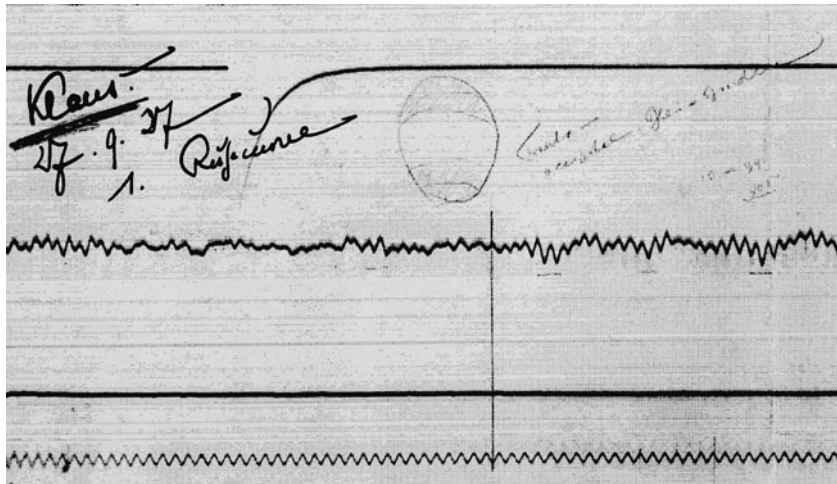


Figure 7 Cerebral current recording dated 27 September 1927 generated by the moving-coil galvanometer, which first recorded black-on-white curves on photographic paper. Center of image: EEG signal; bottom: marking of time as a regular wave. Berger classified the dominant fluctuations on the right half of the image as “waves of first order” (the later alpha waves).

experimental shape. In this process of continual experimentation, the EEG took on a form that at the beginning had been neither predictable nor articulable as a goal.

Artifacts and noise

The establishment of a somewhat reliable inscription technique with the moving-coil galvanometer in 1927 may have led to enormous advancement; but certainly not all the obstacles for the development of electroencephalography were overcome. On the contrary, the productivity of the experimental system posed a new hurdle because noise no longer simply meant the failure of the trial but appeared in a variety of forms. Until then the hoped-for special currents could hardly be found anywhere; now currents of the most disparate kinds confusingly similar to cerebral currents were lurking about everywhere. Up to then, Berger had been unduly straining his experimental system with exaggerated psychophysiological operationalization; now, its empirical productivity was stifling him. In the sea of electric current plots that Berger's analyses were continuously producing, orientation was difficult and each determination of position could be drawn into doubt by subsequent observations.

Compared to Berger's other brain-curve projects, the special difficulty that the EEG presented was that its standard was only determinable during the process of generating the curves. No archetype of electrical brainwaves was available yet. The work involving the registered EEG curves begun in autumn 1927 can be characterized as a phase in which the most reliable and selective EEG inscription was determined. Ostensibly, the point was just to establish appropriate recording procedures and distinguish the EEG from artifacts. The complexity of this research is missed, however, if it is reflected off the much later defined standard. Berger was in search of first orientational marks to draw the brain curve out of the sea of attendant current oscillations. Determining what could count as an EEG was the core of the problem—and this required just as much technical evaluation as it required modifications of his starting hypothesis. Berger checked the registrations that his experimental system produced very carefully and scrutinized them from every conceivable angle, but neither at this stage nor in later years did he seem to address those doubts in any systematic form. Alterations of the technical conditions, exclusions of artifact sources, and revisions of his hypotheses were inextricably entangled and permanently influenced each other, with the result that he was often shifting different parameters at the same time. The existing records and reflections document a vacillation between confidence and doubt that could continually draw into question even already established findings or make him return to claims that he had once raised but subsequently dismissed.

Nevertheless, three ordering strategies can be distinguished (Figure 8). A first form of the work on the curves was their optimization solely

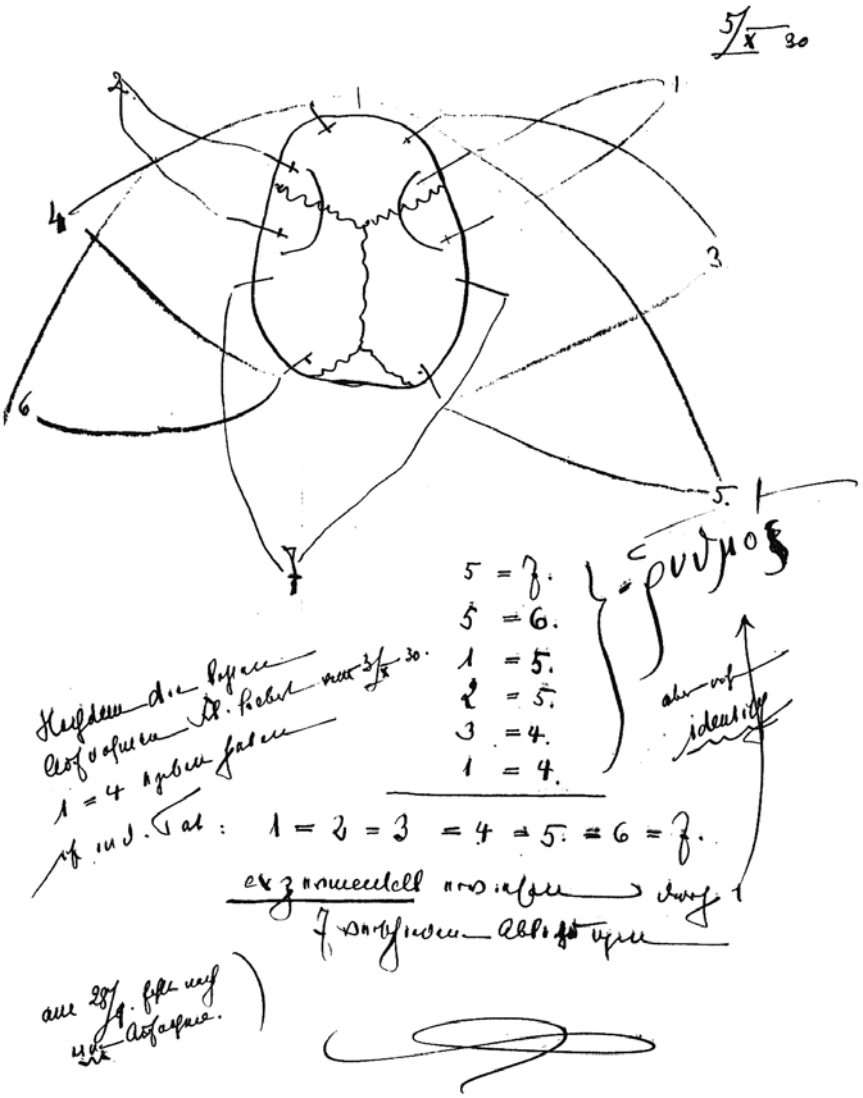


Figure 8 Trial analysis of different variants of EEG registration from 5 October 1930. This trial confirmed Berger’s assumption that the EEG was a record of a uniform cerebral process.

regarding their graphical inscription in the two-dimensional space of representation. The identification of the “waves of first order” allowed comparative evaluation of different approaches, to see how prominently they recorded that type of wave; and Berger purposefully aimed his experimental system

toward their largest possible registration.⁷³ A second form of the work was the separation of the EEG from other curves. For the *Elektrenkephalogramm* to be valid, the inscribed waves had to be verified as genuine brainwaves, that is, against every conceivable form of interference and parasitic current. For that the moving-coil galvanometer with its two circuits offered comparative registration of two electric curves. The technical arrangement of his inscription apparatus thus suggested the parallel representation—so typical of Berger's *Mitteilungen* written around this time—of the EEG and ECG. When curves traced in parallel in this way showed numerous common waves—thus, for instance, EEG and ECG curves, or pulse waves and brainwaves became confusingly similar—many a pattern that had already been definitely recorded as an EEG threatened to become a Fata Morgana again.⁷⁴ A third form, finally, remained focused on identifying special brainwaves as traces of psychophysical processes, even at this stage of Berger's work on curves.⁷⁵ However, this project modified to the extent that Berger began to interpret a continuous oscillation of current as an EEG, that is, when a conceptual difference between the EEG and the actual psychophysiological brainwaves began to be built into his experimental system.

Thereby a new problem arose: identifying the psychophysiological significant events in the registered brain curves. A note from April 1928 documents how closely the search for artifacts interacted with the optimization of recording conditions and the guiding issue of special psychophysical potentials:

One curve can be recorded from the upper & forearm. Either the accord with a curve recorded from the skull with an intracerebrally recorded one must be [demonstrated?], or else the oscillations of the one recorded from the skull may only occur during t[he] ψ work! The latter would be the most worth striving for & would agree with the 1st observation with Z[.]: filament oscillations just during calculation!

[R., 18 April 1928]

The recorded waves did occasionally show clear psychophysiological dependencies and regularities, but they could not easily be made to suit

73 This was one reason why Berger favored so-called bipolar conductors with the distance between the electrodes as large as possible, even after others had criticized this form of conduction as being too aspecific.

74 Comparative conductors with electrode foils or needles, electrodes out of very different materials, using different attachment and fixing methods, etc., had the aim of eluding "other" currents and distilling out the EEG as a "pure" brain curve. Large foil electrodes, for example, were supposed to make the fluctuations in skin resistance a negligible curve source; needles pierced down to the cranial bone were literally supposed to undermine skin conductance.

75 Consequently, this was not a radical change over to pure curve description, as happened at other laboratories later on.

Berger's hypothesis of the representation of special psychic activity of the brain. Sometimes a test exhibited a good agreement between wave and psyche through an increase in amplitude and accentuation, but soon afterwards its opposite—namely, a vanishing or at least a diminution of the regular oscillations of greater amplitude. Berger frequently and regularly produced such contradictory results in his experimental system. They repeatedly provoked new doubts about the EEG and occasionally compelled him to draw contrary conceptualizations within the span of a few weeks:

Results O[.]: Intellectual exertions and emotive excitation, specifically also alarm, cause a considerable height increase and slowing down, above all of the 90 σ waves.

[R., 1 November 1927]

[.], that during intellectual exertion the oscillation[?] of the EEG decreases. [. . .] Cerebral thermal development from a chosen idea, along the lines of my P.E.

[R., 23 November 1927]

Amid all these oscillations, only swaying ground could be gained. This point still remained unclear in the publication from 1929, which was why Berger chose an extremely circumlocutory closure to that notice:

Is it possible to detect the influence of intellectual work on the human Elektrenkephalogramm, insofar as it has been communicated here? One naturally should not cherish too great hopes from the start, because, as I have explained elsewhere, intellectual exertion adds only a slight supplement to the constant cortical work going on not just in the waking state. But it would be entirely possible that this supplement, which accompanies the constant activity of the brain, could make itself recognizable in the Elektrenkephalogramm. I have, of course, performed numerous trials of the kind but did not arrive at any clear solution. I am inclined toward the opinion that upon strenuous mental exertion the larger waves, lasting on average 90 σ , the waves of first order, fall back more, and the smaller 35- σ waves of second order become more frequent.⁷⁶

Berger had not just performed “numerous trials of the kind.” The attempts to make that “slight supplement” from “mental exertion” visible had been the goal of the whole enterprise from the very outset. Having embarked on the cortex current experiments in 1910 in order to prove specific psychophysical transformations of energy in the sea of energetic

76 Berger 1929, p. 569.

processes in the brain, he had now arrived by a very circuitous route back at the sum of "cortical processes." The many changes in the medium from volume and temperature measurements to the registration of currents from the brain had not proven to be a suitable filter for representing psychical activity in distilled form.

The downright inflationary reappearance of "*Εὔρηκα!*" in Berger's laboratory notes (which he always noted down in Greek letters) demonstrates the fundamental upheavals that accompanied the design of electroencephalography. At the same time, it illustrates as no other detail Berger's idealization of this process according to the model of a single, all-important pivotal point (Figure 9). Instead of giving the final revelation he was yearning for, his experimental system continually produced new quakes that forced him to give up the business more than once, even though he was incapable of stopping: "The Elektrenkephalogramm business must be finally abandoned" (R., 10 July 1928). On the following day he added: "closed 11.7.28," but two months later it reads: "I've got it, I've found it!", just when I had already given up the matter in despair! *Εὔρηκα!* I've found the Elektrenkephalogramm!" The problem gave him no rest, the tracks of brainwaves had him spellbound, even though this *eureka*, too, hardly lasted three weeks: "Thought: All foregoing curves = one electrocardiogram modified by the various pressure and therefore the various magnitudes of the contact surfaces between skin and electrode" (R., 21 October 1928).⁷⁷ And under the date 18 December 1928 it reads: "I once again had reservations about whether my cortex currents, or my: Elektrenkephalogramm, don't perhaps only present vibration or flow currents." (R.) In this situation Berger even performed a series of conductions from his shinbone where he likewise detected very small deflections but also found waves of a frequency that were similar to the supposed brainwaves.⁷⁸

Vibration currents, flow currents, noise, skin conductance, pulsation waves, electrocardiograms: All these interferences ultimately forced Berger at the end of 1928 to dislodge his Elektrenkephalogramm from the currents of psychophysical activity and to examine the permanent oscillations of the electric potentials as such. The currents from skin conductance, in particular, that he had once again considered as a research alternative exactly that autumn 1928, Berger could not just "easily" record, as it reads in a note. They always got in the way whenever he was trying to record psychophysical brainwaves. The ubiquitous potentials of the psychogalvanic skin reflex finally motivated him at the end of 1928 to separate his Elektrenkephalogramm at least temporarily from psychophysiology and interpret it as purely

77 He later softened the radical nature of his doubt somewhat by inserting "skin" before "curves," thus recognizing the needle conductors and intracerebral EEGs as such again, after all.

78 "My curves from the tibia included just perceptible oscillations of 100 and also 80 s [. . .] Shouldn't the skull curves also just be vascular curves, after all?" (15 October 1928).

It was only at the turn of the year from 1928 to 1929 that electroencephalography became a space of representation for brainwaves, in the sense that the technical specifications of the experimental arrangements and the associated experimental practice that Berger had been gradually distilling out since 1910, established brainwaves as an epistemic thing. "Brainwaves" were henceforth defined methodically as the product of a particular inscription technique. They were still not even nearly exhaustively described yet but had stabilized enough to produce new open questions in research on this epistemic thing at the Jena laboratory and later at countless other laboratories. Over the course of almost two decades, there emerged out of the vague notion of "cortex currents" a scientific object. Formerly mainly extant as the difference of its technical inscription and as the project of an ideal psychophysiological experimental system, this scientific object was henceforth a reproducible effect of a specific arrangement of test person and technical setup. Thus, at the same time, the stage had been reached at which Berger's experimental system also became reproducible outside his laboratory, although more years would have to pass for that.⁷⁹

Berger's extreme vacillation between effusive enthusiasm about the discovered currents and radical self-doubt or scathing criticism of his curves, the recurrent fundamental questionings of his results, and the infinite variations of details of his experimental arrangements earned him the reputation of a badly informed recluse. In one epistemological respect, though, Berger's vagaries document the difficulties along the way from a firm concept, in which cortex currents were *ideally* anchored as an indicator of psychical processes and a brain speculum was supposed to function as their detector, to an *empirical* process guided by the inscribed curves for the registration of electric processes in the brain. Berger's constantly recurring basic doubts about whether the curves he had inscribed could be an image of electrical brainwaves at all, evidence that new experiments in principle did not offer a way out of the dilemma of having to establish a plot in uncertain new terrain. Even after the EEG was published, Berger would continue to revise his hypotheses repeatedly in his various subsequent *Mitteilungen* about the "true" shape and significance of the curves traced by his apparatus.⁸⁰

Berger would only find a way out of this self-referential experimentation and his encapsulated reflections about the inscribed curves by publishing the results he had gathered. The exchanges with others and social deliberations on the observed phenomena also retroactively decided on the existence and form of the EEG in Berger's experimental system. According to Harry

79 On differential reproduction as a characteristic of experimental systems, see Rheinberger 2001, pp. 76–87.

80 Even after his retirement he was planning a new research program in which he wanted to examine with scientific precision all the high EEG frequencies eliminated up to that point as noise and artifacts, because at that time he interpreted them as a new track of psychophysiological events (see below, pp. 120 ff.).

Collins, experimental scientific findings cannot be refuted in principle because each researcher can always retreat to the special conditions of his or her own experimentation. Berger's case illustrates, conversely, that "on their own" the findings of private science cannot become refutation-resistant phenomena.⁸¹ The circularity of Berger's experimental system between 1927 and 1929 hence roughly presents the mirror-image case to Collins's "experimenter's regress" and then could perhaps be allusively constrained to "regress of the experimental system."⁸² Each achievement also reproduced doubt in Berger's experimental system. The stabilization of his experimental system by the measuring technique itself led to a series of crises that drove Berger's cerebral current research to dramatic heights again and again. The technical perfecting did, in fact, have a catalytic effect, but in a direction that was existentially threatening to Berger's experimental system, because it produced problems for which there was no system-immanent resolution. In retrospect it becomes less a question of why he hesitated to publish his experiments in 1929 than, rather, how he did arrive at the view at that time that his results were worthy of publication.

Invitation to Stockholm

The developments regarding the EEG reconstructed here were surely only known to a very small group. Apart from him, presumably only his wife Ursula knew about the dramatic circumstances. Some test subjects and assistants might have had an inkling about what Berger was experimenting on with his mysterious apparatus.⁸³ The select assistant physicians allowed to participate in his trials— all just as test subjects, excepting his sole "genuine" pupil Paul Hilpert—presumably understood more and might well have had a differing opinion on them.⁸⁴ The EEG appeared in Jena as

81 The trivial dependence of a scientific observation's validity on its (social) acknowledgment is not meant here but the nontrivial dependence on the materiality of its production, which is tied to its context.

82 Collins 1985.

83 Apart from choosing various patients, Berger favored his own children as test persons. Quite different from during the period of their engagement with their joint experimentation on psychogalvanic reflex phenomena—his wife no longer seems to have volunteered for the EEG experiments, which was probably mainly for family reasons: By then the married couple had four children.

84 See the portrayal by Raphael Ginzberg, who was employed at the clinic from 1929 until 1932 initially as assistant to Heinrich Boening but from 1930 on as Berger's head physician: "Certainly at the time I was at the hospital no one, with the possible exception of Hilpert, had the remotest idea of electroencephalography. And that was five to seven years after Berger's discovery, and after his early papers had been published! There can be no doubt that Berger was the sole creator of electroencephalography. He let nobody into the secret of his investigation. What he achieved, he achieved by his individual effort" (1949, p. 364). These statements should be taken with a pinch of salt, though, as it is hardly conceivable that not even Berger's colleagues in Jena would have read his papers, which were, of course, already published by then.

an individual product that was developed largely in isolation. The publication in 1929 only changed this gradually. Berger then began to include a select circle of his assistant medical practitioners in his experiments as test subjects; but under Berger the EEG never went beyond purely experimental application. Neither did Berger ever do any routine EEG investigations as a part of his activities as a doctor at the clinic, nor did he commission others at his clinic with the execution of such analyses. After his retirement in 1938, the EEG laboratory was dissolved and most of the apparatus was apparently handed over to other institutes. Later plans made with Rudolf Lemke to establish a new EEG laboratory in Jena could not be materialized under wartime conditions (see below, p. 140). But it would surely be wrong to draw from this almost autistic handling of the EEG any conclusion about Berger's position in the academic community at Jena. In order to reconstruct the EEG's path to publication in 1929, in particular, it is necessary to break open this isolation historiographically and place Berger within the context of his professional activity.

Two phases of great scientific productivity characterized Berger's lifetime. The first phase, which coincided roughly with the first decade of the twentieth century, incorporated the lengthy monographs up to and including *Untersuchungen über die Temperatur des Gehirns* and the subsequent search for a suitable way to detect "P.E." physiologically. The second productive phase began with the consolidation of his covert researches on cerebral currents in 1927 and continued on from the publication of the EEG in 1929 up to his retirement from the university in 1938. During the first phase Berger worked toward his academic certification through his scientific research; as his reputation grew he managed to attract cooperation in other branches but he remained independently active. After his habilitation degree in 1901, he was appointed supernumerary professor in 1906 and in 1912 obtained the position of *Oberarzt*. At this head physician post in the civil service he was responsible for general patient care at the clinic, excluding Binswanger's private practice.⁸⁵ While the EEG experiments were under way, though, he had already been director of the clinic for many years and conducted research after official working hours, mostly only supported by his personal assistants.

At the transition from one phase to the next there was a four-year period of wartime service. At the outbreak of World War I, Berger first became staff doctor of the reserve in Erfurt before he was transferred in February 1915

85 Binswanger chose as head physician for his private patients Berger's one-year-younger colleague Wilhelm Strohmayer, who also stayed in Jena throughout his life, finally working under Berger as *head physician*. Kurt Kolle, who completed his medical studies at Jena at the beginning of the 1920s, compared his two teachers Berger and Strohmayer in his autobiography as follows: "The psychiatrist Hans Berger, my later boss, was altogether a poor teacher. The introductory lecture by his head physician Strohmayer, on the contrary, was extremely vivid. This sensitive person, who was something of an artist in character, introduced the sick to his audience" (Kolle 1972, p. 33).

to a field hospital in Rethel at the western front. From October 1915 until war's end he was directing the psychiatric department of the field military hospital in Sedan. His military duty offered him, as well as many of his professional colleagues, the opportunity to conduct extensive neuropsychiatric observations.⁸⁶ On the other hand, it also left him an unaccustomed amount of time for leisure, self-observation, and reading.⁸⁷ His free time spent during his field hospital duty mainly on the study of philosophical and religious texts—by Kant, Spinoza, Gracián, Renan, and the New Testament—surely reflected his way of dealing personally with the trauma of that war.⁸⁸ The metaphysical motivations already guiding his philosophical approach to his psychophysiological research program were remolded by religious ethics. As a student Berger had voluntarily registered for military service in 1893 after his first, disappointing term of studies in mathematics and astronomy in Berlin, and for a time he had been unsure about whether to pursue a career in the military as an officer. It was only after a serious, nearly fatal accident that he began to study medicine. During the war he was relieved to be deployed as a physician and not in direct combat.⁸⁹ His later withdrawn, overly correct conduct and rigorous regard for discipline as director of the *Nervenlinik*, that was often described as militaristic, might well have been a consequence of his wartime experiences. Apart from such an accentuation in his personal style, the war seems hardly to have affected the course of Berger's further researches. During the war, while reflecting on future experiments, just as after the war as he resumed his analyses, he would always return directly to the plans and considerations he had made during those critical years after 1910.⁹⁰

P.E. is the major project! It is the task posed for me especially. Naturally also do enough besides in another field for t[he] tenured professorship o[f] psychiatry not to elude me, because the capability for me to work along my lines is, of course, connected to that.

[22 August 1910, II, p. 35]

86 Berger processed most of these observations for papers only after the war had ended; see Berger 1920, 1921b.

87 E.g., his scrupulous series of rectal temperature recordings mentioned above (see p. 48) in search of a monthly cycle of “mental efficiency.”

88 In the context of Helmut Lethen's thorough analysis of that generation's strategies to come to grips with their experiences and the effect they had on the intellectual culture of the Weimar Republic, this choice of reading material, and particularly the author Gracián, was rather specific to that generation, certainly not a matter of chance; see Lethen 1994.

89 “I sure am glad that I'm not a combattant, don't need to wound or kill any people, but can rather help and heal! [. . .] How much I like to help even the French, those poor Russians, who are dying here so far away from home.—T[hat] general humanity—that which Christ brought into our consciousness.—Socrates considered only the Greeks humans, not the barbarians, not the slaves!” (17 January 1916).

90 “Stick with your cortical measurements. No experiments on human beings!” (5 August 1915, KT 2, p. 35).

Berger heeded this self-admonition before and after World War I by increasingly devoting himself to publications in anatomical histology, clinical experimentation in neurological and psychiatric pathology, as well as to the results of his activities as an expert consultant.⁹¹ With these comparatively conventional publications, it might well be doubted whether he did, in fact, merit the professorship. When the Jena chair was to be refilled in 1919 when Binswanger unexpectedly resigned as director of the clinic to go to Switzerland, Berger was only placed third on the list of candidates, behind Robert Wollenberg and Karl Kleist.⁹² Despite his variety of experimental investigations, scientific originality was denied him in a vote by the committee—apparently his researches in the wake of Ziehen, Mosso, and Lehmann, with their often sweeping and speculative psychophysiological interpretations, were situated so far out on the periphery of established psychiatry that he did not reap sufficient academic recognition out of them. That he got the chair nonetheless was mainly thanks to Binswanger's active support.⁹³

Attendant with the appointment came the academic and social obligations of a director of a famous psychiatric clinic, which Berger evidently quickly met. In 1920 he was engaged as a reader for the Prussian medical continuation courses for physicians on "Psychology and Its Importance to Medical Practice."⁹⁴ In 1921 his *Psychophysiologie in Vorlesungen* appeared and he was commissioned to analyze Ernst Haeckel's brain jointly with the anatomist Friedrich Maurer.⁹⁵ In 1923 he joined the elevated circle of editors

91 Here may be mentioned, above all, papers on localization diagnostics, such as Berger 1911a, 1911b, clinical papers such as Berger 1914, and his expert opinion on accident assessment (Berger 1915).

92 University Archive, Jena, holding C 390, sheet 4.

93 Binswanger wanted Berger as his successor and won the backing of the dean of the medical faculty; in addition, he arranged for positive references by Gabriel Anton and Theodor Ziehen (University Archive, Jena, holding C 390, sheets 117 f.). How much the political unrest of 1918–19 might have helped, in addition, to having the appointment be issued to the locally residing candidate, after all, and not to the first choice, the renowned pupil of Westphal and Hitzig, Wollenberg—who had lost his position in Strasbourg with the war, and therefore was in need of employment—is no longer ascertainable. Berger's later assistant Ginzberg (1949) insinuated helpful contacts among the revolutionary councilors; but no evidence of this can be found among the university files.

94 Precisely because of his special psychophysiological interests, he maintained considerable distance from psychotherapeutic approaches, particularly also psychoanalysis. He much preferred such proven methods as electrotherapy and hypnosis. One note in his journal from 1930 pointedly indicates Berger's skepticism: "Among primitives the treatment of the sick is purely ψ [psychic]! [. . .] Modern exaggerated ψ therapy is hence actually a relapse back to primitive states—as in art, etc." (V, p. 59). In view of Berger's mystically religious reverence of nature, "science" seems also to have simultaneously served as a magical amulet against the powers being sought there.

95 According to Berger's journal entry dated 6 February 1921. Haeckel had died in 1919. Maurer's (1924) study gave no indication of any collaboration with Berger, but a report by his assistant doctor Waldemar Weimann "About the histological finding on Haeckel's brain"

of the journal *Archiv für Psychiatrie und Nervenkrankheiten*. In addition, he devoted himself to the clinic and to teaching with a regularity and punctuality famed in Jena.⁹⁶ His clinical diagnostic expertise primarily in localizing brain tumors quickly won the particular admiration of his surgeon colleague Nicolai Guleke, with whom he jointly published a paper on the operative treatment of cerebral tumors.⁹⁷ Briefly put, Berger established himself with some success as a neuroscientifically orientated psychiatrist. Eight years after his professorship appointment, Berger was elected university rector, on 4 February 1927, with a great majority voting against another candidate from the theology faculty; Berger had reached the highpoint of his academic career. Even during the year of his rectorship, Berger proceeded with his experiments on the EEG with the customary continuity, and the decisive first series of trials with his son Klaus happened in autumn of that same year. Berger did not number among the prominent group of German neurologists and psychiatrists, such as Oskar Vogt, Karl Bonhoeffer, Oswald Bumke, Viktor von Weizsäcker, or Kurt Goldstein, though, for the simple reason that Berger usually did not participate in the annual conventions of the professional associations. However, he was certainly not an outsider and reclusive crank. This role was only assumed during the development of electroencephalography, when he began to isolate himself from divergent opinions about the EEG and from criticism about his approach.

But the positive development of his academic career perhaps indirectly encouraged this isolation of his research on the EEG and raised the publication hurdles. By then, after so many years of preliminary trials and long since started systematic experimental series, it was far too late for any preliminary notice about his observations. As *Ordinarius* and rector he certainly could not risk coming forward with an only half-heartedly formulated paper that he himself was still unsure about.⁹⁸ Only on one occasion did he

was appended which, quite in contrast to Maurer's hymn-like brain analysis, reported dryly about atrophy and Alzheimer's. On Maurer's analysis, see Hagner 2004, p. 265.

96 Berger's "pedantic punctuality" (Boening 1941) is one of the few details that is mentioned in all the obituaries and almost all the later biographical writings on Berger. His life followed a strict rhythm that he supposedly only allowed himself to deviate from during his four-week summer vacations: 6:30 breakfast, 7:00–8:00 work on his journal entries at the clinic, 8:00 starting time at the clinic, 10:00 conference, 12:00 stopping time at the clinic and 90-minute walk with his wife or, during the summer, family visit to the pool, 15:00 private consultations, 16:00 research or laboratory work, 19:30 dinner at home, followed by 1–2 hours of dictations to the assistant Schlömilch (see Jung 1963, p. 26). About Berger's psychiatric instruction, cf. Wiczorek 1988.

97 Berger and Guleke 1927; see also the studies on localization diagnostics Berger 1923a, 1923b, 1923c.

98 Quite in contrast to his close collaborations of 1910, Berger avoided almost any form of cooperation on EEG research and asked for foreign advice only about technical details, which could be a sign that Berger did not want to relay anything before he knew for certain that the matter was sound. One of the few indications of consultations about the EEG is a note dated 22 November 1927. Berger mentions having contacted Professors Brauersfeld



Figure 10 Berger holding a lecture at the *Psychiatrische Universitätsklinik* in Jena.

publicly reveal what he was currently working on in those years. It was during his rectorial address at the academic award on 18 June 1927. In a side-remark he revealed more clearly than anywhere else his expertise on the localization of brain functions, a matter of controversy at the time, and his grand, secret research project:

It is probably true that in general during the waking state the entire cortex, if I may put it this way, is in a certain state of readiness, is electrically live, as it were, but that—if I may continue my metaphor—the

and Esau (both from the physics department) about a special request for lead for a new form of electrode. He only seems to have had a more detailed exchange about the EEG and the technical requirements for its inscription with the company engineers of Siemens & Halske.

electric current is tapped for activity only in very particular regions, now here, now there.⁹⁹

On the day of his election he was already thinking about the topic of his rectorial address and noted down the title: “On the bodily expressions of psychic processes” (R., 4 February 1927). This was shortly before the arrival of the long awaited moving-coil galvanometer which then did not produce the expected breakthrough. It remains speculation whether Berger was, in fact, already thinking of speaking about the EEG in his rectorial address. Those investigations clearly were what he considered to be the final and crowning achievement of his life-long occupation with the bodily expressions of physical processes. But in June 1927 those investigations were in such a state of deep crisis that any publication would have been unthinkable.

But then, how did the first official announcement come about? What finally persuaded him to dare to publish it? The way out of Berger’s solitary and self-referential research on the EEG seems literally to have been brought to him from the outside, in the form of an honorable but challenging invitation to deliver a speech. The entry in his journal under the date 8 April 1929 reads: “I’m going to write to Henschen today that I shall come & speak about the Electrenkephalogramm!” (IV, p. 191). The neurologist Salomon Henschen, already 79 years of age at the time, was preparing an international congress in Stockholm for summer 1929, which, however, had to be cancelled shortly after Berger’s note in his lab journal.¹⁰⁰ An invitation to Stockholm at the *Karolinska Institutet* was, of course, a challenge for Berger also owing to the special location. Entries in his journal, mainly from the later period, clearly document his ambitions for the Nobel Prize.¹⁰¹ Berger would not live to see Stockholm, either as a private person or as a Nobel Laureate. But without his knowledge he was nominated for the Nobel Prize for the year 1940 by Douglas Adrian, Walter Cannon, and Tracy

⁹⁹ Berger 1927, p. 26.

¹⁰⁰ It is unknown to me what the topic for this congress had been and what the reasons were for it not having taken place. The cancellation was presumably related to an accident that eventually led to Henschen’s death in the following year. How important Henschen must have been for Berger can be gathered from the fact that he wrote a contribution to a volume published in commemoration of his eightieth birthday and also invited his pupils Paul Hilpert and Heinrich Boening to submit papers. Other authors included Gabriel Anton, Max Bielschowsky, Karl Kleist, Walther Riese, and Cécile and Oskar Vogt. This *Festschrift* appeared as a special issue of *Journal für Psychologie und Neurologie*. Berger contributed his second communication, which consequently appeared there on the strength of his scientific connections.

¹⁰¹ In temporal proximity to the first wave of popularity in Germany, there is the following note: “Ursel said today, I would surely have to go to Stockholm again, after all, in order to pick up my Nobel prize. I talked her out of it, in order not to awaken false hopes, although I do hope so & believe I have achieved as much as Barany, for ex” (5 September 1930, V, p. 63).

Putnam, which was then not awarded because the war broke out. Considering the widespread international acknowledgment of the EEG by that time and the nominations by three such famous scientists, it is entirely possible that Berger would have been awarded the prize, especially considering that Ulf Svante von Euler wrote a favorable opinion of him.¹⁰² And after such a distinction, Berger would hardly have fallen into that depressive crisis that led to his suicide on 1 June 1941. Instead of leading to a trip to Stockholm, the invitation catalytically prompted the first publication about the EEG. It must be left to historical speculation how the history of Berger's EEG would have continued with an international presentation as the prelude.

In spring 1929, when Berger received the invitation to Stockholm, his EEG experiments were once again in a phase of consolidation. "Just now brilliant Electrenkephalogramms taken with chlorinated silver needles! I thank you, my God!" (3 April 1929, IV, p. 186). Up to the moment of the conference cancellation, Berger's preparations for the talk had evidently already been making good progress, because on the following day he sent out his first notice to the editors of *Archiv für Psychiatrie*.¹⁰³ The completion of the notice initially gave Berger an enormous boost and he had the feeling of "sitting firmly in the saddle": "Yesterday also for the 1st × performed gymnastics on the horizontal beam again; it went well, beyond expectations" (21 and 24 May 1929, IV, pp. 216, 218). The paper had scarcely gone out before doubts began to creep in on Berger again: "Still cowardly thoughts, anxious vacillation: E.E.G. a mistake, etc.?" (7 June 1929, IV, p. 222). This time it was literally a retreat back into the snail shell of the private EEG. Just when he only had to wait for things to take their course and for the issue containing the so arduously wrung out paper, Berger decided to conduct a series of trials on himself, in which he wanted to observe his own EEG as it was being recorded:

31 May 1929 I would like to once observe my own curve in progress: The mirror supplied by Zeiss that was supposed to serve entirely different purposes shall do the honors thus, after all!

102 This expert opinion is in the Nobel archives. I thank the Nobel Committee on Physiology and Medicine for access to this material. The political escalation after the award of the Nobel Peace Prize in 1935 to Carl von Ossietzky and the Nobel Prize in physiology or medicine to Gerhard Domagk in 1939, motivated the National Socialists to forbid German scientists from accepting the Nobel Prize anymore. See Liljestrand 1962, pp. 170–182, and Crawford 2000.

103 It is no longer ascertainable whether it was planned as a double exploitation of the material or only came to be in reaction to the cancellation of the Stockholm conference. Just the day before, he had noted: "I have picked out 11 slides for Stockholm! (Limitation)" (19 April 1929). In the end the first published *Mitteilung* had 17 illustrations.

June 1929 I have established that with those mirrors I can observe my own EEG continuously. Doubting Thomas that I am, never believed that it would fall to my lot to discover my mission so entirely and to work on it.— Nil nocere! [Do no harm!] [IV, pp. 220 f.]

That which fifty years later would become fashionable as biofeedback, the paradoxical coupling of control and observation, had to lead to a performative collapse of self-referentiality for Berger. In a sober note, Berger jotted down in his journal: “Yesterday observed my own E.E.Gr. with mirrors, no determinations of psychophysiol. processes possible, because one cannot be observer & observed subject in one person simultaneously” (13 June 1929, IV, p. 223). Having relinquished the EEG curve, he had to concede that he would never be able to get his own EEG under control.

3 Electrotechniques of the live mind

Cultural currents 1918–1933

The “current of major events,” the massive political and technological revolutions of the Weimar Republic, made the present day itself become, in the eyes of contemporaries, a gigantic current of energy that menaced everyone with its “deadly shock.”—That, at least, is how the official advertisement by the Berlin Allotment Gardening Exhibition, “Sun, Air, and Home for All!” of 1932 phrased it:

Our time is so full of mighty upheavals and forceful events, most people are so swept up in the current of major events, that they hardly see how other special currents of energy are flowing alongside the large, roaring flow. If these energies did not exist, our time would be a thousand times more gruesome than it already is and, after those years of war and scarcity, would have ground the individual down. It is the lofty purpose of those energies to dampen that deadly shock of our time, its qualities and conditions, and rescue the individual and keep it viable.¹

This metaphorical identification of events and energies with currents turned electrotechnics into an allegorical expression of the historical situation. But, to paraphrase Hölderlin: “in danger” there would arise “salvation, too”;² as—in this scenario—only “other special currents of energy” could promise to save “the individual.” As in the antique trope of the smiting spear being the only possible healer of the wound, a special current of energy

1 Exhibition guide to the summer show in Berlin 1932: *Sonne, Luft und Haus für Alle! Ausstellung für Anbauhaus, Kleingarten und Wochenende*, organized by the Ausstellungs-, Messe- und Fremdenverkehrsamt of the City of Berlin. Quoted from a copy preserved among the holdings of the German Federal Archive—*Bundesarchiv*, henceforth abbreviated as BA—(BA R 86/882/3).

2 “Wo aber Gefahr ist, wächst Das Rettende auch,” Friedrich Hölderlin: *Patmos*; cf. Heidegger’s analysis of salvation in the essence of technical science (Heidegger 1962, pp. 28–36).

was supposed to help against the revolutions of energy and technology.³ The apocalyptic image of an encompassing electrotechnical revolution was the short-circuit here in a cultural history, in which energy currents were threatening to eliminate, or promising to save, the individual. The discourses on current and energy, rays and electricity at the close of the Weimar Republic articulated far more than a process of technical modernization of civilization or economic optimization.⁴ Electrotechnics advanced to a medium of ambivalences between the body and mind, the soul and society. Electrotechnical *dispositifs* formatted the social, psychological, philosophical, and biological relations within the medium of technical science.

The years of the Weimar Republic were a phase of upheaval, debate, and experimentation in a number of respects. In addition to the political instability after the lost war, the aborted revolution, and the economic crises, particularly during the inflationary years 1922–1923, the new republic was also marked by profound social and cultural processes. The technical mechanization and rationalization of human labor and daily life counted among these, as well as the rapid series of changes in *avant-garde* art, or the spread of radio and cinema.⁵ The 1920s were a time of accelerated electrotechnical

3 The exhibition guide continued by following this metaphor outright: “Technical science, which was the source of painful upheavals, [can] now also be the best helper at overcoming them.” On the *trosas iasetai* as a philosophical figure, see Adorno 1973, pp. 62f.—This utopia of modernization within the medium of energetic technology was bested scarcely half a year later by another, in which “events” became forceful—more precisely: violent—not just in energetic respects and in media technology. In view of the historically directly following political sanction of violence under National Socialism, it seems in retrospect macabre that these words are not borrowed from a political or esoteric manifesto but from the official announcement about a Berlin summer exhibition.

4 The history of electrification has often been one-sidedly presented as a series of technical innovations in the course of the so-called second industrial revolution (Steen 1981, Schmid 1991). An account of the interwar period is duly slim (Fraunberger 1985, Lindner 1985, Kloss 1987). The undoubtedly multifaceted analyses by Giedion (1969, pp. 512–527) and Hughes (1987, slightly altered in 1991, pp. 298–354) of the interactions between industry, science, and culture are nonetheless histories largely written from the perspective of producers. (Such perspectives taken on the commercial assertion of technically defined artifacts do often also define technically critical work and research in social history, though; see, e.g., Landes 1973 or Zängl 1989.) The history of electrification, in particular, documents the collective construction of technologically transmitted realities (Bijker, Hughes, and Pinch 1994; Nye 1990; Marvin 1988). Christoph Asendorf (1989), David Gugerli (1998), and Beate Binder (1999) have described how, as a consequence of the broad discourses since the turn of the century, “electrification” became established as a firm component of modernization and progress; see also Maria Osietzky’s analysis (1996) of the gender-specific construction of electrical progress.

5 The many interpretations of these short years compete with the plurality of depictions of that period. Peter Gay (1970) has spoken of a “republic of outsiders” with regard to the political confrontations and the plurality of cultural currents. If one takes Detlev Peukert’s version (1987), these extreme sides were rather embedded within the social, political, and cultural upheavals that gripped not only the visible peripheral figures. Anson Rabinbach (1990) diagnosed, in the convergence of research on efficiency and energy theory in the

integration, from the progressive electrification of private households, to the large-scale technical grids of the German Reich with their high-capacity power stations and interlocking high-voltage current systems, to informational consortia of electrical news media, transport, and communications technologies.⁶ As these developments were under way, electricity did, in fact, become that current coming out of the wall plug to connect city with countryside, to be an almost universally usable source of power also in the private home, and on top of it all, even to perform the exchange of information.⁷ During the Weimar Republic, society literally joined the web, and the burgeoning branches and superposed electric circuits became the obvious expression of the network, as it was transforming into the *dispositif* of electrotechnics.

The establishment of electrical technologies for the home, transportation, power, and communications, had already changed the daily lives of broad swathes of the population during the Weimar Republic. In 1914 only 5 percent of Berlin households were connected to the mains, whereas in 1926 this had risen to one-third, and by 1930 to two-thirds.⁸ The universalized “power currents” and “communication currents” of electrical transport and information technology, ranging from the telephone to the street car, were joined in the middle of the 1920s by the “live currents” (*Erlebnisströme*) of the new medium, radio. Public radio broadcasting also began in Germany on 29 October 1923, which by the end of the Weimar Republic was already reaching around 10 million listeners, despite strict regulations and licensing fees.⁹ These various new currents and the social discussions about them formed the technological and discursive environment in which the organizers of the Berlin summer exhibition could then, in 1932, mention in summary

Weimar discourse of rationalization, a scientification of the view on human careers, which he claimed to be the starting point of modernity. Wolfgang König (2000) instead diagnosed in the developing consumer-goods industry of the Weimar Republic the beginnings of a consumer society that placed the individual at its focus.

6 Braun and Kaiser (1991).

7 One period document of this primacy of electrotechnical integration is Arthur Fürst's monumental history of technology, *Weltreich der Technik, Entwicklung und Gegenwart*, the first volume of which, on “communication by wire and the ether,” *Verkehr im Draht und im Äther*, appeared in 1923 (see Fürst 1985). Fürst conceived the history of technology as a whole as the history of transit, subdividing it into four volumes covering; communications, transportation by surface, water or air, and by road.

8 Zängl 1989 and Landes 1973. Electricity in one's own residence initially primarily meant electrical lighting; but during the Weimar Republic period the rapidly developing household-appliance industry quickly popularized new applications of electricity, in the first place, laundry irons and vacuum cleaners. Electric irons were coming off the assembly line at Siemens from 1924; and in 1928 about a quarter of all Berlin households owned an electric vacuum cleaner. As has been reconstructed by Martina Heßler (1998), it was not an easy or straightforward campaign for those new household technologies, however; for a comparison with the American context, see Goldstein 1997.

9 Führer 1997; on the psychological dimension of the new medium, see Schrage 2001.

“mighty upheavals” and “special currents of energy.” Electrotechnical *dispositifs* had hence long since become a medium of everyday experiences before the electrotechnical discourse, as in the cited example, became a medium for historical reflection on issues regarding society, the times, and social philosophy.

This rapid spread of electrotechnical apparatus and facilities during the interwar period was just the technical aspect of the electricity *dispositif*. The new omnipresence of electric current and its multiple effects provoked the most disparate considerations about the biological and psychic effects of electricity or about electrotechnical manipulations on people. The electrification of everyday life went hand-in-hand in cultural history with a process of electrification of the human self-image and popular psychophysiology. Maria Osietzky has shown convincingly that the sociocultural change enforced by electrotechnics since the nineteenth century did not just propagate the vision of a bright, enlightened, and healthy future world. The physiological limits of visibility and the bounds of corporeality were reassessed when, during the course of electrification, the simple pressing of a button caused illumination, a motion of the hand steered a heavy machine, or the telephone relayed the voice kilometers away.¹⁰ Borrowing Mary Douglas’s concept of a social rating of body limitations, it shows how notions about nature, the human self-image, and cognitive concepts were historically subjected to the influence of electrification.¹¹ The process diagnosed by Osietzky for the turn of the century, of a displacement, overcoming, and redesigning of bodily limits within the medium of electrotechnics, can be carried even further for the constellation of the Weimar Republic, because it then extended beyond, to an at least partial electrotechnical reconfiguration of the biological and psychic body. Electrification had allowed the body to outgrow itself teletechnically and visionarily for the future during the *Kaiserzeit*. Then followed a virtual and real invasion of the body by electrotechnics and the electrotechnical transformation of the human being.

In the interplay between the concrete electrotechnical web of the everyday, from wall plug, electricity grid, telephone, and radio, there distilled out the image of the electric circuit with multifarious fantastical notions and conceptions about the interdependence between man and the soul, life and nature.¹² The human being and the psyche were connected by countless switching, inscription and recording circuits, to a machine, in ever-changing new ways, and the *Seelenleben*—mental existence—the way the psyche and the mind function, advanced to a precarious juncture between the network

10 On the interaction between the history of electricity and technologization of the body, see also Armstrong 1991 and Morus 1999.

11 Osietzky 1996.

12 Volker Roelcke (1999) has pointed out the role of the “electrification of the nerves” in the appearance of neurasthenia as a complaint due to modernization during the nineteenth century.

and heterogeneous discourses. In such psychophysiological inscription systems, electricity became much more densely interwoven with the experimental culture than a merely instrumental source of energy. Electricity became the medium of psychic processes. This syncretic psychophysiology amalgamated psychology and electrotechnics in changing variations, which blurred the dividing lines between holism and modernism, between science and technology, between popular psychology and academic discourse, and between the *avant-garde* and occultism.¹³

In the following, first, four fields of an electrotechnical mobilization of body, mind, and soul during the interwar period will be analyzed: (1) Representation techniques in which electrotechnical apparatus and graphical methods created mobile representations of organic as well as psychic phenomena; (2) design techniques to make a neurotechnics merge bodily functions with machines; (3) communication techniques, taking the contemporary debate about brainwaves and telepathetic communication as an example; and (4) manipulation techniques that, during the Weimar Republic, led to material switchings between human and electrotechnology, for example, high-frequency therapies according to d'Arsonval or radio-wave treatment. This resonant cultural space for electrotechnical psychophysiologicals of the interwar years prepared the ground for the enormous popular reception of the EEG before there were any internal discussions even within the scientific community. In summer 1930, ahead of any scientific conversation, the EEG followed the career of a sensational announcement in German-speaking newspapers, because Berger's observations evidently fit precisely into this field of electrotechnical psychophysiologicals. The history of brainwaves offers an example of the decisive role of the public space and publicity as an actor in the genesis of scientific objects, models, and concepts. Popular and academic discourses were so tightly intertwined that the typical confrontation between academic knowledge production versus popular reception falls short. From a cultural historical perspective, the electrification of the brain, rather, seems to be part of an *experimentalization of everyday life*.

The bioengineer and psychodiagnostics

"The physician of the future," the article in the *Berliner Illustrirte Zeitung* declared on 7 June 1925, was no longer that "good old home-visiting doctor who issued his mysterious prescriptions with a dignified demeanor"; the physician of the future would be a "bioengineer."¹⁴ The occasion for this

13 The ambivalences between psychic and psychophysiological investigations in Germany of the interwar period have been discussed i.a. by Mitchell Ash (1995) and Anne Harrington (1996) by the coordinates of the opposition between modernism and holism (see also Lawrence and Weisz 1998). The blurring of this opposition seems to me to be characteristic of electropsychology.

14 To my knowledge there is no evidence of an earlier usage of this word. The article and drawing originated from the pen of the gynecologist and medical journalist Fritz Kahn

article was the successful attempt by the radio channel *Berliner Rundfunk* to broadcast throughout Central Europe human cardiac sounds, on 24 April 1925.¹⁵ The medial conjoining between diagnostic techniques and telecommunication hence transferred the human body into a mobile data space during the mid-1920s and turned the physician into a teletechnician. A sketch attached to the program article depicted the future medical practitioner at a kind of control center that played back all the required data anytime for him without any patient being present (Figure 11). A wall behind the control console assembled a broad arsenal of instruments for the teletechnical representation of biophysical parameters, such as cardiac sounds, the ECG, temperature, and x-ray images. To one side, a large file cabinet served as documentation and archiving of the findings established and managed there at the data center. A telephone handled the transmittal of therapeutic instructions and connected the flow of information to the feedback loop. Conventional media, such as books and paper, lay about unused like set pieces from bygone times on the desk, which only served as a base for the switch panel. The medical hand did not write and touched no patients. It only pressed the buttons in order to switch between the data sets for the different patients. In the era of telecommunication, consultation with the patient was replaced by an exchangeable ensemble of parameters in laboratory science. Fantastic visions of comprehensive recording and centralized control went hand-in-hand with the dissolution of the body into its techno-scientific representations.

The new representational techniques not only produced mobile equivalents for biological phenomena.¹⁶ A few months after this “bioengineer” in the *Berliner Illustrierte Zeitung*, the next topic of its cover illustration became the objective checking of performance in play-acting by means of the graphical method. An actor couple are depicted in recital, he being connected to an imposing recording apparatus by cabling to the eye, the mouth, the breast, and belly, while she is holding his hand. According to the related article, this machine is a six-channel polygraph, which had proven successful in America as a lie detector (Figure 12). The picture caption reads:

An apparatus for measuring the actor’s emotional intensity and to test his suitability for a particular role. The stage director reads the most gripping passage, the actor and his female counterpart attempt to become emotional, and the apparatus registers how well they have succeeded.¹⁷

(1925). Kahn (1888–1968) became conspicuous during the Weimar Republic for his active opposition to anti-Semitism (Kahn 1920); his popularizing books on science (Kahn 1914, 1924–1929) made him more famous. Kahn emigrated to the USA in 1935 and returned to Europe in 1949 (Kahn 1949).

15 “Vortrag des Herrn Dr. med. Leo Jacobsohn: ‘Fernübertragung der menschlichen Herztöne’ (mit Experimenten),” *Der Deutsche Rundfunk* 3 (1925): 1036, printed in Jacobsohn 1927.

16 Bruno Latour’s “immutable mobile” conceptualizes the functionality of such representations (Latour 1990).

17 *Berliner Illustrierte Zeitung*, dated 8 November 1925.



Figure 11 The techno-medical practice of the future physician, according to Fritz Kahn. The legend reads: “The physician of the future, who monitors the heart graph, cardiac sounds, blood pressure, respiration curve, and body temperature, of his patients with his remote electrical apparatus from his room.”

It was hardly coincidental that the man’s “emotionalness” was what was deemed in need of objectivized gauging. Superimposed on the technical arrangement was the established gender order, when it was the woman holding her partner’s hand with caring attentiveness or feeding emotional signals in through this coupling link, which he converted into impulses appropriate to the machine. At the same time, the technology undermined such superficial attributions of man and technical things or woman and surrender. As, in the end, it remained unclear who was the subject and who was the medium of the emotive events, or their representation. In the accompanying article, such kinds of technicistic personality research were dismissed as the propaganda of American film directors, with the critical comment: “One would have to put many a question mark behind experiments of this sort—even here at home, the testing of psychotechnical suitability has



Figure 12 Objectivizing emotive diagnostics for the selection of suitable theatrical actors. On the cover of *Berliner Illustrierte Zeitung*. See the main text for the legend.

advanced quite far.” In actual fact, during the Weimar Republic such electrotechnical equipment was not used to examine play actors; but it was promoted as a way to diagnose the professional and psychological suitability of prospective trainees, students, and socially maladjusted persons.

A small black metal box that the Ukrainian physician Zachar Bissky was carrying around with himself as he traveled through Germany at about the same time caused more of a stir than the great lie detector. Its purpose was to analyze character traits and create a personality profile.¹⁸ Sensational reports raised expectations. One of the most popular writers of the Weimar Republic, Emil Ludwig, a friend of Stefan Zweig, subjected himself to this “screening of the mind” (*Durchleuchtung der Seele*): “There lay before me the line of my character, in a cipher-rich curve. A portrait of my inner essence, almost like the portrait that I carried in my heart.” Ludwig lauded the device with the compositional ability of an author whose historical novels and biographies achieved print runs in the millions and were translated into many languages. He thought the new apparatus represented a decisive advance in the history of the twentieth century and should secure its designer a place in the pantheon of scientists:

As far as I am concerned, [... I] would certainly not speak about it if I hadn't put it to the sole test that I trust. After what I have seen, I need not guard against any reservations. The name Zachar Bissky steps alongside Bunsen and Helmholtz, alongside Edison and Marconi, alongside Curie and Röntgen. With him begins a new science. He has unmistakably attached numbers to the analysis of the human character, which we others only attempt to unfold by intuition; he has carried this out with an apparatus.¹⁹

Ludwig's combination of scientists, technicians, and inventors not only attributed to Bissky a portrait gallery of august ancestors but positioned his device at the center of research and innovation in the fields of radiation and radio development. Ludwig did make generous use of his author's license as a successful writer, of course, but he was not the only one, by far, to vote in favor of this procedure called “diagnoscopy” or “neuroscopy.” Regular

18 For details about diagnoscopy, see Borck 2001. Little biographical information on Zachar Bissky has survived. He was born in 1885 in Proskurov (Khmelnyskyi) in Ukraine and suffered since childhood from migraine, which was the motivator of the experiments that supposedly allowed him to discover his method. He evidently did not specifically pursue the track that he construed of intrinsically rhythmic electrical brain activity. There are no known physiological papers by him. He rather concentrated completely on the practical application and marketing of his process. Soon after his presentations in Berlin, he was apparently working in Paris. Other details about his life are lacking.

19 Ludwig 1926, pp. 299 and 301. Ludwig (1881–1948) earned his fame during the 1920s with biographies of Goethe, Napoleon, and Wilhelm II. After his emigration, there followed biographies of Cleopatra, Jesus, Beethoven, Schliemann, Lincoln, Bolivar, Hindenburg, Masaryk, Stalin, and Mussolini. In the *Dialektik der Aufklärung*, Horkheimer and Adorno chose him, together with Hemingway, as examples of “enlightenment as mass-deceit” (*Massenbetrug*) (Adorno 1996, p. 165). On Ludwig see Mosse 1992, esp. chap. II, and Gradmann 1993.

newspapers such as *Vossische Zeitung* or *Berliner Börsenkurier* also published equally sensational articles. Hans Berger's former colleague and assistant in Jena, Adolf Friedländer, also praised Bissky's invention in March 1926 in the *Frankfurter Zeitung* (Figure 13).²⁰

This method agreed with the phrenological approach in more than just basic outline.²¹ The test person held in one hand a stimulation electrode and the examiner touched the head at exactly determined places with a second electrode, thus closing an electric circuit and causing a tingling sensation on the head and a sound in greater or lesser volume was produced by a connected loudspeaker. Unlike the EEG, what were registered were not brainwaves as an expression of brain activity, but the variously modulated conduction of alternating current through the head. The volume level of the electrically generated sounds at 70–80 exactly defined points on the head surface (so-called “reaction fields”) represented the degree of expression of personality traits, such as imaginativeness, logic, dutifulness, color vision, mathematics, diligence, dexterity, verbosity, intelligence, vanity, or speech faculty. Bissky himself went even further and recommended his method not only for psychodiagnostics but also as an interventional procedure:

We have before us a person of ideally calm and gentle character. We now attach the electrode with the red wire to point 43 (maliciousness) on the right-hand side and must experience how the test person becomes more and more angry and increasingly intolerable. If we touch this point with the blue wire, the tempest lifts and the old, sympathetic, good-natured person is sitting before us again.²²

20 Friedländer (1926) revised this positive assessment within that same year, however, in a second article on diagnoscopy in the Christmas issue of *Umschau*.

21 The literature on the history of Gall's craniology and on phrenology is copious; see Young 1990, Cooter 1984, Hagner 1997. Friedrich Karl Walter of the Psychiatrische und Nervenlinik in Gehlsheim, near Rostock, established by minute comparison that Bissky's reaction fields largely corresponded to Franz Joseph Gall's craniology, not only regarding the way psychic characteristics were subdivided but also the way they were topographically arranged (Walter 1927, p. 314). Nevertheless, Walter did not want to abstain from performing a revealing test and tricked his colleagues from the Bios Institut with a blind test on a violin virtuoso, whose talent promptly failed to be detected. Perhaps it is more than just an irony of history that, synchronously with the diagnoscope, an electromechanical phrenology machine was developed in America. Phrenology had been recommended there in career counseling since the nineteenth century. The machine fully automatically scanned the skull for significant protuberances; and it eventually became a coin-operated self-service attraction in public places; see Risse 1976, Borck 2005. One functioning version of these automats is presently being maintained by Bob McCoy at the Museum of Questionable Medical Devices in Minneapolis.

22 Bissky 1925, p. 23. Despite such great activity, little material seems to have remained; I only managed to locate an account of diagnoscopy from 1925 and the description of a “Centre de bioradioscopie de Bissky” in Paris, 22 rue Auguste-Vacquerie from 1936. “Bioradioscopie” was a variant of radionics founded by Albert Abrams that is still a

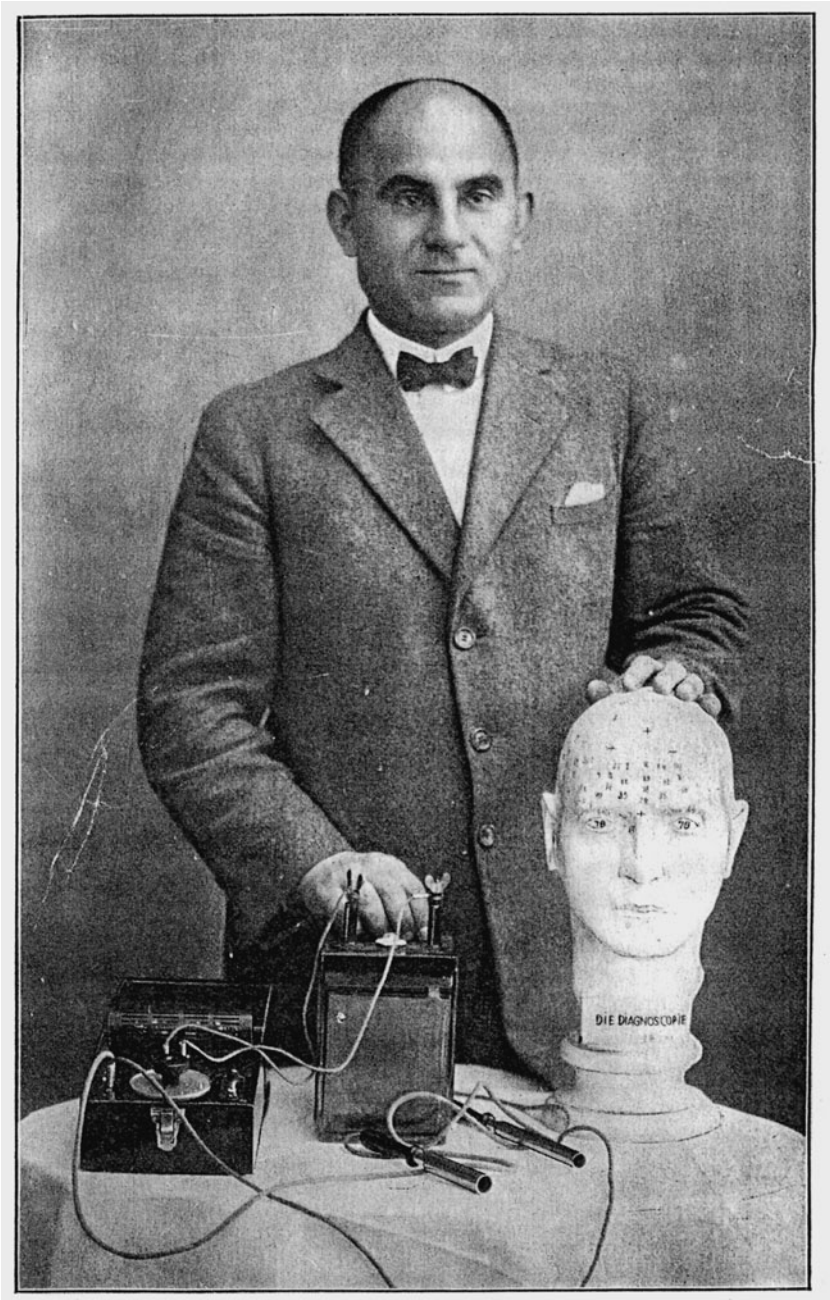


Figure 13 Electrical research on the mind by diagnoscopy according to Zacher Bissky.

Typically, the device found supporters among representatives of applied subfields of medicine, psychology, engineering science, and philosophy; whereas criticism and opposition came from the more academically oriented directions of those fields. A three-day conference specifically on this method, held at the polytechnic, *Technische Hochschule* in Karlsruhe in January 1925, seems to have been decisive for the spread of diagnoscopy in Germany.²³ As the introductory report explained, the conference was a direct consequence of good experiences with the new method in other countries. The Swiss postal service, the Genevan clock industry, and the Swiss Society for the Rationalization of Labor had purportedly introduced diagnoscopy as their official testing method.²⁴ Soon after this conference, a brochure by the *Bios Institut* could already add over a dozen institutions in Germany, including the Criminal Investigation Department and Police in Berlin, the Berlin Sexology Institute, the locomotive manufacturer *Maschinenbau-Gesellschaft* in Karlsruhe, and the mining company *Gelsenkirchener Bergwerks-AG*.²⁵

This steep rise for diagnoscopy developed mainly by interaction with psychotechnology, which was just establishing itself. Ambitious psychologists looking for new fields of activity created a disciplinary specialty in suitability testing and career choice. Fritz Giese was one of them. His presentation of promising diagnoscopy data at the Ninth Congress of Experimental Psychology in Munich in April 1925 provoked stormy debates.²⁶ The national research funding organization *Deutsche Forschungsgemeinschaft* (DFG) supported diagnoscopy studies involving 300 test subjects in 1925 by Robert Werner Schulte, who was director of the psychology department of the sports college *Hochschule für Leibesübungen* and a psychological counseling station of the social welfare office in Spandau, near Berlin.²⁷

flourishing nonconventional method. I thank Elizabeth Ihrig of Bakken Library and Museum of Electricity in Life for assistance.

23 An article from autumn 1924 reported about the “Radiodiagnoskop von Dr. Bissky” as a still completely new and unknown matter primarily employed in Geneva (Gomberg 1924).

24 Paulcke 1925.

25 Listed here according to the compilation by Walter 1927.

26 Giese 1925a. “Psychotechnik” had begun in Germany in 1914 with the book under that title by Hugo Münsterberg (1914) as a branch within applied psychology that was tightly interwoven with the organizational tasks of the nation at war. After the defeat, economic reorganization and modernization under the cue-word rationalization then offered new fields of action. Polytechnics in particular set up chairs and laboratories for applied psychology or psychotechnics; numerous firms developed their own psychotechnical departments or test programs. The most important professional journal to be established was *Industrielle Psychotechnik* (1924–1944). On the history of psychotechnics, see Jaeger 1985, Hinrichs and Peter 1976.

27 See Schulte 1925. There is unfortunately no documentation in the files of the DFG in the Federal Archives. Schulte possibly knew about diagnoscopy since Bissky’s visit to Walter Moede’s newly opened laboratory at the Charlottenburg Polytechnic in 1921, where Moede was assistant.

This study, which appeared at the end of 1925 in Schulte's own periodical, *Psychologie und Medizin*, certified for the new technology a positive correlation with psychotechnical suitability tests at 86.3 percent, backed by extensive tables, graphs, and statistical assessments as proof of its mechanical objectivity.²⁸ Giese and Schulte both left aside any discussion about whether Bissky's method was physiologically conceivable at all. They purely empirically tested his claim that diagnoscopy would permit "henceforth to forestall nonexploitation of social, intellectual, and physical energies to a maximum and to lead toward their purposeful utilization."²⁹ On the basis of these results they viewed the new method as the suitable procedure for their high-flying plans for a new science of rationalized professional life and the working world.³⁰

Challenged by the astonishing reports by Giese and Schulte, opponents of diagnoscopy formed broadly branching alliances in order to gain equally persuasive force. At the 1st Conference on Psychotherapy in Baden-Baden in 1926 as well as at the Xth International Congress of Experimental Psychology in Bonn in 1927, panels and committees were hastily formed to critically scrutinize diagnoscopy. Within the local network of debaters

28 In the meaning of Daston and Galison 1992; see also Porter 2003.

29 Bissky 1925, p. 29. Schulte dismissed as immature any speculations about possible physiological relations between the reaction locations and the observed properties, using a language that revealed his openness toward esoteric lines of reasoning (1925, p. 78): "Whether in this regard any detectible relations exist at all between the activity of the central nervous system, particularly of the cerebral cortex, and the already peripherally situated dermal locations on the cranial surface (one could think of trophic relations, tonic, electric—especially radiative—or the subtlest chemobiological influences), any discussion about this at the moment would still represent the grossest materiality and be utopian."

30 Giese (1890–1935) and Schulte (1897–1933) had both studied in Leipzig under Wilhelm Wundt and afterwards had established their own small institutions in Halle and Berlin, respectively. Their professional biographies reflect the heterogeneity of the new field that confronted psychology with a variety of social problems. In addition to their academic pursuits, both developed multifarious activities to advertise and popularize psychotechnics in lectures, newspaper articles, radio broadcasts, exhibitions, expert opinions, and essays. No branch of professional employment was too out of the way for them to be subjected to a polished psychotechnical analysis of its career attribute profile, ranging from hairdressing to quarrying to stenography. Even beyond psychotechnics, both were founders of sports psychology in Germany, both shared an interest in issues of occultism, and they both pursued literary ambitions. Schulte published poetry, and Giese wrote a cultural history of Americanism in Germany under the title *Girlkultur* (1925b). Giese received an appointment in 1923 to the Stuttgart Polytechnic whereas Schulte never obtained a professorship. Both died young. Schulte committed suicide after his academic plans had made hardly any progress, his marriage had failed, and a friend of his had died in a crash in his airplane (see Lück and Rechten 1994). Giese died as an SS applicant, from complications of a prophylactic appendectomy. (I thank Stefan Petri for this information about Giese's death.) Giese's most important scientific achievement was the publication of his comprehensive reference manual on ergonomics, *Handbuch und Handwörterbuch der Arbeitswissenschaft* (1925–1934). Schulte published numerous articles in addition to his own periodical.

in Berlin, where Bissky was operating his *Bios Institut für praktische Menschenkunde*, the secretariat of the Kaiser Wilhelm Society organized a campaign in cooperation with Oscar Vogt of the Kaiser Wilhelm Institute for Brain Research, Count Georg von Arco, technical director of *Telefunken* AG, and Alexander Herzberg in the Faculty of Philosophy of the University of Berlin. The purpose was to expose and publically discredit electrodiagnosis as scientifically invalid in critical reanalyses, public lectures, and hurriedly published texts.³¹ In the end, the personality line graph recorded via electrodiagnosis remained just an episode. The discourse about a comprehensive rise in efficiency was able to integrate the outmoded concepts of phrenology with novel electrotechnics only for a short time. After being received in a brief wave of enthusiasm, the device apparently quickly lost its prominent position at the intersection between popular culture, electrotechnics, and personality diagnosis again and was forgotten. Occasional references to diagnosis reappear in the context of Berger's EEG papers, because Bissky had already alleged to have found by his electrotechnical stimulation procedure "the physiological rhythm of the nervous system."³²

Nerve apparatus and psychic circuits

Surely no organ of the human body has been conceptualized as consistently by the aid of communications technology as the nervous system. Wilhelm Wundt was already speaking of the comparison of nerve fibers with telegraph cables as an "often used metaphor" in 1874 and a few years later Ernst Kapp noted in his *Grundlinien einer Philosophie der Technik* a "continual drawing of a parallel between the telegraph system and the nervous system on the part of science."³³ This parallel meant more here than just an illustrative and popular comparison of a biologically defined matter per se. The purpose of Kapp's usage of the concept of "organ projection" was to

31 Arco and Herzberg 1927. They finally even planned for one of Vogt's co-workers to anonymously borrow apparatus from Bissky in order to conduct a verification covertly, which was apparently never carried out, because the wave of Bissky euphoria had already ebbed by then. Arco to Vogt, 15 July 1926; Vogt to Arco, 16 July 1926; and Rose to Arco, 18 August 1926, in dossiers 34C and 91A, Cécile und Oskar Vogt Archiv, Düsseldorf. I thank Prof. Adolf Hopf and Ursula Grell for granting access to this material.

32 Bissky (1925, p. 16) had evidently experimented with alternating current at different frequencies (18 to 672Hz) and finally found a frequency of 335Hz to be the most suitable examination current. He suspected this frequency to be the brain's characteristic rhythm, which was why resonance effects supposedly occurred during the examination. Berger himself drew the link to Bissky's procedure in his first communication, albeit with the intention of disassociating himself from it (1929, p. 567). A paper by Alfred Gradenwitz regarded Berger's electroencephalography as a direct continuation of Bissky's neuroscopy (Gradenwitz 1930).

33 Wundt 1874, p. 346; Kapp 1877, p. 139. On the epistemological dynamics of the telegraphable metaphor in neurophysiology up to the middle of the nineteenth century, see Hoffmann 2002.

identify structural identities behind the only-apparently metaphorical relations. Kapp conceived the nerve and the telegraph cable as structurally identical, since there was no better explanatory model of a nerve than the cable; indeed, no more exact a replica of the nerve than a cable. As his crown witness, he cited—not without some pride—Rudolf Virchow: “In fact, the conditions correspond entirely: The nerves are the cabling of the animal body, just as the telegraph cables can be called the nerves of humanity.”³⁴ The chapter on the electromagnetic telegraph in the *Grundlinien* therefore constituted the crowning conclusion to Kapp’s historical survey on the anthropological genesis of technology, by which he attempted to prove that from the primitive hammer up to advanced electrical machinery, all technical inventions form largely unconsciously as an “organic projection,” i.e., as the externalization of bodily principles of design and functionality. In the case of the nervous system and the telegraph system, he contended, science—that is, the contemporary physiological research—had reflexively sought as a progressive finding this unconscious projection of organic functions in technical artifacts. Kapp’s notion of a technical replication of organic principles of structure and functionality, which was continued a hundred years later by Marshall McLuhan’s often-repeated statement that the media are the extensions of our nerves and senses,³⁵ hence tried to find its focal point of departure in a biologism with an anthropological turn.

Kapp’s finding that “the telegraph system has been accepted by physiology as proof of the electric behavior of the nerves” does not necessarily have to be explained as biological determinism, however. It is, rather, fertile ground for historical accounts of technology and the media. Timothy Lenoir, for instance, described Hermann von Helmholtz’s analyses on the physiology of hearing and vision as largely open interactions with the contemporary telegraph technology that are unforeseeable.³⁶ Contingent technical developments are, here, not interpreted as the expression of predetermined organic structures that only still need to be correlated scientifically and historically, but as mutually networked subregions of historical constellations. An archeology of the physiological sciences from the development of technical media, conversely, would run the risk of missing the open dynamics

34 Virchow 1871, p. 10; cited here after Kapp. See Mazzolini 1988.

35 Kapp (1877, p. 140) put it as follows: “Organic projection can claim a major triumph here. The main requirements for this: the production done unconsciously according to organic patterns, soon afterwards the encounter, the meeting of original and copy by the logical necessity of analogy, and then the agreement to the highest degree of sameness conceivable between organ and artificial tool, which strikes the consciousness like a flash—these moments in the process of organic projection have occurred most distinctly also for the telegraph system.” McLuhan’s reduction of Kapp’s thoughts about the close-to-nature reproduction of organic structures in technical science is: “With the arrival of electric technology, man extended, or set outside himself, a life model of the central system itself” (1994 [1964], p. 43).

36 Lenoir 1994.

of mutual interactions between science, technology, and society by virtue of a media a priori, if only the historical state of technical media is to determine the concrete form of the sciences and of human self-reflection.³⁷ The Virchow quote documents that at least for the actors, *explanans* and *explanandum* were interchangeable in the relation nerve–telegraph cable.

As opposed to during the *Kaiserzeit*, during the Weimar Republic the telegraph was largely replaced by more modern arrangements in neurotechnics, in keeping with the technical developments in media. The multiplicity of electrical devices, such as the incandescent lamp, telephone, gramophone record, radio, photographic camera, etc., meant there were simply many more diverse identification possibilities available between organic structures and technical artifacts. But the double game by neurotechnics, the mutual defining in this comparison and identification, continued also with these new possibilities.³⁸ Illustrated magazines prove to be a particularly rich trove of such referencings between the human body and electrotechnical devices. The automatic telephone dialing system of a large modern office is introduced as its “nerve center,” for example, or under the heading “From Flatiron to Thinking Iron,” Siemens’s thermostat “Protos-Regler” was described as intelligent technology, long before cybernetics.³⁹ Explanatory purposes were not the only reason for combining the body with electrotechnics. Fritz Lang brought the artificial woman in the film *Metropolis* to life by electrostimulation,⁴⁰ and weaker shocks by the same construction could produce new stimuli to the senses:

It makes for intense enjoyment of theatrical performances, [. . .] also for normal people, if not only the eye and ear be engaged but also the sense

37 Just as Friedrich Kittler asserts with a media a priori: “What it means to be human is not determined by attributes that philosophers attach or propose to people for intercommunications, but technical standards. Any psychology or anthropology presumably only reiterates which functions of the general data processing are set in reality by machines, hence are implemented” (“Die Welt des Symbolischen—eine Welt der Maschine,” in Kittler 1992, pp. 58–80, esp. p. 61.)

38 Youthful Karl E. Rothschild (1932), for instance, referred with impressive consistency to *Biotechnik*, in the “popular monthly journal for technology and science,” *Wissen und Fortschritt*, which appeared from 1927 to 1943, under the sponsorship of the electrical industry.

39 “Die elektrischen Nerven im modernen Großbüro,” *Wissen und Fortschritt* 5 (1931) no. 10: 86–88; an international office exhibition in Berlin was the motivation for this article. *Wissen und Fortschritt* 4 (1930) no. 2: 214–217 and no. 3: 348–353.

40 This is presumably the most effective example of electric anthropotechnics on the masses of the interwar period. At the same time, it illustrates the problems of finding an appropriate visual idiom for the effects and efficacy of electrotechnics. There the “moment” of resuscitation was definitely not that vitalizing electroshock which was to be added to the psychiatric therapeutic inventory ten years later. It was rather staged as an astonishingly lengthy process, virtually as a kind of electrochemical inflow of life, with various boiling cauldrons under high pressure, radiation fields catalyzing syntheses of life, and generators under an extreme constant load all interconnected at the turn of a switch.

of touch at the same time. This is effectuated in the form of electrical pulses that are conveyed to the audience through the microphone and electrodes.⁴¹

This dual play of neurotechnics during the Weimar Republic literally ranged from the laundry iron to multimedia special effects.

Following this logic, the brain became a veritable technological rearmament site, since a whole electrotechnical arsenal had to be driven into position for “the brain and its apparatus,” as the essay bearing the title “Das Gehirn und seine Apparate” in the volume *Vom Schaltwerk der Gedanken* (literally: about the switching device of thoughts) by the author and practicing surgeon Carl Ludwig Schleich demonstrates. The newest electrotechnical gadgets were supposed to disclose the way the brain functions and the brain became, at the same time, just as much an expression of modernity and the brain researcher a “brain engineer.”⁴² Technical science not only delivered the appropriate instrumentation for the description of neuroanatomical structures and the functioning of psychophysiological processes; Schleich also drew the parallel between the brain and technology as advanced civilizing phenomena. Consequently, “brain engineer” Schleich viewed himself in the role of cultural scientist. In a bizarre turn of this text toward science fiction, in which Schleich compared the post mortem sectioning of a brain with a civilization extinguished in a gas accident, Schleich identified himself with an archeologist exposing the brain in the excavation field of modern culture:

Let us imagine all life on this planet having been obliterated in a single blow by some catastrophic accident, let’s say by the cyanic gases of a cometary explosion; people died on the spot or suffocated in their homes, factories stood still, the electrical centers let their currents continue to pulsate for a while through the artificial nerves by which the human mind and technology had reshaped the Earth into a brain-like being—then everything would have stopped. Lamps would have extinguished, cable transmissions would have ceased, the tin plates and antennae of the wireless apparatus would have stopped rattling, all telephone connections would be asleep. And then after a long period of time an expedition corps from Mars landed on our planet under a lead explorer. Like the anatomist before a dead brain and spinal cord, he would find everything—the trackage, arc-lamp poles, wiring, control

41 Panconcelli-Calzia 1932, p. 3. This experimental phonetician was not citing his own views here, however, but plans by the American electrofantast and science fiction author Hugo Gernsback.

42 The term *Gehirningenieur* is taken from Schleich, see “Die physiologischen Grundlagen zur Erkenntnistheorie,” in Schleich 1920, pp. 164–182, there p. 169. On Schleich and the local context of this brain theory in the culture of *fin de siècle* Berlin, see Dierig 1999.

centers, on-and-off-switching apparatus, telephones, Marconi plates, cables, spotlights, etc. Having come so far as to construct a ship that had brought him all the way to us—we may imagine him being in possession of some scientific methods and surely capable of reconstructing many connections. Thus, I think, the honest researcher stands before the problem of the relationship between the brain and the soul, the nerve and the mind.⁴³

In exact coincidence with the deployment of gas grenades on the battlefields of World War I, Schleich spied a portrait of modern civilization in the industrial ruins of the fatally stunned brain, which alone promised to give insight into the functions of that organ.

Thirteen years later this synthesis of brain and technical civilization returns in the likewise popular but highly vital metaphorical language of Fritz Kahn's *Das Leben der Menschen*.⁴⁴ The supplementary oversized folded plates forming the conclusion to this five-volume work, "The human as an industry palace," reduced this metaphorical program to a handy denominator. Wherever complex relations, such as the way an organic system interrelated, were in need of visualization, Kahn resorted to the strategy of superimposing industrial and communications technology on the body and that way imagined a complete fusion between body and civilization. His drawing "Physician of the Future" had played off teletechnical representations against the body. Now, in these illustrations, the body came into its technical own, so to speak. Above all, the nervous system and the sensory organs inspired Kahn to representational scenes showing the functional organization of the human body as the product of modern technical transmission systems, i.e., as effects of media. In this way, perception became a cinematographic event: The image of a key, focused through the lens apparatus in the eye, illuminates the film strip on the retina. After its developmental and recopying passage, the film strip is projected as in a cinema by a film projectionist in the back of the head onto the screen of the memory storage in the area of the central gyrus, where a cinema spectator allocates the image conceptually. This homunculus in the forebrain plays the word melody of the recognized sign on an organ keyboard that controls the organ pipes via electric cable in the larynx and produces air oscillations. These oscillations finally leave the mouth as the articulated word "key."

Even where a sensorial quality could not be comprehended by analogy to some form of media, such as the sense of balance, for example, Kahn staged

43 "Das Gehirn und seine Apparate," in Schleich 1916, pp. 13–45, esp. pp. 16f.

44 Schleich's *Vom Schaltwerk der Gedanken* experienced fifty reprintings within ten years. Kahn's five-volume work, whose title translates as "The Life of Mankind," bore the subtitle "A popular anatomy, biology, physiology, and developmental history of humanity," and was distributed by the *Gesellschaft der Naturfreunde*.

technical correlates to life in a big city. The movements of a person of the present day, such as acceleration and braking in an automobile, the accelerated rising motion against gravity inside an elevator, and the rotational swaying in a social dance turned the organ of equilibrium literally into a seismograph of modern culture (Figure 14).⁴⁵ The dominance of cultural, electrotechnical models is particularly demonstrated by those examples in which Kahn could not resort to a clear media equivalent, and yet, the sensorial path of sensitivity could still become a radio apparatus. In the explanation of the perception of pain or heat, the sensory cell becomes the antenna, the neuron becomes the conducting wire, the nerve nucleus in the brain stem becomes the radio device, and the apperception in the cortex becomes a homunculus wearing headphones. In short, Kahn's illustrations spelled out boldly neuroanatomy with the technical media of the 1920s. But this does not say everything about Kahn's representation. In this example he drew the radio arrangement as a nocturnal street scene at a busy metropolitan intersection (Figure 15). The neuroanatomical diagram inside the image mutates into a giant advertisement poster on the building wall. The penetration of physiology and technology became pictorially a product of the culture of the present; it was an expression of modern times and a feel for life in the spirit of *Neue Sachlichkeit*—New Objectivity.⁴⁶

Kahn's media technology of the nervous system according to New Objectivity, and Schleich's machine archeology of the brain with its neuro-technical rhetoric, expressly and successfully addressed the public at large. Even so, it would be wrong to see in this some alienation by a neuroscientific model of the brain within media technology from the purposes of popular science, because the same interferences are to be found in academic research, as even the famous "drafts" (*Entwürfe*) by Sigmund Freud and Sigmund Exner for scientific psychologies on the basis of electrotechnical connection methods already evidence at the end of the nineteenth century.⁴⁷ The title of Schleich's bestseller *Vom Schaltwerk der Gedanken* could just as well have

45 Besides presenting technical modernity in the form of an elevator and automobile, this illustration could depict modern culture doubly through fashion: The woman's bobbed hair is clearly discernible in the schematic depiction of the dancing couple. For a deeper analysis of the brainy worlds of these images, see Borck 2002b and 2002c.

46 See Buderer 1994.

47 Freud 1987 [1895], Exner 1894. The electrical stimulations of the human brain by Fedor Krause and Otfried Foerster up to Hans Berger manifest, for instance, how—in continuation of Gustav Fritsch's and Eduard Hitzig's experiments—the brain was designed as an electrical control center and, as such, was made manipulable. Albeit, the "era of nervosity" (*Zeitalter der Nervosität*) and the boom of organic brain models lie between the time of the electrical telegraph, the experiments by Fritsch and Hitzig, and the time of automatic telephone switchboards, and the experiments by Foerster and Berger (see Radkau 1998 and Borck 1999). That means, a more detailed cultural history of cerebral research would have to reconstruct just this double rupture rather than continuity.

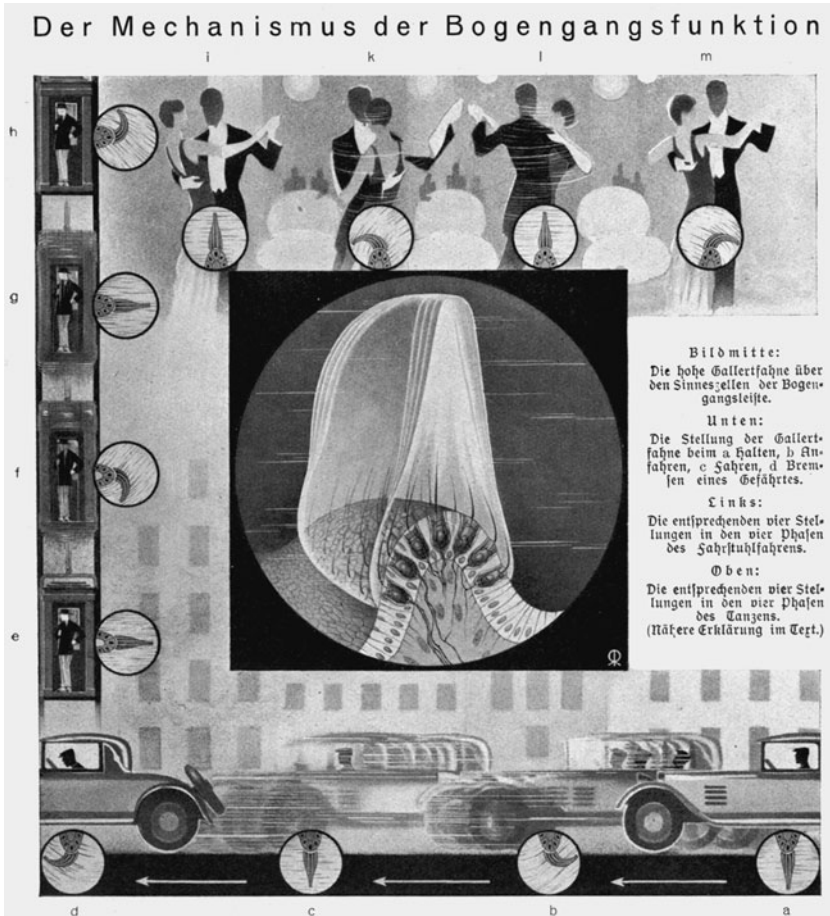


Figure 14 Fritz Kahn, modern life as stimulator of the organ of equilibrium. The caption reads: "The mechanism of how the semicircular canal functions." Center of illustration: The high cupula above the sensory cells of the ampulla of the semicircular canal. Bottom: The cupula's position during (a) stopping, (b) starting, (c) driving, (d) braking of a vehicle. Left: The corresponding four positions in the four phases of traveling in an elevator. Top: The corresponding four positions in the four phases of dancing.

been borrowed from Eugen Bleuler's neurophilosophy.⁴⁸ In 1894, hence synchronously with Sigmund Exner's and Sigmund Freud's *Entwürfe*, Bleuler published a brief "attempt at a scientific consideration of psychological

48 Bleuler, director of the psychiatric clinic of the University of Zurich at Burghölzli, was the originator of a biologically conceived sociocultural theory of evolution, which he called *Mnemismus*, with reference to Richard Semon; see Semon 1904.

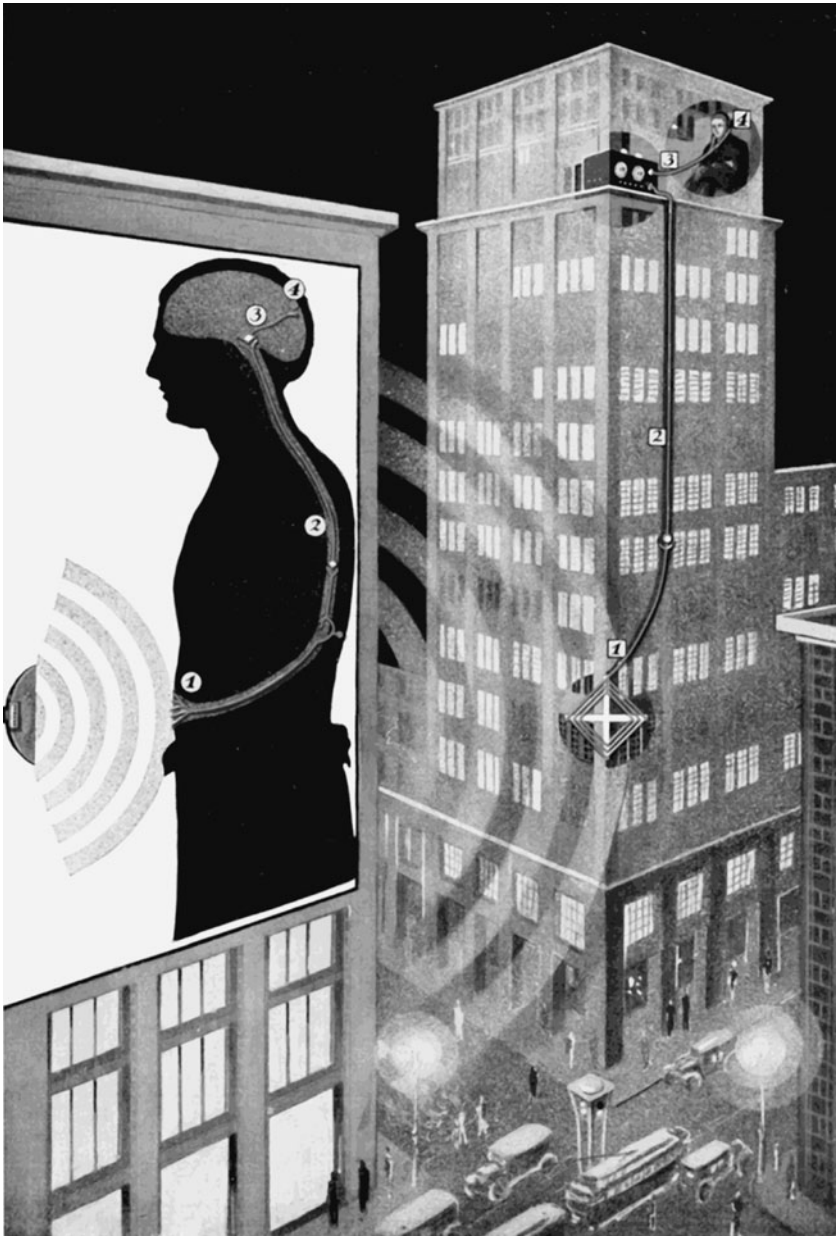


Figure 15 Fritz Kahn, big-city life and radio apparatus to illustrate the function of nerves.

fundamental concepts” (*Versuch einer naturwissenschaftlichen Betrachtung der psychologischen Grundbegriffe*) that presented his program of a biological evolutionary grounding of all psychological, social, and intellectual phenomena, under the concept of a “dynamic trace” (*dynamische Spur*). Barely thirty years later and probably hardly by chance in close temporal connection with the electrification at Burghölzli,⁴⁹ Bleuler had this brain theory culminate in detailed expositions on “switchings” and “tensions” (*Schaltungen* and *Spannungen*) in his “Natural History of the Mind and Its Gaining of Consciousness” (*Naturgeschichte der Seele und ihres Bewußtwerdens*). The brain was modeled as a complex electrical switchboard plant:

The impact of different psychologisms upon one another happens [. . .] similar to in an electrical plant, where functions are switched on and off and the controlling moments only activate the switches. [. . .] All central nervous functions perform such switching actions upon each other. [. . .] We, first of all, have two kinds of settings, the stand-by setting [. . .] and the activation setting. [. . .] Among the specific settings should be mentioned: 1. Those of the personality as a whole, which are engaged in accordance with a particular form of reaction: to speak English, to behave politely or familiarly, etc. 2. The hierarchy of mental goals is a combination of switch settings, in which each involved notion pursues its corresponding goal, and impedes the other, so the train of thought is unambiguously determined. 3. Many psychic functions proceed without interconnecting with the conscious ego and are then unconscious.⁵⁰

What was discussed here under the heading *Der psychische Apparat*, would soon afterwards be sketched by the inventor of this expression, Sigmund Freud, with a decidedly anti-identificatory intent simply as a *Wunderblock*. For Freud the wondrous thing about the psychic apparatus was that it could not be fit into any technical model.⁵¹ Bleuler, on the contrary, regarded electrical switches and cerebral “switchability” as the key to an electrotechnical articulation of psychopathology. Article titles such as

49 See Wottreng 1999, pp. 268–272.

50 Bleuler 1921, p. 287.

51 In 1898 Sigmund Freud announced in the *Wiener klinische Rundschau* the imminent publication of the above-mentioned description of his theory of innate drive in *The Interpretation of Dreams—Traumdeutung* (1900), as: “certain assumptions about the composition and way of working of the psychic apparatus,” thereby coining the term (Freud 1977, esp. p. 512). The *Wunderblock*, Freud’s model for the psychic apparatus from 1925, was the familiar wax tablet for writing erasable text while still retaining traces of it.—It is a seemingly simple memory machine; its aptness as a model was that it recorded the limitations of the mechanical metaphor (Freud 1999a); see on this Derrida 1972, pp. 302–350, and Borck 1998.

“On psychic situational apparatus and abreaction” or “Hallucination and weak connection” document the range of Bleuler’s electropsychiatry in those years.⁵² Despite his by then quite advanced age, Bleuler attentively reviewed the publications about electrical brain activity by Berger and Kornmüller, and in his last text, which was published posthumously in 1939, he was still surmising the essence of live organisms, what he called *Biokym*, to be an “oscillatory form” of electricity.⁵³

While Bleuler identified the psychic apparatus with an electrotechnical connection method, the co-founder of gestalt psychology Wolfgang Köhler conceived an electrodynamic theory of structured perceptual processes. According to this theory, electric fields represented the neurophysiological substrate of experimentally established principles of gestalt psychology.⁵⁴ In 1920 Köhler attempted to offer plausible arguments, in his “natural philosophical study” on the physical form at rest and in the stationary state, *Die physische Gestaltung in Ruhe und im stationären Zustand*, in support of his conception of isomorphism between the perception as a gestalt and its neuronically represented, as an effect by electrostatic field forces on neural stimulation.⁵⁵ The electric fields and telephone connections in the head were—like the electric neural grids of modern cities—an expression of exploratory and constructive strategies by which popular science and neuropsychiatry of the interwar period designed their range of possibilities. In this process, elements of the psyche were electrotechnically reconfigured to the degree that electrification remolded into anthropotechnics.

Thought rays and radio-telepathy

Mental Radio, the title of Upton Sinclair’s bestseller from 1930, put in a nutshell how the brain was conceived in modern apparatus.⁵⁶ The analogy

52 “Über psychische Gelegenheits-Apparate und Abreagieren,” or “Halluzination und Schaltschwäche.” Later the electrotechnical grounding of Bleuler’s mnemism fades into the background, although the pertinent section reappeared unaltered in the second edition of *Naturgeschichte der Seele* from 1931. Bleuler’s psychopathology of weak connections and leak currents was among the portions of his work least reviewed by scholarship. Constantin von Monakow declared that Bleuler’s book had been “rejected quite bluntly by the majority of his colleagues in the profession” (1922, p. 324). Karl Jaspers, for example, could only “caution” against the section on psychic apparatus in his review of *Naturgeschichte der Seele* (1922, p. 22).

53 Bleuler (1933) mentions Berger and Kornmüller. On the *elektrische Schwingungsform* as the model of the *Psychokym*, see Bleuler 1939, p. 12.

54 See the exposition in Ash 1995, pp. 388f.

55 Köhler 1920, esp. pp. XVI–XX: “Einleitung für Physiker.” After World War II ended, when the EEG had already become an established research method, Köhler and other gestalt psychologists conducted series of experiments in search of the electrophysiological substrate of engrams; see Köhler 1949, 1951, Hebb 1949 (esp. the chapter: “Field Theory and Equipotentiality”), as well as Orbach 1998 and Weidman 1999.

56 The book describes the telepathic abilities of the wife of a much-read writer, Mary Craig Kimborough. A German translation only appeared in 1973 and adapted the title to the

between the brain and radio as electromagnetic apparatuses of communication also formed a fixed point of reference in the discourse about telepathy in those years. Parapsychology around the turn of the century had primarily mobilized mechanical and photographic detection methods for the documentation of occult phenomena. Now telepathy and clairvoyance were re-examined in light of radio technology as the effects of as yet unknown “thought rays.”⁵⁷ Particularly in the popular press, reports were continually making the rounds about psychophysiological experiments on the puzzling nature of electromagnetic waves as currents of energy and information that drew into question the apparently firmly established boundaries of the human body and its sensory faculties. “A whole range of internationally renowned scholars is occupied with demonstrating that any willful or mental concentration emits measurable or at least detectible electric waves from the human nervous system.”⁵⁸

For example, the above-mentioned psychotechnician Fritz Giese explained in his textbook on brainwaves, *Lehre von Gedankenwellen*, phenomena of mass psychology as well as structures of a collective subconscious as electromagnetic resonance effects of oscillating nervous systems.⁵⁹ Another of these “internationally renowned scholars” was the Italian psychiatrist Ferdinando Cazzamalli from the University of Rome, who had been researching interferences between concentration waves and radio waves since the mid-1920s. The brains of particularly suitable test persons were supposed to act as sources of disturbance for radio waves. The best results Cazzamalli obtained, entirely in the tradition of occultist research, were with a female “medium,” the telepathically gifted Irma Maggi, whom he personally had discovered and who later was able to make a successful career for herself with her

technical register of the postwar period, as *Radar der Psyche*. But the book was already being broadly discussed in the German press and in parapsychological periodicals after its original appearance in 1930.

57 The discovery of x-rays and radioactivity gave new impetus to notions of special “cerebral radiations” (thus the title of a lecture held at the Franklin Institute on 1 March 1892 by the co-founder of General Electric and chief-electrician of the Chicago World Fair, Edwin J. Houston. And thought waves (*Gedankenwellen*) or *brainwaves* were being hypostatized from various quarters at the turn of the twentieth century as a special kind of ray of unknown character. For example, so-called N-rays or *Nerven-Strahlen* of Blondlot and Feerhow were supposed to act “directly,” i.e., without the mediation of other senses, from brain to brain (Blondlot 1904, Feerhow 1912). See the historical essays in the two exhibition catalogs Bracke 1997 and Ehrhardt 1995.

58 *Wissen und Fortschritt* introduced in its December 1928 issue Soviet experiments on the transmission of thoughts between a human and a dog by means of cerebral electric waves, in which a telepathically gifted animal psychologist telepathically commanded his German shepherd dog “Mars” to fetch a book from the neighboring room. The experiments only worked when the electric concentration waves in fact reached Mars telepathically and not by conduction through a simple current cable laid in the Moscow sewer system; Caesar 1929.

59 Giese 1924a, 1924b.

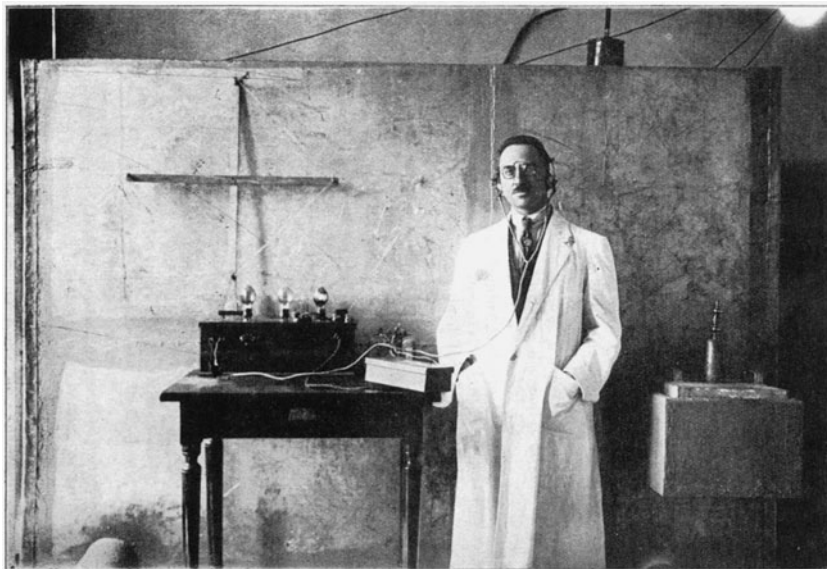


Figure 16 Ferdinando Cazzamalli with radio-wave detector in front of his testing chamber.

talent in Argentina. Less pronounced “interferences” were produced by other brains, above all those of psychiatric patients inflicted with the “epileptic,” “paranoid,” “hallucinatory,” or “hysteroidal circuit form.” Cazzamalli’s detection of “cerebral radio waves” in such telepathically pathological brains, which was published in 1925 in *Revue Metapsychique*, and in German translation in *Zeitschrift für Parapsychologie*, ignited a debate that lasted for years (Figure 16).⁶⁰ When the EEG was being internationally popularized during the 1930s, Cazzamalli’s experiments were still so present that the Roman daily newspaper *Il Messagero* referred to Cazzamalli as Berger’s decisive precursor in an article under a headline wildly mixing metaphors and material interactions entitled: “Il telegrafo umano e le onde cerebrali. (The human telegraph and the brainwaves)”⁶¹ The EEG certainly did not assume the place that the debates about

⁶⁰ Cazzamalli 1925, 1926; Anonymous 1926.

⁶¹ *Il Messagero* from 13 December 1933 used as an illustration a figure from Schlemmer’s “Triadic Ballet” carrying the emanating oscillations on her body. Cazzamalli, meanwhile president of the *Associazione Italiana Scientifica di Metapsichica*, experimented with cerebral radio waves to the end of his life. *Il cervello radiante. Fenomeni elettromagnetici radianti dal cervello umano durante l’intensa attività psicosensoriale degli stati onirici, allucinatori e telepsichici* appeared posthumously (Cazzamalli 1960). I thank Claudio Pglano for assistance in procuring this book.

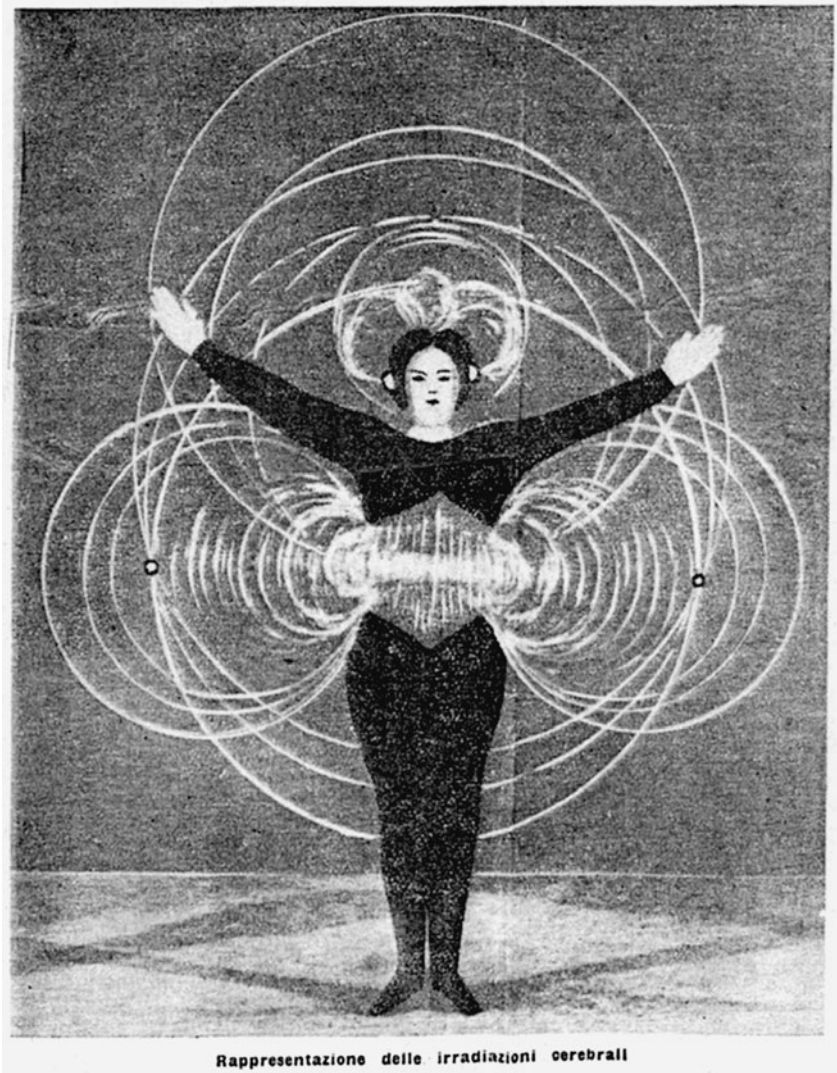


Figure 17 The Roman daily paper *Il Messaggero* depicted Berger's EEG as a fusion between Cazzamalli's brainwaves and Schlemmer's "Triadic Ballet."

Cazzamalli's research, for instance, had claimed; rather, it superpositioned itself upon it (Figure 17).

How broadly the radioactivity of the brain affected public emotions at the time is illustrated by a large-scale experiment on the transmittal of telepathic concentration waves performed on Berlin radio. Alexander Herzberg and Count Georg von Arco, who had been arguing so avidly against Bissky and diagnoscopy just the year before, broadcast "an hour of telepathy" on

Berliner Rundfunk on 16 October 1927.⁶² The headphone-wearing audience was carefully instructed about how to receive the telepathic message:

We now begin with the trials themselves. Count von Arco has already gone into the experimental room and drawn by lot the first numeral; in a moment, which I shall signal to you by the word “now,” he will begin to look at the number lying before him with concentrated attention. So then please act passively for 2½ minutes and observe which number occurs to you. Now! (2½-minute pause.) Ladies and gentlemen! The 2½ minutes are over; please write down the number that you think is right under rubric (a) of the reply form.⁶³

The program periodical *Der Deutsche Rundfunk* had printed in the issue for that broadcast a reporting form to be filled out and cut out; and within a week 4,563 listeners between “10 and 77 years of age” throughout Germany sent back the messages they had received, to the broadcasting station by postcard. In the accompanying article the phenomenon being experimentally examined was described as “scientifically explicable” and “certainly not to be confused with so-called occult phenomena.” Then, it was only being tested whether “an energetic force field forms by wireless ‘thought waves’ being emitted into the aether.”⁶⁴ The article was part of a plan to deceive the trial participants about the experimental method. Herzberg and Arco were intending to disprove by their large trial the existence of telepathic effects:

My proposal thus was, to form 2 groups among the participants, those whose surnames begin with A to K, and those with beginning letters L to Z. [. . .] We then wanted to tell the participants that exactly the same transmission experiments were being conducted on each of the two groups; in reality, though, the transmission tests would just be conducted with the group L to Z, whereas nothing should happen during the trials with group A to K, so that the responses would definitely have to be pure chance results. Those were supposed to serve us as a comparison basis; then a reliable conclusion about telepathy could be possible from an excess of hits among the findings of the transmission trial.⁶⁵

62 *Der Deutsche Rundfunk* (1928) 5: 2924. Half a year before, the BBC, under the direction of Oliver Lodge in Great Britain, performed a similar experiment; see V. J. Woolley in *Proceedings of the Society for Psychological Research* 38 (1928) no. 105. A few years prior to that even, radio experiments had been conducted in Cambridge, Mass., and Chicago.

63 Herzberg 1928, p. 84.

64 “Telepathie im Rundfunk. Zu dem Versuch der Berliner Funk-Stunde am 16. Oktober,” *Der Deutsche Rundfunk* 5 (1928) no. 42: 2893–2894, esp. p. 2893.

65 Herzberg 1928, pp. 80 and 84.

In the name of the higher truth of science and for the advancement of knowledge in the field of parapsychology, around half of the test persons were deceived in order to arrive at statistically significant findings.⁶⁶ On the other hand, at least a third of the listeners with surnames beginning with L to Z were honest enough to admit on the response form that contrary to explicit instruction they had already started listening for secret messages during the first six trials. But the radio, or the unconsciously working brain radio of the experimenter, was also operating in this experiment of deceit and simulation. All the trials produced more hits than anticipated by the probability calculation, most of them in the so-called control trials. Compared with the technical possibilities of the new medium, transmission and deceit in the Berlin broadcast hour were a relatively harmless game of hide-and-seek that translated the debates among the Berlin circle of parapsychologists into the radio era. Without demonstrating telepathy, radio had proven the manipulability of thought by the technical media. Completely irrespective of whether the brain “really” was a radio apparatus, it could be very definitely influenced by the radio broadcaster; and precisely there is where the “electrophysiological problems of the future” lay, which would be specifically exploited technically by German power politics in the years that followed.

Configurations of electrotherapy in the radio age

Radio, without a doubt, numbered among the most fascinating electrotechnical innovations of the 1920s: “And in astonishment we see in radio the dawn of a new age, which will seek energies in the novel rays and will find them to an enormous measure.”⁶⁷ It is hardly likely that any other technology prompted such precocious speculations about all the possible things that could be influenced electromagnetically or which transmissions could be explained as radio phenomena. In the United States, the former general practitioner George Crile published “A radio-electric interpretation” of all phenomena of life. With their rental service for radiation detectors, Albert Abrams and Ruth Drown founded the radionics movement, which is still being monitored by the FDA.⁶⁸ In Great Britain, Otto Overbeck sold his *Electronic Theory of Life* in print runs into the tens of thousands, and *radiesthésie* flourished in France.⁶⁹ In Germany, Ewald Paul founded a

66 On the development of statistical methods from parapsychological tests, see Hacking 1988 and Mauskopf and McVaugh 1979. On the debate about the deception of a test person, Kaptchuk 1998.

67 Mack 1925/26, p. 288.

68 Crile 1926, 1936. Abrams (1916) and Drown (1938) postulated the fundamental processes of life in fine-grained vibrations. They designed series of seemingly complicated diagnostic devices that concealed just a few simple display mechanisms, with which they organized a lucrative trade; see Janssen 1993.

69 Overbeck 1925, Chantereine and Savoie 1932.

“scientific society for high-frequency and light research” (*Wissenschaftliche Gesellschaft für Hochfrequenz- und Lichtforschung*) and the off-duty general physician Felix Buttersack speculated about special “mind rays [*Seelenstrahlen*] and resonance” as the “engendering forces of life.”⁷⁰ Parallel to electrotechnical industrialization and the revolutions in media technology, the widest variety of electrospeculations were making the rounds in many European countries and also in America, some of which could cite true scientific authorities. For instance, the following brief metaphysics of electricity was formulated by Erwin Schrödinger: “Electricity is [. . .] nothing extraordinary; it is a protophenomenon—if not to say the protophenomenon—from which we must actually learn to understand everything that occurs in nature.”⁷¹

One of the most successful entrepreneurs in this area was Georges Lakhovsky. His recipe was evidently a combination of electrotechnics, radiation philosophy, and radiotherapy. Like many of his contemporaries, Lakhovsky postulated that electromagnetic oscillations were a basal phenomenon of life. He considered “cosmic waves” and “vital vibrations” as “the secret to life,” as illustrated by the title of his bestseller. It sold successfully in many countries and the author of the foreword to its second edition from 1925 was Arsène d’Arsonval, no less, professor of physics at the Sorbonne. His last book, which appeared shortly after his emigration to America in 1941, offers a concise summary:

All living cells are composed of two essential elements; the nucleus and the protoplasm in which it is bathed. This nucleus is itself composed of many tubular filaments: the chromosomes. In addition, hundreds of such small filaments or chondromes are present in the cytoplasm. Chromosomes and chondromes are present in the cytoplasm. Chromosomes and chondromes are sheathed in an insulating substance and contain a liquid like serum with the same mineral content as sea water, and consequently a conductor of electricity. Thus, these filaments constitute ultramicroscopic oscillating circuits of very short wave lengths. I have demonstrated in my works that these cellular oscillating circuits, chromosomes and chondromes, vibrate electrically under the stimulus of electromagnetic waves: cosmic, atmospheric and telluric. Now, many internal and external influences may upset the oscillating equilibrium of these cells.⁷²

70 Paul 1925; “Seelenstrahlen und Resonanz” als den “Triebkräften des Lebens,” Buttersack 1929, 1937.

71 Schrödinger 1930, pp. 110f. This was his contribution to a series responding to the question: “Why is science being conducted at all?” posed by the popular periodical *Koralle*; Adolf von Harnack, Werner Sombart, and Ludwig Klages were other authors.

72 Lakhovsky 1941, pp. 29f. Georges Lakhovsky (1869–1942) had come to France from Russia before World War I. *La secret de la Vie* was translated i.a. into German, Spanish, Italian, and English. The German edition from 1931 had already sold 4,000–6,000 copies

In the mid-1920s Lakhovsky's successful experiments at the *Salpêtrière* utilizing a generator of high-frequency electromagnetic waves to cure a carcinogenically infected geranium were much discussed. In the following years he developed, together with the high-frequency physicist Nicola Tesla, a universally applicable device that produced weak electromagnetic waves of various wavelengths for therapeutic purposes (Figure 18). With this "Multiple Wave Oscillator" any cells, including those in the human body, were supposed to be stimulated into their natural oscillatory rhythms and, in that way, allowed to vibrate into new equilibrium:

After much research, I was able to construct an apparatus creating an electrostatic field from 3 meters to the infra-red, so that every cell can find its natural frequency and vibrate in resonance. We know that in physics, a circuit fed by damped or weakened high frequency currents creates many harmonics. Consequently I conceived an oscillator of multiple wave lengths with a broad scale in which every organ, every gland, every tissue, every nerve, could find its natural frequency.⁷³

Lakhovsky's radio apparatus transformed the cultural oscillations around electricity and radiation materially into a universal biotherapy, which quickly became a success in the industrialized or electrified world.⁷⁴

Lakhovsky's speculative radiotherapy thus joined established electrotherapy as a kind of universal medical tool. In view of the mostly limited repertoire of medical healing methods, electrotherapy offered an important treatment option for doctors just opening their practices. During the 1920s refined electrotherapeutic instrumentation belonged among the standard equipment of a doctor's practice, at least in larger cities, to administer electric current in every possible preparatory form, mostly for treatment of chronic illness, but above all, "nervous conditions."⁷⁵ Siemens, the leading

by the following year and a new edition appeared in 1981 (Essen: Verlag für Ganzheitsmedizin). I thank David Rhees and Elizabeth Ihrig from Bakken Library and the Museum of Electricity in Life for access to plentiful material by and about Georges Lakhovsky.

73 Lakhovsky 1941, p. 35.

74 In the United States, Lakhovsky's "multiple wave oscillator" is still being marketed for therapeutic purposes; e.g., in the Internet at: www.copenlabs.com/copenmwo.htm (8 November 2004).

75 Special departments for electrotherapy or light and radiation applications were standard equipment in larger city hospitals and university clinics at the beginning of the twentieth century; see Cohn 1924; Hubenstorf 1993; Nelson 1973. The model character of electrotechnics as a "technology of the future" at the turn of the twentieth century is mirrored by electrotherapy not least in the continued rapid development of accumulations of electrotechnical appliances to keep abreast of this progress by ever newer and improved forms of current and radiation treatments. The traditional methods of galvanization and Faradization were joined by Franklinization, diathermy, and D'Arsonvalization or high-frequency treatment. Thereby the focus of electrotherapeutic treatments within university medicine shifted to ailments of the organs, see Rosner 1988.



Figure 18 Therapy of a female patient with the multiple wave oscillator by Georges Lakhovsky (second from the right).

German manufacturer of electromedical installations, advertised at considerable expense after its take-over of the Reiniger Works in Erlangen in 1926, the continued sale of its “Pantostat” under the new Siemens company name as an electrotherapeutic universal device, because its marketability was evidently more promising than ECG appliances, for example.⁷⁶

As more and more private households became connected to the municipal electricity grids, the electrical appliance industry discovered the electrotherapeutical sector as a new market for home therapy and self-treatment. The propagation and reprintings of manuals, primers, and handbooks by companies such as *Badische Wohlmut AG*, bear eloquent witness to the boom of this medical practice.⁷⁷ Electric current was presented as a general tonic

⁷⁶ Catalog E 30: *Apparate und Instrumente für Elektrodiagnostik, Elektrotherapie, Massage u. Chirurgie* by Siemens-Reiniger-Verfa from 1931, Siemens Archive, Department of Medical Technology, Erlangen. I thank Ms. Doris Vietinghoff for access to this material.

⁷⁷ E.g., *Elektro-galvanische Heilkunde. Ein Handbuch zum Heilgebrauch galvanischen Stromes für Kranke und Gesunde* by Wohlmut AG (Wohlmut 1925) was already in its tenth edition by 1930 and was translated into English, French, Italian, Spanish, Swedish,

to cure a whole variety of illnesses and to assist in overcoming daily crises. The spread of radios secured even greater attractivity for therapy with electromagnetic rays. What was called “blue light treatment,” with a vacuum tube that emitted bluish radiation, was so popular for a while that in many places those small high-frequency appliances evidently caused interference with broadcast reception.⁷⁸ During this boom in electrotherapeutic methods for self-treatment, the sociotechnical acquisition of electricity became the “modern” energy form for individual and private health maintenance.

Self-treatment was only one of the interferences in the intersection zone between apparatus, the body, and communication, which contained other entirely different potentials for targeted influencing of organic and psychic systems. If the nerve therapy disturbed radio reception, then conversely a radio therapy of the nerves should also be possible:

If it becomes possible sooner or later to establish more specific data about these ether waves, arising physiologically—or psychologically?—from voluntary or involuntary activity of the mind or brain as well as from suggestive and hypnotic influencing, i.e., their wavelength and intensity, course and character, [. . .] then the outcome of this is all those fantastic possibilities that emerge if a machine can radiate vital will and vital energies and in that way become sort of like a hypnotist. [. . .] The hothouse-like development of radio engineering certainly lets the execution of the suggestion introduced above no longer seem impossible: namely, to generate and emit ether waves of a specific frequency and specific character by means of radio technology, that be fed directly into the human brain and consciousness, i.e., without either intermediary switches or the application of antenna, detector, and earphones, and be additionally emitted at such a great intensity that it could mask, i.e., have a crippling effect on the average person and thereby force him under its control.⁷⁹

The programming periodical of German radio published in 1924/25 a series of articles under the heading “Electrophysiological problems of the future” that swept through the panorama of electrotechnical interventions

Czech, and Dutch. Wohlmuth AG also published its own promotional periodical, *Die Wohlmuth-Kur*, on electrotherapeutical questions for some years.

78 Möhringer 1927: “Everywhere in the city and countryside [. . .] one can now see in almost every third family those small remedial apparatus with the glass tubes glowing and sparking in violet light, that have been recommended and impressed upon people with all sorts of eulogies by door-to-door salesmen to cure their ailments.” See Gernet and Habrich 2000, pp. 86–89.

79 Fiala 1924, p. 1036. The author “A. K. Fiala” was presumably an electrical engineer, but he is otherwise not biobibliographically identifiable. I thank Dominik Schrage for pointing out this text.

up to the perfect surveillance state (Figures 19 and 20). After the first half of that series had pointed out the functional identity between the electricities of biology and communications technology using such practical inventions as frog-muscle intensifiers or earthworm amplifiers, and ended with the above-cited hypnosis by “spotlight emitters” (*Scheinwerfersender*), the second half of the series of articles in the following year mainly reflected on the social, psychological, and philosophical implications of this practically turned radio-electrophysiology. In line with Lakhovsky’s electrophilosophy, the life of a human being, ranging from sensory impressions to the sexual act, was defined by the electrical nature of his nervous system. In the “spontaneous philosophy”⁸⁰ of this not more specifically identifiable electrical engineer A. K. Fiala, even wars counted as environmental catastrophes because they were the expression of electric turbulence on an interplanetary scale. Supposed differences between various “national mindsets” (*Volksseelen*) found natural explanation in the various climatic regions on Earth with their various spectra of electromagnetic radiation, which was why England, for instance, was spared from “electronervous tensions.” What initially might have remotely reminded one of Willy Hellpach’s popular reflections at the time about environmental influences on the human psyche,⁸¹ ended directly in explicit racism on the basis of conformed electric waves. The indubitable superiority of the “compelling” glare in the “steel-gray, cold eyes of the Nordic *Herrenmensch*” found its political counterpart in the conformed harmony of monochromatically emitted ether waves of a eugenically homogeneous populace:

Just a few years from now—and one will have found the deeper grounds and justification for such abstract concepts as honor and morality, self-esteem, and shame in the unconscious striving of man for the preservation of the purity of electrophysiological nerve vibrations away from other, foreign frequencies, an ambition that despises any compromise (i.e., mixing and contamination) with electronervous oscillations of foreign origin.⁸²

Using this bizarre and vague terminology, the “nervous currents at foreign frequencies” were accordingly not just an apocalyptic danger to the highest of national values but were also the intervention principle of Fiala’s electrotherapy, which was a directed “physiological radio transmission”

80 Louis Althusser denoted as “spontaneous philosophy” the constituent mix of basic assumptions, philosophemes, and world-views that scholars produce in their work, in order to distinguish this from the systematically reflected philosophy of philosophers (Althusser 1974).

81 Hellpach 1911, which last appeared in its eighth edition in 1977 under the title *Geopsyche*, thus modified in 1935.

82 Fiala 1925, p. 205.

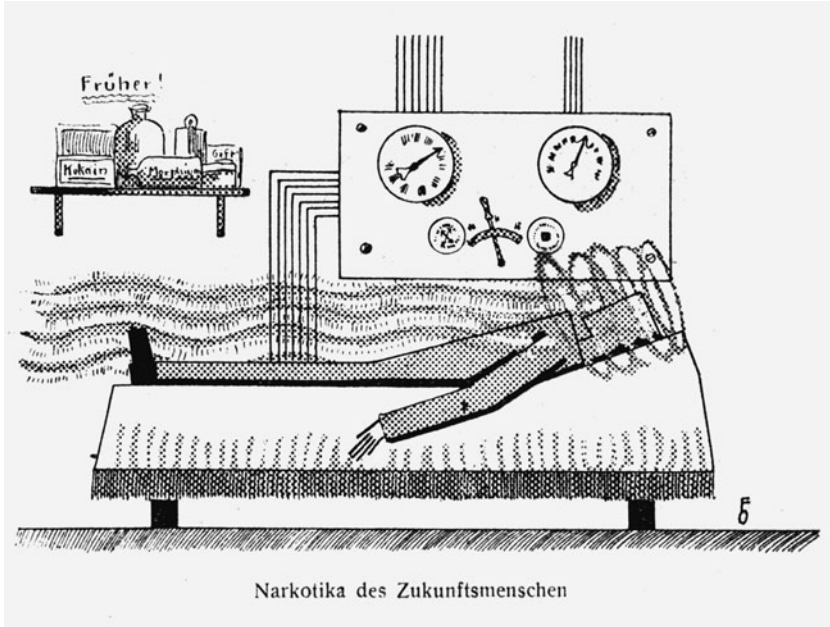


Figure 19 Brain washing by electrotherapy—the German radio listener as imagined by electrical engineer Fiala in 1925. The legend reads: “Narcotics of the human of the future.” The caption above the shelf: “Formerly!”; bottle labels: “cocaine, morphine, poison.”

that intentionally made “people completely into the toy of electronervous vibrations.” Because, if the “man of the future” continued to expand “his knowledge only while asleep,” when his brain was “impressed upon with telephonic streams of speech” through “attached electrodes,” then “those kinds of things” could be “taught to him that the limited time devoted to his daytime profession does not allow.”⁸³ From raising emotional mood, to the “probing” and “putting under fire” of resistant centers of recalcitrant brains, active electrophysiology was supposed to forge out of the human being a “two-legged machine [of the] twenty-first century.”⁸⁴ This electrotechnical “telepathy of the future” was supposed to move “on highly mechanical grounds”; and this meant to Fiala that man and machine would become interchangeable: “The human will become a machine and a wireless receiving system and in those machines warm, pulsating life will stir [. . .] a reevaluation of all values.”⁸⁵

83 Fiala 1925, p. 267.

84 Fiala 1925, p. 267.

85 Fiala 1925, p. 339.

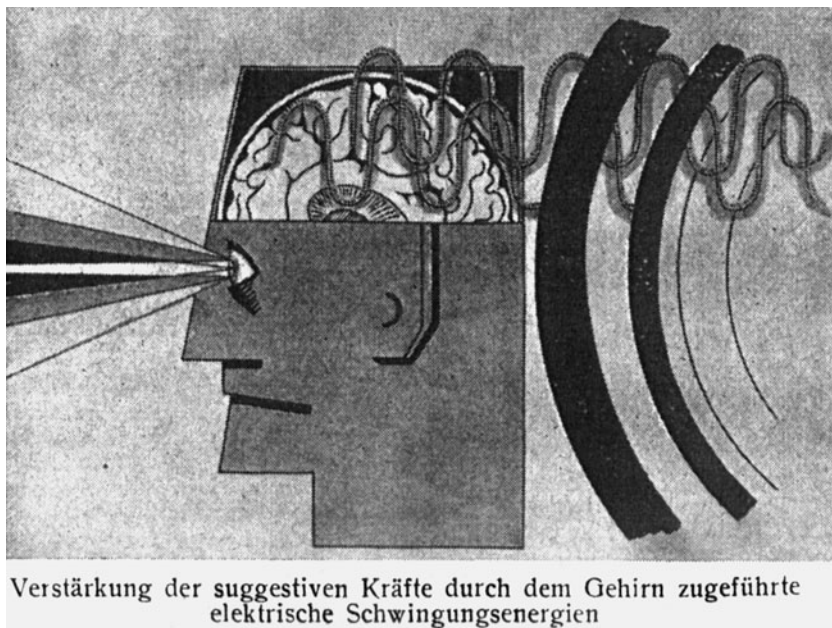


Figure 20 Electrosuggestive therapy according to Fiala. The legend reads: “Intensification of suggestive forces by the supply of electrical oscillatory energies into the brain.”

Between the mass-produced, hand-held, vitalizing electro-shower for civilization-weary metropolitans and the dream of large-scale technical steering of human brains by machines, there lies a truly wide field of therapeutic and manipulative intervention options comprehending visions of a technical evolution of human kind. Crisis-ridden Germany must have been especially fertile soil for such omnipotential fantasms. In “retroperspective” (Catherine David), this brew of ideas cannot be separated from the racist practices of National Socialism, but during the 1920s technical utopism overarched those political opposites. Lenin was known to propagate the victory of communism by a combination of “soviet might plus electrification.”⁸⁶ Lakhovky fantasized salvation on the cosmic scale:

⁸⁶ Lenin expressed this idea repeatedly and condensed it into a rhetorical formula. One of the first occasions for it might have been the address at the VIIIth All-Russian Congress of Soviets from 22 to 29 December 1920: “Communism—this is soviet might plus electrification of the whole country. Otherwise this country will stay a land of small farmers, and this we must clearly recognize. We are weaker than capitalism not only on a world scale but also in the interior of the country. This is generally known. We have realized this and we shall make this economic basis change from small-farming to big industry. Only when this country has been electrified, when industry, agriculture, and transport have obtained a modern major industrial technical basis, only then shall we finally be victorious” (Lenin 1964, p. 513).

Now we are seeking to grasp life and cellular vibrations mentally, but who will give us the eye to detect vital and cerebral oscillations? On that day we shall be the masters of those oscillations: not only in biological and therapeutic respects will new paths and findings of indisputable usefulness to humanity result; but also in social respects powerful upheavals will be the consequence. We shall place those waves at the service of our economic needs; we shall realize the transmission of thoughts; we shall come into direct contact with the blind and the deaf and dumb; we shall know what is being thought elsewhere; we shall correspond amongst ourselves by means of our own waves, perhaps even with animals. [. . .] Let us await in full confidence the day that this eye or this apparatus uncovers for us to its full extent and majestic grandeur this new world that progressive science has just now begun to lift one minuscule veil.⁸⁷

Poetics of new objectivity in brain script

Projects such as Bissky's diagnoscopy, Lakhovsky's radiation therapy, or Cazzamalli's thought radio had already highly sensitized the public to brain currents and thought waves when Berger published a brief and popular description of his method in *Medizinische Welt*, a weekly supported by the Ministry of Social Welfare.⁸⁸ Those three pages as the opening article of the issue published on 28 June 1930, must have been Berger's most successful publication. Brainwaves became *the* topic of the summertime break for that year, only to fall into the background again toward the end of August because of the upcoming parliamentary elections.⁸⁹ The highpoint of press attention fell in the first week of August: Reports about Berger's electroencephalography appeared in *Schlesische Volkszeitung*, *Bergisch-Märkische Zeitung*, *Stadt-Anzeiger Düsseldorf*, *Hannoverscher Kurier*, *Braunschweiger Neueste Nachrichten*, *Neue Wiener Extrablatt*, and *Jenaer Volksblatt*. Various photo and press agencies, including Keystone View from New York,

87 Lakhovsky 1981, p. 202. Our translation from the German.

88 Berger's first communication on the EEG in a psychiatric journal had no major public repercussions. Only Berger's colleague from their common assistantship days at Binswanger's clinic, Adolf Friedländer, wrote about it in *Frankfurter Zeitung* issued on 31 July 1929. But the chief editor of *Medizinische Welt* wrote to Berger on 18 March 1930 to ask about the first communication, when he had optimistically just finished the second one. A week before its appearance, Berger struck "a few somewhat showy sounding words" in a "very last correction proof" (Berger 1930b; lab journal V, p. 44, on 21 June 1930).

89 "The papers have luckily completely calmed down again about my 'zig-zag curve,' thanks to the election events." Lab journal V, p. 61, dated 30 August 1930. Berger collected the reports about the EEG himself and carefully saved them up in an envelope with the note, "Some articles from the papers are of somewhat grotesque nature!" Berger papers, Neurologische Universitätsklinik Freiburg.

requested illustrated reports. Berger had hoped the EEG would win him fame, but hardly in this form. That was why he resolved in future to decline “all popular accounts a[bout the] E.E.Gr., film exposures, etc.,” as “the newspaper ballyhoo up to now is already more than would be conducive to the serious business!”⁹⁰ He kept his resolve, even when *The New York Times* contacted him in 1932 and 1934. Only the national scientific press office, *Reichszentrale für wissenschaftliche Berichterstattung* received press notices from him, which were printed in *Forschungen und Fortschritte* and *Research and Progress*, the official organs of scientific propaganda in Nazi Germany.⁹¹

The texts of most newspaper announcements from summer 1930 were often brief but mostly added two graph excerpts taken from the article in *Medizinische Welt*, along with a portrait of Berger in passport-photo format (Figure 21). The press used this image material purely iconographically. The existence of the curve was the news. Together with Berger’s portrait, the curves gave occasion to celebrate the “invention by a German professor.” The headlines of those reports seismographically documented the associations that Berger’s experiments evoked: “The Electric Script of the Brain,” “The Zig-Zag Curve of the Human Mind,” “Making Thoughts Visible,” “Electricity Brings All to the Light of Day—Finally We Learn What’s Going on inside Our Brains,” “The Electrical Record of Thoughts,” “Electrical Brain Script,” “The Machine That Reads Thoughts,” “The Electrical Thought-Reader.” Following the logic of these announcements, Berger had finally transferred brain, electricity, and psyche into their technical context, into the constellation of a psychic recording apparatus. Berger’s machine not only made the mental states of an individual person objectively visible, by virtue of Berger’s registering device, technology had developed far enough to promise to have the brain explain itself. Brain script was a method “by which the human brain can be made to record its activity, thought, and perception.”⁹²

Despite its regularity, brain script remained cryptic, though, and precisely this made it that much more of a mystery: “As a graphologist,” one woman wrote to Berger,

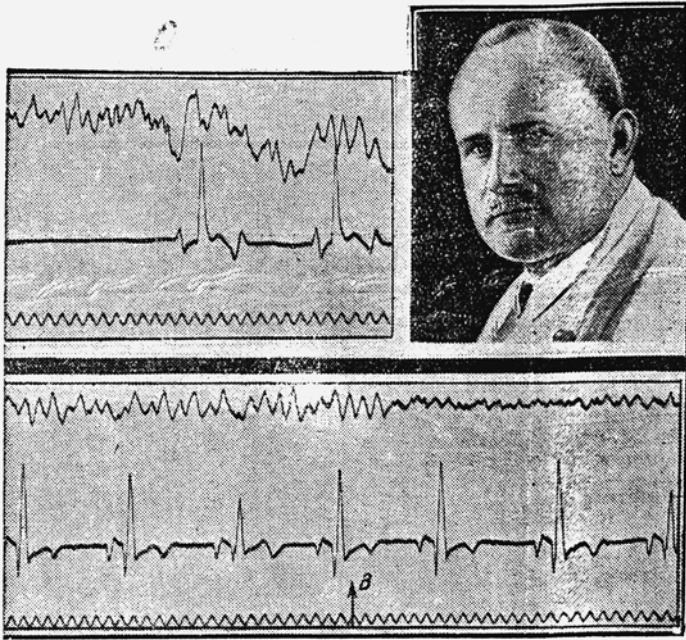
it is becoming more and more clear to me, the longer I immerse myself into this science, that handwriting = brain script. What about if

90 Lab journal V, p. 60 dated 28 August 1930. See Berger’s reply declining a request by the publisher Mauritius Verlag from 18 April 1935: “I informed you then that I have made it a principle only to publish communications about my analyses in scientific periodicals. I tend never to deviate from a principle once recognized as useful, however, and must therefore also give negative notice to your more recent inquiry.” Folder “Laien-Briefe über EEG,” Berger papers, Neurological Universitätsklinik Freiburg.

91 Berger 1933a, 1935a, 1937b. According to information from this *Reichszentrale*, those press notices were sent out to c. 900 newspapers inside and outside of Germany.

92 *Alpenländisches Morgenblatt* dated 30 August 1930.

Bergisch-Märkische Zeitung, Elberfeld



Eine sensationelle deutsche Entdeckung: Die elektrische Niederschrift der Gedanken
Figure 21 A typical example of the echo in the press in summer 1930 about Berger's publication of the EEG. The legend reads: "A Sensational German Discovery: The Electrical Record of Thoughts."

relations existed between the experimentally-to-be-established cerebral currents and a person's handwriting?—My request is, hence, to be permitted by you sometime to make a comparison of the same test person's electroencephalogram and handwriting.⁹³

As long as brainwaves remained so puzzling, graphology offered one physiognomical interpretation of the new script to read the signs from the machine as individual expression, similar to the traces of personality in

93 File labeled "E.E.G u. auswärtige Ärzte," Berger papers, Neurologische Universitätsklinik Freiburg, letter dated 29 January 1939 from Käthe Blau. This pupil of C. G. Jung living in Jena had acquainted herself with graphology under Max Pulver in Zurich after her retirement. The motivation had been Berger's talk on the oscillations of the human brain, "Über die Schwingungen des menschlichen Gehirns," delivered a year before at the *Medizinisch-naturwissenschaftliche Gesellschaft* in Jena.

handwriting.⁹⁴ The expression used in newspapers, *Hirnschrift* (brain script), particularly suggests this connection between writing by machine and that psychodiagnostics which during that period had found more than a niche existence in applied psychology as a result of Klages's *Handschrift und Charakter*.⁹⁵

The tale of the equation: handwriting = brain script, thus historically proved its legibility in both directions. Prior to the EEG and for lack of any direct inscription option for cerebral currents, handwriting counted as a brain script and not vice versa. Wilhelm Preyer, for instance, had suggested in his *Psychologie des Schreibens* in 1895 that handwriting be interpreted as a sign system of the brain, according to the model of sphygmographic tracings by the heart, in which the functional states of the brain are represented in addition to, and beyond the symbolical ordering of language:

If from time to time one lets the cardiograph or sphygmograph record the transmitted heart beats and then one day instead of the regular cardiac curve or sphygmograms one obtains an irregular heart tracing, then the deviation from the norm can be fabricated [by interferences. ...] This comparison is more than just an example for clarification. For, the arm with accessories (or another inscribing body part) is the registration apparatus for cortical parts of the cerebrum entrusted with the psychical functions.⁹⁶

Along the lines of such considerations, Emil Kraepelin soon afterwards performed detailed analyses of the autographic hand as a foundation of his psychiatric nosology.⁹⁷ Some fifty years later, however, there were good prospects of making capital out of the boom of brain script established by the EEG, for the benefit of handwriting interpretation. On the basis of the latest state of neurophysiology, the medical doctor and graphology chairholder at Hamburg, Rudolf Pophal, declared cerebral research as the reference point of a scientific graphology.⁹⁸ Berger, by contrast, never seems to have drawn the comparison between his brain curves and handwriting or even to have spoken generally of his curves as *Hirnschrift*. He was astonishingly

94 On the cultural upswing of physiognomical theory during the Weimar Republic, see Schmölders and Gilman 2000, esp. the contribution and bibliography of Blankenburg (2000a, 2000b) therein.

95 Klages 1917; this book was reprinted fifteen times just during the Weimar Republic and appeared in its twenty-ninth edition in 1989. On Klages' position in the history of graphology, see Avé-Lallemant 1989.

96 Preyer 1895, pp. 205f. Known as the founder of developmental psychology, Preyer (1841–1897) invested a professorship of physiology at Jena 1867–1888. I was unable to find out whether Berger knew about his writings.

97 See Schaefer 2005.

98 For his principal work (Pophal 1949) not even a novel title was needed: *Die Handschrift als Gehirnschrift*—i.e., “Handwriting as brain writing.”

ambivalent about autograph analysis, although his own handwriting, oscillating between technical precision and calligraphy seems like a symptom of his never-ending research on brain script.

The implementation of cerebral currents for graphological purposes was but one of many options that Berger found himself confronted with as soon as the EEG became the object of public attention. The spectrum of examination proposals made to Berger illustrates in a spectacular way the potential that people were prepared to attribute to electrodiagnostic research on the brain and the mind. Prof. August Mayer, head of the women's clinic at the University of Tübingen, proposed to employ Berger's apparatus to test the much-discussed correlations "between electrical behavior in the head and pregnancy."⁹⁹ The director of an association for the study of electric lighting hoped to gather "objectively" by means of Berger's apparatus the effects of light "on mood, efficiency, and similar factors"; and Dr. Huxdorff from the cavalry school in Hannover, wagered on establishing by means of the EEG the "temperament of a horse."¹⁰⁰ The economist Dr. Fritz Dobberkau tried to win over Berger to investigating differences in brain activity from problem-solving in the head as compared to operating a *Brunsviga Nova*. He evidently had important company ties and wanted to have the advantages of this newly introduced calculating machine confirmed by electrophysiological expertise.¹⁰¹ The chair manufacturer Anton Lorenz from Schöneberg near Berlin was hoping for objective confirmation by Berger about the relaxation effects of a new reclining chair.¹⁰² Senior Medical Councillor Tjaden from the research division of the coffee retailer *Kaffee-Handels-AG* in Bremen, finally, was mainly interested in Berger's trials with caffeine, because he was speculating about new advertising strategies for a decaffeinated product *Kaffee-Hag* by his commercial business:

If one places side by side caffeine's relatively long stay inside the body and its stimulating effect upon the brain cells performing psychic functions, as graphically verified by you, then the question of the

99 Letter by Prof. Dr. August Mayer dated 11 October 1932. Folder labeled: "Laienbriefe über das E.E.G.," Berger papers, Neurologische Universitätsklinik Freiburg.

100 Letters by Prof. Dr. M. Pirani dated 30 December 1932 and by Dr. W. Huxdorff dated 24 January 1935, both *ibid*.

101 Letter by Dipl. Volkswirt Dr. Fritz Dobberkau dated 20 March 1931, *ibid*.

102 "I have succeeded in creating a new piece of reclining furniture with which the body is positioned in such a way that complete relaxation occurs and the currents of muscular activity become very small. Prof. Schütz used this chair for his electrocardiogram recordings and obtained with it tremor-free curves. [. . .] I permit myself herewith to direct the inquiry to you whether my assumption is correct that through E.E.G. recordings it could be established whether a body is uncomfortably, hence wrongly and badly, positioned or comfortably, hence well and correctly." Letter by Anton Lorenz dated 24 May 1939, folder labeled: "E.E.G. u. auswärtige Ärzte," Berger papers, Neurologische Universitätsklinik Freiburg.

significance of both these facts to national health can no longer be passed over. The purpose of the activity of the three upper brain layers is work of adequate, usefulness; the price paid for it is physiological wear. This wear defined by caffeine is not the consequence of a useful task; the aphysiological stimulation determined by this alkaloid rather constitutes unnecessary additional strain. The brain cells in question work aimlessly under the action of caffeine, often even against the will and without coordination. It remains open whether these latter two side-effects additionally define an even higher strain.¹⁰³

Others among Berger's correspondents were less interested in economic consequences and rather regarded his experiments as confirmation of their conceptions of thought rays and telepathy. For instance, one letter writer informed Berger about experiments with a "remote telepathic radio telephone," by which test persons after "taking a radium tablet" could be "simply connected with a short-wave apparatus [and] have the entire brain functions recorded."¹⁰⁴ Dr. Edmund Merkl, a lawyer in Br ux, reported about his efforts to develop a "will intensifier," an apparatus intended to technically impose one's own will upon other persons.¹⁰⁵ Such fantasies, reminiscent of Fiala's, document how exuberantly Berger's discovery was being celebrated. Only a few of them expressed fears. Richard F., for instance, wrote to Berger because he had been observing and monitoring himself for years with a similar kind of electric device and knew he had been injured as a result. He was at that time seeking help to "confiscate from a group of mean criminals an invention that is being most horrendously misused."¹⁰⁶ And the businessman Wilhelm P. asked whether it was possible to impede the "heliographic thought radiations" (*heliodischen [sic] Gedankenausstrahlungen*) recorded by Berger's apparatus to prevent their "reception by any other counter-device."¹⁰⁷ But not all victims of telepathic control suffered under their fates. Administrative Secretary M. found access to his own mediumistic abilities through Berger's discovery:

When I now sit down at a typewriter and release a spiritual mental act of will, then in almost all instances I immediately feel an electric current running through my right arm down to the fingertips, which glide over the keys continually with such matchless rapidity that I am in a position

103 Letter by Obermedizinalrat Tjaden dated 15 October 1937, *ibid.* Berger reported about experiments with caffeine in his twelfth and thirteenth communications (Berger 1937d, 1937e).

104 Letter from Gustav H. to Hans Berger dated 17 September 1930, folder labeled: "Laienbriefe  ber das E.E.G.," Berger papers, Neurologische Universit tsklinik Freiburg.

105 Letter by Edmund Merkl dated 12 December 1934, *ibid.*

106 Letter by Richard F. dated 1 July 1933, *ibid.*

107 Letter by Kaufmann Wilhelm P. dated 28 August 1930, *ibid.*

to write in unbroken sequence an entirely new treatise at a single go and in a single day at a length of some 30 pages and more.

This current was a spiritual power that usually commanded the administrative secretary of Nazi Germany to retranslate into German the sections on “hell” and “purgatory” of Dante’s *Divine Comedy*, so that it be finally seen how perfectly the Italian poet had foreseen the two “stars” Hitler and Mussolini in the heavens of humanity. This time the current was steering him to ask the cerebral researcher for elucidation of his “spiritual mental act.” Enclosed with this letter to Berger was a document that M. had produced in his capacity as a medium:

I, too, a spiritual force, equipped with all energy attributed to an intellectual mind, turn to you and declare that this man, who is applying to you today, has been directed by me to do so. For it is I who directs those people who have concerned themselves with the problem not out of pure curiosity but proceeding just as devotedly and scientifically as any true scientist, although this man is a layman in this field. How he has come to do so shall not be aired here today. It suffices that this man has already come so far as to be able to work as a wholly perfect and enlightened human textual medium.¹⁰⁸

Berger did not doubt that an “excellent textual medium” was involved here but evidently hesitated to cooperate with this “spiritual force.” Instead he recommended reading Alfred Lehmann’s book on superstition and magic, *Aberglaube und Zauberei*.¹⁰⁹

Like a kaleidoscope, the numerous letters written by interested laymen reflected that cultural landscape of a new configuration of the brain in the electrotechnical and medial technical sense, which I have initially differentiated here as regards the technologies of representation, construction, communication, and manipulation. Precisely this new objectivity of electrotechnical elucidation of the mind and the brain offered euphoric potentials:

My dear, good Prof. Dr. Berger!

What I find in the paper is amazing! Eh?—When you’re far enough along to detect sicknesses by a curve. How fine that would be! [. . .] Maybe the expression psychopath will disappear then. One knows at once what’s going on and can intervene. Then nobody has to walk around anymore with that stamp of inferiority. All psychopaths would become *free* people, like the rest. [. . .] When the term psychopath disappears, then psychosis will soon also disappear.—Continue your

108 Letter by Verwaltungssekretär M. dated 22 May 1938, *ibid*.

109 Letter from Hans Berger to M. dated 27 May 1938, *ibid*.

work. Start first with psychopaths.—Now I have to sleep. It's time.—First, one more Luminal, and then, that was it.¹¹⁰

The experimentalization of daily life

Powerful energy streams *contra* secret energies was the opposing cry in the advertisement of the Berlin Allotment Gardening Exhibition quoted at the beginning of this chapter. The electropsychologies of the interwar period were playing on all registers of this keyboard: Telepathy waves generated widely branching discursive resonances as “fine-grained vibrations.” Electromagnetic fields of force compelled thousands of radio listeners to practice their concentration every Sunday. Vitalizing high-frequency eddy-current showers substituted painful electrical shocks applied on soldiers unwilling to go to war; and the gentle force of “electronervous oscillations” were supposed to bring sleeping brains into conformity. Kahn, Schleich, and Bleuler found in electrotechnical industrial culture the key to the anatomy and physiology of the psychic apparatus. Bissky proclaimed the discovery of the “physiological rhythm of our nervous system.” And Berger was finally celebrated as the German discoverer of the secret script of the human mind.—The electrification of daily life did not stop at psychophysiology. Electrotechnical concepts proved to be particularly flexible organizers of emerging psychology. Electrotechnics was less an imperial power that simply colonized ever more areas of private life and everyday culture. Gadgets, concepts, theories, and practices in the environs of electrotechnics, rather, proved to be formable elements that allowed themselves to be connected just as well with esoteric points of view as with disparate psychological models or classical questions of philosophy. The electrotechnics of the live mind of the Weimar Republic mirror a continual experimentation with apparatus and concepts in ever newer arrangements.

This cultural constellation of permanent experimentation can be understood as the expression of an expansionary movement by which the discourses and practices of experimental science diffused out of the laboratories of the life sciences into everyday life: into the feuilletons of illustrated weeklies, into radio programs, and available world-view interpretations, and thus also into the worries and fantasies expressed in letters to Berger. This expansionary movement can be characterized as the *experimentalization of everyday life*. Physiology was constituted as an experimental science during the nineteenth century, which has been called “experimentalization of life” because the introduction of laboratory practices into the biological sciences meant transforming concepts of life into experimentally observable and influenceable processes.¹¹¹ This reconstituting of the life sciences as

110 Letter by Erna R. dated 24 January 1935, *ibid.*

111 Rheinberger and Hagner 1993.

laboratory sciences led, over the course of industrialization, to a “scientification of the body” (*Verwissenschaftlichung des Körpers*) that extended far beyond physiology and elevated it to the “lead science of the nineteenth century.”¹¹²

As a success model of scientific research practices, physiology exported its experimental cultures at the turn of the twentieth century into the human sciences and life sciences and became part of the *avant-garde* culture of diverse arts.¹¹³ The phase after the end of World War I distinguishes itself from this in that the experimentalization of life then became a mass movement within the framework of the general discourse on rationalization and the growing scientification of ever more areas of society, ranging from the care of cripples and occupational physiology to rational kitchen organization and beauty care.¹¹⁴ The electrotechnics of the live mind reconstructed here also belong within this context. Experimentalization had thus arrived in everyday life in a twofold manner: On one hand—and in the sense of a totalizing movement—more phenomena, that is, more everyday phenomena, became the object of scientific analysis in the laboratory. On the other hand, in the dual play of popularization and public efficacy of science, everyday life became increasingly the arena and actor of this experimentalization.

The electropsychology of the Weimar Republic united both aspects of this experimentalization of everyday life in a poignant way: The “electrodiagnosis of mental properties,” the “switches” of mnemonic theory or psychopathology, the electroresonances of harmonizing minds, the radiodetection of intellectual concentration, or the “deformations” of brain curves after drinking coffee, mark the incursion of technical science discourses into the daily life of the individual. Scientists as well as laymen participated in these discourses at public forums, such as in newspapers, on radio, or in popular magazines. Publicity by the media was the site of this discourse—and this perhaps even more strongly in the crisis-shaken society of the Weimar Republic than in other industrialized states. Electropsychology only formed in the interplay between heterogeneous and contingent individual projects within the public realm.

Whereas the first move toward a broadening of the laboratory sciences into other aspects of daily life is well documented specifically for the period

112 Sarasin and Tanner 1998.

113 The project “The Experimentalization of Life. Configurations between Science, Art, and Technology” at the Max Planck Institute for the History of Science in Berlin examines these interactions and networks among different disciplines and experimental cultures; see www.mpiwg-berlin.mpg.de/en/research/projects/ExperimentalizationOfLife (27 August 2002).

114 From the great quantity of contemporary sources on rationalization, the following titles document the close interlocking between commercial, psychological, physiological, and social aspects: Reichskuratorium für Wirtschaftlichkeit 1931, Atzler 1927, Eliasberg 1926, Bauer 1931, and Riedel 1925.

of the Weimar Republic,¹¹⁵ the contrary direction of the permeation of publicity and science seems to be historiographically rather underexposed.¹¹⁶ It is hardly coincidental that a model that formed as part of just this culture of the Weimar Republic would be applicable here. Robert Musil formulated it by exemplifying larger political history turned upside-down, in a cultural history of incremental steps and ancillary circumstances in *The Man without Qualities*:

But for the most part history takes shape without any authors. It does not form from a center outwards but from the periphery. From small causes. It probably wouldn't take as much as one would think to turn a Goth or an Ancient Greek into a modern civilized person.¹¹⁷

“History without any authors” is being promoted from all sides in history of science writings; but they usually focus on a clear center, namely, the scientific dealings and exclusive sites of science, thus the experiment, the apparatus set-up, the laboratory, the recording technology, professional journals, etc.¹¹⁸ Only seldom are peripheral locations examined as zones of the production and shaping of knowledge. The experimentalization of everyday life describes the phase of a scientification of the day-to-day, or an epistemologization of everyday and popular knowledge.

It was specifically characteristic of the electropsychology sketched here that relevant knowledge could be generated everywhere in the discourse. Obviously, the practices and processes that took place in specialized and closed scientific laboratory spaces stayed relevant to electropsychology. But alongside sites of exclusively scientific activity there came numerous laboratories in technical institutes, industrial concerns, advisory establishments, or private enterprises; and entirely in the meaning of Musil's history of the periphery, those interactions in which electropsychology acquired its contours only took place in the open. This openness was not a place on the other side of a semipermeable membrane that separated a space of genuine scientific activity off from an area of diffusion of scientific findings. It was, rather, the zone of a mixing of scientific as well as extrascientific discourses;

115 Rabinbach 1990, Hinrichs and Peter 1976, Price 1998.

116 Prospects of such a project are offered by Cooter and Pumfrey 1994, Orland and Brecht 1999. Daum 1998 and Lightman 1997 have reconstructed the ambivalent functions of the public discourse in science of the nineteenth century.

117 *Der Mann ohne Eigenschaften*, our translation from Musil 1978, p. 361.

118 This, it seems to me, is where the boundary lies between the epistemological revolution of so-called “laboratory studies” (Latour and Woolgar 1979, Knorr-Cetina 1984) and the history of science of Shapin and Schaffer 1985, as well as Rheinberger, Hagner, and Wahrig-Schmidt 1997. Above all, in the discourse about the popularization of science, the periphery often figures one-sidedly as the location of the dissemination, pervasion, and effectiveness of science, or of an autochthonous scientifically legitimated knowledge, e.g., Shinn and Whitley 1985; critically on this: Irvin and Winne 1998.

and precisely this inhered in the potential for stabilizing electropsychological constructs. With the experimentalization of everyday life, the public space became, in a way, a laboratory for experimentation on the electrification of the human image. Walter Benjamin's characterization of the Moscow workaday routine of that period seems to me transferable onto the Weimar Republic: "Every thought, every day, and every life lies here as if on the laboratory bench."¹¹⁹ In this pervasive electrification of everyday life, not only the practices of daily life were reconfigured but, thus, also the human mind and psyche.

In the popular discourses on the electrotechnics of the live mind, the electrical brain experienced its first boom before electrophysiological research and electroencephalography would stabilize the electrical brain as an epistemic thing. Different from other branches of brain research, the discourse on the electrical brain seems to have circulated relatively independently of interventions by professional scientists in the public realm. The history of the electrical brain began with a form of public experimentation dealing not with objects in the laboratory but with credibility within the public space. A variant of the social construction of science took effect here, whose actors were the voices interconnected by feedback loops in the play of opinions—the recording machines, researchers, radio listeners, and newspaper readers. During the Weimar Republic, the human being's psychophysiological life had already become the collective experimental arrangement that Leon Trotsky had presented in 1923 as "an enthusiast's dream":

Life, even purely physiological life, will become collectively experimental. The human race, petrified *Homo sapiens*, is being radically reworked anew and is becoming—by his own hand—the object of the most complicated methods of artificial selection and psychophysical training.¹²⁰

119 Benjamin 1927/28, p. 79. Whereby it goes without saying that the changes in German society after the lost World War were hardly comparable with the upheavals in the Soviet Union.

120 Our translation of Trotzki 1994, p. 250.

4 *Terra nova*

Contexts of electroencephalographic explorations

Epistemic resonances and material cultures

With the publication of the human electroencephalogram in 1929, the EEG left the realm of the shadows of the Jena director's office and experimental room. Only in historical retrospect was this step reconstructed as the beginning of a coherent field of scientific research. Only after Berger's studies had been received by other researchers and his trials had been made to resonate with other neurophysiological, neuropsychiatric, and psychological experimental systems, could Berger's EEG be stylized as the point of departure of something.¹ When the fortieth anniversary of Berger's first EEG paper was being celebrated during the VIIth International EEG Congress, the by then almost eighty-year-old keynote speaker, Douglas Adrian, explained why he had not reviewed Berger's work before 1934 and why there was a five-year delay before international research on the EEG began:

If we want yet another excuse for our lack of curiosity about work on the brain, it might be added that most electrophysiologists then were engaged in work on the peripheral nervous system and not on the central. We were reaping the harvest due to the new techniques of electronic amplification. This was giving important results in the problems of transmitting information by nerve fibres and most of us probably thought we were better employed in following up this line of advance than in paying attention to the much more complex field of the cerebral cortex.²

In 1969, Adrian and the scientific community evidently regarded it necessary to provide an explanation. (It was otherwise usually dealt with by indicating the out-of-the-way publication in a German psychiatry journal and Berger's odd exposition style.) But the very question of this postponed reception distorts the view on a historical situation in which initially no

1 On the concept of retrospective reconstruction of history in the process of it being written down, see Certeau 1988, 1997.

2 Adrian 1971, p. 1A-6.

linking points to Berger's researches existed. Those examinations were not what they were later seen to be until well into the 1930s.³ If the subsequently reconstructed discipline-building effects are ordered as moments of a developmental history, it doubly obstructs the view on the historical process. Such an account is just as blind to the openness of a scientific field as to the local determinants along its disciplinary contours. This is where Bachelard's historical epistemology of altering research perspectives comes in. It aims less at mobilizing "passed over" sources and events to correct the history of the specialty than at exposing differences and research options in the specific contexts of various experimental systems.⁴

Between Berger's first publication in 1929 and the first review articles in 1937–1938, electroencephalography went through a phase of largely explorative experimentation,⁵ in which no uniform procedure had yet been established, the individual analyses were instructed by very different theoretical constructs, and also in technical respects most laboratories were experimenting with apparatus that had been developed *ad hoc*. In the various laboratories that took up investigations on electric potentials in the brain, although those tests had been triggered by a (mostly vague) knowledge of Berger's research, they remain guided by theoretical presuppositions and established experimental arrangements from other contexts. At each of these places, the EEG experiments were fitted inside a microcosm that in each case endowed the knowledge space of the EEG with specific contours. This is where the EEG was fashioned into the scientific object that only became known through this process. The indefiniteness of a scientific object at the beginning of its inquiry is not arbitrariness but openness that is constrained and directed by other stocks of knowledge, presuppositions, the availability of particular research objects, and the routines of experimental practice. At the same time a scientific object articulates itself as something new out of the theoretical and technical differences from what preceded it. The EEG, too, was a hybrid in this sense, into which traces of its history and production were inscribed.⁶

3 A novelty is initially not yet that which it will later be deemed to be, as we can say with reference to François Jacob (1983, p. 94, cited here according to Rheinberger 1992, p. 52): "What we can surmise today, will not become reality. Changes will occur in any event, yet the future will be different from what we believe. This is particularly valid for science."

4 For this Bachelard (1974, pp. 165f.) introduced the concept of "regional determinism." Even though supposedly the same or at least similar phenomena were being worked on in different laboratories and their interpretations argued about, the various results were not simply cumulative or conflicting findings on the same "thing," but were part of a negotiative process about the EEG as a scientific object.

5 I borrow this term from Friedrich Steinle (1998).

6 In principle, this process is uncompletable. Even modern decontextualized accounts of the EEG do not eliminate this hybrid nature of it, but largely suppress it in a process of standardization. When introductions in modern EEG textbooks combine a brief historical outline with an introduction to method, this disciplinary practice also reveals an epistemic residue of the genesis of electroencephalography.

Berger's further voyage through brainwaves

Between Berger and his experimental system a lasting tense relationship prevailed because even after its first publication he “overburdened” his trials, asking too many questions at once, or demanding answers to overdrawn interpretations. Berger did not make a school out of his research on the EEG. Excessive worries about “his” EEG prevented him from even forming a group of his own students in Jena. Toward the end of his academic career, he advanced to becoming the first exponent of the EEG above all abroad, and a number of American EEG researchers visited him in Jena.⁷ In the upwind of this international acknowledgment, for instance, thanks to Adrian’s initiative, Berger delivered the opening talk at a section on the EEG in 1937 at the International Congress of Psychology in Paris.⁸ But throughout his life his achievements remained controversial, especially in Germany, as the expert opinions that were repeatedly sought for Berger’s admission to the Leopoldina, the German Academy of Scientists and Physicians, evidence.⁹ The matter was clear to Adrian, although he hardly took Berger seriously as a physiologist:

His work on the electrical activity of the human brain is of outstanding importance: it has introduced an entirely new method of investigation + has already become the starting point for numerous lines of research in Europe + America, in fact there are several laboratories in the United States almost entirely devoted to the investigation of the phenomenon which Berger has discovered. [. . .] It might be objected his papers are sometimes obscure, that he is unfamiliar with certain developments in physiology + in electrical technique, or that some of his conclusions appear to be naive + out of touch with the most recent thought in

7 Jasper came to Jena from Paris following the award of his doctorate in July 1935; at the end of August Frederic and Erna Gibbs visited him together with Hallowell Davis on their return trip from the Physiology Congress in Moscow, which led to a closer friendship with Berger and to plans for a two-week lecture tour through the USA by Berger in 1939 which eventually had to be cancelled. Also in 1935 Berger received Grey Walter as his visitor, while Rohracher and Cazzamalli started exchanging letters with him during that same year.

8 There he met Adrian for the first time. For lack of a common language he could barely converse with him, though, and was introduced by Jasper to a few American scientists. See Berger’s official report about his Paris trip, University Archive of the Friedrich-Schiller-Universität Jena, holding D, no. 176, sheets 52–55. He merely participated at the congress in the EEG session and attended the ceremonial events and otherwise seems to have spent the days in Paris on touring excursions with his wife. His report noted in characteristic fastidiousness that in the Louvre they had viewed “above all Venus de Milo, Nike of Samothrace, and also the Mona Lisa.”

9 Berger was elected a member on 29 December 1937. This was the highest distinction he received for his research. Berger immediately thanked Emil Abderhalden for “the first German acknowledgment of my researches.” See Hans Berger to Emil Abderhalden dated 1 January 1938, Archiv der Deutschen Akademie der Naturforscher Leopoldina, MNr. 4421.

neurology + psychiatry. It is quite true that he has not been in close contact with departments of physiology etc. + so has had little opportunity of learning all the most recent ideas + methods. Yet in spite of this he has achieved results which any physiologist would be very proud to claim as his own.¹⁰

The Bonn physiologist Ulrich Ebbecke was not so sure that the EEG was even a relevant observation at all:

Compared to the solidly established findings regarding peripheral nerve fibers and to the way that the experimental methods now progress slowly towards the physiology of the spinal cord, determining the electrical processes in reflex action, his path is a bold advance that his fellow members of the profession do not easily dare to follow, but who certainly do recognize the importance of. [. . .] The question remains: Do the recorded currents have anything to do with the currents of nerve action in cerebral cortical cells? [. . .] You see that I toss and turn somewhat between acknowledgment of the findings and uncertainty about their interpretation. It will surely fortify Prof. Berger in his work if he experienced acknowledgment from your quarter, pointing out the interpretational difficulties.¹¹

These two expert opinions gather, as in a convex lens, the full breadth of differing assessments of the EEG; in 1937 it had simply not yet stabilized as a scientific thing.

Despite this continual vacillation, Berger's first publication about the EEG demarcated a crucial hiatus in his research, not only because that was when the public history of the EEG began. In epistemological respects it was perhaps even more decisive that the publication gradually broke open the autism of Berger's experimental system, because a new obligation to give coherence to the EEG stepped between Berger and his experimentation. A comparison of his published *Mitteilungen* with the doubt-ridden and radically revised entries in his Reflections and lab journals reveal what a stabilizing and ordering effect mere publication had on Berger's experimental system. The first of these communications followed an extremely productive period of continued work on the EEG for Berger. On 5 February 1930 Berger demonstrated his technique with "complete success" before the Jena *Medizinische Gesellschaft*.¹² In the weeks that followed, he turned this

10 Expert opinion by Edgar Douglas Adrian on Hans Berger dated 26 December 1937, Archiv der Deutschen Akademie der Naturforscher Leopoldina, MNr. 4421.

11 Expert opinion by Ulrich Ebbecke on Hans Berger dated 5 December 1937, Archiv der Deutschen Akademie der Naturforscher Leopoldina, MNr. 4421.

12 "My results were generally marveled at & recognized." Lab journal IV, p. 277, dated 6 February 1930. This was presumably the only public demonstration he ever performed.

talk into the second communication and the more popularly written exposition for *Die Medizinische Welt*.¹³ In that year Berger could celebrate his very personal anniversary full of pride:

On 6 VII '30 it's been 6 years since I saw the E.E.Gr. for the 1st × on the trembling filament of the small Edelmann string galvanometer.— How happy am I that I could find this pebble on the beach, which exhibits such a fine crystalline form—to end up with that Newtonian comparison. It becomes ever more precious to me, the more I look at it and handle it: a wonder, of which Nature is so rich & which God let me behold!

[4 July 1930, V, p. 47]

When in September mail arrived from Stockholm as well, Berger's pride swelled into great confidence: "Yesterday on Ruth's birthday, received the Nobel statutes from Stockholm & the request to nominate a prizewinner. An omen? Want to receive the prize on 10 XII 1932" (30 September 1930, V, p. 69). Nothing was to come of that, but Berger was able to convert this interest in the EEG into research funding, with which he could finally purchase a Siemens oscillograph with vacuum-tube amplification in 1931.¹⁴ As with all the other technical innovations, the new instrument brought problems with it, this time "the disadvantage of an almost excessive sensitivity." X-ray apparatus, diathermy instruments, and washing machines, even those in operation in other parts of the clinic buildings, disturbed the analyses just as much as restless test subjects, which made necessary for each trial, screening and special examination precautions that extended far beyond Berger's own laboratory. Even though such measures prevented "the spot of light [from] immediately flashing off the exposure surface,"¹⁵ the new apparatus allowed Berger's experimental system to gather momentum.

13 Berger 1930a, 1930b.

14 With this improved apparatus Berger's experimental system reached its highest technical state. In October 1930 Siemens had already loaned out to him a Siemens amplifier electrocardiograph. Some of those curves from October 1930, written on the typically narrow Siemens ECG photographic paper, have been preserved and are presently with the EEG material among the Berger papers in Deutsches Museum in Munich. The Zeiss Foundation financed the manufacture of a special EEG oscillograph that combined a conventional coil-galvanometer contact with an oscillographic register (see the letter exchanges with G. Link, folder "E.E.G u. auswärtige Ärzte," Berger papers). For the technical details on this oscillograph built specially for Berger, there are a detailed description and user's instructions preserved in the Siemens Archive; see "Bedienungsanleitung zum Elektrenkephalographen" in the folder "Technische Entwicklung/Messung von Körperfunktionen/EKG bis 1944," Siemens Archiv, Abteilung Medizintechnik Erlangen. The new instrument was set up at Jena in April 1931; the first curve recordings were published in Berger's fourth *Mitteilung*.

15 Berger 1932a (4th *Mitteilung*), p. 7.

Berger started to give local lectures on the EEG and was even planning national and international conference contributions at the end of 1931.¹⁶

Before the new apparatus had arrived, Berger provided for a decisive conceptual consolidation of the EEG with his second communication. Employing uncharacteristically concise and terse style in it, Berger introduced new terminology:

For the sake of brevity I shall denote the waves of first order as alpha waves = α w., waves of second order as beta waves = β w., just as I shall apply the abbreviation "E.E.G." [. . .] for the Elektrenkephalogramm.¹⁷

Berger conceived the difference fixed in this terminology between slower oscillations of higher amplitude and faster oscillations of lesser amplitude as an essential difference that became the core of a first "working hypothesis":

I arrived at the assumption that the β w[aves] correspond to the biological activities of the brain tissue and, consequently also, that these currents are always present wherever currents are recorded from living brain tissue. The α w., however, seem to me to be the attendant effects of special functions of the relevant tissue. [. . .] I do tend toward the interpretation that the α w. are probably attendant effects of those nervous processes which have been designated as psychophysical, i.e., therefore, those material cortical processes that under given circumstances could be connected with conscious phenomena.¹⁸

This working hypothesis clearly favored the more regular and slower waves of greater amplitude, which over the years Berger had so tediously stabilized as electric signs of psychophysical activity of the brain in his

16 "All Souls today! Beginning of lectures!—I was thinking a lot yesterday: a man must stand up for his work!—I want to speak at the convention of the Deutsches Verein für Psychiatrie in 1932 about my E.E.G. (May '32 in Bonn), likewise at the convention of the Deutsche Naturforscher & Ärzte. At the convention of German neurologists too is doubtful to me, though, but if possible 1933 at the International Neurol. Congress in London.—I have to register myself. I will do so, too—I can be proud of my achievement!" (Lab journal V, p. 157, on 2 November 1931)

17 Berger 1930a, p. 162. This is more than merely a matter of assigning names, because the terminology isolates two forms from the EEG's recorded frequency spectrum. Berger never discussed waves of a different frequency or different pattern because his EEG was exclusively a combination of alpha waves and beta waves or their modifications. The terminology thus, at the same time, prejudicially attached a structure to the EEG because, using the ECG as a model, it identified *individual, distinct* waves as building blocks of the EEG. The model character of the ECG might also have been one of the reasons for Berger to seek and assert a regular alternation between alpha waves and beta waves or an overlap of one alpha wave with three beta waves as the EEG's basic form, even though his curves showed such a pattern rather rarely (see esp. Berger 1930a, 1931, 1937c, and 1938b).

18 Berger 1930a, pp. 175f.

experimental system.¹⁹ For a long time the alpha waves remained the cardinal pivotal point of his views on the EEG. For a while, the hierarchization of the two types of waves went so far that Berger regarded solely alpha waves as the EEG and assessed, for instance, “an EEG is not yet detectible” in children from 8 to 13 days old, because in spite of slight “fluctuations in the galvanometer curve [. . .] none of the characteristic α w[aves] of the E.E.G.” could be seen.²⁰

The price of this working hypothesis was high, as the psychophysiological tests appeared to be flatly contradicting them: Of all things, the genuinely psychical exertions such as calculating in the head, reading, or processing of sensory stimuli, correlated not with an increase in the main waves or their augmentation, but with a decrease and diminution in the registered current fluctuations. These multiply repeated tests caused Berger “many a doubt,” because their outcomes were “entirely different” from what he “had expected.”²¹ Only by conjecture of a complex brain theory could Berger make the results harmonize with his working hypothesis.²² He considered that the EEG curve, registered from the brain as a whole, with its typical vanishing of alpha waves upon psychical activity, was the imprint of a concentration of neural activity in the interior of the cortex. And he speculated that large, if not enlarged alpha waves did in fact occur in the “working center” (*Arbeitszentrum*).²³ But then the alpha waves registered in the EEG could no longer count as the correlate of psychophysical processes. They then became the sign of the whole brain’s attentiveness readiness, which by a stimulus or by mental exertion could literally become concentrated into psychophysical activity.

Behind this working hypothesis was hidden an epistemologically highly complex interplay between interferences, theoretical basic assumptions, interpretational hypotheses, and interventions in the experimental arrangement. For example, Berger’s instruments reacted so sensitively to omnipresent sound and light stimuli that at first they formed permanent loud background noise and not yet interference magnitudes. Only after Berger could gradually

19 Berger himself noticed this continuity (lab journal V, pp. 47f., on 4 and 6 July 1930): “Today I know that the α w. do in fact have something to do with the functioning of the cerebrum & probably represent the attendant effects of [f] $\psi\phi$ -processes! A long path abundant with failures, doubts, & passing despair lies behind me & it is now a matter of: Impavidi progrediamus! [Let’s undauntingly proceed!] Jena’s old motto! I began my academic career in 1901 with analyses on the effect of medications on circulation in the brain; then I did not arrive at the sought result. At that time, I was imagining ‘cortical currents’ already then, which now are solving the questions!”

20 Berger 1931 (3rd communication), p. 239.

21 Berger 1930a (2nd communication), pp. 169 and 172.

22 In bridging this gap Berger was following a long tradition in neurophysiology to suppose the inhibitory process to be the key to the cognitive work of the nervous system. He took a survey article by Beritoff (1922) as his support, see also Smith 1992.

23 Berger 1930a (2nd communication), pp. 173f.

persuade himself of the validity of incidental observations that even just the noises of the apparatus in operation or open eyes in a normally lighted examination room influenced the recorded wave patterns, was he able to alter the set-up of his experimental apparatus accordingly (Figure 22). This then led to the spatial separation of examination room from registration area or, alternatively, to a darkening of the space in which the trials were conducted.²⁴ Such a seemingly purely technical improvement to the recording conditions implied far-reaching conceptual alterations, because, for instance, the characterization of the brain work that the curves suggested could not be brought into agreement with Berger's theory of psychophysical work. How should the EEG serve as a detector of mental potentials if open eyes or random attentiveness to some sensorial stimulus produced electrical phenomena in the brain equivalent to problem solving or reading? What initially barred the way as a variation in EEG curve registration that was hard to control and later observed by Berger to be interference in the recording technology, finally emerged as an epistemic obstacle posed by the starting hypothesis.²⁵

The slight stress triggered by the mere sight of the experimental set-up could influence the pattern of the subject's brainwaves so strongly that no further differentiation between the psychophysiological states was possible. This meant the identification and control of disturbances on the part of the test persons was especially precarious.²⁶ On this unsurveyable terrain,

24 "I did not point out explicitly above but would like to add it herewith, that the curve segments [. . .] are recorded in that the t[est] p[erson] lies totally at rest, bodily and mentally, as best as possible, with closed eyes in a darkened room. One thus obtains the largest deflections for the E.E.G." Berger 1930a (2nd communication), p. 166.

25 In this already complex system of interconnected variables and additional unknown influencing factors, Berger made the orientation even more difficult by pursuing various optimization strategies simultaneously. While making modifications to the psychological experimental construction of stimulus and work, for instance, he also varied the registration technology. From the third communication on, Berger again favored penetrating needles instead of foils on the temple and back of the head. Those needle electrodes handled the electrical conditions on the skull but the pain attached to this method generated new problems that caused a sensitive response by the EEG. For that reason in his fourteenth communication Berger reverted back to his preference for silver foils, because that way the brain potential could be recorded particularly gently and broadly.

26 "Psychical processes largely influence [. . .] the potential of the E.E.G. Particularly with the sick, who are able to give only incomplete information about their internal condition or none at all, it is often impossible to exclude this source of error" (Berger 1933b (5th communication), p. 253). For such reasons Berger viewed examinations of psychiatric patients as very doubtful from the outset, especially since the findings for clinical pictures in neurological psychiatry remained astonishingly aspecific. He often found an entirely normal EEG with patients suffering from Alzheimer's disease, multiple sclerosis, cerebral arteriosclerosis, mania, melancholia, schizophrenia, or "inborn feeble-mindedness"; see Berger 1931 (3rd communication). Only with so-called "general functional disorders," such as, brain pressure, large brain traumas, or dementia on the grounds of years of epileptic illness, did Berger find clear pathological signs in the form of strongly extenuated

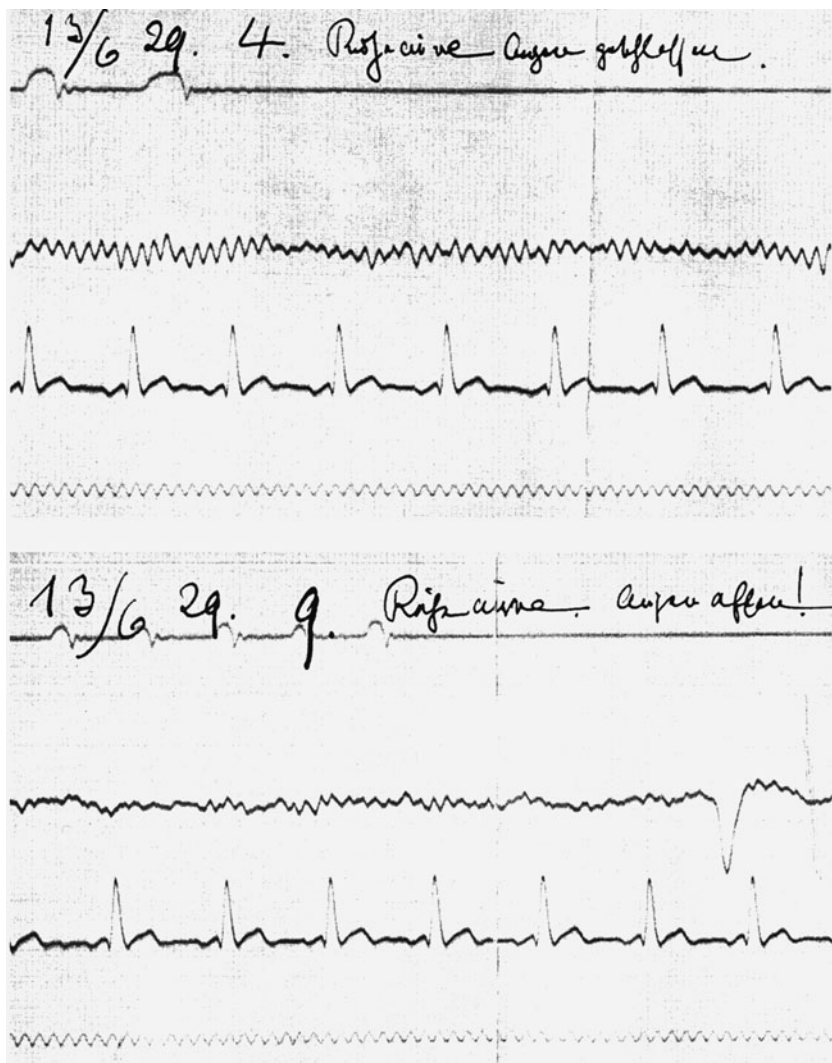


Figure 22 Blockage of alpha waves by opening the eyes in a specific test by Berger 1929. The subject's eyes are closed above, and are open below.

observations during sleep or after the administering of drugs and narcotics promised to provide good points for orientation. When Berger detected the

alpha waves. However, already in this communication, published at the beginning of 1931, Berger reported about signs in the EEG for localizing brain tumors, because the spread of inhibitory effects through the cerebral cortex was slowed by them. A first important clinical application of the EEG would in fact result out of similar findings.

expected reduction in large alpha waves during sleep, and an increase upon waking or after an intake of cocaine, he regarded his working hypothesis as largely confirmed. However, more experiments during the summer of 1933 with the newly marketed narcotic Evipan manifested enlarged alpha waves during the unconscious state.²⁷ At least at the level of his published communications, this paradoxical finding in Berger's experimental system seems only to have been briefly irritating, because on the basis of these findings Berger conceived a pathological disinhibition of alpha waves, as a speculative counterpart to the inhibitory concentration of alpha waves in the psychically active working center. What had begun as interference finally led Berger via conformance of his working hypothesis to an electrophysiological theory of the triggering of epileptic fits as a vacillation by the brain between inhibition and disinhibition during the attack.²⁸ Berger demonstratively approached the public with this complete alpha-wave theory of conscious processes and their pathologies. He proved his influential leadership on the topic of the EEG in three prominently placed articles: the opening article to the Christmas 1934 issue of *Deutsche Medizinische Wochenschrift* (1934c), and as a survey article of *Klinische Wochenschrift* in February 1935 (1935d), as well as for the broader scientific community, in *Naturwissenschaften* (1935b).²⁹

Almost exactly two years later another lead article by Berger appeared in *Naturwissenschaften* in which he turned his previous hypothesis upside down and asserted the psychophysiological significant waves to be beta waves:

I give up the working hypothesis I had first proposed in 1930 [. . .]. I do not hesitate in the least to confess this openly, as we do want to inquire into the truth as far as is ever possible. But now to the point! [. . .]

27 Berger 1931 (3rd communication) and 1934a (8th communication). The motivator of this series was cooperation with industry. Berger's assistant H. Stefan had tested Evipan at the behest of Bayer-Meister-Lucius, a medications manufacturer in Leipzig. He recommended its use for difficult diagnostic interventions, for example, but also for transporting agitated patients; see Stefan 1933.

28 Berger 1934b. Berger had already experimented on epileptic attacks (see Berger 1932a (4th communication), 1933d (7th communication)). They impressively document his selective perception of electrical phenomena in the brain, as although recordings of fits repeatedly worked, he did not grant those curves validity owing to their unduly large deflections, which he evaluated as artifacts and based his alpha- and beta-wave theory about the course of those attacks on relatively few curves. On Berger's epilepsy studies, see also the analysis by Jung and Berger (1979) written on the grounds of modern concepts of electroencephalography.

29 Berger 1934c, 1935b, 1935d; these were Berger's first contributions about the EEG in *Deutsche Medizinische Wochenschrift* as well as in *Klinische Wochenschrift* and *Naturwissenschaften*, where he had otherwise previously only published his essay on the physiological attendant effects of psychological processes (Berger 1913b).

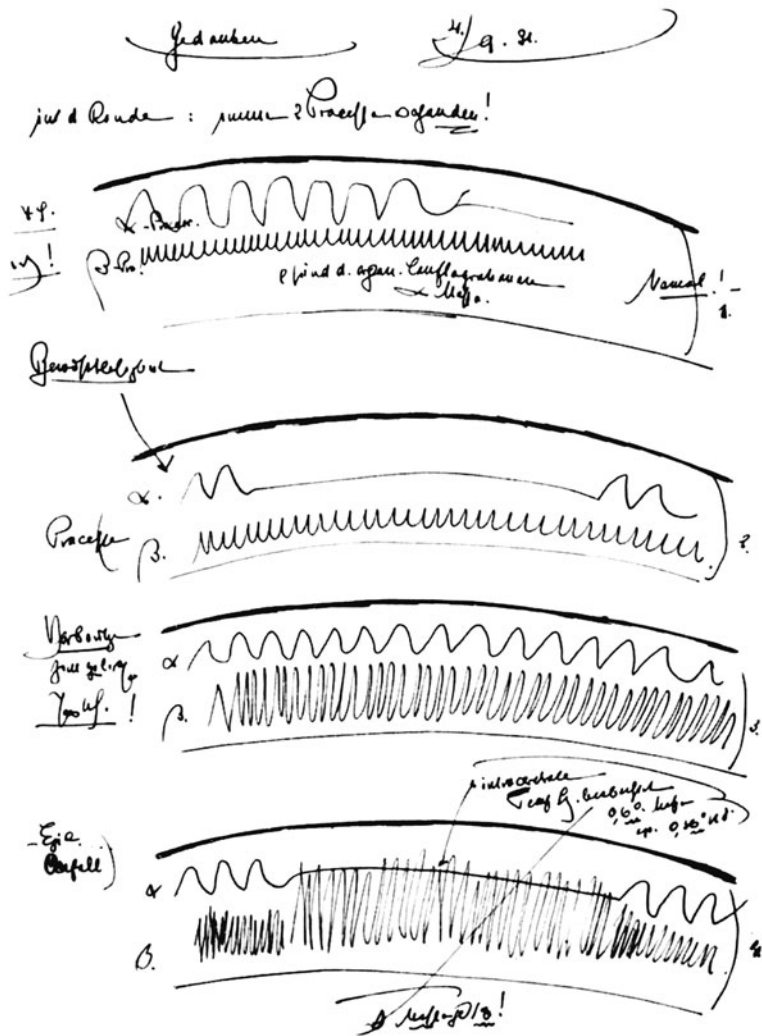


Figure 23 Sketch by Berger to evaluate the participation of alpha waves and beta waves in brain function, and their interference. The entries, partly written in shorthand, read, with reference to Richard Jung's transcription:

“Thoughts, 21 Sep. '31

In t[he] cortex: always 2 processes present!

$\psi\phi$ [psychophysical], α process

[Nourishment]!, β process

these are the organ[ic] conflagrations by Mosso. Normal!

Unconsciousness, Processes α , β

Preparation for epil[eptic attack]

[Attack readiness]!, α , β

Epi[leptic] attack, α , β

intercerebral temp[erature], observe [rise], 0.6° Mosso ip., 0.36° [for human]

[According to Mosso, however, not always!”

I arrive at the following result: The total physiological and psychophysiological work of the human cerebral cortex finds its expression in the characteristic potential curve of the EEG of humans, composed of the action currents of the individual nerve-cell layers interwoven into a unified whole! [. . .] Certain β -waves of a length of 11–24 σ , whose place of origin is probably to be sought in the cell layers of the outer main zone, correspond to the psychophysiological activity of the cortex. They can hence be addressed as material attendant effects of psychic processes.³⁰

During the summer and autumn of 1936 Berger recorded a series of EEG plots that fascinated him very much. Those curves had dominant beta waves at a frequency of 50Hz. It seems ironic that Berger, of all people, who throughout his life had demonstrated so many scruples about his curves, would decide to revise his working hypothesis by reason of a trivial interference, namely, inadvertently recorded technically scattered alternating current from the municipal electricity grid. But by the spring of 1937, the EEG was not the private object of the Jena laboratory anymore and it did not take long for criticism of the curves to arrive. A young psychologist from Vienna, Hubert Rohracher, had just started conducting similar experiments with rapid oscillations of the mind and informed Berger of his reservations in a series of long letters. In a troublesome process of self-critical testing, Berger finally had to concede the erroneousness of his published curves and withdraw almost all of the illustrations on the beta-wave EEG published in the twelfth communication.³¹ Notwithstanding those retracted

30 Berger 1937c, pp. 193 and 196; see also 1937d (12th communication). Berger mentioned the work of Johannes G. Dusser de Barenne and Warren S. McCulloch as the reason for his revision. In 1936 they had shown that alpha waves continue to be generated after the upper cortical layers have been selectively destroyed. Because Berger supposed the center of psychophysiological processes to be in the upper layers of the cortex, he just elevated the remaining beta waves to the status of psychophysical processes that were of interest to him. So Berger definitely was reviewing the literature in 1937 in this already very active field of EEG research worldwide. Even though Berger thereby turned his working hypothesis upside down, the interpretational approach remained the same. He continued to distinguish only between alpha and beta waves, and the EEG remained for Berger the key to psychophysiology. He did not regard the various waves as expressions of different ways of functioning of one and the same neural cells but as signs of the dominance of that particular type of cell, among differing ones, in the cerebral cortex. See Berger 1937d (12th communication), p. 185.

31 The exchange of letters with Hubert Rohracher impressively documents the phases of this process; see the subsection (Rapid Vibrations of Thought) on Rohracher in Chapter 6 of this volume. On 28 March 1937 Berger noted in his journal: "On the 21st, last Sunday, I managed to convince myself that Rohracher and Kornmüller are right with the objections to 6! of my figures in EEG XII. I wrote so to both of them & had a correction printed that is dispatched to all who have received offprints." (Lab journal VI, p. 55). See the correction in *Archiv* 106 (1937): 508; and in *Naturwissenschaften* from 30 April 1937.

curves, Berger retained his revised working hypothesis of a specific psychophysiological function of beta waves, as is shown by the very rapidly composed thirteenth communication and his three last EEG publications, the fourteenth communication, a brief overview on the EEG for the applied journal *Industrielle Psychotechnik* and the monograph for *Nova Acta Leopoldina* (Figure 24).³²

This revision of his working hypothesis did not occur nearly as abruptly as it superficially appeared, since the nature of beta waves had repeatedly been the subject of Berger's laboratory journal entries, notes, and reflections on the EEG. Shortly before the appearance of the first communication, for example, Berger had already considered a working hypothesis that came very close to that published version:

But, according to the result on intell. activity, not the increase in large waves, but the corresponding one of small waves would agree with each peak o[f] attentiveness!!! [. . .] For, pursuant to the outcome of the curves on resting and calculation work, 30-σ waves are the sign for intellectual work & 90-σ waves are the sign for resting!—The 90-σ waves agree with the continual (nourishment?) work in the c[entral] n[ervous] s[ystem] for the preservation of its functional capacity; the 30-σ waves correspond to specific work (!?) Working hypothesis.

[R., 6 June 1929]

Evidently, Berger had determined two distinct building blocks for the EEG early on but wavered about which of the two wave types he should assign psychophysiological primacy to. For conceptual and pragmatic reasons he had first decided on alpha waves, because they suited his expectations better, which were based on his foregoing psychophysiological investigations.³³ Another reason was that beta waves were at the resolving limit, even when the coil galvanometer was used. It is hardly chance that Berger only returned to beta waves in summer 1931 when a recording technique became available to him, the oscillograph, that allowed him to make detailed beta-wave recordings for the first time (Figure 25). His particular interest in beta waves is mirrored in a series of unusual activities at this point in time. He started up a technical cooperation, just to analyze those waves, with the local physics institute, whose director Max Wien advised him on the oscillograph set-up; Wien's assistant Günther Dietsch also executed Fourier transformations of EEG plots to establish the exact distribution of

32 Berger 1937e, 1937f, 1938a, 1938b.

33 Foremost, Berger found only for alpha waves those slow attentiveness fluctuations that had been occupying him since his first psychophysiological studies and continued to occupy him heavily; see Berger 1932a (4th communication), pp. 20ff., Berger 1933c (6th communication), p. 565, Berger 1938b (Leopoldina), pp. 199f.

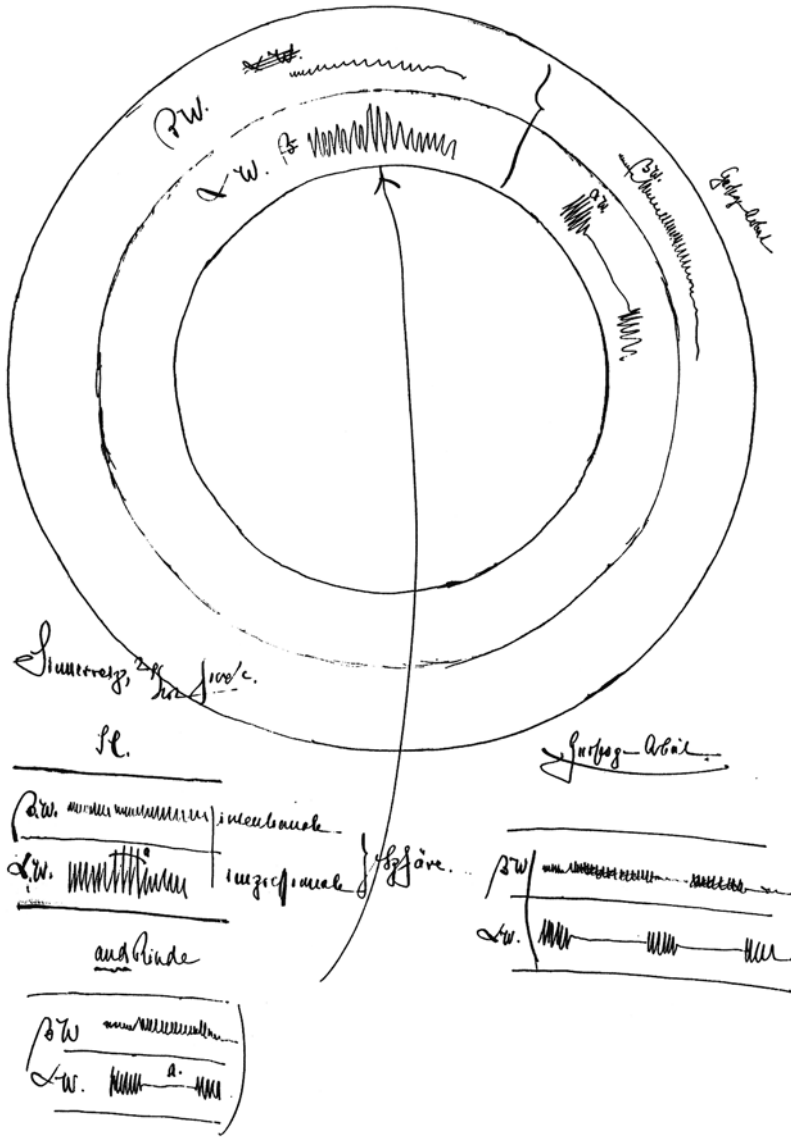


Figure 24 Berger's about-face in interpreting the roles of alpha waves and beta waves in the functioning brain. The entries read, from left to right:

"β w[aves], α w[aves]
 Sensory stimulus, [illegible], β w, α w
 intentional, impressional sphere
 in the cortex, β w, α w
 Intellectual work, β w, α w
 Intellectual work, β w, α w"

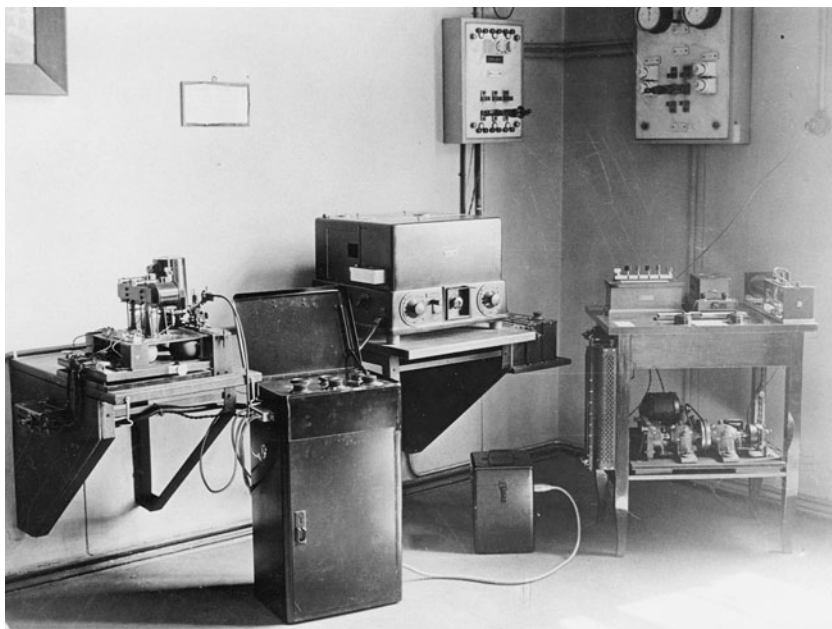


Figure 25 Berger's laboratory with the Siemens oscillograph, in operation as of 1931.

harmonic oscillations in the beta waves.³⁴ In two talks at Münster and Jena in autumn 1931, Berger introduced a beta-wave theory for the triggering of epileptic fits, but unanticipated problems with this theory, which was actually ready for publication, threw Berger into another research crisis in February 1932, which was why he did not attend the international conferences as originally planned.³⁵

34 Lab journal V, p. 139, dated 14 June 1931. Wien, who had been interested in Berger's EEG recordings since 1930, was thus one of the very few with whom Berger appears to have consulted about his EEG. The cooperation with Dietsch rapidly became difficult, though. Dietsch unfortunately destroyed the sensitive loop of the new instrument's measuring circuit right at the outset, and Berger was probably anyway little inclined to share the work on "his" discovery. In March 1932 Berger separated himself from Dietsch after finally compensating him, in the amount of 40 reichsmarks for the curve analyses; see lab journal V, p. 177, dated 13 March 1932, Dietsch 1931 and 1932.

35 Berger's records and reflections include anatomical physiological sketches on this theory; two were published by Richard Jung and Wiltrud Berger (see Jung 1963, p. 47, or Jung and Berger 1979, p. 298). In February Berger noted in his lab journal: "A serious, difficult week lies behind me: I found out that the E.E.G.-observations on epil. attacks are not right, insofar as the b w[aves] are concerned! I now must make new plans re. t[he] E.E.G. researches & have actually already given up Bonn & Mainz. [. . .] On Mo[nday] I wrote to Springer & informed him that I want 11 figs. & part of t[he] text of E.E.G. IV back and will carry the costs." (Lab journal V, pp. 173f., dated 14 and 21 February 1932).

Without publishing anything about the role of beta waves, Berger nevertheless repeatedly conducted experiments on them. In 1933, for example, he registered the EEG of his sixteen-year-old daughter, Ilse, performing the mental calculation: $5\frac{1}{2} \times 3\frac{1}{2}$, which he evidently counted as among his most successful recordings but only had it published in 1937 on the occasion of the revision of his working hypothesis in the twelfth communication (Figure 26).³⁶ In the autumn of 1935, Berger even began a new series of intracerebral recordings to detect beta waves, despite his extreme reservations about such invasive techniques since his temperature studies on the brain. His reexamination of a famous case of isolated memory loss presumably also originally had the aim of establishing modifications in the beta-wave spectrum.³⁷ At the same time, Berger was temporarily probing the possibilities of representing especially rapid small waves in the EEG by means of a new oscillograph with multiple amplified measuring circuit loops. It was only at the end of his career and after his retirement that Berger returned to this plan. At the beginning of 1938 he planned to examine the rapid frequencies in the EEG for his fourteenth and last communication and made inquiries about whether it would be possible to conduct those analyses in the Siemens laboratories, because he still had no suitable instrument.³⁸ The reply by the Siemens engineers reveals what experiments Berger was planning at the time:

The problem broached in your letter, whether apart from the alpha and beta waves discovered by you in the electroencephalogram other waves of higher frequencies occur or whether they involve secondary effects, such as fibrillary muscular vibrations, can only be solved by experiment, no doubt. [. . .] Under the presumption that besides your discovered alpha and beta waves those supposed waves of a frequency of 1,000 or higher likewise have definite character, a solution to the problem of whether muscular vibrations are involved or else real EEG oscillations, would be relatively easily feasible using the oscillogram.³⁹

36 Berger 1937d (12th communication), p. 182. On these trials in 1933 it tersely reads in the lab journal (V, p. 234, dated 1 April 1933): "The b waves are occupying me once again." This recording Berger also used in 1934c, 1937b, 1937c, and 1938b.

37 On 25 October 1935 Berger observed a patient of Gustav Ernst Störing's, who since suffering carbon monoxide poisoning at a blast furnace over nine years before then could "not retain a single event anymore," but found an "entirely normal EEG"; see Berger 1936 (11th communication), p. 684. In this notice there are further traces that Berger was already intensely occupied with beta waves in 1935. He discusses there, among other things the theories of Ferdinando Cazzamalli and Hubert Rohracher, who both postulated rapid electric waves as a substrate of psychic processes.

38 "I wrote to Siemens & asked that I be permitted to perform 2 trials there: I needed the results for EEG XIV, which would then become quite interesting" (Lab journal VI, p. 97, dated 30 January 1938).

39 Letter from 10 March 1938, Berger papers in the Ernst-Haeckel-Haus, Institut für Geschichte der Medizin, Naturwissenschaft und Technik, Friedrich-Schiller-Universität Jena. I thank Stefan Schwarzkopf for referring me to this letter.

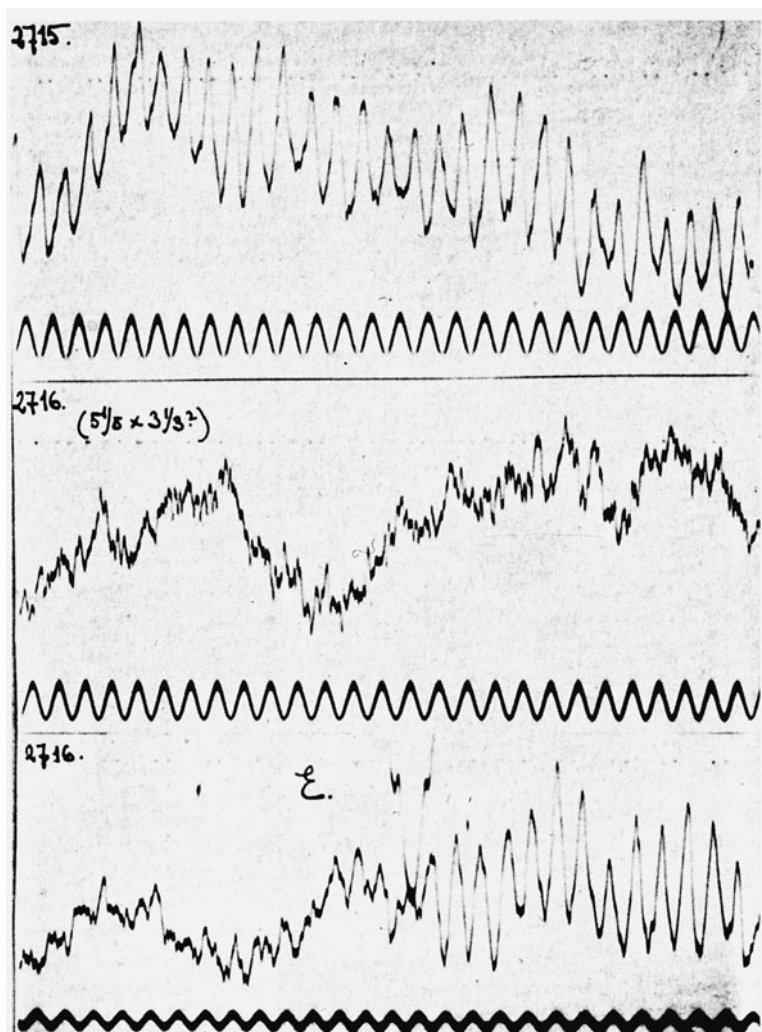


Abb. 30. I. B. 16 Jahre alt. Obere E. E. G. vor dem Rechnen im Ruhezustand: passives E. E. G.! In der Mitte E. E. G. während des Rechnens der Aufgabe $5\frac{1}{3} \times 3\frac{1}{3}$: aktives E. E. G.! Unten bei ϵ ist die Aufgabe gelöst! Nadelableitungen von Stirn und Hinterhaupt. Zeit in $\frac{1}{10}$ Sekunden. Oszillographenaufnahmen.

Figure 26 The EEG of Ilse Berger while reckoning in her head, 443rd EEG-trial dated 28 April 1933. The figure caption reads: "I.B., 16 years old. Above: E.E.G. before the computation in the resting state: passive E.E.G.! In the middle: E.E.G. during the computation of the task $5\frac{1}{3} \times 3\frac{1}{3}$: active E.E.G.! Below at ϵ , the problem is solved! Needle conductors from temple and back of head. Time in $\frac{1}{10}$ seconds. Oscillographic recordings."

Siemens did not have the instruments required for such an analysis available and calculated a developmental period of at least half a year, which to Berger, a few months before his retirement, meant the same as having his experiments rejected. For the fourteenth communication and also for his concluding summary of the EEG in the *Nova Acta Leopoldina* he had to make do without a conclusive decision on the question so central to him. Instead of coming forward with new findings, he had to close with old P.E. considerations and speculative poetics:

Yet, given all these assumptions, we reckon with the experimental finding on the human E.E.G., that short and low β w[aves], howsoever and wheresoever they may form, accompany *psychophysical processes*. In these processes there arises that which one can also, with Kurd Laßwitz, preliminarily describe by the general expression of a psychophysical energy. The processes of consciousness are directly connected with it. This psychophysical energy is immediately converted back into other forms of energy and thus leaves physiological traces in the form of structural modifications to the cortex and the central nervous system generally. [. . .] In any case, though, according to the result of our examinations on the E.E.G. of humans, we have before us material processes of *extremely slight order of magnitude*, linked with psychical processes, which are nonetheless the *most wondrous* and *most powerful* effects on this Earth!⁴⁰

Berger continued to work although his last scientific papers had already been submitted, all the EEG curves together which his records and evaluations were in boxes on their way to the Black Forest to Oskar Vogt's private cerebral research institute, and just a few weeks remained before he would become emeritus⁴¹: "I had a few more enlargements of E.E.G.s with

40 Berger 1938b (Leopoldina paper), pp. 305f., original emphasis.

41 See the correspondence Vogt–Berger at the Oskar und Cécile Vogt-Archiv, University of Düsseldorf, 125B. There are many rumors about Berger's retirement from office. In the secondary literature there is the stubborn contention that he had been dismissed into retirement by telephone at the command of the *Führer*, because he was not appreciated by the Nazi state (cf., e.g., Schulte 1959, Schmidt 1961, Werner 1963, Gloor 1969, Karyofilis 1974, Wiedemann 1994). Susanne Zimmermann (2000, pp. 44f.) inquired into this business: Berger left his university post on 1 October 1938 upon attainment of the age limit of 65 years. He also expected this since the turn of the year 1936/37, when he noted in his journal: "There are accordingly the following 7 possibilities: (1) I die before 1 X 38; (2) I am still alive, do not feel able to continue to work beyond 1 X 38; (3) I am still able to work but must leave and start up a private practice in Jena; (4) [. . .] I go with the fitting additional salary to Vogt's institute; (5) I receive the N[obel] P[rize] and work; [. . .] (7) One leaves me in office until my 68th y[ear of] a[ge]." During the summer of 1938 Berger had settled his successorship; at the beginning of September 1938 Berger sent the EEG plots and his experimental records to Oskar Vogt in Neustadt (see Lab journal VI, p. 125, on

double-templar recordings made and measured the β w[aves] from problem-solving” (Lab journal VI, p. 126, 11 September 1938). Indefatigably in search of the correlate to the P.E., Berger calculated meticulously and planimetrically, down to the very last minute in office, the drop in tension in the transition to intellectual work on EEG recordings in eight-fold magnification.

As emeritus, Berger was unexpectedly offered another chance to examine the rapid frequencies in an EEG. This opportunity arose because his student Rudolf Lemke wanted to continue with EEG examinations at Jena, after all, and had arranged for rooms in the *Nervenlinik* to be refurbished as a technically isolated modern EEG laboratory. At the end of 1939 Siemens began the customization of an EEG instrument for the registration of rapid waves. The Zeiss Foundation provided the amount of 14,000 reichsmarks, the largest grant that Berger had ever received.⁴² Later Siemens had to stop the project because of wartime production restrictions, and Berger’s experiments on the psychophysiological function of higher EEG frequencies fell through. The last note in the laboratory journal (VI, p. 236) on this subject dates to 12 January 1941: “Mr. Haseck informed me that the oscillograph could not be delivered before 1942 owing to urgent war commissions!” This was almost half a year before Berger’s suicide, to which the failure of this large project probably also contributed.

Local appointment in Buch near Berlin

Contemporaneously with the headline-grabbing reporting in German daily newspapers about Berger’s “Zig-zag Curve of the Human Mind,” during the summer of 1930 two physiologists in Berlin began experiments by which electroencephalography would gradually get going after taking a few more detours. Max Heinrich Fischer, until then professor of anatomy and physiology at the agricultural department of the German Prague Polytechnic

4 September 1938), because a new building was being planned for the clinic and Berger was afraid for the survival of his material (see Wiczorek 1981, p. 18). After handing over his clinical duties to his successor Berthold Kihn, he first opened a private practice in Jena before he accepted the directorship of the sanatorium in Bad Blankenburg in the Harz mountains. Berger was not a member of the Nazi party, but an opposing stance toward the Nazi state cannot be gathered from this fact alone. Indeed, Berger was a “supporting member of the SS, no. 31391” since 30 March 1934, according to his entry dated 2 June 1938 on a “questionnaire about my political affiliation” (Universitätsarchiv Jena, holding D no. 176).

42 The Zeiss-Stiftung as well as the Koehler Stiftung in Jena had already supported Berger with the purchase of the first oscillograph. From the Deutsche Forschungsgemeinschaft Berger had merely applied three times for photographic paper, each time in the amount of 300 reichsmarks. How little known Berger still was in Germany even in 1937 can be gathered from a marginal note by the person in charge of his third DFG application: “which Berger? 2 III 37” (BA R 73/10252).

situated in Tetschen (Děčín), and his young assistant Alois E. Kornmüller had been engaged by Oskar Vogt for the newly erected Kaiser Wilhelm Institute (KWI) for Brain Research. This KWI was the largest and most modern institution for research on the brain worldwide at that time. With its 150 rooms, the new building resembled “from the outside a modern industrial facility more than a site of silent research” (Figure 27).⁴³ Whether or not inspired by those press accounts, Fischer and Kornmüller together with the skilled engineer Jan Friedrich Tönnies at the KWI, were the first to begin researching the EEG in Berger’s wake. The contrast to Berger could not have been greater. The experimental system at Buch differed in every respect from the one in Jena. An older, reclusive psychiatrist, who as clinic head could only conduct experiments on the side, on his own children, patients, and assistants in search of physiological traces of psychical processes, was replaced at Buch by a team of young and ambitious scientists specialized in researching bioelectrical signals in animal experiments. Largely unhampered by academic duties, they had optimal resources to work with. These great differences in institutional, biographical, and social respects can only partly explain, however, why the EEG was constructed as an entirely different epistemic thing within the experimental system at Buch.

The new building of the KWI for Brain Research, just recently officially inaugurated in Buch in 1931, was the major achievement of the neuro-anatomist couple Cécile and Oskar Vogt.⁴⁴ For the new institute Oskar Vogt had planned a total of ten departments, which meant enormous expansion of the research activities.⁴⁵ Behind this diversification into ten departments there was nonetheless a single, coherent research agenda—namely, a localization theory interpreted according to evolutionary biology that Vogt had been pursuing since the foundation of his *Neurologische Centralstation*.

43 Wagner 1931, p. 123.

44 In 1898 Oskar Vogt, who had taken his doctorate in 1894, likewise under Binswanger, at Jena (when Berger was just beginning his medical studies there), opened a *Neurologische Centralstation* as a small private research establishment, thanks to the private support of the Krupp family, which was appended to the University of Berlin as a “Neurobiological Laboratory” in 1902. On the lives and works of Cécile and Oskar Vogt, see Haymaker 1951, Kreuzberg, Klatzko, and Kleihues 1992, Richter 1996, Satzinger 1998, Hagner 2004 (pp. 235–287); and on the history of the *Kaiser-Wilhelm-Institut für Hirnforschung*, Spatz 1961, Wolff and Kalinich 1996, Bielka 1997.

45 Oskar and Cécile Vogt headed the section for cerebral architectonics, their long-time coworker Max Bielschowsky the histology department. For the remaining departments Vogt hired relatively young and mostly still unknown researchers. Fischer took over the physiological department and was the only scientist with a professor’s title, whom Vogt had recruited for the new KWI. Tönnies, the son of Ferdinand Tönnies, the sociologist who had been Oskar Vogt’s mentor, moved to Buch in 1929 while the department was still ongoing, to head the physics department. The psychology department was headed by Eberhard Zwirner; Vogt’s daughter Marthe assumed the chemistry department in 1930; the photography department was headed by Ernst-Helmut Heyse; the largely independent genetics department was headed by the couple Nikolaj and Helene Timoféeff-Ressovsky; and Bernhard Patzig (at the institute since autumn 1927) headed the research clinic.



Figure 27 The new building of the Kaiser Wilhelm Institute for Brain Research at Buch, a suburb of Berlin.

He, too, was interested in the “material parallel processes in psychical phenomena,”⁴⁶ but unlike Berger, he did not concentrate on any graphical methods but on fine morphological analysis of the cerebral cortex. Cécile and Oskar Vogt and their co-workers subdivided brains of the different mammalian species and of humans, from microscopic analysis of thousands of series of thin sections, according to so-called cytoarchitectonic parameters in local strictly delimited and functionally specialized “elementary organs,” which in the human brain were supposed to reach a total of 200.⁴⁷ The Vogts’ “topistic” research program, the theory of cerebral elementary organs, formed the most binding frame of all the departments. The physiology department was supposed to rely on studies in which the Vogts had already combined their anatomical analyses with electrophysiological experiments before World War I, in order to also characterize functionally the cytoarchitectonically defined areas of the cerebral cortex.⁴⁸ The 150 rooms in this “modern industrial facility” bundled together the forces of brain research in order to specifically promote the “further development of human intellectual capabilities” according to the rules of topistism and cytoarchitectonic fielding of the cerebral cortex.

46 Vogt 1895, here cited from Hagner 1999, p. 178.

47 The resolution of this program was the cytoarchitectonic atlas of the cerebral cortex by Brodmann 1909 (first published in six communications in *Journal für Psychologie und Neurologie*, 2–6, 1902–1908).

48 A small portion of this material has been published in: O. Vogt, C. Vogt, and Barany 1923. I thank Ursula Grell of the Oskar and Cécile Vogt Archive in Düsseldorf for this reference.

It can now no longer be decided from whom at Buch the initiative for the EEG experiments came, as none of the records on those trials have been preserved. The first publications on it revealed nothing about this and did not even mention Berger, even though his EEG of 1930 was being talked about literally everywhere and his second communication had just appeared in Vogt's *Journal für Psychologie und Neurologie*.⁴⁹ Electrophysiological experiments were unexplored territory for Fischer, Kornmüller, and Tönnies. In Prague Fischer had worked on sensorial physiology; Kornmüller started research only at Buch; and Tönnies had been working as an electrotechnical engineer at Siemens & Halske before he came to Buch and began to conduct scientific experiments.⁵⁰ It is possible that they made a relatively chance observation of brainwaves in 1931 during shared experiments as they were registering exposure-dependent currents, moving stepwise from the retina to the optic nerve and the visual cortex. The first successful experiment on the EEG in Buch supposedly occurred on 16 May 1931, which would have been quite promptly after the completion of the laboratory facilities there.⁵¹ Quite opposite to Berger's lengthy and self-critical belaborings of his experimental system, the EEG researchers at Buch worked extremely purposefully and

49 Vogt is eliminated as cue-giver because he had only envisioned "Stimulations and destructions of the brain" as the research plan for the physiological section in summer 1930, hence a continuation of his own forays into physiology (BA R 1501/126784, p. 35). Only after Fischer, Kornmüller, and Tönnies began to quarrel did a priority dispute seem to flare up between them. Tönnies mentioned later that Fischer and he had become aware of potential fluctuations in the brain during electrophysiological experiments on the eye and then began the investigations on the EEG. Thus, however, he contradicted earlier statements in which he had ceded the initiative to Kornmüller (letter from Tönnies to Stanley Cobb dated 5 March 1969, transcription among the Jung papers, Universitätsarchiv Freiburg C 92/35; cf. Tönnies 1933b, p. 154). Kornmüller insisted retrospectively that he had begun the study of cerebral currents "immediately" after his arrival in Buch, as that had been his project since his student days in Prague (undated curriculum vitae, c. 1958, Archiv zur Geschichte der Max-Planck-Gesellschaft (henceforth: MPG-A) III/16/1; Kornmüller 1961, p. 436). But this also is not very plausible because during the summer of 1930 he worked initially not with Fischer but with Vogt on anatomical morphology (curriculum vitae dated 28 June 1944, BA BDC PK Kornmüller; see also the obituary by Janzen 1972, p. 58).

50 A list of publications by Max Heinrich Fischer, born 1893, from 1935 is preserved in: BA BDC REM M.H. Fischer, sheets 5999–6023. For an obituary see Wittke 1972. Kornmüller, born on 19 October 1905 in Brüx (Most) in Sudetenland (Sudety), had completed his medical studies in 1928 in Prague and then worked with Fischer (Fischer and Kornmüller 1930a, 1930b, 1931a, 1931b) on problems of subjective orientation in space, on nystagmus, and on the control of eye movements (i.a. in a self-experiment in which he injured one of his own eyes pharmacologically, from which he subsequently suffered residual damage, Kornmüller 1931; see also MPG-A III/16/1). Obituaries are Jung 1970 and Janzen 1972 (with list of writings). Tönnies took his doctorate in engineering at the end of 1935. For biographical information see the obituaries by Baumgartner 1971, Eccles 1971, and Schaefer 1972.

51 Kornmüller 1932b, p. 447. Albeit there is now no telling whether the study was conducted as an EEG experiment or was allocated as such retrospectively.

efficiently as soon as their attention was turned to brainwaves. Fischer, Kornmüller, and Tönnies launched their researches on the EEG as a new field of research in a strategically instrumentalized campaign throughout 1932.⁵² As a prelude came preliminary publications in early 1932 in *Psychiatrisch-neurologische Wochenschrift*; that summer all three published their own papers. (Tönnies described a direct-current amplifier with connected pen recorder designed for their experiments, the “neurograph,” in *Naturwissenschaften*; Fischer reported in *Pflüger’s Archiv* on action currents in the cerebral cortex of laboratory animals; and Kornmüller published in *Journal für Psychologie und Neurologie* about “architectonic localization” by means of bioelectrical currents of a rabbit.) That same autumn they also presented their researches at conferences. (Fischer delivered a talk at the 14th International Congress of Physiology in Rome; Kornmüller and Tönnies participated at the annual convention of the *Gesellschaft Deutscher Nervenärzte* in Wiesbaden, which took place jointly with that of the *Deutsche Naturforscher und Ärzte*.)⁵³ After this explosive start, the group’s production began to falter and there merely followed a series of consolidating papers during the next years.⁵⁴ The cause of this were not scientific or technical problems, but serious personal disagreements at the KWI for Brain Research as a result of the takeover of power by the National Socialists in 1933.⁵⁵

With the Nazi takeover, tensions at the KWI escalated in such a bizarre way that they shed as much light on the political constellations at the beginning of the Nazi era in Germany as on the working climate at the KWI. With Hitler’s grasp for power, the few Nazis at the institute caught the scent of opportunity, first and foremost Fischer, who evidently saw that his big chance at his personal “*Machtergreifung*” had come when the altered political circumstances put Vogt under pressure. On the very night that Hitler assumed power, sympathizers of the Nazi party at the institute met at Fischer’s home with the local Storm Troopers (SA) leader; six weeks later

52 Within about two years roughly twenty papers appeared by Kornmüller, Tönnies, and Fischer.

53 Tönnies 1932, 1933a, Fischer 1932a, 1932b, Kornmüller and Tönnies 1932, Kornmüller 1932a and 1933b. Erich Guttman enthusiastically reported in *Münchener Medizinische Wochenschrift* 79 (1932): 1818, about the presentation by Kornmüller and Tönnies in Wiesbaden: “At the assembly’s request they demonstrated their findings practically. The researchers succeeded in recording different action currents from individual brain areas by means of their method. [. . .] The demonstration, particularly also the anatomical preparations, by which the focal delimitedness of reaction was shown, aroused the greatest interest.” Paul Vogel was clearly more skeptical in *Nervenarzt* 6 (1932): 141: “What Kornmüller and Tönnies, Buch near Berlin, communicated about bioelectric effects of architectonic fields was quite interesting but must probably still be judged cautiously.”

54 Kornmüller 1933a, 1933c, 1933d, 1934, and 1935; Fischer 1933 and 1934; Tönnies 1933b.

55 These political quarrels at the KWI for Brain Research have been portrayed at length by Jochen Richter (Richter 1976, 1996, pp. 388–404).

Fischer had himself become an SA member and organized a raid by the SA on the institute at Buch that was actually supposed to be his coup but instead led to his removal from the KWI and finally even cost him his precious party membership.⁵⁶ Things did not settle down again at the institute, by any means. During the years that followed, research was crippled by political investigations and by the corresponding disruptive climate full of suspicion and continual denunciations.⁵⁷ Kornmüller was one of the few to profit from the tumultuous events at the KWI, even though he was a member of the institute's group of Nazi sympathizers.⁵⁸ With Fischer's removal from the institute, he could take over the physiological department de facto; and Vogt's departure and Hugo Spatz's assumption of the directorship led to Kornmüller's official promotion to the position of department head on 1 April 1939.

The title of the first publication about the EEG from Buch mentioned the entirely different starting point of those researches: "Bioelectrical Characteristics of Architectonic Fields of the Cerebral Cortex"—therefore, an electrophysiological continuation of Vogt's line of research. Like other researchers before them, the Buch scientists observed in recordings from the visual cortex electric potentials as a response to light stimuli, but in their trials the brain area from which a uniform pattern could be derived agreed astonishingly exactly with its anatomical boundary. Beyond this area either no electrophysiological responses could be obtained or, if any, specifically

56 According to his own information, Fischer joined the *Sturmabteilung* (SA) on 1 March 1933, see BA BDC, personnel file REM Max Heinrich Fischer, F 224. Fischer's application for membership of the Nazi party (NSDAP) was "refused because of his dubious character" (BA R 4901/alt R 21/11.065a, sheet 6) after the SA campaign initiated by him turned out to be a flop. Until March 1936 the Kaiser Wilhelm Society (KWG) continued to fund a small laboratory for him on the premises of the former Institute for Hygiene and Immunology on Garystraße in Dahlem. Despite the active support of the Reich Ministry of Science, Education, and Culture (REM) Fischer did not manage to obtain a professorship during the Nazi era and "survived the winter" as an associate lecturer on the "anatomy and physiology of the speech apparatus" at the English Seminar of the Faculty of Philosophy at the Friedrich-Wilhelms-Universität in Berlin (Archive of Humboldt University, personnel file Max Heinrich Fischer, PA F 186). This kink in his career during National Socialism brought him rapid denazification after the war's end and he could return as professor of physiology, first at Humboldt University, then as founding director of the Physiology Institute at *Freie Universität*.

57 Just the documentation in the Federal Archive fills many files, see BA R 4901/alt R 21/11.0651; R 1501/126787. The annual report by the *Kaiser-Wilhelm-Gesellschaft*, regularly published in *Naturwissenschaften*, cautiously avoided any mention of the KWI for Brain Research for the year 1933/34, and in the following year merely mentioned Vogt's admission into the Royal Society of Hungarian Physicians. Kornmüller's numerous publications in 1933 were substantially based on experiments from 1932; Kornmüller published only one article in 1934 and two in each of 1935 and 1936.

58 Kornmüller became a Nazi-party member on 1 May 1933; membership no. 2,020,879 (BA BDC Kornmüller).

different ones.⁵⁹ This project demanded a completely different approach from Berger's examinations. A specific comparison between the anatomy and electrophysiology of the cerebral cortex was, first, only feasible in a series of invasive animal trials; and second, different from Berger's registration of the total electrical activity of the brain in the integral alpha wave, the recording of electric potentials had to be limited exactly to a single cortical region. That was why the Buch scientists did not attach electrodes with the largest possible distance away from each other to the head, the way Berger did, but positioned a fine needle electrode exactly in the cortical region of interest and a reference electrode outside of the brain at an electrically neutral point.⁶⁰ This so-called unipolar recording of action currents was the basis of the EEG at Buch and the epistemic dividing line from the EEG at Jena. Instead of Berger's psychophysiological interpretation of the EEG plots, the trio at Buch concentrated on a scientific description of the sensory physiology of their findings. Instead of a uniform curve derived as *the* EEG from the brain as a whole, they observed in their animal experiments a variety of numerous functionally differentiated patterns of stimulus and response that were anatomically and morphologically correlated. At Buch, there were neither alpha waves nor beta waves, nor even an EEG. Initially only "action currents" existed as responses to sensorial stimuli.⁶¹

Individual focuses by the three Buch scientists can nevertheless be identified within this common frame. Fischer concentrated on the description of so-called "cramp currents" (*Krampfströmen*); large rhythmic potentials that, depending on the experimental conditions occurred spontaneously or after the administration of appropriate medications and were accompanied

59 Kornmüller 1932b.

60 The first publications from Buch still show a few traces of how this recording technique gradually emerged with the experimental system as the research progressed. For their first trials on retinograms, the Buch scientists recorded the potential difference between the surgically exposed visual cortex of the test animal and the also exposed optic nerve behind the illuminated eye, which posed high technical demands, above all the preparing of the optic nerve for the recording without injuring it. This first experimental arrangement was motivated by the search for differences between the potentials of the optic nerve and the visual cortex (that was passed over in the publication of the results). It was only in a second step that the comparison electrode became the so-called "reference" electrode, whereupon the recording in this experimental system became termed "unipolar" (although two electrodes were always attached to the test animal in order to obtain a closed electric circuit). First, the comparison electrode wandered from the optic nerve to the cornea of the illuminated eye, which saved the laborious preparation of the optic nerve; then to the opposite side, and only from there, finally, to a pretested electrically neutral point at the root of the nose, on the neck, or at the two ears. See also the remarks on the method in Fischer 1932a and Kornmüller 1932b. Kornmüller first employed the term "unipolar" in Kornmüller 1933a.

61 Spontaneous fluctuations in the currents were also repeatedly seen in the Buch experiments, but they entered into this experimental system at first only as interferences that did not fit into the paradigm of functional units; see Kornmüller 1932b.

by clonic muscular twitchings.⁶² Practical considerations must have played a major part in the interest Fischer had in cramp currents. He was already limiting his experimental apparatus to a simple amplifier–string-galvanometer combination, which was less sensitive than the new generation of instruments otherwise in use at Buch. Because of their particular size and characteristic pattern, cramp potentials could be observed well in this experimental system.⁶³

Tönnies mainly supported the EEG experiments by designing registration and recording instrumentation. By 1932 the “neurograph” was finished. It was an entirely new kind of instrument with a 300,000-fold amplifier with innovative circuitry that would largely eliminate electric interferences despite the enormous amplification and could record the registered potentials in ink on paper.⁶⁴ Thanks to support by the Rockefeller Foundation for operating expenses in the amount of 56,800 reichsmarks, Model II with 1,000,000-fold voltage amplification appeared that same year, followed two years later by a neurograph with five parallel measurement loops (Figure 28).⁶⁵

Tönnies was particularly interested in the transferability of the concept of unipolar recordings to experiments on human subjects. Recordings from the unopened skull of a test person were excluded from the outset, however, because they could not reveal anything about regional potentials; preparations like those in animal experiments were clearly too invasive. Tönnies considered the following compromise:

In cases where noticeable damage to the test object is not allowed to occur, like especially in recordings from human subjects, the drilling of a very small trepanation hole would be much easier and less damaging

62 Fischer tested systematically various known cramping poisons, such as strychnine, cardiazol, and picrotoxin; see Fischer 1933, 1934, Fischer and Löwenbach 1934.

63 When Fischer set up his own laboratory in Dahlem with DFG support, he originally hoped to acquire his own Siemens oscillograph but had to settle for a Siemens & Halske moving-coil oscillograph from the DFG stock, see BA R 73/11017.

64 In principle, Tönnies thus invented a differential amplifier. This was the decisive engineering achievement upon which he based his doctoral thesis and a few patents; see Tönnies 1932, 1935, 1936a, 1936b, 1937.

65 The Rockefeller Archive Center (henceforth RAC), Sleepy Hollow, New York, RAC RG 1.1, series 717: Germany, box 10, folder 64. How revolutionary this instrumental development was can be judged by comparison against a similar instrument by Siemens & Halske. When the developmental research there was destroyed in an air raid in 1943, not even a satisfactory prototype could be put together after 3,000 hours of labor by mechanics (see Siemens Archiv, 1. Abt. Medizintechnik, binder Technische Entwicklung: EEG, Elektrodermometer). Because of his technical proficiency Tönnies received an invitation to the Rockefeller Institute in New York in summer 1935, where among other things he produced with Albert Grass plans for the basic model of the first EEG instruments for serial production. In 1939 he returned to Germany at his own request, see Schaefer 1972. There is a description of the neurograph in Elly Welt’s novel about the KWI in Buch (1987, pp. 188f.); I thank Helga Satzinger for this information.

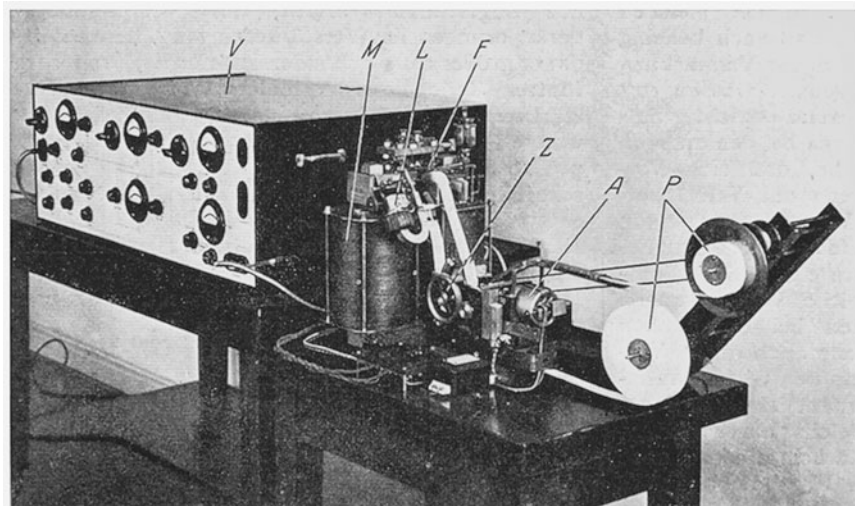


Fig. 2. Ansicht der ganzen Apparatur. *V* = Verstärker, *M* = Magnet des Schreibers; *A* = Antriebsmotor für die Papierstreifenförderung; *Z* = auswechselbare Zahnräder; *F* = Sitz der Schreibfeder; *P* = Papierrollen; *L* = Lautsprecher-system für die Zeitschreibung.

Figure 28 The first version of the neurograph, from 1932. View of the whole apparatus. *V* = amplifier, *M* = magnet of the recorder; *A* = driving motor for the paper-tape transport; *Z* = replaceable cogwheels; *F* = pen receptacle; *P* = paper scrolls; *L* = loudspeaker system for the time recording.

to execute than exposing a larger piece of the bone surface. If one wanted to be very careful, it would probably even suffice to trepan down to the lower edge of the diploë. A considerable amplitude of the cortical effects would generally already be expected in this layer.⁶⁶

Probably at the beginning of 1933, Tönnies let Kornmüller drill a small hole into his skull in order to conduct an EEG from there. The experiment had to be aborted for lack of neurosurgical experience, however, and Tönnies looked for more professional cooperators.⁶⁷ In March 1934 Tönnies registered not his own EEG but one from a neurosurgical patient at the Berlin Augusta Hospital, where he had brought his mobile alternating-current amplifier.⁶⁸ This was the first intraoperative EEG from the surface of

66 Tönnies 1933b, esp. p. 168.

67 Kornmüller 1961, p. 438. Kornmüller omitted to mention in this description that bleeding prevented this experiment from being fully completed and probably did not lead to any EEG recordings.

68 See Tönnies 1934; Richard Jung, who happened to be assisting then as *famulus*, was present at the experiment and described this experience so decisive to his choice of

a human brain. Just a few more intraoperative EEG curves sufficed for Tönnies to launch a frontal attack on Berger's EEG:

This information allows us to recognize that a 'normal' curve image cannot be obtained. It cannot be denied that with reference to the 10-Hertz waves there is a certain uniformity, but the deviations from this type are so frequent that we should not draw any kind of clinical conclusions at all.⁶⁹

In the Buch experimental system, where the EEG had been developed according to the model of localized action currents, every technically successful recording counted as an EEG, precisely because the group refrained from making any presuppositions about wave forms and curve types. The curves that the neurograph inscribed from different points on the cerebral cortex simply were the EEG. Thanks to Tönnies' perfect trimming of this machine, Berger's doubts about the reliability of a registration were already eliminated by interference-suppressing circuitry, compensation currents, and filtering loops. In Jena, on the contrary, where the EEG had been modeled as variation of a basal rhythm in quest of psychophysical correlations, an EEG recording only counted as successful if it showed under resting conditions those particular alpha waves whose regular occurrence Tönnies was now questioning. Tönnies' curves remained worthless to Berger as long as they showed no "normal curve," as he wrote in a letter:

Much more important still than the difference between the results of bi- and unipolar conduction seem to me to be the psychological conditions that, according to my experiences, must be respected in recording an impeccable E.E.G. [. . .]—It would, of course, be the simplest if you came to visit me here once to record a normal curve. I should be very pleased to demonstrate everything to you and record a normal curve from any healthy person in your presence.⁷⁰

At this point in time, Berger could not know that this would be Tönnies' last paper on the EEG and that Otfried Foerster, together with Hans Altenburger, had already undertaken intraoperative EEG recordings, in which they very certainly did observe an ubiquitous alpha rhythm in the human EEG.⁷¹ He likewise only learned from his correspondence with

profession, although Tönnies purportedly had all sorts of problems with the neurograph in that unfamiliar setting. Cf. Jung 1992, p. 480.

69 Tönnies 1934, p. 413.

70 Berger to Tönnies, dated 9 June 1934, file "Tönnies und Kornmüller-Sachen," Berger papers. A reply letter is missing in Berger's carefully maintained correspondence.

71 See Foerster and Altenburger 1935. It is astonishing that these researches in Breslau were apparently never pursued further. A handbook contribution from 1937 merely produced the results that had already been presented in 1934 (Altenburger 1937).

the group in Buch that his alpha waves had just been confirmed in Cambridge.⁷²

At Buch, only Kornmüller continued to work consistently on the EEG (Figure 29). He pursued the concept of localized activity in individual cerebral cortical fields that he had already formulated at his talk in Wiesbaden in 1932: “This principal result, that the architectonic boundary coincides precisely with the bioelectrical boundary, we have astonishingly found confirmed again and again.”⁷³ As Kornmüller showed in the following years, this applied not only to action currents but also to the potential fluctuations occurring spontaneously without any specific stimulus; what were referred to as *Feldeigenströme*—literally, the field’s intrinsic currents. In Kornmüller’s experimental system, a specific EEG pattern corresponded to each morphologically identified Vogtian elementary organ, somewhat as its physiological fingerprint.⁷⁴ During this time Kornmüller was working as a cartographer of field-specific currents, which he compiled in an increasingly exact chart of EEG patterns (Figure 30).

Kornmüller’s conception of the EEG was to develop increasingly into a conceptual barrier. When in 1935 Kornmüller wrote (in German!) in a survey article to the British public that “in the so complex image of bioelectrical phenomena of the cerebral cortex” one could “recognize regularities” solely on the grounds of architectonic fielding, he was thereby defining the feasibility condition of his EEG as well as its limitation.⁷⁵ Kornmüller had made the “data of cerebral cortical architectonics” the basis of his physiological analyses, and he confirmed the cytoarchitectonics from physiological aspects in ever more tiers of EEG patterns. In this research approach, physiology as the morphology of EEG curves, was reduced to expansion of localizing neuroanatomy. Consequently, Kornmüller’s discussions culminated time and again in sterile controversies with critics of the localization

72 The first (still extant) letter from Berger to Kornmüller is dated 6 June 1934 (file: “Tönnies und Kornmüller-Sachen,” Berger papers); Kornmüller replied on 7 June 1934 (*ibid.*): “Although it may be known to you, I would like to draw your attention again to that the last year’s Nobel laureate Adrian has recently been working with the EEG in continuation of your examinations. He also gave a demonstration about it at the Physiology Congress in London that took place about 3 weeks ago.” Berger thanked him the following day: “Specifically, I would like to thank you for having drawn my attention to the research by Adrian, about which I had naturally not yet heard anything.”

73 Kornmüller 1933b, p. 49.

74 See Kornmüller 1934, 1935, 1937. In addition, he examined, for example, the synchronization between different fields and the so-called cramp potentials (see Kornmüller 1933d, 1935). The concept of distinct currents associated with a field (FES) did not prevail. The first to publicly express doubts about them and blame them on the recording conditions was Kornmüller’s former collaborator Reinhold Grüttner, who was promptly demoted to technical assistant by Kornmüller as a result; see Grüttner 1946 and his correspondence with Kornmüller, MPG-A III/16/46.

75 Kornmüller 1935, p. 418.

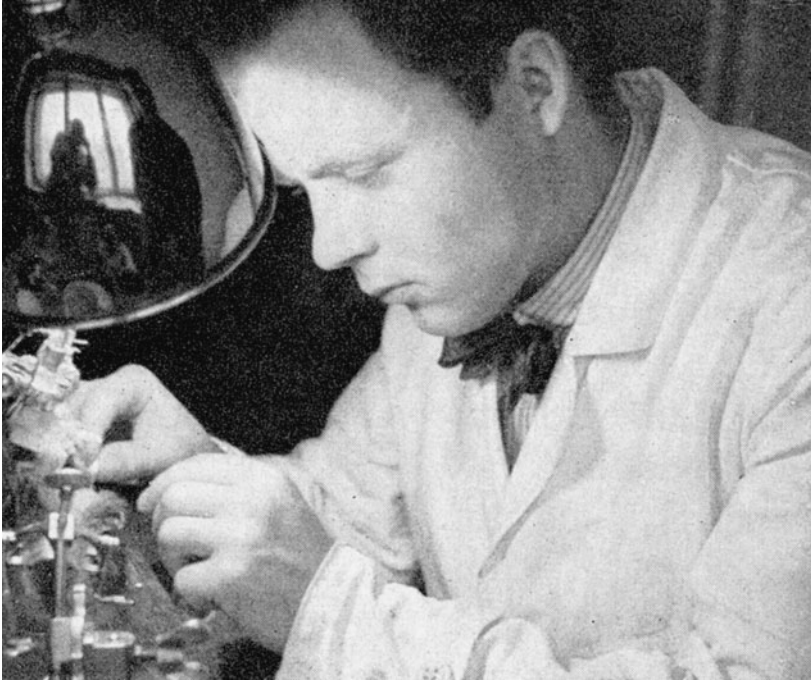


Figure 29 Alois Kornmüller experimenting in 1935 in Buch near Berlin; the photographer reflected in the lampshade is probably Richard Jung.

principle, such as Kurt Goldstein, Viktor von Weizsäcker, or Karl Lashley.⁷⁶ Under Vogt's directorship, the EEG curves of Kornmüller's physiology department remained the vermiform appendix of cytoarchitectonics. It was only when Richard Jung, Rudolf Janzen, Werner Noell, and Fritz Palme began with clinical electroencephalography in Buch that the EEG curves constituted a new knowledge space there as well. Until that time, Kornmüller had never systematically conducted EEG experiments on humans. His monograph on the EEG from 1937 does contain a chapter on "Examinations on bioelectric effects of the human brain," but even there Kornmüller did not go into any detail about Berger's studies, only reviewing Tönnies' results and showing in addition two curves inherited from Herbert Jasper. Nonetheless he wrote in a one-upping tone:

It is very evident that, in view of my determinations from animal brains over many years, I would be of the opinion that [EEG recordings from humans] would exhibit the regional differences in the bioelectrical phenomena of humans long expected by me. In addition, we may anticipate

⁷⁶ See Kornmüller 1933d, pp. 434f.; 1935, pp. 400–402; 1937, pp. 105–108.

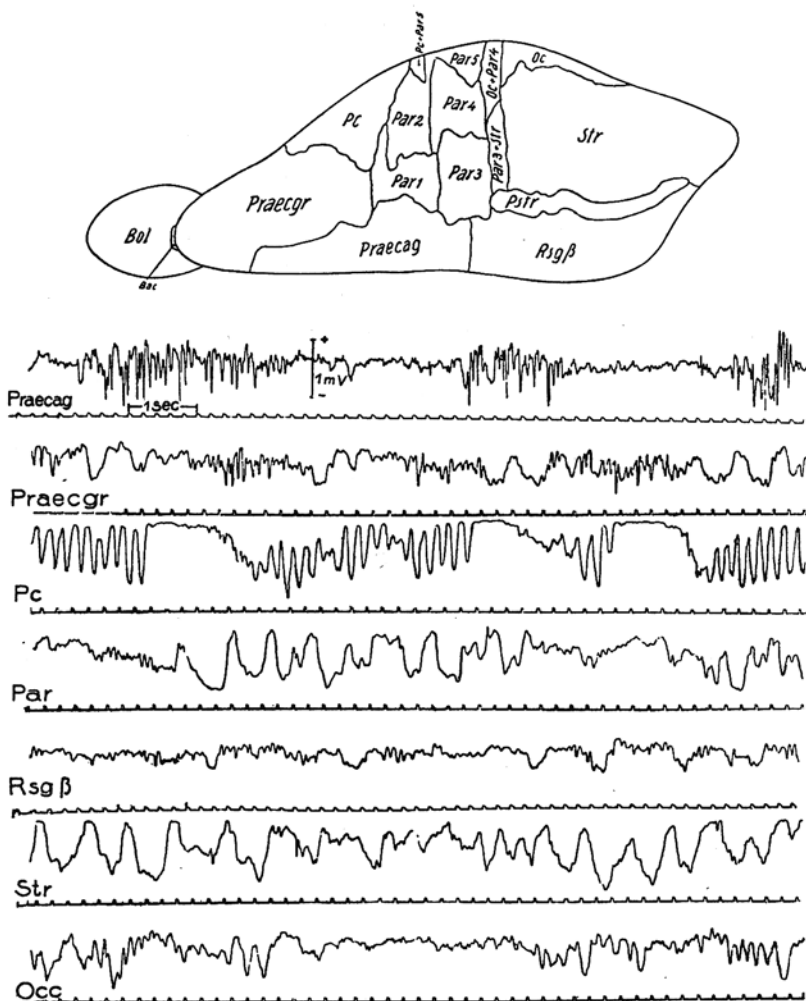


Fig. 2. Oben: die architektonische Felderung der Grosshirnrinde des Kaninchens nach Rose. Eine rechte Hemisphäre von oben gesehen. Darunter: die Normaltypen der Feldeigenströme. Registriert mit Tönnies' Neurographen.

Figure 30 Alois Kornmüller's cartography of a field's intrinsic currents (*Feldeigenströme*) according to the cytoarchitectonic partitioning of a rabbit's cerebral hemispheres. Top: the architectonic fielding of a rabbit's cerebral cortex according to Rose. A right hemisphere viewed from above. Below it: the normal types of *Feldeigenströme*. Registered with Tönnies' neurograph.

of such analyses [i.e., unipolar conductions] greater furtherance of the physiology and pathophysiology of the human brain than from all analyses in which the localizatory differences are not taken into account.⁷⁷

77 Kornmüller 1937, pp. 81f., insertions by the present author.

Acknowledgment with British understatement

“Looking back on my own scientific work I should say that it shows no great originality but a certain amount of business instinct which leads to the selection of a profitable line.”⁷⁸ This is the self-description of one who had been conferred the Nobel Prize besides twenty-nine honorary doctorates, was president of the Royal Society, and was finally elevated to the English peerage. Edgar Douglas Adrian counts, without a doubt, among the most acclaimed scientists of the twentieth century, and yet his self-description reveals more than just the effort to offer a particular scientific *persona*. Compared to Charles Sherrington, the neurotheoretician and neuropoet, with whom he shared the Nobel Prize in 1932, Adrian’s papers remained definitely austere, correct, and cool.⁷⁹ His opinion on the topic: “The conception of nervous and mental energy” presented at the VIIIth International Congress of Psychology in 1923 at Oxford, is a typical example that, at the same time, gauges the difference from Berger’s P.E. researches:

Mental energy may perhaps be regarded as the product of the force into the resistance overcome (though both are imponderables), but because there is an analogy there is no reason to suppose that this mental energy will follow any of the generalizations which have been observed for the energy changes in material systems. [. . .] If we use the word “energy” in its purely physical sense, the conception of nervous energy is unnecessary, and that of mental energy impossible. If we use it in another sense, we must be careful to define its meaning exactly or we run the risk of assuming that it must necessarily follow the rules which have been found to govern the transformations of physical energy in material systems.⁸⁰

Adrian regarded his work as a continuation of the researches of his teacher Keith Lucas, a casualty of World War I, with whom he had conducted his first electrophysiological experiments in 1911 and whose laboratories in the basement of the physiology department at Cambridge he took over in 1919.⁸¹ Owing to his technical expertise, Lucas was deployed in British aircraft development during the war and lost his life in an instrument testing flight. The technical preconditions for Adrian’s later successes lay in

78 Edgar Douglas Adrian: “Unpublished autobiographical note,” quoted from Hodgkin (1979, p. 49), whence all the biographical information on Adrian here originates.

79 See Smith 2001. Adrian was an English scientific aristocrat of the typical university stamp cultivated at Oxford and Cambridge, but at the same time, the “modern” type of matter-of-factual, physically oriented researcher.

80 Adrian 1924, pp. 158 and 162.

81 See Adrian’s reference to Lucas in his Nobel address (Adrian 1965, p. 195), or Hodgkin 1979, pp. 10–16. On Adrian’s laboratory and his research practice, see Shepherd and Braun 1989, or the excellent reconstruction by Frank (1994).

precisely this new form of cooperation between science, technology, and the military, as he himself summarized:

Fortunately the detection of very small and very rapid electric changes has recently become a problem not confined to physiology, and our difficulties can be solved by the use of methods devised for wireless communication. When the academic scientist is forced to justify his existence to the man in the street he is inclined to do so by pointing out the essential part played by academic research in the development of our modern comforts. It is only fair, therefore, to point out that in this case the boot is on the other leg and the academic research has depended on the very modern comfort of broadcasting. As everyone knows, wireless telephony became possible only with the introduction of the three-electrode valve which was developed on a large scale in the war.⁸²

At first glance the development of Adrian's researches seems to confirm perfectly his categorical statement, "the history of electrophysiology has been decided by the history of electrical recording technology."⁸³ Thanks to the massively promoted wartime development of tube technology, Adrian and his American friend Alexander Forbes were among the first in 1921 to apply the method of electric signal amplification to electrophysiology and could experimentally confirm the so-called "all-or-none law."⁸⁴ Industrially produced amplifying tubes for radio receivers later formed the technical basis for the registration of spontaneous action potentials of individual axons by Adrian and Yngve Zotterman, in November 1925.⁸⁵ At the end of the 1920s Adrian discovered in Bryan Matthews a co-worker with excellent electrotechnical expertise. He assumed instrument development at the laboratory in Cambridge and with his oscilloscopes, amplifiers, and oscillographs promoted electrophysiological research far beyond England's borders.⁸⁶ Adrian's compact thesis of technological determinism is of little help,

82 Adrian 1928, p. 39.

83 Adrian 1932a, p. 2.

84 That uniformity of nerve action which Adrian together with Lucas had previously only postulated from indirect evidence (Adrian 1914)—namely: that neural action potentials are always of the same magnitude, independent of the triggering stimulus, as soon as the stimulus exceeds a minimum threshold (Adrian and Forbes 1922), see Frank 1994, Bradley and Tansey 1996.

85 Adrian and Zotterman 1926. Zotterman described this experiment retrospectively (Zotterman 1978, p. 137): "It was a raw and chilly November day. We managed to keep the preparation alive for the whole day and when we went home in the late evening we knew that what we had seen that day would be told in every textbook of physiology within the next ten years." The three-stage tube amplifier used for the experiments was based on the design by Herbert Gasser and Joseph Erlanger in St. Louis (Gasser and Erlanger 1922); see Marshall 1983 and 1987.

86 See the obituary, Gray 1990.

however, in comprehending the specific developmental line of his experimental system.⁸⁷ Comparison with the physiology department of the KWI for Brain Research shows that a very similar technology could also form for a radically different research program. Not the general thesis of technology-dependence leads into the fabric of experimental dynamics, but the question of how a particular problem emerged and mobilized technical solutions.

At the beginning of the twentieth century broad consensus reigned that the messages in the nervous system consisted of electric signals, despite their diverse functions.⁸⁸ Lucas had additionally postulated that these electric signals consisted of uniform smallest units,⁸⁹ and the research in Adrian's laboratory pursued the overarching goal of detecting this universal code in the nervous system by experiment. Adrian and his collaborators did, in fact, confirm their hypothesis in the different parts of the peripheral nervous system, where the activity of individual nerves was more easily observable:

The nerve fibre is clearly a signalling mechanism of limited scope. It can only transmit a succession of brief explosive waves, and the message can only be varied by changes in the frequency and in the total number of these waves.⁹⁰

This begged the question of the transferability of these findings to the brain where the activity of individual neurons was experimentally hardly distinguishable from cell cluster activity. Hence roughly around the same time that Berger began to publish about the EEG, cerebral currents were also becoming interesting to neurophysiology again. They had formerly been largely screened out of its research agenda. The work in Adrian's laboratory shows that even research following such a systematic line can falter as soon as something new appears. Before brainwaves became the object of research they had long since intruded in the laboratory as interferences.

When Rachel Matthews commenced experiments in Adrian's laboratory in 1927 on light stimulation of the eye of a conger eel and of a frog, their purpose was to prove the uniformity of the code also for the optic nerve.

87 Frank (1986) has already pointed this out for the history of neurophysiology as a whole. Finger (2000), on the other hand, presents how technological determinism can harmonize with an ingenious culture because both ultimately take recourse in notions of "pure" insight into nature.

88 Bernstein 1912 gives a representative overview.

89 Lucas 1917, see also Brazier 1961, 1988.

90 From Adrian's Nobel address of 1932 (Adrian 1965, p. 297). This project with its clear orientation toward activity of the smallest units of the nervous system first made it worthwhile to develop new registration instruments. On the other hand, the achievements with the new instruments shifted the direction of research in neurophysiology of the 1920s further and further away from the nervous organ as a whole to the cellular level and thus to peripheral fibers and neurons, because that was where individual impulses were most easily isolated.

A first publication drew the anticipated conclusions: “The action currents do not differ appreciably in time relations or in grouping from those in other sensory nerves.”⁹¹ Despite the clearly posed problem and a tested investigative technique, the sought confirmation was evidently not so easy, though, because she needed more than a kilometer of film exposures. The first report had suppressed a number of disturbing observations that proved so stubborn that Adrian and Rachel Matthews saw themselves compelled at least to mention them in another publication a year later:

When the entire retina of the Conger eel is exposed to uniform illumination the action current discharge in the optic nerve may lose its usual irregular character and may consist of a series of regular waves with a frequency which usually varies between 15 and 5 a sec.⁹²

In addition to producing the sought flash-like nerve action potentials, the eel’s eye also generated regular wave-shaped rhythms at a frequency of 5–15 Hz, which disagreed with the theory of a stimulus-correlated universal code. The eel’s eye had turned out to be “beastly complex,” as Adrian noted, and produced interferences in the Cambridge experimental system that could not be worked on further for the time being.⁹³ Instead, Adrian rounded off his research on the codification of the nervous system enough to be able to review them in a cycle of lectures in 1930, from which his book *The Mechanism of Nervous Action* emerged. This book was obviously not the place to reflect on interferences but an unusually philosophical passage for Adrian seems to suggest that he had reached a crossroads with Rachel Matthews’ excursion into retinal potentials:

In all branches of natural science there are two methods of approach that of the strategist who can devise a series of crucial experiments which will reveal the truth by a sort of Hegelian dialectic, and that of the empiricist who merely looks about to see what he can find. The development of electrical technique has given a new way of looking about, and so much is going on in the nervous system that it is hard to resist the temptation to record anything that turns up. This method has had the merit of showing many unexpected resemblances in the activity of different parts of the nervous apparatus, but it gives us facts rather than theories, and the facts may not always mean very much.⁹⁴

91 Adrian and Matthews 1927, p. 410. Rachel Matthews had started working with Adrian in 1926 as Rachel Eckhard, where she met Bryan Matthews, her husband.

92 Adrian and Matthews 1928, pp. 296–298.

93 Adrian to Forbes on 30 September 1927, quoted from Hodgkin 1979, p. 33. With his next collaborator, Detlev Bronk, Adrian returned to the universal signal code in the peripheral nervous system (Adrian and Bronk 1928).

94 Adrian 1932a, p. 93.

Adrian's next collaborator, an already qualified physiologist and animal psychologist, gave the opportunity to take up the question of electric signals in the central nervous system again. Frederik Buytendijk chose the goldfish as test animal, and as had already been the case with Rachel Matthews' experiments with the conger eel's eye, Bryan Matthews' new oscilloscope again displayed rhythmic potentials of regular frequency, this time in the brain stem of the goldfish.⁹⁵ During the following period Adrian began to occupy himself with the details of these central nerve potentials which, compared to the explosive action potentials, proceeded unusually slowly, manifested a nearly constant rhythm, and evidently were spontaneously generated, not evoked by stimuli. Right in the next volume of *Journal of Physiology*, there appeared a study about such potentials in the abdominal ganglion of the great diving beetle, and on 11 June 1932 he demonstrated before the Physiological Society similar rhythmic potentials in the optic ganglion of the same beetle.⁹⁶ The rhythmic oscillations that Rachel Matthews had excluded as noise in her eel's eye observations of 1927 became an epistemic thing in 1931.

Around this time Adrian must have become aware of the electrophysiological studies in the KWI for Brain Research, perhaps through Fischer's talk at the International Congress of Physiology in Rome, which he also attended. In the following year Adrian and Bryan Matthews started to study the publications by Fischer, Kornmüller, and Tönnies systematically, and on 21 October 1933 they reported to the Physiological Society about similar experiments on cortex currents in the rabbit.⁹⁷ Like the researchers at Buch, Adrian and Matthews also observed large rhythmical cramp potentials effectuated by direct injury to the cerebral cortex, but, unlike the results at Buch, they did not register specific potential patterns of individual cerebral cortical fields but regular, spontaneous, rhythmic potentials. Although they observed very similar variations in the cortical potentials to those of Kornmüller and Tönnies, the Cambridge researchers focused on another aspect. Cytoarchitectonics did not play any role in Adrian's electrophysiological experimental system. Adrian and Matthews were not interested in field-specific action currents but in the summated activity in complex nerve-cell clusters.⁹⁸

95 Adrian and Buytendijk 1931. The first sentence of this paper, which draws the bow far back, accentuates the new beginning just set: "Since the original observations of Caton various workers have recorded changes of electrical potential in the brain."

96 Adrian 1931, 1932b.

97 Adrian and Matthews 1933 and 1934b.

98 See Adrian and Matthews 1934a, pp. 440f.: "The problem, then, is to decide what kind of changes to expect in the individual neurones. [. . .] Are the action potentials of the cortical cells as variable, or are they as uniform as the impulses in a nerve fibre? [. . .] In the present work, [. . .] we have reached the conclusion that the cortical effect is mainly built up out of repeated brief pulsations, slower than the potential waves in a nerve fibre but of the same general character."

It was only through this intermediary step in the Buch studies that Adrian and Matthews became aware of Berger's EEG researches. From the British perspective they were much more relevant, because of the rhythmic potentials described there, than the very specially directed inquiries at Buch.⁹⁹ Directly after completing their first trials on the cortex potentials of a rabbit, Adrian and Matthews therefore resolved to take up Berger's experimental arrangement even though they had hitherto never worked on the human nervous system. In spring 1934 Adrian and Matthews tried out recordings from each other's heads according to Berger's method, which they had meanwhile studied in *Journal für Psychologie und Neurologie*:

We found Berger's alpha rhythm almost at once, but only in one of us. When Matthews was subject with electrodes on vertex and occiput the record showed no regular waves, but when I was the subject the waves at 10 a second appeared whenever I closed my eyes. We were surprised at first to find such great differences in the records from two human subjects but it did not take long to examine other inhabitants of the Physiological Laboratory and we found that a few were like Matthews in showing no sign of the alpha rhythm.¹⁰⁰

On 12 May 1934 they gave a demonstration of the EEG at the well-attended convention of the Physiological Society in Cambridge.¹⁰¹ A report for *Spectator* by William Grey Walter emphasized something as spectacular that to Adrian and Matthews was probably little more than an anecdote, a reference to Berger's investigations, since it was completely remote from the problems being treated in the Cambridge experimental system:

99 "Fischer gave references to the paper which Berger had published in the 'Journal für Psychologie und Neurologie' in 1930 and also to one by Kornmuller in 1932. We found the journal in Cambridge with Kornmuller's paper, which described experiments like Fischer's, recording electrical oscillations from the exposed brains of the rabbit or cat and finding differences in the spontaneous or evoked rhythms in different parts of the cortex. But Kornmuller paid rather more attention to what he described as 'Berger's interesting researches on the E.E.G.'" (Adrian 1971, p. 1A-8). Directly asked about Fischer's and Kornmüller's *Feldeigenströme*, Adrian replied on 4 June 1934 at the annual convention of the American Neurological Association in Atlantic City: "I cannot say that our results lend much support to Kornmuller's view that there are specific types of electrical changes corresponding to areas of different cyto-architecture" (Adrian 1934, p. 1135).

100 Adrian 1971, pp. 1A-8 f. One decisive factor was again a technical refinement of the recording equipment in Cambridge. Matthews had just developed a transportable ECG instrument with ink recorder, with which brain currents could be recorded without any problem.

101 See Adrian 1971, p. 1A-9. The "Proceedings of the Physiological Society" in *Journal of Physiology* made no references to this demonstration by Adrian and Matthews at the meeting on 12 May. I cannot tell whether Adrian was prevented by his departure to the USA from writing a report or decided against forestalling a later publication (in *Brain*) with such a preliminary account.

Adrian and Matthews recently gave an elegant demonstration of these cortical potentials. [. . .] When the subject's eyes were open the line was irregular, but when his eyes were shut it showed a regular series of large waves occurring at about ten a second. [. . .] Then came the surprise. When the subject shut his eyes and was given a simple problem in mental arithmetic, as long as he was working it out the waves were absent and the line was irregular, as when his eyes were open. When he had solved the problem, the waves reappeared. [. . .] So, with this technique, thought would seem to be a negative sort of thing: a breaking of the synchronized activity of enormous numbers of cells into an individualized working.¹⁰²

At the end of the year, the Cambridge experiment turned into a news item for the British daily press, as the president of the Royal Society paraphrased it in his annual address, to offer one example of the broad-ranging research at the Royal Society.¹⁰³ Without knowing the details, the press celebrated the British Nobel laureate and not the unknown psychiatrist from Germany. Viewing this praise as misplaced, Adrian and Matthews formulated a correction that was printed in *Lancet*, *Naturwissenschaften*, *Medizinische Welt*, and elsewhere.¹⁰⁴ This correction was what caused a wave of attention to Berger's analyses in 1935, but this time—different from the sensationalist reports in 1930—Berger's EEG was ennobled by the confirmation of a Nobel laureate.¹⁰⁵ These false reports in the British papers not only promoted Berger's recognition in Germany, but evidently also offered occasion for private contact between them. At the beginning of December 1934 Berger noted in his journal: "From Cambridge a splendid letter from Adrian, in which he apologizes for his having been falsely celebrated in the Engl. papers as the discoverer of my EEG, those 'classical' examinations; he promises corrections: I thanked him."¹⁰⁶ Despite many a divergence between their interpretations of the EEG in the years that followed, there evolved out of this a friendship such as he shared with very few of his fellows in the profession.¹⁰⁷ After a personal encounter at the XIth International Congress

102 Walter 1934, p. 479.

103 Sir Gowland Hopkins: "It is noteworthy that concentrated thought, such as is involved, say, in mental arithmetic, temporarily abolishes the recorded rhythms which would thus seem to be characteristic of the quiescent organ." Hopkins 1935, p. 14.

104 The editors of *Naturwissenschaft*, first had this correction checked by Berger; see the exchange of letters on 17 December 1934, folder: "Adrian," Berger papers.

105 "Even in comics there is everywhere talk about the EEG & me: Whether willingly or not [*nolens volens*], Adrian has helped me very much," Berger remarked on 14 April 1935 in his journal (V, p. 352). I was unable to locate that comic publication.

106 Lab journal V, p. 327, dated 9 December 1934.

107 For example, Berger and Adrian exchanged portrait photographs. Adrian planned to stop in Jena in 1938 on the occasion of the International Congress of Physiology in Zurich, but practical reasons prevented this from taking place.

FROM PROF. E. D. ADRIAN, ST. CHAD'S, GRANGE ROAD, CAMBRIDGE.

TEL. 1359

28. 1. 35

Dear Prof. Berger

I enclose a reprint of the paper which Matthews & I wrote last October. I am afraid we may have misinterpreted your views — partly because neither of us had German at all fluently & partly because we have tried to state them in too short a form. From your last paper (replying to Tomnies) I think our explanation does not differ from yours as much as we thought.

Since we wrote the paper I have tried to localise the origin of the rhythm more exactly by recording with three oscillographs from three pairs of electrodes. The results seem to show that in my head — that of my collapse (a Dr. Yamagiwa) the maximum potential change usually occurs in some part of the occipital lobe but occasionally the focus moves beyond the margins of the lobe. I should think it quite possible that in certain conditions it might be the best input ~~not~~ cover a very wide area but for most of the time in our heads it seems to be confined to the occipital region, or

Figure 31 Letter from Douglas Adrian to Hans Berger dated 28 January 1935, in which he established the basic agreement between their EEG findings.

of Psychology in Paris, Berger wrote to Adrian: “I know that I am indebted to you alone that the scientific world became aware of my analyses.”¹⁰⁸

Even prior to this indirect assistance to Berger’s reputation in Germany, Adrian had already introduced the new brain curves in America, where they

108 Letter from Berger to Adrian dated 3 August 1937, folder: “Adrian,” Berger papers.

were immediately received with the greatest interest. Just two weeks after the demonstration experiment in Cambridge, the Nobel laureate embarked on a lecturing tour through the USA, during which he described the sum of his researches the way they appeared to him then on the basis of his EEG experiments.¹⁰⁹ Whereas the peripheral nervous system responded to stimuli with a uniform action potential, central neurons accordingly had the character of a periodic discharge, which Adrian suggested should be named the “Berger rhythm.”¹¹⁰ What was meant as a homage to a too-little-known colleague, in accordance with the vagaries of a traditionally minded republic of scholars, must have rather been an embarrassment to Berger: “I thank you [. . .] for the kind renaming of my E.E.G., which, however, I cannot quite agree with.”¹¹¹ In his opinion those alpha waves were not yet another unknown anomaly which could be labeled with the discoverer’s name, but a basic phenomenon of the human psychophysical apparatus, to which no researcher’s name could lay claim.

Adrian certainly did not deny the conspicuous correlation between Berger rhythm and psychic phenomena, such as sensorial stimuli, attentiveness, or mental problem-solving, but they remained effects outside of his experimental system which he had never specifically examined. What interested him instead were the rhythmic waves as an electrophysiological phenomenon. As regards the electric potentials, there were no differences between the beetle’s ganglion and the brain of “E.D.A.”—there is surely no better detail to illustrate the difference between Adrian’s and Berger’s researches on the EEG than a figure, in which Adrian juxtaposed the blockage of his own alpha rhythm with the interrupted rhythmic waves in the ganglion of the great diving beetle; since both were, of course, exhibiting the “Berger rhythm” (Figure 32). The special neurophysiological orientation of Adrian’s experimental system, furthermore, probably caused him to move away to other topics again soon afterwards.¹¹² Adrian compared the rhythmic

109 Adrian 1934; see Adrian 1971, p. 1A-10: “A fortnight later my wife and I had been invited to Montreal and we went from there to New Haven and New York and to a meeting of the American Neurological Association at Atlantic City. I was glad to have Berger’s discovery as a theme for several lectures, though we had come to the U.S.A. on Dr. Bronk’s invitation and we were soon enjoying a splendid tour which took us as far as the Teton range in the Rocky Mountains.”

110 Adrian and Matthews 1934b. “These records suggest that many of the cerebral neurons are so constituted that they must discharge periodically. [. . .] There is no direct evidence, but there is distinct support from an unexpected quarter, from the brain of normal, unanesthetized man. [. . .] We assume that the phenomenon, which may be suitably named the Berger rhythm, represents the spontaneous beating of a part of the occipital lobe” (Adrian 1934, pp. 1129–1133).

111 Letter from Berger to Adrian dated 3 February 1935, folder: “Adrian,” Berger papers. See also Berger’s public rejection of the term “Berger rhythm” at the end of the 10th communication (Berger 1935c).

112 From the proximity of friendship Alan Hodgkin characterized this phase of Adrian’s research as follows: “At all events, Adrian certainly did switch subjects a great many times

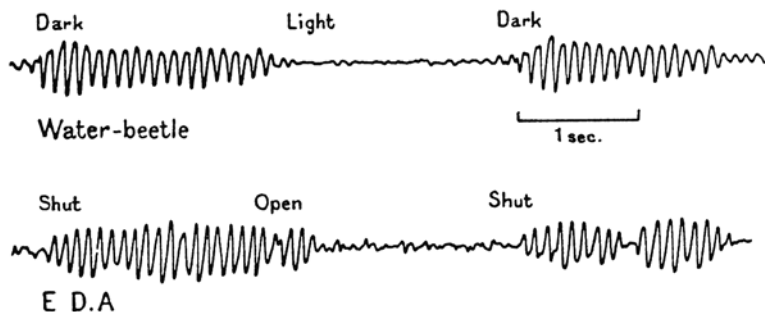


Figure 32 Comparison of the current oscillations in the light responses by the great diving beetle and a human subject (Edgar Douglas Adrian).

behavior of the cerebrum also with the oscillations of potential in the cerebellum and closely examined the origin and the propagation of the periodical potential oscillations in the human cortex.¹¹³ In all these experiments, the Berger rhythm remained a distinct property of cortical neurons, but how it formed could not be explained. To decipher it neurophysiologists had to place their hopes, one more time, on the leaping advances of wartime technical engineering, as Adrian explained:

A repeated noise like that of a machine gun does not give a corresponding series of potential waves large enough to detect through the skull—either because they are not developed over a large enough area or because the area is unfavorably placed. I am afraid, therefore, that the present technique of recording brain events, by oscillographs connected with electrodes on the head, is not likely to lead very far. But such a technique may soon be superseded; judged by the standards of modern physics it is already obsolete, and I think we should look forward to the possibility of being able to record all the electrical events—the changing potentials and ionic movements—within the brain in far greater detail and without hindrance from the skull.¹¹⁴

between 1936 and 1946 although probably not primarily for the tactical reasons mentioned above. In reading his papers from this period, one has the feeling that he was desperately anxious to survey the whole of the central nervous system, as well as the principal sense organs, and that he did not know how long he would be able to keep going in the laboratory” (1979, p. 44).

113 Adrian 1935, Adrian and Yamagiwa 1935, Adrian 1936a and 1936b.

114 Adrian 1944, pp. 356f. Adrian no longer participated in this development as experimental scientist but did figure in it as a highly esteemed elder statesman. In 1951 he became president of the Royal Society and master of Trinity College and in 1957 vice-chancellor of Cambridge University. When he was released from these duties again in 1958 and would have been able to return to research, one of his co-workers at the laboratory inadvertently flooded his laboratory in the basement of the physiology department and

Hardly any other research topic that Adrian had pursued could have better fit his critical self-assessment, quoted at the beginning—of lacking originality combined with a good sense of intuition—than his occupation with the EEG. He had, in fact, picked it up from others, developed it further for a while, and then exchanged it again for other topics, without having built a sufficient theoretical foundation for his observations. And yet, Adrian's research formed the decisive turning point in the history of brainwaves. By Adrian's intervention, the "Berger rhythm" stepped out of the private world of the Jena laboratory and became an object of knowledge of international neurophysiology. Directly after Adrian's accomplishments were announced, sufficient numbers of groups started working on the EEG for an EEG section to be included at the International Congress of Neurology in London just one year later.¹¹⁵ Finally, with this conference, the EEG became firmly anchored in the scientific world. Notwithstanding Adrian's active advocacy of Berger's claim to fame, this signified at the same time a transformation of that which became the brainwave as an object of research. For, the specific perspective of the English Nobel laureate left its mark on this object of research. Only alpha waves had participated in the passage through the Cambridge laboratory, none of the other frequencies, not even Berger's beta waves. The EEG was the portrait of alpha waves in the waking and unoccupied human brain.

The leap over the pond

Different from in Europe with its few specialized laboratories, in the United States neurophysiology formed its own scientific community. It is hardly coincidental that the decisive impulses in electrophysiology after World War I came from America, where discharge-tube technology was developed and industrially applied more quickly than in Europe and where, despite the international depression, neurophysiology was booming, thanks to special support, for example, by the Rockefeller Foundation.¹¹⁶ A whole range of research teams were working with tube amplifiers and oscillographs on the registration and deciphering of signals from the nervous system.

damaged all the instrumentation. To Adrian this meant a probably entirely welcome end to an extremely successful career in research.

115 The second main talk at that conference (by the Harvard neurologist William Lennox) was devoted *in extenso* to EEG findings. The speakers of that section were Adrian, Matthews, Kornmüller, Semen Sarkissow, Johannes Dusser de Barenne, Warren S. McCulloch, and Frederic and Erna Gibbs (see also Mayer-Gross 1935).

116 When in 1929 the International Congress of Physiology took place in Boston, outside of Europe for the first time, that was a clear sign of the new leadership role of USA in this science. From among over 1,300 participants, c. 400 arrived from Europe by steamship; the common passage on board "Minnekahda" turned the trip into a nine-day swaying preliminary conference. Zotterman later published reminiscences of this voyage (1968); on the Boston congress, see Franklin 1938.

They joined together to form a group as “axonologists.” Its name already expressed where the focus of their research activities lay: on the documentation and analysis of individual nerve action potentials.¹¹⁷ A text from 1934, the same year in which Adrian was to introduce the EEG to America, documents particularly well how the field of neurophysiology in the USA was, on one hand, already highly sensitized to cerebral currents and, on the other hand, tended at the same time toward other directions than the EEG offered. Under the title “Electrophysiology of the Brain,” George H. Bishop, a physiologist in St. Louis, formulated the role, tasks, and goals of cortical neurophysiology. Together with Herbert Gasser and Joseph Erlanger, Bishop was a pioneer in developing new, vacuum-tube-based amplification and recording techniques.

Tube technology had been massively promoted during World War I and Bishop too regarded it as the decisive motor behind the most recent boom in neurophysiology. Accordingly, it was only thanks to the new recording techniques that it became possible to observe activity in the nervous system directly, “as if by a physiological television apparatus one could watch the cells concerned in one of their essential activities.”¹¹⁸ This nerve television designed by Bishop, Gasser, and Erlanger, in a way determined the visual habits of a whole generation of neurophysiologists. Bishop was convinced that if electrophysiology attempted to work on the brain in this way, stagnation would be inevitable: “There has seemed to exist a strange indifference among neurophysiologists to the function of the higher centers of the nervous system; [. . .] even Pavlov seems to envisage the brain as a magnified reflex apparatus.”¹¹⁹ The new electrophysiological research methods could describe the communication of information in the peripheral nervous system exactly as a specific consequence of uniform action potentials. These methods were so successful that a dogma was allowed to emerge whose tenacity seemed to Bishop comparable only to the old belief in the immortality of the soul. Namely: the findings from easily accessible peripheral neurons ought to be transferrable onto the brain for the sole reason that nerve cells were also present there.

Although around 1930 a whole array of American teams had started to conduct experiments on the electrophysiology of the central nervous system,

117 See Marshall 1983. O’Leary and Goldring (1976, p. 135) relayed a cute nickname from a later period: “The Needlework Society.” Members of this association, which became quite stable from 1930 on, included John Fulton, Alexander Forbes, Herbert Gasser, George Bishop, Hallowell Davis, Detlev Bronk, Ralph Gerard, Francis Schmitt, and Rafael Lorente de Nó.

118 Bishop 1934, p. 127.

119 Bishop 1934, p. 123. Bishop was precisely informed about the just recently observed spontaneous rhythmic potentials of central nervous nerve-cell clusters, which did not suit the paradigm of a strict stimulus–response mechanism in the least. He had himself just copublished with Howard Bartley recordings of rhythmic waves in the visual cortex (Bartley and Bishop 1932).

thus far research methods that had proven themselves so brilliantly for the peripheral nervous system did not present any similarly clear results here.¹²⁰ Probably also for other reasons, Bishop wagered on “something functional as a physiological counterpart of mental activity” having to be added to the purely numerical difference at the transition from the periphery to the central nervous system.¹²¹ But even this so self-critical author could only imagine progress this way: “The natural next step will be to study the brain as a complex of the same sort of nervous structures as we already know most about.”¹²² The rapid and multifaceted career of the EEG in the USA was to follow quite different paths, however. An electrophysiology of the brain was, in fact, imminent but not as an extension and perfecting of atomistic electrophysiology of nerve action potentials. Rather, as pragmatic curve interpretations—and largely without relating back to cellular neurophysiology. Frederic A. Gibbs, one of the American EEG specialists of the first hour, pinpointed this difference many years later in an interview as follows:

Q: Did you know Lord Adrian?

Gibbs: Yes, somewhat, we had talked at meetings and so on. He was a great friend of Det[lev] Bronk. They were axonologists who whittled the nervous system down to one axon and knocked themselves out studying that. [. . .]

Q: What do you feel, Dr. Gibbs, is your greatest contribution to EEG?

Gibbs: It is trying to persuade people just to use common sense and to record the EEG in a most simple way, [. . .] and then let the brainwaves speak for themselves.¹²³

Among the axonologists, John Fulton, Herbert Gasser, and Hallowell Davis had participated along with Adrian at the Congress of Physiology in Rome in 1932; but none of them seems to have taken away any inspiration for EEG experiments from Fischer’s talk. Otherwise there are no indications of any response in America to Berger’s research prior to Adrian’s appearance at the annual meeting of the American Neurological Association at the beginning of June 1934 in Atlantic City. It is significant that with the exception of

120 Whereas some were working on the cortical representation of optical, acoustical, or other sensorial signals, in continuation of peripheral sensory physiology (Bartley and Newman 1930, Saul and Davis 1933, Travis and Dorsey 1932), others were trying to apply the tested methods of specific isolation of neural activity onto the brain. Dusser de Barenne and Walter S. McCulloch, for example, tried microscopic injury of individual cerebral cortical layers (Dusser de Barenne and McCulloch 1936); Frederic Bremer tested his special preparation of a *cerveau isolée* and of a *cortex cérébral isolée* (Bremer 1935).

121 Bishop 1934, p. 124.

122 Bishop 1934, pp. 131f.

123 Frederic and Erna Gibbs 1990, pp. 178 and 187. The interview was conducted in 1987, shortly before Erna Gibbs’s death; Frederic Gibbs died on 18 October 1992.

Davis none of the axonologists would make a name for themselves in the new field of electroencephalography. It was, rather, left to a younger generation of physicians and psychologists to make the registration of brainwaves into their own new field of research.

About one month after Adrian's talk in Atlantic City, successful EEG recordings were made at two locations supposedly independently of each other. Herbert Henry Jasper mentioned 9 July 1934 as the date of his first attempt in East Providence; Pauline Davis mentioned 12 July 1934 for a group at Harvard, and both asserted having become aware of Berger's papers on their own.¹²⁴ The first American publication about the EEG, in any event, did not come from one of the neurophysiological centers but from a newly equipped laboratory in a small home for physically impaired children in East Providence, Rhode Island. Herbert Jasper had started EEG registrations in summer 1934 at the Emma Pendleton Bradley Home, and his first publication appeared rapidly and prominently in *Science* on 11 January 1935. The first paper by the Harvard team under Hallowell Davis only appeared in December 1935 in *Archives of Neurology and Psychiatry*, subsequent to Davis's and Frederic Gibbs's expositions about the EEG in April 1935 at the meeting of the American Physiological Society. In the interim another group headed by Alfred Lee Loomis had published an article about the EEG in *Science*.¹²⁵ By the end of 1936, five laboratories were specializing on electroencephalography in the USA alone, although researchers such as Ralph W. Gerard at the University of Chicago, Alexander Forbes at Harvard, Bishop at Washington University in St. Louis, or Dusser de Barenne and McCulloch at Yale were also working more "axonologically" on the electrophysiology of the central nervous system.¹²⁶ Unlike in Great Britain

124 According to the account by Cobb 1971, p. 1A-26. The date 12 July 1934 for the Harvard group originates from the description by Pauline Davis (1940a, p. 712). The group's correspondence with the Rockefeller Foundation reports about EEG experiments at Harvard only in November 1934 (RAC, RG 1.1, series 200A, box 72, folder 872). That date matches very well the multiply published photo of a first EEG at Harvard, with Derbyshire and Lindsley before the apparatus by Lovitt Garceau, dated 5 December 1934; see e.g., *The Literary Digest* 119 (1935): 17; or O'Leary and Goldring 1976, p. 137.

125 Jasper and Carmichael 1935; Gibbs, Davis, and Lennox 1935; Loomis, Harvey, and Hobart 1935a and 1935b; Gibbs and Davis 1935. These publications caused some excitement. Many newspapers printed notices and that way the EEG became anchored among the American public from the very start. Jasper was a dominant figure in it, despite having published only one paper in 1935. The report covering the talk about an epileptic EEG by Gibbs and Davis (1935) happened to be illustrated with a photograph of Jasper on his EEG couch; likewise for a background report about the EEG, see *Science News Letter* dated 19 January, 20 April, 22 June, 6 July, 10 August, 14 September, and 30 November 1935.

126 At Jasper's laboratory in Bradley Home, Providence, Rhode Island; at Loomis's in Tuxedo Park, New York; at the labs of Hallowell and Pauline Davis, and of Frederic and Erna Gibbs in Cambridge, Massachusetts; at Hudson Hoagland's laboratory at Clark University in Worcester; Donald B. Lindsley's at the Brush Foundation of Western Reserve University in

and Germany, in America a competitive situation very quickly formed between various research groups, which contributed toward the EEG's consolidation just as well as its differentiation. This will be demonstrated here with the first American EEG studies: those by Herbert Jasper in East Providence, by Alfred Lee Loomis in Tuxedo Park, and by Hallowell and Pauline Davis, and Frederic and Erna Gibbs in Cambridge, Massachusetts.

Herbert Jasper united in his person exactly those interests, qualifications, and material preconditions necessary for successful work on the EEG. In 1934 he already had a technically perfectly equipped laboratory at his disposal and, thanks to his double qualification in psychology and electrophysiology, he obviously had no trouble establishing the registration of cerebral currents in his laboratory. Thus it seems consistent that he would be the first in the USA to publish an EEG and a few years later to erect the world's leading center for preoperative and intraoperative EEG diagnostics in Montreal, Canada.¹²⁷ Nevertheless his research fell peculiarly into crisis about the fundamentals within a matter of two years. It exemplarily illustrates the problems involved in conforming a new scientific object such as the EEG into an existing research context.

When in 1933 Jasper set up his own first research program at Bradley Home in East Providence, there was obviously no mention yet of cerebral currents. This program mirrored the stations of his training and the specific opportunities available at his new location.¹²⁸ Special chronaxie measurements had formed the focus of his electrophysiological training under Louis Lapique in Paris. He intended to apply the same method to evaluate the physiotherapeutic success of treatment of spastically crippled children at Bradley Home. Jasper additionally planned animal experiments for the registration of muscular action currents in sidewise comparison, in order to study phenomena of bilateral coordination or the dominance of one side. This referred back to a theory by his doctoral advisor in psychology, Lee E. Travis, that the two halves of the brain were functionally differentiated. Jasper consulted with the neurophysiologists at Harvard (who would soon become his competitors in registering EEGs) about technical details of these

Cleveland; George Kreezer's laboratory at the Training School, Vineland in New Jersey; and Lee Edward Travis's laboratory at the University of Iowa.

127 On Jasper's biography, see the two autobiographical texts, Jasper 1975 and 1996 as well as Gloor 1988 and Feindel 1998.

128 This is gathered from a listing of the required research instruments of September 1933 that Jasper compiled for the Rockefeller Foundation; see Jasper to Alan Gregg dated 25 September 1933, RAC, RG 1.1, series 200A, box 73, folder 882. A comparatively unknown researcher such as Jasper would at that time have rarely attracted funding by the Rockefeller Foundation. In this case the head of Bradley Home, the psychiatrist Arthur Ruggles, arranged for the contact. He was a friend of Max Mason, director of the Rockefeller Foundation. Jasper erroneously wrote in his autobiographical texts that he had already received a fellowship from the Rockefeller Foundation; the fellowship that enabled his European sojourn was sponsored by the National Research Council.

studies on the “neurophysiological nature of bilateral asymmetry of function in the central nervous system.”¹²⁹ Without their tips he could not have made the EEG his topic so quickly. The first mention of this new project is in a letter to Alan Gregg, head of the Medical Sciences Division of the Rockefeller Foundation, dated 24 August 1934, with which Jasper was already able to enclose an EEG curve that he himself had recorded.¹³⁰ Jasper’s first publication on the EEG from January 1935 still bore traces of the original research plan by emphasizing an asynchrony between the two halves of the brain as a detail of his research, besides confirming Berger’s findings.¹³¹

Jasper’s successful EEG registration attracted great public interest and the Rockefeller Foundation was evidently also very impressed with this unanticipated yield of their funding, which suited their new focus on “psychobiology” so well (Figure 33).¹³² In spring 1935 the leadership of the Rockefeller Foundation visited Jasper in his laboratory in order to personally persuade themselves of his research. Jasper promptly received approval of a three-year grant from the Natural Sciences Branch of the Rockefeller Foundation because its head, Warren Weaver, took a personal interest in the EEG. Ironically, this particularized support by Warren Weaver was to lead to a dead end for Jasper. His approach to the EEG by issues of lateral asymmetry were trimmed down by Weaver to a reductionistic line of basic research:

W[arren] W[eaver] is interested in the purely mathematical aspect,—as for example the desirability of periodogram analysis in the record; also in the close analogy that exists between this work and various aspects of the geophysical problems of measuring potentials on the surface of a sphere and interpreting these potentials in terms of subsurface activity of the structure.¹³³

129 See the letter by Leonid Carmichael, professor of psychology at Brown University and therefore Jasper’s academic superior, to Alan Gregg dated 21 February 1934, RAC, RG 1.1, series 200A, box 73, folder 882.

130 RAC, RG 1.1, series 200A, box 73, folder 882. In this letter Jasper mentioned Adrian’s investigations and also pointed out that Davis was planning similar experiments at Harvard. Jasper requested financial assistance in revamping the Westinghouse oscillograph specifically for recording those relatively slow EEG waves. Later Jasper wrote (e.g., 1996, p. 328) that he had heard of Berger’s research already in 1932 in Paris or shortly thereafter from his colleague William Malamud, who was a German speaker. This obviously cannot be argued against, but Jasper only refurbished his laboratory for EEG registration in summer 1934.

131 Jasper and Carmichael 1935, p. 53: “In the case of a young girl who suffers from convulsive disorder and is quite ambidextrous, the alpha-wave frequency was observed on repeated tests to be about 10 per second across the left side of the head and but 6 to 8 cycles across the right side of the head.” The characteristic degree of dexterity was a central part of Travis’s theory of cerebral dominance; however, ambidexterity was a sign of an unstable brain, see Travis 1934.

132 See Brown 1987. Allan Gregg, Warren Weaver, and Max Mason visited Jasper. RAC, RG 1.1, series 200A, box 73, folder 882.

133 “Excerpt from WW’s diary,” RAC, RG 1.1, series 200A, box 73, folder 883.



RECORDING BRAIN WAVES

While the subject lies comfortably at rest, scientists can tap the electric waves that accompany his brain action and make a photographic record of any disturbances. This picture shows the set-up of Dr. Jasper and Dr. Carmichael for some of the pioneer research in this field.

Figure 33 Herbert H. Jasper having his own EEG registered.

His first suggestion was an analysis of the EEG in categories of mathematical physics and he arranged contact with a mathematician at MIT. Jasper willingly followed this advice and raised the precision of his derivations until finally “only 5 or 10 brain cells” lay between the electrodes so that he could undertake the suggested triangulation experiments in search of the electrically active focus in the brain. Because the electrical properties of the diverse tissues in the brain and the skull were largely unknown, again at Weaver’s prompting, Jasper changed over from trials on healthy subjects and handicapped children to experiments with a simple spherical model of the brain. He attached point-shaped sources of current onto this model in order to be able to measure the electrophysics of the skull with physical precision. Finally, Jasper replaced the spherical model with the head of a butchered calf but the quest for the exact biophysics of cerebral currents failed to yield results.¹³⁴

134 Letter from Jasper to Mason dated 24 March 1935, RAC, RG 1.1, series 200A, box 73, folder 883. When Weaver visited Bradley Home again in November 1935, he had anyway

Jasper's failure was due not only to too much support but also to excessive numbers of cooperations and contacts. The defense of his dissertation on chronaxie in Paris occurred just at the time of his first EEG studies. In May 1935 Jasper embarked for Europe after having quickly submitted a report about the EEG to the Sorbonne as his second *thèse*.¹³⁵ Jasper used the opportunity provided by this European sojourn to travel to almost all the EEG laboratories on the Continent, financed by a travel stipend from the Rockefeller Foundation. Between June and August 1935 he first visited Berger at Jena, then Kornmüller in Buch (where he shook the Rockefeller Foundation's trust in him by making the diplomatic blunder of almost coaxing Erich Guttman away). He last visited Adrian at Cambridge, also attending the International Congress of Neurology in London, before returning to the USA with an irritatingly profuse amount of detailed knowledge. When he took up his own research at Bradley Home again in autumn 1935, Jasper attempted something of a synthesis of the different approaches by Weaver, Berger, Adrian, and Kornmüller. His intimate insight into the variety of EEG methods paradoxically proved to be an obstacle to research rather than a crystallization point of a synthetic program. From Berger, Jasper adopted the concept of the beta wave as the second characteristic of the human EEG, which Berger had evidently discussed with Jasper despite having not yet published anything on it. Adrian's findings on the occipital origin of alpha waves also convinced him, and Kornmüller's search for field-specific electric potentials looked promising as well. Jasper's synthesis consisted methodologically in the development of miniaturized button electrodes, with which he made bipolar but strictly localized conductions. Conceptually his synthesis consisted of a theory of ranked levels of central nervous excitation, which he assumed underlay the principle of the generation of different brain rhythms.¹³⁶

What Jasper hoped would be a fundamental synthesis rapidly exhausted itself in a boundless study of the published literature. Instead of producing his own approach, he presented an extensive review article, the conclusion

already resolved to give Jasper back to the Medical Sciences Branch; the meager new results strengthened him in this resolve; see "Excerpt from WW's diary, 11/2/1935," RAC, RG 1.1, series 200A, box 73, folder 883.

135 The submission of a second thesis besides the actual dissertation was part of the requirements for a doctorate at the Sorbonne. It therefore does not indicate unusual productivity on Jasper's part.

136 This synthetic approach is primarily executed in Jasper and Andrews 1936. Jasper presented the theory in 1936 at the 4th Cold Spring Harbor Symposium in Quantitative Biology on "excitation phenomena" (Jasper 1936c). This meeting marks something of an end to joint research between neurophysiologists and EEG researchers. Jasper gained entrance presumably because he had done research at Woods Hole during the summers of 1932 and 1933. My account here is abbreviated. For example, Jasper observed EEG alterations from children with behavior problems (Jasper, Solomon, and Bradley 1938, see also pp. 239–242).

of which was as grandiose as it was sobering: “The autonomous bioelectric activity from each cortical region is complex.”¹³⁷ Jasper had one of the best EEG laboratories in the world; a graduate physicist constructed excellent instruments for him according to his own specifications; he could acquaint himself with the different research approaches by personal communication with all the leading EEG scientists; the Rockefeller Foundation was generously funding his project; and he himself was doubly qualified as psychologist and electrophysiologist. In spite of this quick start, his own experimental system soon got stuck because Jasper had entangled himself in the clutter of inputs.¹³⁸ It must have felt like liberation when he persuaded neurosurgeon Wilder Penfield to test the EEG as an instrument of localization diagnostics for epilepsy patients and already his first experiments in January 1938 were successful.¹³⁹ Within a year Jasper had moved to Montreal.

The second paper published in the USA on the EEG was composed in a field with entirely different contours and thereby demonstrates the attractive pull that the topic evidently immediately exerted. Exactly half a year after Jasper’s article, a paper appeared in *Science* by a group that needed no research support because it was financed and headed by one of New York’s wealthiest lawyers and investment bankers. Alfred Lee Loomis was, in a way, another American model of philanthropic research promotion compared to the Rockefellers.¹⁴⁰ He rose rapidly professionally as an investment banker for public investment projects, but this occupation clearly did not drain his energies because he opened a physical research laboratory near his luxurious private home in Tuxedo Park in New York State, where he

137 Jasper and Andrews 1938, pp. 113f.

138 Personal reasons were surely an additional factor. Others have portrayed Jasper in this period as ambitious and even arrogant toward his colleagues. The Rockefeller Foundation criticized the clumsy manner of his verbal expression and his unreliable accounting, as the following office memo from 30 January 1936 reveals (RAC, RG 1.1, series 200A, box 73, folder 884): “Jasper is doing splendid work; has two weaknesses—he lacks finesse in dealing with people, and is a careless bookkeeper.”

139 Jasper in a letter to Robert A. Lambert of the Rockefeller Foundation dated 5 February 1938 (RAC, RG 1.1, series 427A, box 6, folder 53): “I have just returned from a most interesting visit with Dr. Penfield at the Montreal Neurological Institute. [. . .] It occurred to both Dr. Penfield and myself at this time that his organization and experience would provide a good opportunity to evaluate the use of the electroencephalogram in focal epilepsy.” Three years later, on 17 May 1941, Lambert could report about a visit in Montreal (RAC, RG 1.1, series 427A, box 6, folder 53): “Herbert Jasper looks happier than I have ever seen him. Says his coming to Montreal was the wisest decision he ever made.”

140 Alfred Lee Loomis, who during World War II would become known as director of the combined American radar research program at MIT, initially studied science at Yale, graduated from Harvard Law School with honors in 1912, and during World War I proved his technical proficiency as a ballistics expert by designing a special chronograph for projectile photography, before he made a career for himself on Wall Street as a lawyer in commerce and finance; see Alvarez 1980.

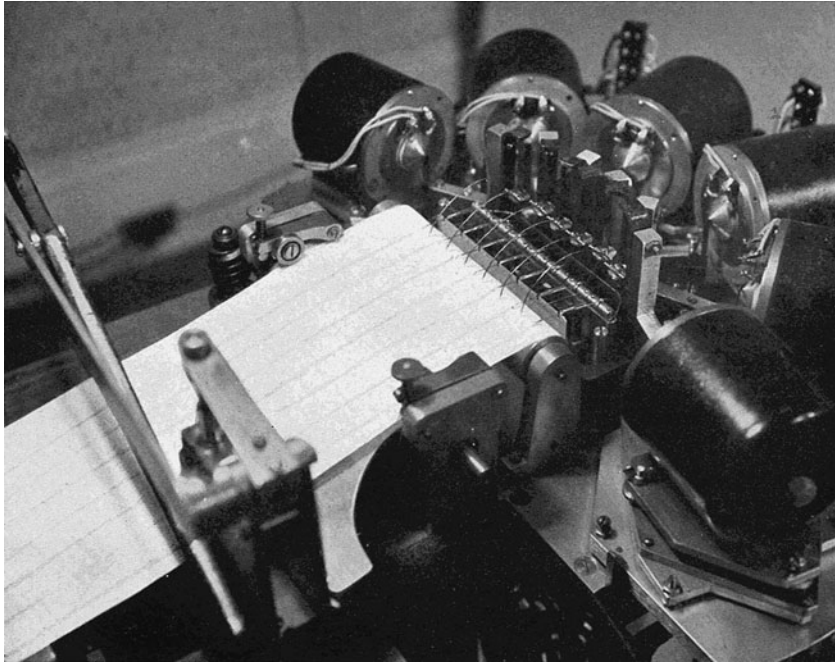


Figure 34 Alfred L. Loomis used high-precision instruments for his EEG experiments in the extravagant setting of his private estate.

initially worked on supersonic research and precision measurement. His financial circumstances allowed him not only to purchase the best and most modern instruments in the world but also to invite internationally famous physicists to give talks at extravagant science festivities in his “palace of science.”¹⁴¹

Loomis’s occupation with the EEG was the quick reaction by a curious amateur to the broad interest that the brain plots aroused in America. His interest in this topic was evidently so great that he decided to give up banking and dedicate himself entirely to scientific research.¹⁴² The electric amplifiers and registering instrumentation required for the precision measurements were already available in Tuxedo Park. Among Loomis’s

141 Alvarez 1980, p. 321. The physics Nobel laureates James Franck, Albert Einstein, Niels Bohr, and Werner Heisenberg were supposedly visitors of Tuxedo Park.

142 At the beginning of the 1930s, besides working on time-measurement problems and spectrography, Loomis also tackled physiological problems for the first time. He also designed an ultracentrifuge, for example, with which cells could be observed microscopically and photographed while being subjected to high gravitational forces. Nevertheless he had no preliminary neurophysiological knowledge. Newton Harvey came to Tuxedo Park to study ultracentrifuges.

laboratory equipment was a 2½-meter-long recording drum just over one meter wide with which it was possible to record up to four bioelectrical signals continuously for the duration of up to eight hours.¹⁴³ This machine, and presumably also the aristocratic and bucolic ambience motivated the specific question of longer-lasting EEG recordings when a few test persons were allowed to fall asleep during the ongoing process. As a consequence, in their first *Science* article Loomis and his collaborators were able not only to confirm EEG findings one more time but also to report about the extinction of alpha waves with the onset of sleep and the occurrence of typical spindle-shaped potential waves during sleep.¹⁴⁴ Another article in *Science* two months later already distinguished between three different EEG forms during sleep: alpha waves (10 Hz), sleep spindles (14 Hz for 1–1½ s), and irregular brain activity with slow delta waves (2–5 Hz).¹⁴⁵

This one idea of registering the EEG during sleep seems to have already exhausted the field of EEG research for the scientists at Tuxedo Park.¹⁴⁶ Work was conducted on the EEG in Tuxedo Park only between 1935 and 1939. Thereafter a new topic infatuated Loomis. He organized funding for the cyclotron at Berkeley for Ernst Lawrence and in the following year began his career as administrator of American radar research and co-organizer of the Manhattan Project. The EEG was only temporarily an object suitable for proving Loomis's originality—but during this time the effective staging of cerebral currents at this location, where daily appearance in a dress coat at dinner time was obligatory, allowed the EEG to shine in the fantastic brilliance of that laboratory with its “science parties.” In November 1935, the EEG was on the agenda for one of those legendary weekends, and Gregg, Jasper, and the Davis couple joined Loomis's guests there. Perhaps it was on

143 The pens moved gradually from right to left as the drum rotated; that way, the full derivation of 800 meters total length fit on one large scroll of paper. There is a photograph of this recording drum in *Science News Letter* 27: 397, from 22 June 1936. Other extravagances also formed a part of the laboratory installations, such as a photoelectric bed-movement monitor; simultaneous registering of respiration, pulse, muscular action potentials; and a noise recorder. See Loomis, Harvey, and Hobart 1935a.

144 Loomis, Harvey, and Hobart 1935a. They additionally observed that sensory stimuli during sleep could occasionally even trigger alpha waves in the EEG, which they usually blocked with a waking subject.

145 Loomis, Harvey, and Hobart 1935b and 1937. Thus, in principle the later division into five phases was already preset, because afterwards only the transitional zones had to be added as phases of their own. See the modern accounts on the sleep-EEG, such as, Tononi and Cirelli 1999, or Kenton Kroker's analysis of the sleep EEG research (Kroker 2000).

146 Apart from one more *Science* article, in which they showed that according to their EEG criteria, the hypnotic state was not a form of sleep but a special state of relaxation because it was correlated with an EEG of pure alpha waves, all the subsequent research produced in this laboratory merely offered more detailed descriptions, differentiations, and orderings than in the existing literature. This was even though Loomis cooperated from 1937 on with Hallowell and Pauline Davis from the Harvard Physiology Laboratory; Loomis, Harvey, and Hobart 1936a, 1936b, H. Davis, P. Davis, Harvey, and Hobart 1937.

this occasion that Newton Harvey from Princeton brought Albert Einstein along to have his EEG registered:

They put him to sleep, and at first he showed the typical slow waves of sleep. Then the EEG changed to the rapid waves of arousal. He awoke suddenly, asking for a telephone. He called his laboratories in Princeton to tell his colleagues there that he had been reviewing his calculations of the day before and discovered an error which should be corrected. This done, he was able to go back to sleep again.¹⁴⁷

The two first American EEG papers, by Jasper and Loomis, document exemplarily the brilliance and poverty of this research: As long as electroencephalography was merely used as a method for the inscription of brainwaves, impressive curves could be rapidly and easily produced—at least up to the state of the engineering art in America. As soon as these curves were used to address neurophysiological or psychophysiological issues, however, one got lost in a thicket of unsolved questions and problems to which the EEG itself left no traces toward their clarification. The closer the microstructures of those curves were analyzed, the more the link shifted away from neurophysiological knowledge spaces.

In Cambridge, Massachusetts, electroencephalography initially was situated in a similar neurophysiological context as in Cambridge, England; but then it chose an entirely different path because there the bridge was cast to the clinic. Patients produced unexpected findings for the EEG and thereby secured an application for the technique independent of all those unclarified questions in physiology. As in Adrian's laboratory, in that of his colleague Forbes at Harvard, questions about the makeup of cortical potentials gradually became the center of attention. There Hallowell Davis and his team had been working since 1930 on the electrophysiology of the inner ear and auditory nerve, to get to the bottom of spectacular observations made by Glenn Wever and Charles Bray. Supposedly using a simple telephone apparatus they had managed to convert impulses from the auditory nerve back into coherent sound signals.¹⁴⁸ This finding threatened to throw out the theory of a uniform coding in the nervous system, because the auditory nerve seemed not to be emitting a digital neural code but plain analog sound waves per action potential. For that the cells in the auditory nerve had to be able to send signals on a frequency scale between a few perceptible hertz and still audible ones of many tens of thousands of hertz. But all the known neurons could only generate signals of frequencies up to a maximum of 1000Hz.¹⁴⁹

147 Jasper 1996, p. 329.

148 Wever and Bray 1930. Besides Davis, Forbes himself had also been working on cortical potentials during the mid-1930s; see Derbyshire, Rempel, Forbes, and Lambert 1936; Forbes, Renshaw, and Rempel 1937.

149 As had been the case with Rachel Matthews and Buytendijk, the research problem in Adrian's laboratory again lay exactly at the intersection between peripheral and central

Davis began in 1930 to monitor systematically the action potentials from the ear through the auditory nerve up to the cerebral cortex.¹⁵⁰ It is conceivable that Davis and his collaborators on these experiments with cats already noticed those slow rhythmic potential waves that Pauline Davis later claimed as the first American observation of an EEG.¹⁵¹ At the same time, such observations lay far away from the problem at hand of coding tones of many 1000 Hz; they remained unpublished and were evidently not pursued further either. Instead, Davis had a special amplifier arrangement with a cathode-ray oscilloscope constructed for the examination of rapid action potentials. Although an EEG could be observed with it, there were no recordings because the luminosity of this oscilloscope was so faint that the signal traces had to be taken many times over for exposure on film.¹⁵² Presumably only in summer 1934, hence in direct connection with Adrian's EEG presentation in Atlantic City, Davis had an ink recorder constructed specifically for EEG trials. The EEG was demonstrated at Harvard Medical School by Donald Lindsley with this one-channel apparatus, as depicted on a photograph dated 5 December 1934 (Figure 35).¹⁵³

At this time another group at Harvard started to take an interest in the EEG. William Lennox at the Neurological Unit of Boston City Hospital had been intensely researching the pathophysiology of epilepsy since 1921. Lennox was mainly looking for alterations in brain circulation as a cause of seizures.¹⁵⁴ After countless animal trials, his co-workers Frederic A. Gibbs and Erna Leonhardt developed a special microcannula to measure

neurophysiology, but this time not in the form of surprisingly slow rhythms, but surprisingly rapid ones.

150 Davis and Saul 1931, Saul and Davis 1932. In these papers Davis showed that the sensory cells in the inner ear did, in fact, act in total like a microphone. But the neurons of the cerebral nerve followed the principles of the uniform slower signal coding. Thus he delivered important proof for the theory of location-bound perception of pitch (Davis, Forbes, and Derbyshire 1933).

151 Davis 1975, pp. 316f.

152 See Saul and Davis 1933, Garceau and Davis 1934. This technical difficulty was another reason why, in neurophysiology, experiments with evoked potentials were preferred (over observing spontaneous rhythms such as an EEG), because the oscillographic representation frequency could be adjusted exactly to the stimulus frequency so that the permanently repeated stimulus response would produce a standing and luminous wave on the luminescent screen.

153 Davis's engineer Garceau modified the pen module of a morse recorder of the telegraph company Western Union. It was relatively simply connectable to the amplifier available at Harvard but was not tuned to the frequency range from 1 to 20 Hz; see Davis 1975, p. 317, and O'Leary and Goldring 1976, p. 137.

154 See White 1984. Lennox had returned to Harvard from Peking in 1921, where he had been working at Peking Union Medical College with a Rockefeller Foundation grant. He particularly wanted to start working with Cobb on epilepsy research because his daughter Margaret had become epileptic. Margaret Lennox became a neurophysiologist herself and worked on epilepsy research, first under John Fulton at Yale, later with her husband Fritz Buchthal in Copenhagen.

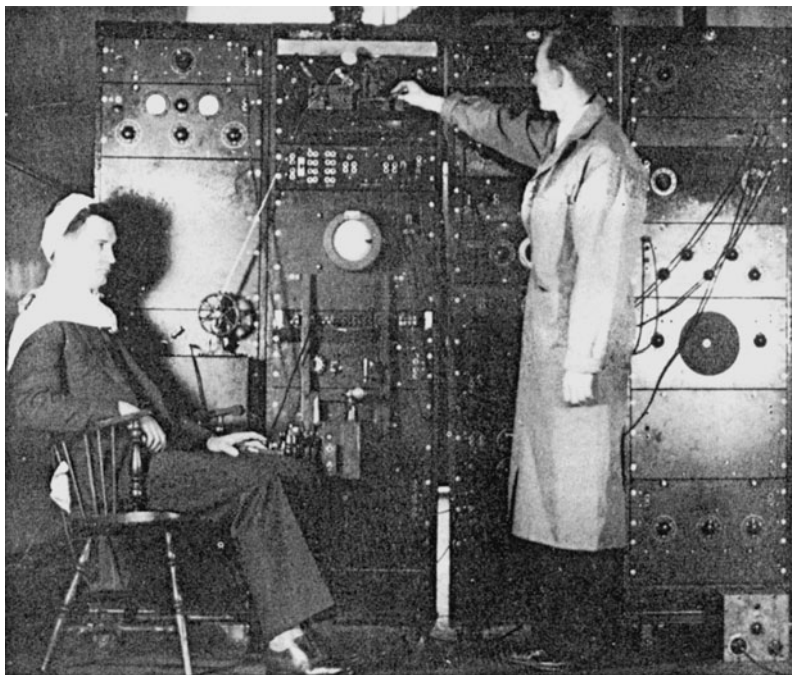


Figure 35 A. J. Derbyshire, research student of Hallowell Davis, registering an EEG of Donald B. Lindsley at Harvard, dated 12 December 1934.

thermoelectrically the blood supply to the brain directly in the cerebral artery of epileptics.¹⁵⁵ Without making any significant findings by the new method, Lennox's team eventually published the fortieth contribution to a series on "Cerebral Circulation."¹⁵⁶ The team was urgently searching for research alternatives when the news about the EEG was making the rounds. Erna Gibbs, thanks to her German origins, was additionally one of the few in America capable of reading Berger's papers.¹⁵⁷ The first experiments on the EEG were just being performed in Davis's nearby laboratory. What could have been more obvious than a cooperation? Lennox brought along his patients, Davis the EEG instrument. Based on simple methodological

155 Gibbs 1933, see F. Gibbs and E. Gibbs 1990. Frederic Gibbs had come to the Neurological Unit directly after completing his medical studies at Yale and Johns Hopkins Medical School; that was where he met his later wife Erna Leonhardt, who came from a family from Bad Homburg. Lennox reported that Erna Leonhardt had returned home to Germany in 1931 to marry a German baron whereupon Frederic Gibbs had proposed to her in a transatlantic telephone call (see RAC, RG 1.1, series 200A, box 87, folder 1043).

156 Lennox, F. Gibbs and E. Gibbs 1935.

157 See White 1984, p. 192.

considerations, EEG analysis only seemed to make sense with a specific subgroup of epileptic patients, so-called *petit mal* patients who suffered from extremely frequent, brief attacks of unconsciousness. Only with them was it possible simply to wait for the onset of a seizure during the EEG registration, and only with them was there a chance to register curves not superposed and interfered with by muscular cramping during a major epileptic fit:

Hal[lowell Davis] had all the equipment there and he told us to come on over. Bill [William Lennox] had all the patients, and Bill said the right thing to do is to get a *petit mal* patient. They can be absolutely still, no movement artifact, while having a seizure. So we hooked up two of his *petit mal* patients. The one that Bill thought would be particularly good came first, and sure enough when the patient saw the projection of her own EEG oscillations, she said, "Don't do that, it gives me a seizure every time you do it."¹⁵⁸

The prompt results of this trial must have been impressive to all those involved. Each seizure manifested itself in the curves by an unusual, very characteristic wave pattern. Synchronously with the attacks, the electroencephalograph registered so-called spike-wave complexes, a sharp peak followed by a large wave at a frequency of three per second (Figure 36). This regularity was so conspicuous that Lennox's attentive secretary, whose *petit mal* epilepsy was being documented electroencephalographically, promptly perceived her seizures as machine-controlled.¹⁵⁹

Unlike in Jasper's case, the rapid initial success at Harvard immediately led to an entirely new perspective on the EEG as an instrument of clinical diagnostics. Without even touching the range of difficult questions on how the observed waves arose in the brain, the Harvard scientists immediately hit upon new path-breaking findings from their epileptic patients. The formulation in the first publication about EEGs by Frederic Gibbs, Davis, and Lennox in December 1935 was correspondingly provocative: "The method is exceedingly simple."¹⁶⁰ This declaration at the end of 1935 must have jarred Jasper, as he was just maneuvering his experimental system, charged full of ideas from his European trip, into crisis. He was in regular contact with his colleagues at Harvard and evidently could not believe that they had not seen his difficulties at all. When, six weeks after the appearance of

158 Gibbs and Gibbs 1990, p. 179. See also the descriptions of this episode from Davis 1975, p. 318, and White 1984, p. 192. Frederic Gibbs was already involved with Davis's EEG experiments in November 1934, and in December the first experiments with patients took place. This is gathered from a letter by Abraham Myerson to Alan Gregg dated 26 November 1934, RAC, RG 1.1, series 200A, box 72, folder 872.

159 This experiment revolutionized research on epilepsy; see the next chapter.

160 Gibbs, Davis, and Lennox 1935, p. 1134.

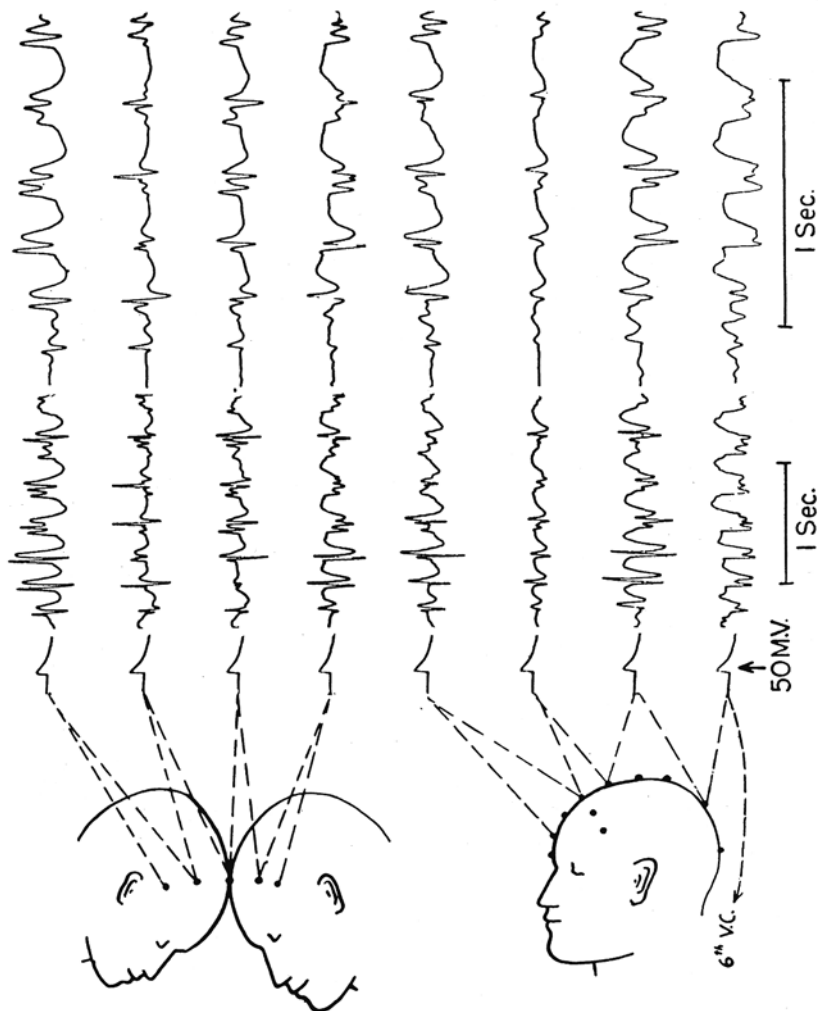


Figure 36 Illustration of a typical curve pattern for a *petit mal* seizure in the electroencephalography textbook by Robert Schwab from 1951.

the paper from Harvard, the Boston Society of Psychiatry and Neurology met, he used this opportunity to refer to that statement by his fellow professionals:

Since the recent statement of Gibbs, Davis and Lennox that the method of electroencephalography is exceedingly simple [. . .], I believe that it is important to point out that the method is actually exceedingly complicated and that even the most experienced electrophysiologist cannot always at present distinguish between the potentials of the brain

and those of extracranial origin. [. . .] In fact, I have been able to simulate closely both the form and the frequency of the seizure waves in epilepsy described by [. . .] Gibbs, Davis and Lennox. This was done merely by imitating the rhythmic clonic movements associated with some *petit mal* seizures.¹⁶¹

By training rhythmically jerking movements of his eyes, ears, and the muscles of facial expression, Jasper managed to simulate a *petit mal* EEG perfectly. Davis and Gibbs were forced to concede that their graphs, produced with the ink recorder constructed by Garceau, were not of the same technical quality as Jasper's photographic registrations.¹⁶² That, however, was completely unimportant for their work on the EEG, because they had pioneering findings to show for it. After those successful EEG experiments with epilepsy patients, the two teams at Harvard Medical School went their separate ways again.¹⁶³ In 1935 Gibbs set up his own EEG laboratory at Boston City Hospital and from then on the Neurological Unit concentrated on EEG examinations and became the seed of EEG research on epilepsy worldwide. Meanwhile research at the Physiological Laboratory shifted the EEG to healthy test persons.

161 Jasper 1936a, pp. 1131f. The subsequent discussion (pp. 1133f.), in which Davis politely allowed Jasper to finish in silence and Gibbs accused him of intentional dissimulation, is a short lesson on the context-dependence of scientific observations, as Jasper's critique was, in principle, not so easily dismissed, either. Soon after this appearance, Lennox characterized Jasper in a report to the Rockefeller Foundation as follows (RAC, RG 1.1, series 200A, box 86, folder 1039): "He suffers from isolation which is due in part to geography, but in larger part to his peculiar temperament. He apparently believes that his own position will be enhanced by public disparagement of the work of others."

162 There are some indications that problems with the ink recorder were at least partially responsible for the long delay with this first EEG publication from Harvard. In June 1935 Frederic Gibbs contacted the electronics engineer Albert Grass. Directly afterwards during their Europe trip the Gibbs couple became acquainted with Tönnies at the KWI for Brain Research in Buch near Berlin, who gave them design drawings of the neurograph. Grass had already finished building his first electroencephalograph in May 1936 to the point that it could be demonstrated publicly. By 1938 Grass had developed an EEG apparatus with four EEG channels that he was already manufacturing in numbers together with his wife and brother. It appeared on the market as Grass Modell II. Over a hundred were produced and it demarcated the standard registration technology until the end of World War II. On Albert Grass, see Henry 1992; on the history of the production of Grass devices, see Gibbs and Gibbs 1990, O'Leary and Goldring 1976.

163 In a review from 1938 Davis added a section on "The electroencephalogram in epileptic seizures" by Gibbs (in Davis 1938b, pp. 128–130); and in 1941 they jointly published another study on the effects of alcohol on EEG findings (Davis, Gibbs, Davis, Jetter, and Trowbridge 1941).

The matrix of the waves

The EEG was somewhat tardily received in the USA, but the new technology found a much more receptive environment there compared to Europe, and within an extremely short period the EEG evolved into one of the most important topics of science. In 1937 the USA already clearly dominated the field of EEG research, as regards the number of research laboratories and publications as well as with respect to the prospects of innovative research. One reason for this rapid spread of the EEG as a research method in the USA was surely better technical facilities. In Europe only a few specialized laboratories had access to the requisite registration devices and even firms as specialized as Siemens & Halske had to invest many months on new designs. In the USA, there was evidently no shortage of parts or suitably trained electrotechnicians to assemble them into highly sensitive yet robust measurement instruments. The subsequent rapid reception and innovative resonance that the EEG experienced in the USA thus raises the question of whether this would manifest any particular “national style.”¹⁶⁴ The EEG seems to confirm one more time that cliché of pioneer-country America specifically nurturing technical ideas. Without borrowing any collective construct of national mentality, one can nevertheless itemize some framing conditions that influenced the EEG’s career in the USA: Advanced industrialization, better economic resources, and especially the greatly superior radio technology afforded electroencephalography more favorable conditions overall. Furthermore, in America the still young discipline of neurology betted on the new procedure earlier than elsewhere to establish its own independence by applying a special diagnostic method. In addition, the directed promotion of science in the USA, in connection with an evidently more flexible organization of science, promoted interdisciplinary cooperations for prompt and efficient explorations of new fields of research.

This glance at the American projects shows, at the same time, the limits of the concept of a national style in EEG research. The epistemological space of brainwaves gained its contours less by national differences than by very localized research cultures. The examination of epileptic disorders with the EEG by Lennox and by Frederic and Erna Gibbs; Loomis’s demonstration of an EEG under changing states of consciousness; or Jasper’s quest for the biophysics of cerebral electric currents: These inquiries by the most important EEG research teams pointed in diverse new directions. Together with Berger’s psychophysiology, the cytoarchitectonics at Buch, and Adrian’s neurophysiology of cortical potentials, therefore, in 1936 at least six possible developmental directions were available for the EEG, all of them with still vague prospects for the future, but the initial direction of each being directly tied to the local research culture involved. Compared to the USA, by

164 See Harwood 1987, Reingold 1991, Geison and Holmes 1993.

the mid-1930s Europe only had a few laboratories active in this new area. Berger continued to work largely in isolation; Kornmüller was the sole EEG researcher left at Buch in 1935; and Adrian soon moved away from the EEG to other things. It seems that interest in the new method spread in Europe only circuitously via the EEG boom in the USA. During the second half of the 1930s, EEG laboratories appeared in France, Belgium, Holland, Austria, Italy, and the Soviet Union.¹⁶⁵

A conceptual and technical openness of a scientific field at the beginning of its development is surely ascertainable in many cases in the history of science. But the early history of electroencephalography does not exhaust itself in such a typical collection of hardly secure initial observations out of which a new discipline would gradually form. The EEG was positioned at an intersection between very different discourses and research practices. Neurophysiological exploration of the activity of individual nerve cells was just as much a part of it as were histological analysis of brain fine structure; classification of psychiatric and neurological clinical pictures; differentiation of normal and healthy responses by the brain from pathological ones; psychophysiological characterization of attentiveness, intellectual work, and emotions; classification of personality traits; or physiological studies on the working mind. In this border region between physiology, psychology, neurology, and psychiatry, cerebral currents offered divergent points of departure before it became possible, at all, for what an EEG showed to take shape.

165 In Paris in proximity of Lapique's center for neurophysiological research, an EEG research team formed that included Alfred Fessard, Jean Delay, and Ivan Bertrand (Durup and Fessard 1936, Bertrand, Delay, and Guillaín 1939). An EEG laboratory was furnished at the *Salpêtrière* already in 1937 and an EEG apparatus was additionally set up for the international exposition in the *Palais de la Découverte* (Albe-Fessard 1996). In Belgium, Frederic Bremer and Leon Ectors worked on cortical potentials, and Frederick Lemere on the EEG; and in Holland there was L.J. Koopman (Bremer 1938, Ectors 1935, Lemere 1936, 1937; Koopman and Hoelandt 1936). In Austria, the young psychologist Hubert Rohrer was interested in Berger's EEG as early as 1933. In Milan, Mario Gozzano started to conduct animal trials, with which he had acquainted himself during his stay at the physiology department in Buch near Berlin, from whence the daughter KWI institute in Moscow had gathered its inspiration. In this international comparison the faint reception in England is most surprising, despite Adrian and even though the method was presented internationally at the Second International Congress of Neurology. Dennis Williams only started clinical electroencephalography in 1936 in National Hospital at Queen Square, with a Grass EEG device taken along from Boston (Cobb 1981). This lack of interest among British clinicians may have been due to their abstinence from technical matters (Lawrence 1985, Porter 1996).

5 Set to and survey much!

On the cultural practice of a new technology

At the beginning of the 1950s a young graduate of the Parisian *École normale supérieure*—with an interest vacillating between philosophy and psychology, but evidently insufficiently challenged intellectually by a tutorship at the *École* and an assistantship in the Institute of Philosophy at the University of Lille—engaged his personal contacts to acquaint himself with the daily routine and research in psychiatry. For a period of time, under Jacqueline and Georges Verdeaux, he was an auditor in the EEG section at the neuro-psychiatric *Hôpital Sainte-Anne* in Paris, where he himself had once been a patient, while a student, for a depressive condition. As a control test subject, he became, literally, a participatory observer of their studies and also accompanied them during their EEG analyses in the centralized French examination station for medical psychological evaluations of prisoners in Fresnes. This overlap between the two EEG-application sites manifested a nexus of therapeutical and disciplinary practice that would repeatedly occupy the intellectual as an overlap of knowledge and power. Although Michel Foucault did not make any decided statement about his experiences in EEG research, they coincide more than merely by chance with his first book *Maladie mentale et personnalité*. There, in 1954, he formulated a challenging epistemological perspective on the development of psychology:

One must not forget that “objective” or “positive” or “scientific” psychology had found its historical origin and its basis in pathological experience. [. . .] The human being became a psychologizable species only ever since its relationship toward insanity first made psychology possible, i.e., since its relationship toward insanity was defined, externally by exclusion and punishment, and internally by arrangement within morality and by guilt.¹

1 Translated here from the German *Psychologie und Geisteskrankheiten*, Foucault 1968, p. 113. For the biographical background on Michel Foucault’s clinical employment and the context in which he wrote this work, see Eribon 1989, pp. 85–88, and Macey 1993, pp. 47–59.

Written here with the goal of putting madness back into its rightful place so as to liberate it from the distortions of moral or scientific pathologizations, Foucault is known to have taken an even more radical view afterwards in the form of a fundamental critique of rationality. He analyzed the exclusion mechanisms at the social margins of society as the conditions for the constituting of the modern human sciences and the types of rationality connected with them.

This thesis on the operational mode of scientific discourse can easily be referred back to Foucault's observations in the neuropsychiatric EEG laboratory, to the phase of the establishment and standardization of electroencephalography. For, the tuning of knowledge in electroencephalography, which was shaping itself into a discipline, went unavoidably along with a perfecting of exclusion and monitoring techniques from the new techniques of cerebral-electric diagnosis. The registration and assessment of brainwaves produced new classificatory practices with respect to the various social groups, such as children, women, the insane, epileptics, geniuses, or the simple-minded. The disciplinary effect of quantifying procedures in the life sciences has meanwhile seeped away as a topos of biopolitics.² Such a big-picture description of the overlap between knowledge and control runs the risk of itself becoming "the blind spot, from which the things around us are arranged, the way we now see them."³ Against a one-sided history of science geared to the disciplinary effects, recall Foucault's talk of the "historical a priori," by which he describes the irreducibility of historical conditions of a discourse as a "space of manifold bifurcations, many different opposites" that do not end in a "smooth and continuous text."⁴ Among the bifurcations in the space of electroencephalography are the unsimultaneities in its development and establishment in various local or national contexts, just as much as the multifarious contradictory findings and competing inscription strategies. The disparate research strategies from the early years of research on cerebral electricity were standardized during the process of establishing electroencephalography but, at the same time, this process generated new open research questions and more examination techniques that could not be entered seamlessly into the register of techniques for medicalization or disciplinarization. A cultural history of electroencephalography becomes a detector of the multiple strata of these researches, if it compiles that biopolitics of the establishing EEG in the sense of Foucault's archeological procedure, without pre-emptorily drafting a panoptic panorama of perfected brain diagnostics.

2 On the term "biopolitics," see, above all, Foucault 1983, pp. 166–183; as an example from its reception history, Jones and Porter 1994.

3 Translated from Foucault 1981, p. 287.

4 Foucault 1981, p. 222.

Dynamics of standardization

With the surprising registration of a distinct curve pattern from *petit mal* patients at the end of 1934, electroencephalography demonstrated its usefulness in clinical diagnostics, which was to develop into the most important area of diagnostic application of the EEG to the present day. By this method, phenomena could be recorded that only occurred with epilepsy sufferers during a seizure and partly also during the interval between seizures, which made it possible to distinguish this disease from others. Consequently, it is hardly surprising that the analysis of epileptic patients quickly advanced to become one of the most important areas of EEG research. Electroencephalography became a Latourian “obligatory passage point” for the diagnosis and classification of epileptic disorders; and the pioneers of the epilepsy EEG advanced, at the same time, into a new field as experts.⁵

The introduction of electroencephalography into the clinical area of epilepsies signified much more than mere improvement of their diagnoses. The clinical picture of epilepsy and its various forms was reconceptualized around cerebral currents and curve findings.⁶ At the beginning of the twentieth century, “epilepsy” was largely considered a social stigma. The “sacred disease” of the *Corpus hippocraticum* had turned into a clinical picture of biological and moral degeneration, in spite of its neurologization at the close of the nineteenth century.⁷ At the center of this sickness model was the malicious characterization of the disturbed personality of an epileptic, paradigmatically described in the opening article of *Epilepsia*:

It is known that the civil sphere can be seized while the actual intellectual sphere may seem to be intact, and this leads to a lessening of the individual’s resilience at all moments of excitement; therefore the brutal impulsive acts, which lead to conflict with society. There is accordingly a constitutional epileptic condition that pursuant to Ziehen occurs in 80% of the cases. A large proportion of these individuals is incapable of conforming to the social milieu and cannot be intimidated by the punishments threatened by law. It must hence be admitted that the trustworthiness of these constitutionally abnormal cases is reduced. The consequence of this

5 Latour 1987, p. 132.

6 When Owsei Temkin published his great history of epilepsy in Western civilization in 1945, the changes due to the new research on electrophysiology were already so clearly perceptible that Temkin decided to end his history with an account of the neurologization of the epilepsy concept by J. Hughlings Jackson and J. M. Charcot at the close of the nineteenth century. When a second edition appeared over twenty-five years later, Temkin (1971) revised and expanded the manuscript considerably but notably retained this periodization. *The Falling Sickness*, whose cultural history Temkin had written, had become a closed chapter in the intervening time. With and by means of the EEG, epilepsy had become a new disease.

7 See Dwyer 1992 and Porter 1995.

reduced trustworthiness thus cannot be an alleviation of the punishment, which would be illogical and would only encourage the viciousness of such abnormal, antisocial troublemakers, but rather an essential alteration of the measures to be taken. These anomalies accordingly belong neither in jail nor in the madhouse but in a special security asylum.⁸

Based on EEG findings, on the contrary, the disease was reconceived as an electrical disorder in the functioning of the brain. The electroencephalographic description of epileptic seizures marks an epistemic break that had consequences not just for the concept of epilepsy and its social handling. It became a success model of a neuropsychiatry in search of supposedly objective, biological parameters for psychic disorders.

The clinical diagnostical evaluation of EEG plots in epilepsy research also reflected back on electroencephalography as a science. The success in seizure diagnostics made obvious the usefulness of a descriptively correlative interpretation of the EEG curve. The unexplained physiology of the EEG could simply be passed over. Open debate about the neuronal mechanisms was replaced by the classification of divergent curve patterns and their attributions to particular clinical pictures. Basing themselves on the model of epilepsy classification by EEG findings, numerous studies claimed EEG depictions of specific psychiatric pathologies as legitimate, citing allegedly specific curves. These filled the spectrum, ranging from the major psychotic clinical pictures to ontologizations of social deviance as a biological defect. With epilepsy diagnostics serving as a model, electroencephalographic findings were reshaped into independent criteria of exclusion of social deviance, which is clearly manifest in studies on applications in social psychiatry, pedagogy, and jurisprudence. The “seizure EEG” is thus an example of how the possible uses of a new scientific technique can modify discourses.

The leading psychiatric textbooks of the 1920s essentially agreed in their characterizations of epilepsy. But not one of them is likely to offer as impressive a description as Freud’s short study on Dostoyevsky from 1928:

It is superfluous to repeat here the whole pathology of epilepsy, which does not yield anything decisive, but one can say this: The old *morbus sacer* [sacred possession] still stands out as a seemingly clinical unity, that uncanny illness with its unpredictable, apparently unprovoked seizures, with the character change into irascibility and aggressiveness, and the progressive diminution of all intellectual capabilities. But all the edges of this picture fray into uncertainty. The seizures, which can occur brutally, with biting of the tongue and emptying of the bladder, culminating in the life-threatening status epilepticus that causes severe self-injury, can moderate into brief absence seizures, to mere rapidly

8 Raymond and Sérieux 1909, pp. 28f.

passing dizzy conditions; they can be replaced by brief periods during which the sufferer does something outlandish to him, as if under the command of the subconscious. Otherwise in an incomprehensible way purely corporeally determined, the seizures can have a purely mental influence (scare) to thank for their occurrence or can continue to react to mental agitations.⁹

Ten years later the world was not the same anymore, because the EEG curves had turned epilepsy into something else. Frederic and Erna Gibbs and William Lennox deemed the number and explanatory force of their EEG findings large enough to declare 2,000 years of epilepsy history as closed and to introduce a new clinical picture in its place, “paroxysmal cerebral dysrhythmia”:

Diseases change their names with increase, not of age (like Chinese children), but with increase of medical knowledge. [. . .] However, some diseases never have outgrown their baby names. For example, ever since the days of Hippocrates, recurring and sudden loss of consciousness and of muscle control has been called “the falling sickness” or (in Greek) a seizure, “epilepsy.” Thanks to the pioneer work of Berger in developing the electro-encephalograph, we can now make good the lack of thousands of years and adopt for this condition a name based on the underlying pathological physiology. We now know that epilepsy is due to the development of abnormal rhythms in the cerebral cortex; it is a *paroxysmal cerebral dysrhythmia*. This discovery places the study and understanding of epilepsy on a different and deeper level and requires a reorientation of our thinking.¹⁰

Epilepsy has remained the name in use until now, but Lennox and the Gibbses did substantially carry their point: The electrical disorders recorded by means of EEG plots became the core of the disease, behind which the psychiatric description of the abnormal or psychopathic personality gradually receded.¹¹

This neurobiologization of a psychiatric clinical picture would surely not have been so easily possible without the conspicuous EEG findings. This new diagnostic method yielded no instructions about how to functionalize the findings made by it though. The cultural constellation of neuropsychiatric

9 Freud 1999b, pp. 402f.

10 Gibbs, Gibbs, and Lennox 1937, p. 377.

11 Lennox already made this argument in 1937 (p. 24): “The great majority of epileptics are normal except for comparatively short periods of time. Therefore, (unlike persons with other nervous or mental disorders) epileptics can be an economic asset. The majority of patients (and the great majority of those who have received proper medical and social treatment) do not deteriorate mentally.”

research in the USA generated the dynamics for this epistemic break. At the end of the 1930s, massive efforts were made there to revolutionize neurology and psychiatry by scientific research methods.¹² Lennox's development of epilepsy research at Harvard allows this process to be reconstructed from the perspective of this leading laboratory.¹³ His laboratory was the only research team in America that was continuously and exclusively dedicated to this topic since 1921. After those years of futile research on a vascular genesis of epileptic seizures, Lennox gained a sudden decisive advantage with the registration of seizure-specific EEGs, which he immediately capitalized on. Lennox himself once described as his "invasion force" the inquiries that from then on would issue from his laboratory in large numbers and revolutionized epileptology.¹⁴ Lennox was working on the production of science not just as a military strategist. He was leading the battle against what in his opinion were antiquated and inhumane conceptions, on two different stages at once, and thus maximized his success. In short, he corresponded to Bruno Latour's portrait of the scientist as a "wild capitalist."¹⁵

Lennox's scientific success, the drastic reorientation of his research, and his numerous activities are describable by Latour's capitalization thesis as an intermeshing frame that locks together the apparently apposite roles as researcher, fundraiser, investigator, science organizer, etc. Like Latour's interview partner, Lennox himself also reflected on his research in economic terms: "As with the use of 'venture capital' in industry, money may be expended without any important return. [. . .] Such accounting is difficult, yet in the case of this epilepsy venture, certain rough samplings of costs and profits can be made."¹⁶

12 See Jack Pressman's analysis of the new orientation of neuropsychiatric research in the USA 1921–1935 (1998a, pp. 18–46). In continuation of Pressman, Ellen Dwyer (2000) noted the beginnings of a biologization and physiologization of epilepsy research already during the 1920s. It is paradigmatically formulated in a fundamental paper by Lennox and Cobb from 1928, which only discusses the psychiatric and psychodynamical aspects on the side. Even if the ground for a neurologization of epilepsies was already prepared, the EEG still delivered the decisive new findings to allow this project to rapidly gain the upper hand.

13 Among the 238 EEG papers on epilepsy listed in the bibliography by Brazier (1950), forty-three originate from Lennox's team alone.

14 Lennox to Gregg dated 31 August 1942, RAC, RG 1.1, series 200A, box 87, folder 1043.

15 Latour 1996. Because Lennox hardly fits into a psychologizing reading of Latour's scheme of the purposeful and ambitious researcher, his career illustrates the structural identities of economic as well as academic profit-making. The alteration in his course of study, a period as missionary physician in China, his daughter becoming epileptic, and the thus motivated return to America: all these show that his course in life was certainly just as much influenced by contingent events as by strategic planning. Thus Lennox is at the same time an example of the limitations of Latour's description: The range of sciences might well still be offering "enthusiasts" (among whom Latour explicitly counts himself) more spheres of activity and opportunities for recognition possibilities than the current increasingly globalized economy.

16 Lennox: Report on the Department of Neurology, Division of Epilepsy [1949], in: RAC, RG 1.1, series 200A, box 87, folder 1046. See also Lennox 1941, pp. 188–190. Lennox's

Lennox reorganized the epilepsy research as a businessman with a research team of his own. His assistant Gibbs banked his career entirely on the new method of electroencephalography; and by admitting Albert Grass, an engineer, to the group, Lennox's slim temporal advantage could be transformed into a lasting technical advantage with more and more perfect recording instruments. After the first promising findings were made in 1935, all the research conducted by the group was promptly subordinated under the EEG. First the group secured national and international attention by carefully placed talks, such as at the International Congresses of Neurology in London and of Physiology in the Soviet Union in 1935,¹⁷ at the annual meeting of the American Medical Association in Kansas City in 1936, or else by offering a public demonstration of the EEG during the tercentennial celebrations of Harvard University and, in 1937, a day-long session at the annual meeting of the American Psychiatric Association in Pittsburgh. On the occasion of the neurologists' congress in London, Lennox revitalized the International League against Epilepsy that had been dissolved in the interim and let himself be elected its president. At the Kansas City meeting, he organized the founding convention of an American branch of this League, likewise assuming its chair.¹⁸ Within a matter of a few years Lennox had succeeded in creating a national and international network for epilepsy research, centered on his person.

In addition, Lennox launched epilepsy research as a new area of funding by the Rockefeller Foundation in 1936; by 1937 Lennox's research team was financed almost entirely by the Foundation.¹⁹ In February 1936, he was still complaining that in the USA 12 million dollars were being spent on the upkeep of epileptics in homes but at most 25,000 dollars on epilepsy research. From 1 July 1937 on he alone received 17,500 dollars annually from the

comparison with "venture capital" was anything but coincidental. His father William Lennox (1850–1936) had made money from "mining investments" in the Cripple Creek District and created the preconditions for a career as a "philanthropist."

17 These two international conventions, together with the International Congress of Psychology in Paris in 1937, formed the highpoint of interest in the EEG, albeit the London convention left room for the EEG rather by chance because the topic of epilepsies had already been set beforehand in honor of Hughlings Jackson's life's work. About 700 brain researchers from around the world met in London; 1,500 physiologists attended in Moscow.

18 See Goletiani 1994.

19 The Rockefeller Foundation had already funded Lennox's China sojourn and for a time also the Neuropathological Unit at Boston City Hospital. But only from 1936 on does Lennox appear as an applicant in the Rockefeller Foundation files. 1936/37 he applied for travel funding to visit all research institutions for epilepsy and many homes for epileptics in the USA. With this fact-finding trip he not only opened personal relations with all the relevant researchers or energetically advertised the League as a crucial network, but also positioned himself as the leading expert, foremost at the Foundation. Lennox ultimately became one of the rare few to receive support from the Rockefeller Foundation all the way up to his retirement, even though according to the program only initial funding was supposed to be granted. Lennox, together with Walter B. Cannon, had long since become the "ideal recipient these many years" for Alan Gregg. See RAC, RG 1.1, series 200A, box 87, folder 1046.

Foundation, which certified him as “probably the world’s leading investigator in this field.”²⁰ Up to the outbreak of World War II, Lennox had positioned his epilepsy research so centrally that he could continue to build upon it systematically under wartime conditions and obtain additional funding. Twelve to fifteen persons were employed at the expense of the Works Project Association (WPA, a support program for the unemployed) just for electro-mechanical data processing of EEG results. Lennox’s own team, including his secretary, counted only nine persons. After World War II, Lennox was able to increase his research grant one more time to 115,000 dollars annually, despite his advanced age and despite the departure of the Gibbs couple for Chicago, because the Veterans Administration established a special epilepsy center at Cushing Hospital, with Lennox acting as consultant even as emeritus.²¹ In 1951, finally, Lennox and Gibbs gained great symbolic capital when they were conferred the Albert Lasker Award for Clinical Research.

In his campaign against epilepsy, “our common enemy,”²² Lennox orchestrated private funding and public agencies to inform the public at large about this illness, its causes, and new treatment methods. In 1939 he founded the “Laymen’s League against Epilepsy” specifically for raising funds for epilepsy research. His social engagement was no less active than his scientific research; in both he remained the medical missionary who had been in China.²³ In 1941 he addressed the general public in a book about epilepsy. It celebrated the triumph of scientific and technical progress:

The unknown is most dreaded. A flash of lightning used to be an instrument of destruction hurled by an angry god. Now under the name of electricity it operates our carpet sweepers and telephones. A convulsive seizure is but the visible evidence of an electrical storm within the brain. [. . .] The fundamental disorder of epilepsy—written in ink for every layman to read—is a disturbance in the rate of pulsation of the electrical waves of the brain. [. . .] A convulsion is no more supernatural than a poor telephone connection or than fire from “spontaneous” combustion. The solution of the problem of epilepsy, like the development of the

20 “5/21/37, resolved RF 37060,” RAC, RG 1.1, series 200A, box 86, folder 1039.

21 Lennox to Gregg dated 27 November 1948 and Lennox: Report on the Department of Neurology, Division of Epilepsy [1949], in: RAC, RG 1.1, series 200A, box 87, folders 1045 and 1046. He also launched a legislative proposal to create a national fund for epilepsy research in the amount of 200,000 dollars, but it fell through in a wrangle over competence with the Public Health Service.

22 “Message from the president,” inaugural article of the new periodical *Epilepsia* 1937.

23 This was how Lennox viewed himself as well: “A former medical missionary, lacks aggressiveness and has probably been too content to carry on research as a continuation of missionary work, on basis largely voluntary and with little thought for academic advancement” (Lennox: “Notes concerning men and clinics able to contribute to a study of epilepsy,” RAC, RG 1.1, series 200A, box 86, folder 1039).



Figure 37 Peter Paul Rubens's "Miracle of Saint Ignatius of Loyola" healing the possessed, used by Lennox as the frontispiece to his educational book about epilepsy from 1941.

telegraph and television, of Nylon stockings and of synthetic rubber tires, depends on research-minded men and on money.²⁴

24 Lennox 1941, p. 8. A list from 1942 comprised twenty-six "educational articles." See RAC, RG 1.1, series 200A, box 87, folder 1043. Later the talks, articles, and books were followed by radio broadcasted presentations and interviews as well as a film about epilepsy, for which Lennox provided the script; see "Annual Report of the Seizure Unit of the Children's Medical Center" [1950], RAC, RG 1.1, series 200A, box 87, folder 1046.

This literally fantastic science journalism, in which radio-tube amplifiers and registering apparatus did away with demonic concepts of epilepsy, was, according to Lennox's own categorization, a firm component of the "occupation forces of areas of new knowledge"—as opposed to the "invasion force" of research. Such passages underscore once again the close interweaving of science, technology, enlightenment, and the spirit of the times.

Lennox's campaign became successful mainly by sheer luck. Within the context of cooperation with the pharmaceutical industry, his team tested a series of new substances that had been developed as hypnotics but had presented no corresponding effectiveness spectrum. By chance, one of the first of these substances that they tested, Diphenylhydantoin (Dilantin), proved to be an effective anti-epileptic drug.²⁵ Its clinical trial in 1937 and subsequent introduction onto the market signified the most important therapeutic innovation since the introduction of Phenobarbital into epilepsy therapy in 1912. Over 1,000 other substances were tested, but only very few exhibited any anti-epileptic potential, and most of those were very toxic as well.

The biopolitical dimension of this concerted action manifested itself in Lennox's EEG investigations primarily in the boundlessness with which he engaged himself for what he simply held to be scientific enlightenment. In the name of a good cause he saw no limits. All the same, the totalizing expansion of EEG diagnostics did not follow any preconceived plan. It emerged more or less haphazardly when pathological EEG patterns were discovered for the father and a sibling of an epileptic boy. Relatives of an epileptic patient, who had entered Lennox's laboratory as entirely healthy individuals, left it with a pathological finding, which motivated Lennox to include groups without complaints or symptoms into his analyses (Figure 38).²⁶ As a first step, Lennox sent out special questionnaires to his colleagues in the field, to gather information about the relatives of a total of 2,000 epilepsy patients. The enormous amounts of data that this project generated could not be analyzed manually anymore. They were transferred by temporary workers that Lennox had employed with WPA funds onto punch cards and electro-mechanically evaluated.²⁷ A high rate of conspicuous or pathological EEG findings within this group of apparently healthy family members then successively prompted a cascade of measures: Now not only epilepsy patients were to be controlled but all people with a family member suffering from epilepsy. Consequently, Lennox, who had long presumed that epilepsy was hereditary and then saw confirmation in the new statistical data, demanded medical marriage counseling and stringent eugenic measures up to "mercy killing"

25 See the passages of an interview with Houston Merritt in White 1984, p. 194.

26 See the portrayal in "Trustees Confidential Bulletin, June 1941 issue," RAC, RG 1.1, series 200A, box 87, folder 1042.

27 See Lennox, Gibbs, and Gibbs 1940, Lennox 1941, pp. 34–39.

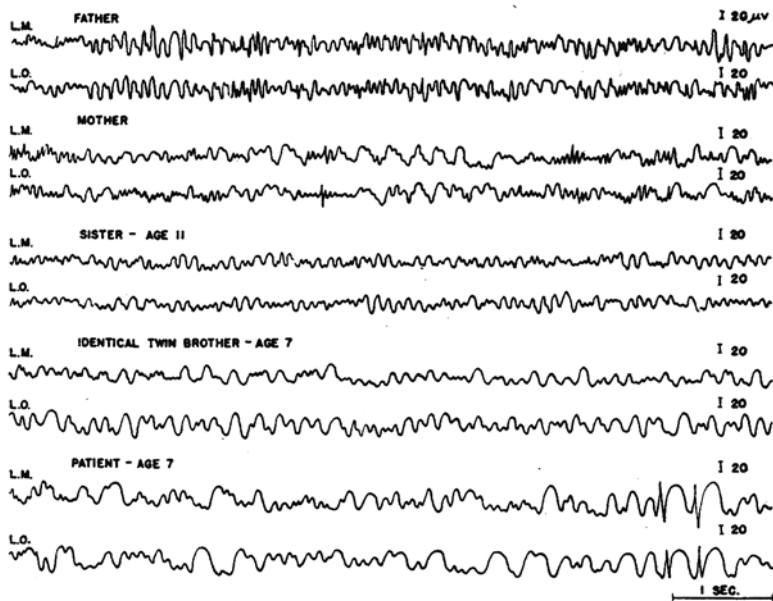


Fig. 8.—Tracings from a family of 5 in which seizures occurred in one of similar twins. The only normal tracing is that of the youngest child. There was no family history of seizures. The tracing of the epileptic twin contains many patterns typical of petit mal but otherwise resembles that of the normal twin.

Figure 38 The search by William Lennox, Erna and Frederic Gibbs for pathological EEG signs from relatives of epilepsy patients.

for patients hopelessly suffering from epileptic dementia.²⁸ And Lennox was following this logic of controlled selection further when during the war he included more and more new collectives: “These observations are grist to our mill, which is grinding out the brain wave patterns of samples of the

28 In his first epilepsy report to the Rockefeller Foundation in 1936, Lennox was already speculating about how much money could be gained for research if the 10,000 “hopeless cases” were liquidated (see “Notes concerning men and clinics able to contribute to a study of epilepsy,” RAC, RG 1.1, series 200A, box 86, folder 1039); and he did not hesitate to vote publicly for “mercy killing” in such cases even after the German euthanasia murders had become known: “Let us imagine that we have arrived at the land of ‘could be’ in the year 2048. Thanks to intelligently applied eugenics, [. . .] epileptics are less numerous than a century ago. Also, heeding at last the injunction of Christ, ‘be ye merciful,’ imbecile epileptics are no longer kept alive to endure a meaningless and miserable existence. Freed of these mindless lumps of flesh in human form, and staffed with adequately trained medical and social workers, institutions are no longer just stagnant pools of patients.” (“Epilepsy—then, now, and a century hence,” address during the centennial celebration of the Boston University School of Medicine on 22 October 1948, quoted from the manuscript at RAC, RG 1.1, series 200A, box 87, folder 1045. See also Lennox 1938.

population. We are now sampling a prison population and hope to round up a bunch of geniuses.”²⁹ Here the EEG was executing Foucauldian biopolitics, as there was

occasion for infinitely trivial surveillances, for controls at every instant, for extremely conscientious spatial orderings, for endless medical or psychological tests: for full microscopic might over the body. [There was,] however, also occasion for comprehensive measures, for statistical estimates, for interventions in entire groups or in the total body of society.³⁰

What had started in 1934/35 as a specialized study of an individual clinical picture by a new electrophysiological method was transformed within seven years, in principle, into a total surveillance of all human brains (Figure 39).³¹ Everyone, whether male or female, was potentially a carrier of pathological brainwaves. Although Lennox’s team originally only observed sensational spike-wave complexes and subjected those to scientific analysis, the work on the curves developed its own dynamics that grew, as it were, from inside outwards and beyond itself into an outpouring of tendentially infinite curve inscription.

The research strategy was set up so that where and how the line was to be drawn between “normal” and “pathological” would be negotiated only by comparative analysis of the different examined collectives.³² The EEG’s “normalization” literally emerged as the positive counterpart to cerebral-electric pathologization of large groups of the population. From this fund of tens of thousands of EEG examinations accumulated at Boston, Frederic and Erna Gibbs published an *Atlas of Electroencephalography* in 1941 that then became the international reference work.³³ The technical superiority of the EEG devices perfected by Grass in their own laboratory provided the material precondition for the Boston laboratory being able to proclaim itself the

29 Lennox to Gregg dated 6 February 1942, RAC, RG 1.1, series 200A, box 87, folder 1043.

30 Foucault 1983, pp. 173f.; allusion there, of course, is to “sex” and not to “the EEG.”

31 The electroencephalographic control of cerebral electricity in this research program only involved the organic functioning, just the biology of the brain. The total surveillance into which the Boston program had evolved was not mental police, contrary to popular fantasies and different from some war research projects.

32 See Carson’s (1993) reconstruction of the genesis of the term intelligence in the testing of socially marginal groups. Lennox was following the logic of inductive research established since Claude Bernard in the life sciences (Bernard 1961), as Georges Canguilhem (1974) so concisely criticized it. On the normalization discourse, see Link 1996, Sohn and Mehrtens 1999.

33 A report to the Rockefeller Foundation dated 31 August 1942 mentioned EEG examinations of 10,000 persons; for many of these persons multiple EEGs were recorded; see RAC, RG 1.1, series 200A, box 87, folder 1043. This single-volume atlas (Gibbs and Gibbs 1941) was printed three times by 1948; a four-volume second edition appeared between 1950 and 1978. The enormous growth of the second edition as regards period of issuance and compass illustrates the principal inability for closure of an archive of EEG curves tuned toward totality.

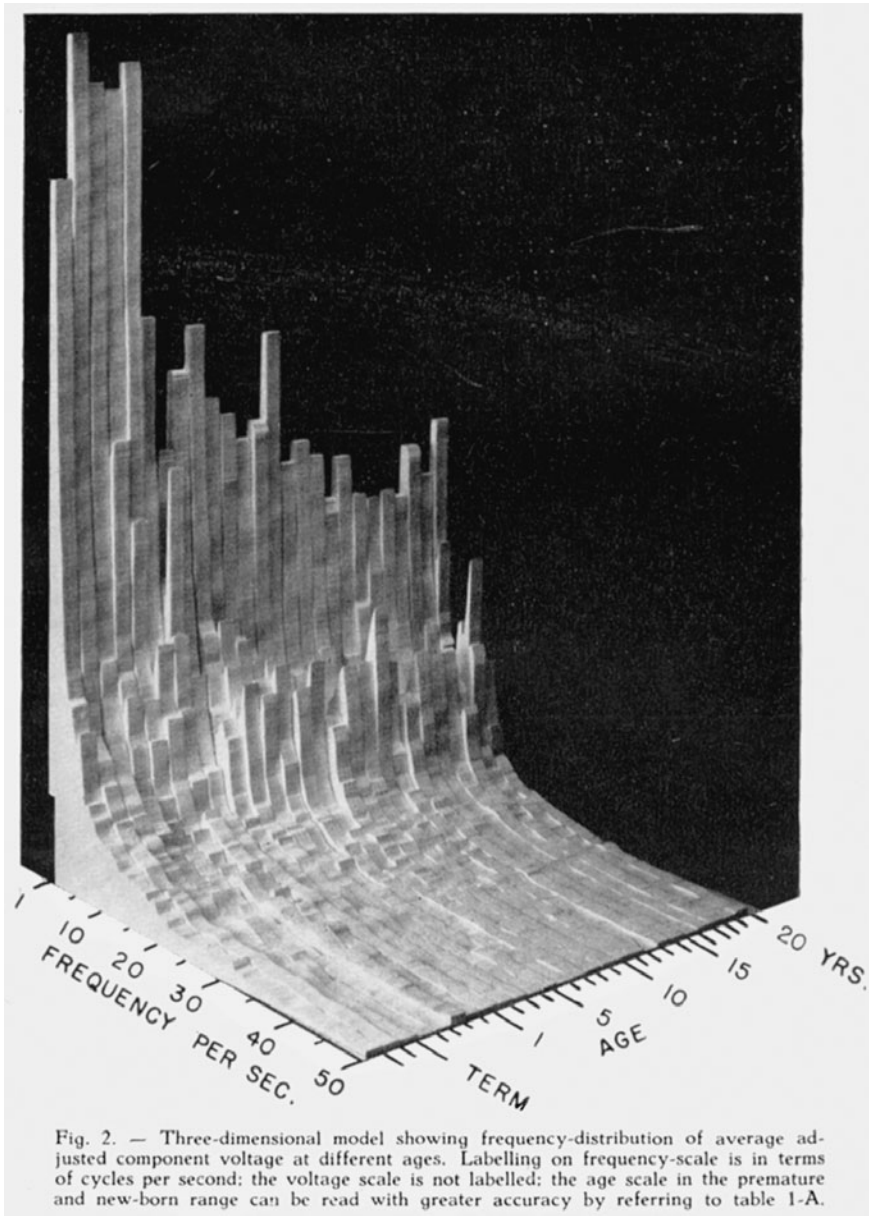


Figure 39 Three-dimensional wooden model to illustrate the childhood development of EEG frequencies by Gibbs and Knott.

standard of electroencephalography and maintain this position for a long time.³⁴

As the publication from a single laboratory, the *Atlas* manifested a specific perspective on the EEG without entering further into this perspective. In the foreword the authors merely explained their work as a physiognomy of brainwaves, but explicitly resorting to racial typologies:

This book has been written in the hope that it will help the reader to see at a glance what it has taken others many hours to find, that it will help to train the eye so that he can arrive at diagnosis from subjective criteria. [. . .] For example, although it is possible to tell an Eskimo from an Indian by the mathematical relationship between certain body measurements, the trained eye can make a great variety of such measurements at a glance and can often arrive at a better differentiation than can be obtained from any single quantitative index or even from a group of indices. [. . .] A “seeing eye” which comes from complete familiarity with the material is the most valuable instrument which an electroencephalographer can possess.³⁵

Significantly, the laboratory in Boston had just recently undertaken those statistical mathematical analyses of EEG curves on a grand scale which were now being so speedily brushed aside. Evidently the physiognomic typologization of “normal” and “pathological” curve patterns represented the handiest evaluation practice for EEG plots, especially for purposes of clinical diagnosis. The abyssal depths of this cerebral-current mission lay less in the racism behind the legitimization of its physiognomy, however. They are divulged of all places in the dedication of this atlas to Hans Berger, where Frederic and Erna Gibbs insinuate the political situation in the world at the end of 1940:

[Berger] clearly perceived that an increased knowledge of the mechanisms operating in the human brain strengthened the hope of controlling not only the “abnormal” mental states which manifest themselves as psychoses, but also those “normal” mental states which manifest themselves in crime, oppression and war.³⁶

34 How much Frederic Gibbs had advanced toward becoming the EEG authority is shown not least by his participation in one of the most famous suits in the history of American law. After the assassination of John F. Kennedy on 22 November 1963, when two days later the arrested assassin suspect Lee Harvey Oswald was shot in the police building in Dallas by Jack Ruby, the defense engaged Frederic Gibbs as medical expert, who attested to Ruby's suffering from psychomotor epilepsy; see F. Gibbs and E. Gibbs 1990, pp. 186f. Ruby repeatedly insisted on undergoing a lie detector test, the results of which, ironically, were likewise rejected as inconclusive. Whereas the defense wanted to prove him not responsible for his actions at the moment of the offense by means of an electrophysiological diagnostic technique, Ruby likewise attempted to prove his reliability electrophysiologically.

35 F. Gibbs and E. Gibbs 1941, p. VI.

36 F. Gibbs and E. Gibbs 1941, p. V.

The control of “normal” brains had become the task of electroencephalography—for this the laboratory in Boston had delivered the decisive preconditions.

A diagnostic panopticon

By the registration of brainwaves typical of epileptic seizures, the EEG had gained within the shortest span of time the status of an irreplaceable diagnostic instrument, without any consensus having been reached on the mechanisms involved in cerebral currents. Irrespective of what exactly was being registered in an EEG, great utility could evidently be attributed to those inscriptions. This early success was exemplary in at least four respects. First, the EEG had cast a main group of neuropsychiatric illnesses comprising epilepsy in an entirely new light and thereby raised hopes of uncovering by this method other psychiatric clinical pictures as cerebral-current disorders too, foremost schizophrenic and manic depressive illnesses, which were as yet pathophysiologically and nosologically unsatisfactorily explained. Second, the chance discovery of a pathological curve pattern suggested the possibility of repeating this success with other diseases. Third, the demonstrable clinical utility of brainwave curves motivated further strategies to measure the total range of variations in the EEG of healthy subjects in search of significant patterns in correlation with biopsychological factors such as intelligence or personality traits. Fourth, finally, the method had proven to be relatively easily extractible from the neurophysiological context and seemed to be available at least to electrotechnically versed scientists for innovative studies in the human sciences.

A success similar to the one for epileptic disorders would not be repeated, however. The diagnosis and classification of their various forms remained the most important clinical field of application for electroencephalography to the present day. Otherwise, the identification and registration of unusually slow rhythms, so-called delta waves, in the vicinity of a brain tumor, were also of major clinical relevance. That led to a decisive improvement in their preoperative localization and became the standard up to the introduction of new visualization procedures, such as computer tomography and magnetic resonance tomography.³⁷

The exploratory spread of electroencephalography among psychiatric institutions led to no stable findings and practices. Especially in the core area of psychiatric disorders, the EEG remained largely mute. Initial observations

37 This accomplishment, also falling within the early period of EEG research and rather made by chance by Grey Walter (1936) in London, initiated his research on cerebral currents before he started developing complete theories of the brain from increasingly difficult EEG analyses. Berger (1931, p. 30; 1933d, pp. 303–305) had already published findings in this direction; but Walter’s work first opened up EEG registration to diagnostic applications.

of irregular rhythms were expanded here and there into hypotheses but could not maintain their ground.³⁸ One of the few to propagate a consistent theory of psychoses based on EEGs was Frederic Lemere. His soon abandoned theory of psychoses would not have been worth mentioning if it did not provide a clear example of how it was possible around 1940 to speculate about how the brain operated solely on the basis of EEG parameters: "Studies suggest that the low alpha rhythm in schizophrenia is due to a low activity cortex that permits irrelevant ideas to exist side by side without the energy necessary for proper segregation and rational correlation."³⁹ Notwithstanding such and similar studies, what Walter formulated right at the beginning of a review article from 1944 quickly became clear: "The history of electroencephalography contains both triumphs and disappointments. The most profound of the disappointments is the relative failure to elucidate any of the important problems which concern the psychiatrist."

The rapid spread of electroencephalography was characterized not by a consolidation of diagnostic application of the EEG to chosen clinical pictures, but by a veritable surge of its applications to every possible problem. Above all in the USA, the early competitive situation promoted this expansion, because many EEG teams were forced to specialize on new fields of application or to secure an advantage by new data-processing techniques with which they could find and maintain an audience on the flourishing market:

It has been about five years since Adrian and Matthews convinced the scientific world that Berger's work was sound, thus opening the flood gates for a general inundation of brain waves from all quarters during the past few years. In a remarkably short period of time the human brain in most every healthy and pathological condition has been caused to trace its varied waves upon miles and miles of ever running paper.⁴⁰

Jasper's words were supposed to be taken verbatim. With scientific recognition of the EEG as a valid parameter of brain function, the entire life of a human being, from conception until death, could count as the subject of electroencephalographic examinations. In fact, hardly any human activity was omitted from representation in the form of an EEG curve.

The decision about what was to be examined by EEG was often reached less because of some convincing problem to be solved, than because of the availability of suitable analytical collectives, as Donald B. Lindsley's path in

38 Frederic and Erna Gibbs and Lennox (1936) attempted to apply their electropathological model of dysrhythmia to examinations of schizophrenic patients. Pauline Davis (1940b, 1941, 1942) also concentrated, up to her early death in 1942, on EEG examinations of psychotic patients.

39 Lemere 1941, p. 154. Lemere's schematic correlation of psychotic illness with the stability of alpha waves was criticized by many, including Berger (1937d, 12th communication).

40 Jasper 1940, p. 505.

EEG research documents. More or less by chance, Lindsley had been a test person for the first EEG tests at Harvard. He was thus acquainted with the technique and findings first hand before he transferred to the Brush Foundation in Cleveland in 1935, where the Rockefeller Foundation was funding a large research project for an exact survey of adolescence. For this study, established cohorts of children, juveniles, and adults offered an ideal opportunity to study the development of the EEG dependent on age.⁴¹ The installation of his EEG laboratory in Cleveland coincided with the beginnings of Lindsley's life as a father, and consequently he immediately published studies on the development of brainwaves in early childhood, from his own children, including a prenatal EEG examination, that is, of his wife's belly.⁴² When he heard about Hallowell Davis's animal trials on special electric potentials during ovulation, he promptly started a collaboration with his colleague Boris Rubinstein, who directed the gynecological examinations in the adolescence study in search of the EEG of ovulation in female medical students.⁴³ They were not successful with it but such investigations were in fashion. Five years later Dorothea Dusser de Barenne and Frederic Gibbs were able to publish systematic examinations of EEG changes during the menstruation cycle and during pregnancy.⁴⁴

The end of a human lifetime evidently awaited its electroencephalographic exploration with less urgency, although Berger already had reported in his first communication that the electrical activity in a dog's brain continued for a while after the heart ceased beating. A field of activity for EEG diagnostics developed of importance to organ-transplant medicine in 1968 when Harvard Medical School added a so-called "isoelectric" EEG to its catalog of death criteria for a vital body.⁴⁵ Just a short time later, the last diagnostic gap in the human life cycle could be closed with the registration in 1972 of the brain curve of the orgasm.⁴⁶ Between conception and death there was a

41 Lindsley 1936. Donald Lindsley had actually wanted to go to Cambridge to work with Adrian in 1930 but was not awarded the grant required for that. In the following year he went, not to Europe, but to Forbes at Harvard, where he worked on the electromyogram (Lindsley 1935; cf. Lindsley 1995).

42 Lindsley 1942.

43 Reboul, Davis, and Friedgood 1937, Lindsley and Rubenstein 1936/37. See Lindsley (1995, p. 110): "During each woman's experimental period she took her rectal temperature and placed a vaginal smear on a microscope slide each day before getting out of bed. She came to the laboratory at 6:30 a.m. before breakfast and before medical classes began for EEG and physiological recordings during two basal metabolic rate tests. [. . .] Unfortunately, in each case the Pap test revealed one day it was too early and the next day too late! Ovulation had occurred during the past 24 hours."

44 Dusser de Barenne and Gibbs 1942, Gibbs and Reid 1942.

45 Report of the Ad Hoc Committee 1968, Schlich 2001. First findings on the EEG during coma and at death had already been presented in 1940, however (Jonesco-Sisesti, Sager, and Kreindler).

46 Heath 1972.

wide span of diverse opportunities for EEG examinations. Sleep had been the subject of one of the first EEG articles. Others picked up where Loomis had left off, and with the observation of what is referred to as REM sleep an EEG image of dream activity could be constructed.⁴⁷ Psychologists were additionally interested in electrical traces of a cerebral processing of sensorial stimuli, for instance, whereas physiologists rather experimented with registrations from the various structures of the brain.⁴⁸ When in the mid-1940s psychosomatic medicine formed in the USA, electroencephalography had established itself well enough to be a useful gauge for evaluating psychophysiological assumptions.⁴⁹ Given the capacity for electronic data storage and averaging from the mid-1960s on, it became possible to filter out the basal activity of a brain through repeated registration of the specific electrical response by it to definite sensory stimuli. This recording of so-called evoked potentials gave psychophysiology new impetus and electroencephalography became a constituent part of “functional neuroscience.”⁵⁰ Not everything that was displayed and peddled at this fair was recognized and confirmed. Some observations remained a curiosity, were heavily criticized, or simply proved to be irreproducible.⁵¹ It is presumably unavoidable, in an expanding science with a high publication frequency, for a number of tracks to lead into dead ends or to peter out, even after an initial good start. Such “bubbles” are of relevance to a cultural history of electroencephalography to the extent that the careers of failed research efforts along faded lines of inquiry are reconstructible.

EEG research clearly encountered its most remarkable passing focus in the area of psychopathology. Located in the overlapping zones of physiology, neurology, psychiatry, psychology, and sociology, the EEG promised new scientific answers to questions about the measure of human normality. In countless studies the cerebral currents were registered of children with behavioral disorders or of adults classed under different supposed levels of intelligence or character types. The point of departure for this research orientation was the consistent but irritating observation that not all test persons were equally suitable for the registration of alpha waves, which was why Adrian, for instance, had demonstrated his own brainwaves in Cambridge and not those

47 Lundholm and Löwenbach 1942, Thomson, Forbes, and Bolles 1937, Blake, Gerard, and Kleitman 1939, Aserinsky and Kleitman 1953; see Kroker 2000.

48 For contemporary reviews of psychophysiological EEG literature, see Knott 1941 and Lindsley 1944.

49 For example, the diagnostic profiles and therapy success would be worked out from EEGs of asthma and ulcer patients; see Rubin and Moses 1944, Moses 1946. On the development of psychosomatic medicine in the USA, see Pressman 1998b.

50 Walter et al. 1964, Regan 1972, Barber 1999.

51 Such as the EEG of William Sassaman, who could bristle his body hair at will, see Lindsley and Sassaman 1938.

of his collaborator Matthews.⁵² “Do brain waves have individuality?”, Lee Edward Travis and Abraham Gottlobler had provocatively asked as early as 1936 in *Science*, while making the astonishing claim that with some practice they could correctly reassemble fragments of different EEG curves based on their individual patterns. Notably the group at Harvard followed this track. In Davis’s view, alpha waves impressed an individual pattern and the EEG served as an “electric fingerprint” for that reason.⁵³ Further research revealed that it was harder than anticipated to identify individual EEG markers, whereas the EEG curves were relatively easily classifiable into groups against a measured dominance of alpha waves in an “alpha index.” In cooperation with the Institute for Psychoanalysis in Chicago, Hallowell Davis and his wife, the psychiatrist Pauline A. Davis, began soon afterwards to correlate the groups found in the alpha index with personality types. Curiously enough, these investigations proceeded with an inversion of the valence of alpha waves. In the search for suitable test subjects, Adrian, Walter B. Cannon, and Hallowell Davis had turned out to be persons with a stable alpha rhythm. The psychoanalytic typology of personality, however, was strong enough to then suggest a relation in the opposite direction between an alpha-dominant EEG and a passively dependent personality, and conversely, between the “low alpha type” and an “active, driving, independent type of personality.”⁵⁴

Seeking a profitable share in this upswing for the EEG, some scientists saw their chance in slight variation. Pauline Davis wagered on psychoanalysis, whereas other groups combined the EEG index with a classification of personalities based on psychological testing by questionnaire, such as for the Nebraska Personality Inventory.⁵⁵ Hudson Hoagland, for instance, constructed a “delta index” as a scale for sociopathologically significant slow waves. This delta index (D taken alliteratively for “disintegration”) was already supposed to insinuate the hypothesized psychopathological

52 Adrian 1971, p. 1A-9: “It was easy to fix our roles in the demonstration. I could be trusted to produce a regular alpha rhythm and Matthews to record it on the ink-writing electrocardiograph which he had designed. So I was the subject and Matthews was the recorder.”

53 The fingerprint analogy was mentioned at the meeting in Kansas City in 1936, which Davis later weakened to a similarity between voices, at the meeting of psychiatrists in the following year in Philadelphia (H. Davis 1938a, p. 831). The Harvard team established already in their first publication: “If a normal subject with electrodes applied to his head sits relaxed with eyes closed, an electroencephalogram is obtained which is characteristic for himself but which may differ considerably from the record of another person” (Gibbs, Davis, and Lennox 1935, p. 1135; see also Pauline Davis 1940a, p. 713).

54 Saul, H. Davis, and P. Davis 1937, H. Davis and P. Davis 1937, Pauline Davis 1940a. These findings stayed controversial. Whereas Gottlobler (1938) observed a positive correlation between alpha index and an extroverted personality, Henry and Knott (1941) found a negative one, for example.

55 J. P. Guilford and R. B. Guilford 1936, Henry and Knott 1941.

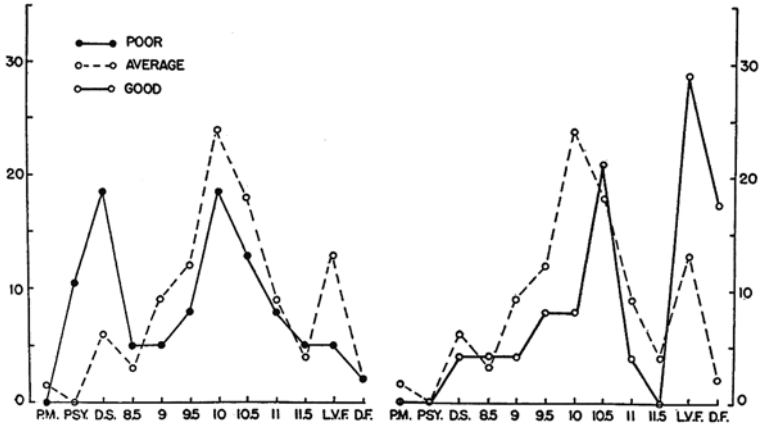


FIG. 3. Percentage Distribution of Boys with Poor, Average and Good Personalities. Electroencephalographic Categories Labelled as in Fig. 1.

Figure 40 Group forming should present a high proportion of slow and irregular frequencies among boys of “poor personality” compared to more rapid frequencies of “good personality.” Data analysis by Roswell Gallagher and Erna and Frederic Gibbs.

meaning.⁵⁶ And the trained eye of an electroencephalographer helped Frederic and Erna Gibbs in this case also to draw a particularly blunt conclusion about person-specific physiognomy from the curve pattern: “In general cortical activity which is unusually slow is likely to be associated with poor personality, and cortical activity which is unusually fast with good personality” (Figure 40).⁵⁷ From there it was only consistent that others would find a high rate of sluggish and slow cerebral rhythms among “criminal psychopaths” and demand psychopharmaceutical therapy for them.⁵⁸ Notwithstanding recurrent criticism that here “two unknowns” were being explained “in terms of each other,” the EEG counted for some years from 1940 on as a firm part of the inventory of personality psychology.⁵⁹

56 He found a strong dependence of his index on emotional stress, when he confronted healthy or mentally ill subjects with sentences like: “What would you do if someone called you a son of a bitch? Would you go mad or pass it over?” or “You wished you were a girl and believed your sex organs were shrinking and would drop off. Think it over.” See Hoagland, Cameron, and Rubin 1938, pp. 232 and 230. This is one of the relatively sparse contact points between electroencephalography and experimental research on the emotions; see Dror 1999.

57 Gallagher, E. Gibbs and F. Gibbs 1942, p. 139.

58 Gibbs, Bloomberg, and Bagchi 1942, Brill, Seidemann, Montague, and Balsler 1942, Silverman 1944a, 1944b, Pacella, Polatin, and Nagler 1944, Simons and Diethelm 1946, Leonardo 1947, Rockwell and Simons 1947.

59 Knott 1941, p. 951, see also Walter 1944 and Gottlieb, Ashby, and Knott 1946.

The term “personality” was a typical label for the heterogeneous cultures assembled within the psychology of the interwar period.⁶⁰ From intelligence testing to psychoengineering, from characterology to variants of individual psychology, from “mental hygiene” to the sociology of the “authoritarian character”: here the most disparate currents met at a forum that was both scientific and popular. Psychology had become established as a socially relevant branch of science by mass testing of American recruits during World War I and by successful marketing of psychodiagnostic testing procedures built upon that. Electroencephalography could then quickly spread into psychology along the lines of personality psychology developed by psychological testing. Brainwave curves promised to explain traits by scientifically empirically established psychological tests:

The term “personality” as used here is admittedly vague but it covers the order of phenomenon in which we are interested. The point of view is medical, the essential problem being to determine whether boys who appear to be handicapped because of their personalities are suffering from a deviation of central nervous function, and whether, in turn, boys who have an advantage because of their personalities gain this advantage as a result of a deviation of central nervous function.⁶¹

Conversely, the keyboard of personality psychology opened up the prospect of a valid psychological interpretation of EEG findings. Between both regions there arose a “trading zone,” an area of exchange, in which formed a specific research culture at the junction between two scientific fields.⁶² Commonly established criteria of differentiation in psychology, and particularly social and psychological value judgments, wandered into the description of EEG findings in the form of concepts of “good” or “bad,” “sluggish” or “energetic” brainwaves, whereas electrophysiological diagnostics, in turn, scientifically underpinned particular personality traits.

This adaptation of the EEG to social value scales and socially determined concepts of personality in particular begs the question of the construction of gender-specific EEG criteria. For instance, in the EEG *Atlas* by Frederic and Erna Gibbs the results from pregnant subjects under the heading “diseases/gynaecology” were placed between epilepsy and migraine, which continues the stereotypical pathologization of women, the most frequent sign being their lack of mention without further comment.⁶³ On the other hand, the

60 On the following, see Danziger 1990, pp. 156–178, and Smith 1997, pp. 575–636.

61 Gallagher, F. Gibbs and E. Gibbs 1942, p. 136, see also Sokal 1987, Carson 1993, Zenderland 1998.

62 Galison 1988, 1995.

63 In the *Atlas* by Frederic and Erna Gibbs, seventeen of the twenty-one normal curves on the EEG were from male subjects. For the EEG of childhood development, up to age five about equal numbers of curves were from boys and girls; from age six up, significantly, reference

central EEG phenomena, such as alpha and beta waves, as well as the blockage of alpha waves had been constructed by all the scientists explicitly as gender-neutral findings. Relatively many women were working in this field from the outset, as technical assistants, such as Ursula Berger, Elfriede Kornmüller, Hildegard Biebricher, or Lennox's secretary; but also as research collaborators, such as Erna Gibbs, Pauline Davis, Ruth Cruikshank, Katherine Cutts, Margaret Lennox, Vivian Walter, Margaret Rheinberger, and Mary Brazier. That was probably why within the community of EEG laboratories, female and male test subjects were largely considered interchangeable, until personality psychology with its firmly set repertoire of clearly "male" or "female" codified behavioral patterns provoked a gender-specific analysis of the curve plots. Pauline and Hallowell Davis's collaboration at the Chicago Institute for Psychoanalysis yields one more shining example, this time for the ascription of gender-specific stereotypes to EEG curves:

The following psychological correlations with type of EEG appeared consistently: 1) Very passive individuals have "high-alpha" EEGs. (A much higher percentage of our men than our women fall in this class). 2) Women with strong masculine trends have "low voltage fast" or at least "low alpha" EEGs; and, less clearly, women with very active maternal drives have "low-alpha" patterns. [. . .] 3) Frustrated, demanding, impatient, aggressive, hostile women have the "mixed fast" or "mixed" type of EEG.⁶⁴

The maternal EEG and the untidy one of maladjusted women remained individual observations that scarcely produced any response. In most of its constructions, the EEG remained conspicuously indifferent to gender difference.

The electrical brain had no gender, but it did have character. An unusually high number of studies credit the EEG highly with the investigation of personality disorders. Above all, children became the victims of a well-meant but therefore overly vigorous clarification of the neurophysiological foundations of maladjusted behavior. Instead of suffering from educational

was only made to EEGs from boys. Different from physicians, as a rule psychologists noted in their EEG publications whether the test persons were female or male.

64 Saul, H. Davis, and P. Davis 1949a, p. 515; see also Saul, H. Davis, and P. Davis 1949b. This form of materialistic brain research, made to conform to Freudian theories of drive dynamics, encounters Canguilhem's critique of sociotechnical biopolitics (1989, pp. 21f.): "Out of a model of scientific research, an ideological propaganda machine had been created other than for its original purpose, namely, with a double intent: to stifle or cripple in its germ opposition to the advancement of a tool serving automated control of social conditions; and to make the really existing decision-makers vanish behind the anonymity of the machine."

damage or difficult social conditions, children with conduct disorders simply had disturbed brains, as the EEG proved:

Abnormal brain function as revealed by the electroencephalogram is an important component in the aetiological picture of the majority of a group of problem children whose disorder had been considered as primarily psychogenetic previous to using this method of diagnosis.⁶⁵

Jasper's paper on "behavior problem children" probably rather represented something like an escape attempt from the dead ends of his neurophysiological basic research, by simply applying the EEG to that clientele happening to be available to him at Bradley Home. Nevertheless, he seems to have thus had an influence on one line of research.

The reifying consequences of this research on EEG curves can be followed exemplarily in these studies. The interplay between study design, curve analysis, selection criteria, and classification of findings gradually solidified the soft social concepts into ontological categories. Although Jasper initially stated that the "behavior problem" in children is known to represent a very heterogeneous group," as a result of this research on the plots he could draw the fundamental conclusion of a causal participation of brainwaves. This ascertained heterogeneity made it just as plausible as it was deemed necessary to divide up the various children at Bradley Home into groups based on psychological criteria also of possible relevance to brainwave differences, prior to performing the EEG investigations. That was why Jasper classified spontaneous, hyperactive, and impulsive children under the EEG-suggestive group of "epileptoids," while bizarre, immature, and withdrawn children were subsumed under "schizoids." Almost half of all the children were thereby excluded from the study. They presented disorders that conflicted with this classification, such as, "school problems, delinquency, problems apparently growing out of difficult home situations." This initial selection filter permitted observation of epilepsy-like wave patterns from a significant proportion of the children in the "epileptoids" group. "The electroencephalogram has succeeded in revealing a definite abnormality of brain function in over one half of a group of child behavior disorders."⁶⁶ It is not a matter of making accusations here about manipulation. These details rather allow one to retrace how the significance of scientific statements is constructed by the mere selection of the examination collective, strengthening the persuasiveness of a new method at the same time.

When Lindsley took over the EEG research at Bradley Home after Jasper's move to Montreal, he continued down the path chosen by his predecessor.⁶⁷

65 Jasper, Solomon, and Bradley 1938, p. 657.

66 Jasper, Solomon, and Bradley 1938, p. 655.

67 In 1939 Lindsley published, among other things, five case histories in the German *Zeitschrift für Kinderpsychiatrie* as evidence for the thesis that the EEG was "an aid to understanding certain behavior disorders of childhood" (Lindsley and Bradley 1939).

In 1940 he could already prove similar findings of disturbed brain functions in children not hospitalized because of behavioral problems but classified as “constitutionally inferior.”⁶⁸ A report to Gregg shows how the dynamics of their research program had generated this sociopolitical expansion of EEG diagnostics: In search of a same-aged control group for the children at Bradley Home, they examined orphanage children without neurological or other medical symptoms; but abnormal EEG waves were likewise found in the majority of them. What at the outset had seemed to be a disorder in the sense of the initial hypothesis, looked at second glance as if it were an extension of its range; the children were useful not as a control group but as a further collective of the analysis:

Questioning the housemothers at the School revealed that several of the children were considered distinct behavior problems and that there were indications that others in the group [with abnormal EEG patterns] might well be behavior problems under a less rigidly controlled environment. The group as a whole come from poor stock. The parents of a number of them are in state institutions and in general the biological and social heritage of these children is extremely poor.⁶⁹

In this study no specific EEG patterns were characterized either, but the relative frequency of abnormal waves as compared to a control group counted as confirmation. When the findings from the control group showed pathological waves instead of the anticipated comparison values, Lindsley thereupon constructed the group of “constitutionally inferior children.” The published findings were consequently the result of an adaptation of the observations to an explicitly formulated expectation after the control collective had been appropriately restructured.

At the beginning of the 1940s Lindsley and Henry began to treat the disturbed brains of children with behavioral problems with psychopharmaceuticals and to evaluate by EEGs the pharmaceutical improvement in their conduct. Some medications, also including the amphetamine Benzedrine (which had just been developed and Bradley Home was one of the first places where it was being tested), clearly influenced the behavior of the children positively, even though their EEG curves did not get “better.”⁷⁰ Bradley

68 Lindsley and Cutts 1940. Lindsley mentioned to Gregg (28 April 1941, RAC, RG 1, series 200A, box 73, folder 885) great public interest in this publication; reports about it appeared even in *JAMA* and *Lancet*.

69 Lindsley to Gregg dated 22 October 1940, RAC, RG 1, series 200A, box 73, folder 885.

70 Lindsley and Henry 1942. The involvement of the pharmaceutical industry in the development of psychoactive medications for children is another indicator of greater attention in society to behavioral disorders at this time.

Home thus became the source of Ritalin therapy for hyperactive children—albeit this treatment had no prospect of correcting brainwaves. The analyses at Bradley Home were certainly not singular; they point out in a startling way how far the medication of a child's world had advanced in America before the outbreak of World War II.⁷¹

With the entry of the USA into World War II, new fields opened up for Lindsley, because the US military was seeking possibilities to optimize its personnel by scientific methods, such as innovative EEG diagnostics. Another 'trading zone' immediately formed when in 1940 Lindsley, together with a group of American psychologists, was supposed to examine British marines for symptoms of "battle stress." Using this concept from military psychiatry he could continue to differentiate his EEG studies. For example, the stress concept opened a theoretical avenue for Lindsley on the psychophysiological variability of EEG findings from Bradley Home children. In spring 1941 Lindsley planned to examine the dependence of abnormal EEG signs of physiological (physical exertion, hyperventilation, oxygen deficiency, insulin) and psychological stress (provoked fearful states, frustrating situations, conflict situations).⁷²

When behavior problems among children or personality traits among adults were correlated with supposedly objective findings, these analyses not only legitimized existing social stigmatizations but also transformed them into biological forms of psychiatric deviance.⁷³ On one hand, false assumptions were manifest here that social control was possible by means of neurobiological surveying technology, particularly, for example, when organic therapy with psychopharmaceuticals was administered on the grounds of brain pathology as construed by EEGs. On the other hand, these studies

71 Similar studies were later also conducted at other institutions, e.g., at Burden Neurological Institute in Bristol; see Golla to Gregg dated 8 October 1950, RAC, RG 1.1, series 401A, Box 15, folder 210: "For the past two years we have been examining electroencephalographically the boys committed by magistrates to special schools on account of asocial conduct not complicated by intelligence disorders. [. . .] In the boys we found abnormal cortical dysrhythmia in over sixty per cent." Other investigations include Eickhoff and Beevers 1947, Kennard 1947. A positive correlation between an abnormal EEG and conduct problems was certainly not universally confirmed (cf., e.g., Solomon, Brown, and Deutscher 1944). But negative results encouraged discussions about the specific relevance of the EEG findings rather than about their general refutation.

72 Lindsley to Gregg dated 28 April 1941, RAC, RG 1, series 200A, box 73, folder 885. Owing to the massive occurrence of mental breakdowns during World War I, the military leaders during World War II reacted extremely sensitively to the first signs of similar conditions. "Battle" or "combat stress" was the conceptual substitute for "shell shock" or the traumatized tremor of "*Kriegszitterer*" during World War I; see Binneveld 1997, Viner 1999, Borck 2004b.

73 Signs of abnormal activity in the EEG still continue to count as physiological characteristics of children with conduct or personality disorders but, significantly, over the course of 60 years of research no consensus has yet been reached on their diagnostic or etiological value; see Small 1993.

mirrored the hope of finally being able to do more with this delicate brain-recording instrument than just register alpha waves and their blockages. Such false visions of power or manipulability by the actors, particularly in sociopsychological EEG studies, yielded a phenomenological occupation with the curves to correlate psychological and electroencephalographic findings, in an effort finally to advance beyond Berger's psychophysiological EEG interpretation of 1930. This inordinate preoccupation with the curves is what turned social irregularities into ontological differences.

Under the shock spell

The revolutionization of epilepsies was the decisive step toward the establishment of the EEG as a method of clinical diagnosis but other developments overshadowed its effect on psychiatry. When Stanley Cobb summarized the advances made in neuropsychiatry in 1937, he naturally also reported about electroencephalography and the renaming of epileptic disorders as "cerebral dysrhythmias." But even in this review by Lennox's superior, the EEG came only third and last in line. The decisive innovations were the introduction of psychosurgery and shock therapies.⁷⁴ The "great somatherapies"⁷⁵ of psychiatry do, in fact, mark one of the most radical breaks in clinical practice. Within ten years, worldwide a psychiatry that had mainly kept patients secured in large institutions turned into an active therapy-oriented discipline. The quest for new biological therapies during the 1920s had prepared the way for this change in the wake of successes in treating syphilis with therapeutic fever, then perceived as revolutionary.⁷⁶ But from the mid-1930s on, events followed in quick succession when insulin shock therapy, Cardiazol shock therapy, leukotomy (or lobotomy, the surgical separation of fiber connections in the frontal lobes), and finally, electroshock therapy were introduced into clinical practice around the world.

Among these somatherapies only electroshock treatment has remained in the repertoire of clinical practice to this day, which fact alone calls for its

74 Cobb 1937, pp. 1109f. These new therapies quickly took the upper hand in public reporting just as did its scientific interest in psychiatry. See the listing of reports on shock therapies in American news magazines and science magazines in Grob 1983, p. 392, or the 40-page list of publications in Kalinowsky and Hoch 1950.

75 Linde 1994; on the following see Braslow 1997.

76 As early as after World War I, Julius Wagner-Jauregg in Vienna had been inspired by earlier views on the favorable influence of feverish infections to start to treat patients suffering from progressive paralysis, the final stage of a syphilis infection, by artificial infection with malaria. Antibiotic therapy with Salvarsan had had no positive effect on these patients, but this malaria treatment was astonishingly effective in a great number of cases. As a result Wagner-Jauregg became one of the very few psychiatrists to be awarded the Nobel Prize, in 1927. See Wagner-Jauregg 1950, Whitrow 1990, and Braslow 1996.

inclusion in this historical account of brainwaves.⁷⁷ Precisely because this form of treatment does not come from within the context of electrophysiological brain research portrayed up to now but from pragmatic therapy research within psychiatry, an analytical look at the genesis of “active therapy” permits a contextualization of electroencephalography. Shock therapies and psychosurgery turned the brain into a site of therapeutic interventions on a scale hitherto unknown. All these therapeutical forms were applied excessively, as regards the numbers of treatment cases, as well as, often, the procedure in the individual case. This radicalization of psychiatric practice, in which the EEG merely took part in attendance, was not without consequences on the electrical brain as a knowledge space. With some exaggeration, it could be said that in the therapeutic short circuiting of an artificial seizure, the brain was first made into a catastrophically reacting electrical automat before it was reconstructed as an electrical machine during the postwar years.

The speed with which the various shock therapies and psychosurgery were established was an example *par excellence* of the central disciplining function of psychiatry at the service of an authoritarian conformist policy, not just in the opinion of the anti-psychiatry movement of the 1970s. The implementers of the shock procedure evidently attended their therapies with veiled control from the very outset.⁷⁸ In 1941 Medard Boss already recognized in the imagined punishments by shock therapists that he analyzed, clear indications of the primarily disciplinary character of these therapeutic procedures.⁷⁹ From intimate knowledge about psychiatric practice, Thomas Szasz eloquently described psychiatry as the modern form of the Inquisition, which used the “myth of mental illness” to subject the socially marginalized to new domesticating tortures.⁸⁰ This “knocking down” of patients by electroshock into the unconsciousness of an epileptic seizure later became one

77 Fink 1993.

78 Carl Schneider wrote, for example (1939, p. 282): “The technique of Cardiazol therapy starts with the preparation of the patient for treatment. This includes the elimination of talk by the patient about the injections. As Mader has already set forth, one should not let gossip to arise, such as ‘the loss of consciousness could perhaps damage the brain’ or generally uncontrolled propagandistic whispering, especially in the women’s divisions.”

79 A particularly impressive example quoted by Boss is a dream melding electroshock treatment with the political situation of the France campaign (Boss 1941, p. 780): “I was the commander of a German shock troop that had to storm the Maginot line. I and all my soldiers were carrying electroshock apparatus instead of knapsacks. The electroclamps were a flame-and-spark thrower that we only needed to point at the enemies to burn them and all life around them down, the plants too. The horrifying thing about the dream was that behind us the enemy corpses continued to writhe in epileptic convulsions and I had the uncanny feeling that the whole mass of jerking corpses could suddenly roll over us from behind and suffocate us.”

80 Szasz 1961. To him, Ugo Cerletti, the inventor of electroshock therapy, for example, was a modern revenant of Friedrich von Spee, the author of *Cautio criminalis*, Szasz 1977, p. 31.

of the main targets of anti-psychiatric activities during the 1960s and 70s and found popular expression in Miloš Forman's film "One Flew over the Cuckoo's Nest."⁸¹ In succession to the biologicistic turn of psychiatry, historiography had also again subjected this therapeutical method to revision since the 1980s.⁸² What had first been celebrated around the world as a therapeutic breakthrough counted a few decades later as scientifically badly legitimated practice that ethically clearly must be rejected. A couple of years hence it was rehabilitated as the prehistory of a science now primarily arguing molecular biologically. Neither the criticizing nor legitimizing reconstructions of the history of shock therapies in psychiatry shed much light on the dynamics of the formations of knowledge in psychiatry.⁸³ The political context points to the special dimension of this problem, considering that psychiatric shock therapies were introduced in National Socialist Germany similarly speedily as they were in England and the USA.⁸⁴

Between 1933 and 1935 two relatively new substances were proposed for shock treatment of psychoses, one of which—insulin shock therapy—emerged pragmatically out of modifications of former therapeutic practices, while the other—Cardiazol shock therapy—originated from theoretical considerations. The blood-sugar-reducing pancreatic hormone insulin had been isolated in 1921 and was available as a therapeutic from 1923 on. Cardiazol was introduced into the clinic in 1923 as a medication to stabilize the circulatory system.⁸⁵ Insulin had initially been introduced into psychiatric practice during the 1920s to treat serious cases of weight loss by anorectic

81 On the development of anti-psychiatry in the USA, see Dain 1994; Leonard Roy Frank's (1978) critical collection of sources is still very instructive. For the professional history of psychiatry, the critical distance maintained toward shock therapy and the belief in progress thereby expressed by the actors is downright constitutive. Foucault's classical study *Madness and Insanity (Folie et déraison)* was just one possible point of reference (Castel 1976); Klaus Dörner (1969), for instance, takes recourse in critical theory, see Scull 1994.

82 Certainly most conspicuous with Edward Shorter, who stylizes the interventionist procedures as precursors to biological psychiatry and reconstructs the introduction of somatic treatments together with the development of effective penicillin therapies; see Shorter 1997, pp. 195f. See the critique by Kneeland and Warren 2002.

83 A historically and epistemologically reflective historiography must start right here; see Pressman 1998a and the contributions to a small colloquium on the occasion of his premature death, in *Bulletin for the History of Medicine* 74 (2000): 773–802.

84 Medicine and especially psychiatry in Nazi Germany meanwhile count among the most thoroughly researched periods in the history of medicine (see Walter 1996 and Siemen 1999, and the bibliography Beck 1995). Less so for the history of psychiatry than for historical accounts of Nazi medicine generally, they were often motivated by a high moral impetus that denied it any scientific merit, appalled by the murderous practices of German physicians during those years (see Klee 2001). The explosive power of the inhumane practices of Nazi medicine was in that they occurred not just as heinous and unscrupulous excesses but, as a rule, with scientific arguments attached to them that found an audience inside and outside of Germany, see Schmuhl 1991.

85 Bliss 1982, Schmidt, Hildebrandt, and Krehl 1925.

patients. In addition, insulin was used to calm down morphine addicts during withdrawal. When Manfred Sakel happened to observe from such morphine-withdrawal cures that conditions of hypoglycemia, although not intended but not entirely avoidable, acted favorably on withdrawal, he believed he had found a new principle of psychiatric therapy with the artificial lowering of blood sugar to the point of triggering coma.⁸⁶ In autumn 1933 Sakel began to experiment with an insulin treatment at the Viennese clinic of psychiatry, where the malarial treatment of paralysis had also been developed. Over the course of many weeks he administered insulin to schizophrenic patients in such high doses that they fell into a coma that was terminated four hours later by artificial feeding. Sakel's new method was "comparable to earlier experiments, such as a life-or-death operation with a bland symptomatic treatment," as his superior Otto Pötzl pointed out with matter-of-fact emphasis.⁸⁷ Those patients for whom this insulin therapy with its life-threatening coma additionally triggered epileptic seizures seemed to profit the most. Coma shock therapy began to turn into coma seizure therapy.

Thus insulin shock therapy entered into competition with another new method using pharmaceuticals to set off cramp attacks. The initial idea for these experiments had been a surmised antagonism between the clinical pictures of schizophrenia and epilepsy,⁸⁸ which was why Ladislaus von Meduna supposed that epileptic seizures had a specific therapeutic efficacy for schizophrenic patients. Just a few weeks after Sakel, in January 1934, Meduna, a senior physician at the Psychiatric University Clinic in Budapest, commenced his first clinical experiments after conducting some animal trials.⁸⁹ The intravenous injection of relatively high doses of Cardiazol led to the rapid onset of generalized cramp attacks that occasionally were even accompanied by bone breakages. In addition, the patients regularly anticipated the attacks in a fearful aura of annihilation that they recalled as extremely excruciating. These dramatic cures by Sakel and Meduna caused public sensation; they were purportedly pathbreaking therapeutic successes for schizophrenic conditions that had otherwise proved to be impervious to influence.⁹⁰ Particularly after the Swiss psychiatrist Max Müller began to do insulin cures in 1935 at the institution in Münsingen after having familiarized himself with Sakel's method in Vienna in early 1934, shock therapy became an international model of success for a new "active therapy." Müller developed Münsingen into the "Mecca of psychiatry,"⁹¹ where researchers from

86 Sakel 1930. These cures took place in Kurt Mendel's sanatorium in Lichterfelde near Berlin.

87 Quoted from Sakel 1937, p. 1277.

88 On the questionable statistical foundations of these notions, see Berrios 1997.

89 Meduna 1937, see Linde 1994, pp. 132f.

90 One reason was Sakel's jealous advocacy of his therapy; see the characterization by Müller (1982, above all pp. 151–157), which is not devoid of anti-Semitic overtones.

91 Müller 1982, p. 171.

all over the world learned insulin shock therapy. There the psychiatric clinic obtained its own intensive care center, where a patient was treated for hours in an operating theater. Müller reported good therapy successes for about half of the 560 treated schizophrenia patients.⁹² By the circuitous route through Switzerland, shock therapy reached National Socialist Germany; and at the end of the 1930s practically all German neuropsychiatric university clinics were applying the shock method:⁹³

In this immensely aggressive epoch we all are filled with anxiously tense expectation. Around one, nearby and far away, one sees only untethered activity, that is, destructive activity. [. . .] Every permitted, legitimately destructive activity is therefore perceived as a liberation. Thus is explained in part the general enthusiasm about shock methods. The epileptic fit is a discharge not only for the ill person but also for the doctor and the nurse. We perceive the therapy as a release from the nightmare of therapeutical nihilism.⁹⁴

“Active therapy” obviously suited the restless mood in German psychiatry well, which became the invasive individualized therapeutic counterpart to the eugenic measures on the “body of the nation” (*Volkskörper*).

Shock therapies fell on fertile soil not only in Germany, even though time and again insulin shock therapy caused fatal incidences; and Cardiazol shock therapy was not without its extremely unpleasant and dangerous side effects, either. One should not jump to the conclusion that the enthusiasm

92 See “Bericht über die wissenschaftlichen Verhandlungen auf der 89. Versammlung der Schweizerischen Gesellschaft für Psychiatrie,” *Schweizer Archiv für Neurologie und Psychiatrie* 39 suppl. (1937): 1–238. In addition to Sakel and Meduna, Lucio Bini also reported on his animal trials performed in collaboration with Ugo Cerletti in which epileptic seizures were electrically induced. Although electroshock therapy would develop out of this soon afterwards, this paper attracted little notice at the time.

93 Rehwald 1940, see also Hall 1996 and Hamann-Roth 2000. Egon Küppers, psychiatrist at the institution in Illenau, calculated on the basis of the dramatic success in Switzerland that the introduction of shock therapies would make superfluous new buildings for asylums for the coming 20 to 30 years. The Reich Interior Ministry had initially cautioned against participating in this “Jewish-Muscovite staging.” But Küppers’ report changed its mind. (“Whoever came to Münsingen in the opinion that this merely involved a preparation by international Jewry with the purpose of propagandistically celebrating the achievement of the Jew Sakel would only be disappointed. The applause given to the two inventors was thoroughly spontaneous and suited the importance of the matter” (BA R 4901/2947, sheet 248).) The Ministry of Science became so interested that it requested an expert opinion from the Berlin psychiatrist Karl Bonhoeffer. Bonhoeffer’s assessment was skeptical (*ibid.*, sheet 246): “The successes of insulin therapy very much remind one, it seems to me, of the passing successes achieved 100 years ago here and elsewhere with the dunkings of 50 buckets of freezing water and with Horn’s rotary machine. Shock effects were involved there, too.”

94 With this remarkable document from the time, Otfried Linde (1988, p. 112) quotes how a German participant at a conference on shock therapy in Amsterdam in 1938 received such a policy on therapy, albeit without any bibliographic reference.

about the “destructive activity” of these methods was directly related to the political circumstances. The “nightmare of therapeutical nihilism” bore down equally on psychiatrists in larger American psychiatric institutions; and the German faith in genetics as scientific progress found its correlate there in an openness to “modern” therapeutic approaches.⁹⁵ From 1939 on, more than half of all psychiatric hospitals in the USA applied both the Cardiazol and insulin shock therapies, and by 1941 over 75,000 patients had been subjected to shock treatment.⁹⁶ There was general unanimity that shock therapy produced particularly good results for patients with short histories of schizophrenia; but its incredible success motivated trials on other psychiatric diseases or abnormalities stigmatized as such. Even homosexual orientation allegedly could be successfully “corrected” by a series of Cardiazol shocks.⁹⁷ The depths of this psychiatric practice came to light when attempts to make shock therapy less hazardous by combining it with dosages of curare for preventing bites and fractures⁹⁸ prompted the question of whether sheer brutality was not the underlying principle of therapeutic shocks:

The terrifying fear of annihilation produced by an intravenous injection of metrazol, the ensuing loss of consciousness experienced subjectively as death, the subsequent awakening with a feeling of re-birth and of infantile helplessness and the turning to parental figures in the environment for help and support have each been considered important to the process of recovery. It has been suggested that the patient experiences the treatment as sadistic punishing attack which satisfies his unconscious sense of guilt, obviating the necessity for self-inflicted punishment.⁹⁹

One characteristic of research on shock therapy in America and Great Britain was its alliance with the EEG. Early EEG studies during insulin shock therapy at the end of 1936 had turned out more interesting than Hudson Hoagland “had dared to hope,” as he put it.¹⁰⁰ Hoagland had previously postulated a dependence between alpha-wave frequency and the metabolism of the brain. Because insulin reduced the blood-sugar level and thereby

95 Sakel was invited to New York in 1936 to demonstrate his therapy and he stayed there. American psychiatrists dedicated a symposium to Sakel’s therapy at their annual meeting; see *American Journal of Psychiatry* 94 (1937): 89–182. Meduna then also worked in the USA in exile from 1939 on, first at Loyola University, from 1942 at Illinois Medical School with Warren Sturgis McCulloch. On the lives of Sakel and Meduna, see Freeman 1968, pp. 31–45.

96 Kolb and Vogel 1942; see the summary in Pressman 1998a, p. 158. Cardiazol was marketed in America under the name “metrazol.”

97 Owensby 1940.

98 Bennett 1940.

99 Levy and Grinker 1943. This quote alone shows that the lines of argument were very much more complex than suggested by Shorter (1997, chap. 6) with his simplistic opposition between progressive biological psychiatrists and fundamentalist psychoanalysts.

100 Hudson Hoagland to Alan Gregg, RAC, RG 1.1, series 200A, box 130, folder 1599.

deprived the brain of its energy supply, he regarded the drop in frequency of alpha waves during shock therapy as confirmation of his hypothesis, even though nothing was known yet about the way insulin therapy worked.¹⁰¹ Penfield and Jasper in Montreal speculated that it was not the epileptic seizure caused by the shock therapy that influenced the psychosis favorably, but the induced change in blood circulation in the brain.¹⁰² Electroshock therapy, which in the USA was advocated above all by Lothar Kalinowsky, was then also combined with EEG observations of the induced seizures.¹⁰³ In Great Britain, Grey Walter took an early interest in electroshock therapy and combined his shock studies with EEG analyses.¹⁰⁴ In Germany, the monitoring of shock treatment by EEG only started after the war with the studies by Richard Jung and Johannes Cremerius.¹⁰⁵

These inquiries into medicated shock therapies were soon crushed by the success of a faster, less dangerous, and above all cheaper alternative. Ever since Fritsch's and Hitzig's experiments, or Foerster's and Cushing's operations, it was of itself not new that an electric stimulation of the brain would trigger seizures; but the swelling wave of shock therapies opened the possibility of making out of a feared complication of neurosurgical operations a directed therapy. Ugo Cerletti was a generation older than the inventors of medicated shock therapies and came upon electroshock therapy quite by chance.¹⁰⁶ At the beginning of the 1930s in Genoa he was looking for a

101 Hudson Hoagland had heard of the EEG early on, thanks to Adrian (Hoagland 1974, p. 55), and soon afterwards, in January 1936, published in *Science* an astoundingly simple hypothesis about a way to control cerebral rhythms. Hoagland (1936a, 1936b, 1936c) observed rising alpha-wave frequencies in paralytic patients whose body temperatures were being artificially raised by diathermy for therapeutic reasons. This rise in frequency followed a metabolic rise according to the Arrhenius equation, which Hoagland regarded as a clear indicator of a direct dependence between the activity of the human brain and its rate of sugar consumption. The neurophysiologists assembled at the Cold Spring Harbor Symposium during the summer of 1936 tore Hoagland's thesis apart (Hoagland 1936b, Jasper 1936b).

102 They postulated a specific chemical factor whose identification ought to make shock therapy superfluous. But these studies evidently did not go beyond a detailed description of the cerebral blood supply during metrazol-induced seizure. See a letter from Wilder Penfield to Alan Gregg dated 29 March 1938, RAC, RG 1.1, series 427A box 6, folder 53, as well as Jasper and Erickson 1941.

103 See the literature in Kalinowsky and Hoch 1950. During the first stage of his exile after his expulsion from Germany in 1933, Kalinowsky worked in the Roman clinic where Cerletti began his experiments. With his insider knowledge in 1939 he also assisted in the first electroshock experiments in Paris and England during later stages of his exile. Peters 1992 reconstructs the close interrelation between the expulsion of Jewish scientists from Germany and the spread of shock therapies.

104 Flemming, Golla, and Walter 1939, Walter 1940.

105 Cremerius and Jung 1947, Jung and Tönnies 1950. Even Berger's final communication (1938a) reported about EEG recordings during Cardiazol shock experiments on schizophrenic patients.

106 Endler 1988 gives a description of Cerletti's development of electroshock therapy from the dual perspective of doctor and affected person.

simple and reliable method to induce epileptic seizures in laboratory animals, but more than half of them died upon his application of electric current, because he placed the two electrodes in the mouth and anus and that way regularly triggered cardiac arrest along with the sought epileptic fit. After taking over as head of the Neurological and Psychiatric University Clinic in Rome in 1935, he entrusted his assistant Lucio Bini with continuing the epilepsy experiments.¹⁰⁷ Fatality again was the main problem of these experiments. Help came from an unexpected quarter, namely, from Rome's slaughterhouse, and anti-psychiatrists would later hold against electroshock therapy its repugnant original setting.¹⁰⁸ In the slaughterhouse Bini and Cerletti studied how, at the instigation of an animal rights organization, pigs were electrically stunned before being killed. This happened there quickly and simply by applying current to both sides of the head, which caused seizures at the same time. Italian scientists introduced the ethical standard of Italian pig slaughter into international shock therapy. When on 15 April 1938 the Roman police brought an evidently confused man from the train station into the psychiatric clinic, they made good use of this unusual opportunity offered by the unidentified patient. On 18 April this 39-year-old engineer suffering from persecution mania was subjected to electrically evoked seizure; a month later, after ten more shocks, he left the hospital again cured.¹⁰⁹ That summer Cerletti visited Berger in Jena, perhaps because he was considering combining his shock therapy with EEG examinations. One year later, at the 3rd International Congress of Neurology in Copenhagen, Bini could already report about 3,000 electroshock treatments.

These electroshock experiments fit so seamlessly within shock therapies that the technical improvement from Italy was eagerly adopted in other countries. The German *Reich* was first in line, to present itself as a modern state by introducing electroshock therapy.¹¹⁰ In November 1939 Friedrich Meggendorfer performed the first electroshock trials in cooperation with Siemens at the Psychiatric Clinic in Erlangen. Anton von Braunmühl at the psychiatric institution in Eglfing-Haar followed suit soon afterwards; and within three years the supply of electroshock instruments throughout Nazi

107 See Shorter 1997, pp. 218–224.

108 Thomas Szasz's short essay with its brilliant title "From the Slaughterhouse to the Madhouse" is unsurpassed. It ends with the conclusion (1971, p. 67): "The invention of electroshock is modern therapeutic totalitarianism *in statu nascendi*: the mental patient, a non-person, is handed over to psychiatrists by the police, and is 'treated' by them without consent. The social circumstances in which electroshock treatment was developed are consistent with its 'therapeutic' action."

109 Cerletti 1950, 1954, Shorter 1997, pp. 218f. A note by Bini in his journal reveals, though, that an attempt to trigger generalized seizure in another patient one week before had been unsuccessful; see Bini 1995.

110 On the ambivalent modernization of psychiatry in the Nazi state, see Schmuhl 1991, and critically Blasius 1994.

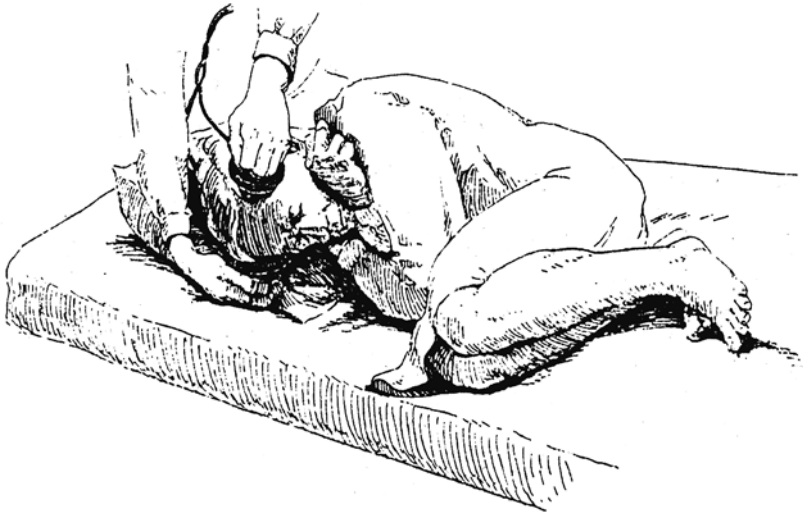


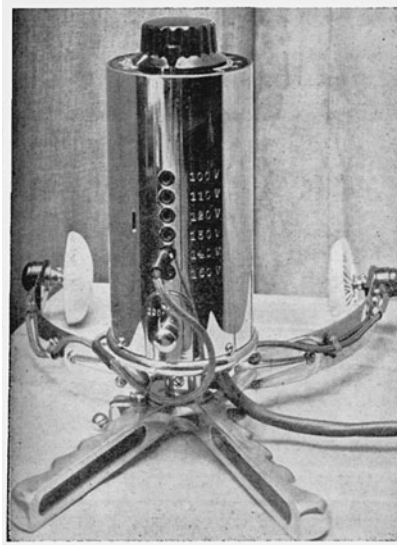
Abb. 2. Lagerung des Kranken zur Krampfbehandlung. Die mobilen Elektroden werden manuell an die Schläfen des Patienten gedrückt.

Figure 41 Sketch of how to administer an electroshock, by Adolf von Braunmühl in introducing electroshock therapy to Germany.

psychiatry was complete (Figure 41).¹¹¹ Wartime shortages additionally enforced conversion to electroshock treatment, because insulin became too scarce to be administered in high doses to schizophrenic patients. On 24 January 1942, insulin shock therapy was banned; in August of the same year, general conversion to electroshock therapy was introduced; and in the following spring, “95 Siemens-Konvulsator units with electrode sets” were ordered “for the treatment technique according to Prof. Dr. Meggendorfer and Dr. Bingel as well as according to Dr. von Braunmühl, at a total price of c. 955.– reichsmarks per unit.”¹¹² Measured by the number of publications

111 Meggendorfer 1940, Anton von Braunmühl 1940. Siemens had evidently spied market potential early on, because already by 1939 the first prototype was developed for clinical testing, which began to be mass produced in 1940 under the name “Konvulsator” (Pätzold 1940). Other firms also rapidly developed their own devices: Wolfgang Holzer’s “Elkra” design became the predominant device throughout Germany. From 1941 Siemens-Reiniger and the Viennese company Reiner regularly advertised their electroshock instruments (as “The handiest, lightest, and cheapest shock device in the world”), for example, in *Psychiatrisch-neurologische Wochenschrift*.

112 BA R 96 I/12, sheet 35. The preserved extensive correspondence of Dr. Herbert Linden, ministerial councilor at the Reich Interior Ministry and Reich expert on sanatoriums and care institutions, reveals that at this point in time many institutions already had electroshock apparatus at their disposal and used the opportunity to purchase a second or third device. However, it appears that Siemens had difficulty producing so many devices, so it is possible that not all orders were eventually delivered.



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Figure 42 Advertisement of an electroshock device in *Psychiatrisch-neurologische Wochenschrift* from 1941. This model offered by Reiner & Co. is described as: “The handiest, lightest, and cheapest shock device in the world. Directly connectable to the mains. No worry for the patient from headbands. Secure initiator of shock and retrograde amnesia. Broad dosage range. Personnel savings, as it is not the patient who comes to the device but the physician with the device to the patient. Multiply tested.”

and application variants in electroshock therapy, German psychiatrists took up the new method especially eagerly.¹¹³ Johannes Bresler, chief editor of *Psychiatrisch-Neurologische Wochenschrift*, wanted to administer electroshocks to the “whole lot of ‘inhibited,’ [. . .] brooding, timid, and weak-willed” types.¹¹⁴ And Meggendorfer had a very special treatment success to show for himself: After electroshock therapy, a man who had, for years, had a “hysterically crippled” right arm promptly raised that arm upon energetic pronouncement of “Heil Hitler!”¹¹⁵

113 Whereas Meggendorfer recommended buckling the electrodes to the head with a special rubber belt, Braunmühl (1942) propagated hand-held button electrodes with a security contact and built-in “feedback mechanism,” so that “the nurse” could walk from bed to bed through a large treatment room and administer shocks serially, signaling her readiness each time to the physician at the switch unit. The Austrian physiologist, electroengineer, and psychiatrist Wolfgang Holzer (1941, 1942) developed a full set of electrodes—ranging from large head clamps to individual electrodes and an electrode bridge—to be equipped for every case of application.

114 Bresler 1941.

115 Meggendorfer 1940.

Alongside the extermination of “unviable worthless life” (*lebensunwertes Leben*) and genetic research, shock therapy developed into a solid component of Nazi psychiatry. In the thinking of its leading representatives, in this way psychiatry was supposed to demonstrate its progressiveness. At the same time that this “active therapy” was intensifying, so-called “wild euthanasia” began at sanatoriums and care institutions; the purposeful starvation and killing of those patients deemed not “profitable.” Shock therapies were not just the “consoling addition to the necessity of sterilizing intervention,” as the Göttingen psychiatrist Gottfried Ewald formulated it.¹¹⁶ In the murderous activism of National Socialist psychiatry, it was the therapeutic counterpart to patient killings. One obviously cannot draw any general conclusions about psychiatric practice from the picture of shock therapies in the distorted view of Nazism, but these therapies fit exactly into its ambivalent reform ambitions. In the second half of the 1930s, the established strategies of segregation and hospitalization of psychically conspicuous people worldwide was supplemented by therapeutic procedures in which corrective but aspecific interventions of human behavior became the goal on a grand scale. The procedure’s very simplicity, compared to other therapies, allowed shock therapy to develop into a universal tool of psychiatry. But often it was also a matter of just testing out on the patient which therapy “worked best.”¹¹⁷ What in EEG research primarily appeared in the USA as an unstoppable totalizing movement of a diagnostic method that in principle sought to record electroencephalographically all situations of life and all forms of life, found here its correspondence in the tendentially limitless application of the “great and desperate cures” (Elliot Valenstein).

Shock treatment had particularly great momentum. The quick success of this procedure led to explorative trials of more and more agents as shock methods, in which nearly any means were conceivable and in which the testing was directed more at the radicalness of the therapy than at postulated effective mechanisms: Because a “retuning” of the body was the supposed effective factor, basically any aggressive method could be considered—up to so-called “annihilation therapy.” Walter Freeman, the preacher of psychosurgery, expressed the therapeutical sarcasm of those years by the paradox: “the greater the damage, the more likely the remission of psychotic symptoms.”¹¹⁸ Shock therapy was applied complexity reduction in and of the brain. Shock, that “therapeutic storm,” and even more so, psychosurgery, liberated ailing brains of a “too much” inside the brain, in the sense of

116 Ewald 1937, p. 899.

117 Worthing et al. 1943, Rosen, Secunda, and Finley 1943. A survey by the American Health Authority yielded that in 1941 electroshock devices were in use in 42% of all psychiatric institutions (“Shock Therapy Survey” by the US Public Health Service from 1941, quoted from Braslow 1997, p. 100).

118 Walter Freeman: “Brain-damaging therapeutics,” *Diseases of the Nervous System* 2 (1941): 83, quoted here from Frank 1986, p. 15.

a new directedness: “It has been said that if we don’t think correctly we haven’t ‘brains enough.’ Maybe it will be shown that a mentally ill patient can think more clearly and more constructively with less brain in actual operation.”¹¹⁹ Shock therapies made the brain, as an organ, manipulable.

The electrical brain at Auschwitz

Maybe it lies in the logic of such inverted argumentations for the electroshock device to become the instrument of survival, of all places, where killing was the task at hand, at Auschwitz. According to Giorgio Agamben, the concentration camp, in which individuals are reduced to “naked existence,” is the biopolitical paradigm of modernity, the “hidden matrix [. . .] of the political space in which we are also still living today.”¹²⁰ He consequently positions his analysis of the fatal high-altitude experiments conducted by Sigmund Rascher in the concentration camp at Dachau, between the extermination of “unviable worthless life” and the “politicization of death” in the brain-death debate. Along the lines of the biopolitics of modernity pointed out by Agamben, one can retrace how the experts in electrophysiology, too, became sovereigns over human life when they drew epileptics out of the obscure dullness of psychiatric institutions into the limelight of neurophysiological explication, or classified behaviorally conspicuous children as electro-disturbed brains, or “corrected” homosexuality by electroshock. Even the electroshock device at Auschwitz participated in this paradigm; but as materialized biopolicy it double-crossed the policy of extermination at the camp at the same time. For, in the paradoxical situation of the camp, the erection and application of this aggressive neuropsychiatric form of therapy primarily offered a prospect of survival. In the perverted world of a concentration camp what lay hidden behind the electroshock was not an especially perfidious therapy unit of German SS physicians, but the intrepid resourcefulness of individual prisoners.

After some weeks of ceaseless interrogations, I left the Gestapo prison in Annemassee; the director of this institution gave back my researches to me, whereby he impressed upon his subordinates that with such an accomplishment “in the Third Reich, colossal possibilities awaited me.”

The most disturbing image of electroshock therapy and of the electrical brain is drawn in a report by the Polish detainee physician Zenon Drohocki. Drohocki had studied medicine in Cracow and from the mid-1930s on had undertaken electrophysiological EEG examinations with Leon Asher in Berne and with Philipp Rijlandt in Brussels. Irritated by the obvious contradictions

119 *Ibid.*, p. 16.

120 Agamben 2002, p. 175.

between Kornmüller's field-specific currents and Berger's holistic cerebral currents, he had developed his own views on cerebral currents in over a dozen publications. Accordingly, the curves inscribed in the conventional EEG were just the summated picture of a multiple of individual rhythmic oscillations. He evidently had some electrotechnical skill, because Drohocki was able to publish recordings of some of these individual partial currents after having decomposed the spectrum of brain currents by filtering and amplifying them in isolation.¹²¹

Additionally, Drohocki must have occupied himself intensely with electroshock therapy before he was arrested at the end of 1943 in occupied France while attempting to escape across the Swiss border:

In the knapsack that I tried to throw as far into the barbed wire as possible when I crossed the Franco-Swiss border, there were among other things twelve of my electroneurophysiological papers which had appeared in the years 1937–1940 in French and German scientific journals; among them was also a diagram of the apparatus for generating electroshocks.¹²²

Obviously, Drohocki was not incarcerated in Auschwitz in order to work there on neuropsychiatry as a detainee physician. But somehow he managed to draw the attention of the medical section to himself. With a fellow detainee, a Philips engineer from Holland, Drohocki built a functional apparatus in Monowitz near Auschwitz out of electrical parts that they could find over there (mainly from shot-down Allied aircraft). With it he began to treat his fellow prisoners. His report noted in the austere precision of a survivor the limited sense of such therapies under camp conditions:

In Monowitz the electroshock treatments for each patient were applied as a rule twice a week over a total treatment period of five weeks, adding the period of observation before and after treatment, i.e., altogether about two months. Every patient was, in a way, untouchable within this period of time. In the case of a cure, the period of survival could last longer, i.e., until death for other reasons and in some cases even until the liberation. It fortunately turned out that the majority of these patients were suffering from depression, which, as one knows, generally responds quite well to this treatment method. The percentage of cures

121 Drohocki 1937, 1939a, 1939b.

122 Drohocki 1975, p. 162. I thank Arthur Zipf for translating this text from Polish. On Drohocki's account see also his statement during the first Auschwitz trial in Frankfurt, depositions before the public prosecutors at the *Landesgericht* in Frankfurt am Main, Vernehmungsprotokolle im Verfahren 4 Js 444/59, sheets 14283–14286.

or improvements was very high, which made it very much easier for me to continue working.¹²³

It is no longer possible to reconstruct the extent of electroshock therapies conducted by Drohocki in Monowitz at Auschwitz. It likewise remains speculation whether Drohocki would have been able to be as persuasive with another advanced medical procedure at Auschwitz. Such questions ultimately remain trivial for the conflicting efficacy of this dual biopolitical constellation, in which absolute control over naked existence ceded room to biotechnical control over the brain, albeit sovereignty over life and death was partially delegated to prisoners. In the political matrix of the camp, biopolitics and biotechnology outbid each other with paradoxical effects.

It was hardly a matter of chance that, of all things, an electroshock apparatus, that is, the technical showpiece of advanced invasive psychiatry, should be in a position to weave a dense web of survival relationships in the extreme situation of a German concentration camp toward the end of World War II. The project of just building the device unfolded a complex economy for winning time; with the start of treatment it solidified into a material culture of diverse bartering relations, because the apparatus “created ever new possibilities for the ill as well as for everyone who worked together with me.” According to Drohocki’s report, not only did its construction require a carefully construed network of agreements and social contacts in order to gain access to the necessary parts and to tie diverse fellow detainees or wardens into the project, but a mesh of complex relations also quickly formed around the functioning device, turning the apparatus into the vehicle of a communication network at Auschwitz:

It is thus interesting and peculiar that the business with electroshocks under camp conditions gradually brought a new and unanticipated dimension to our lives; this perhaps affected the lives of the sick less than of the healthy. It opened up options that would have been unthinkable without this apparatus. It seems to me that one should emphasize this aspect of the enterprise above all, which basically has nothing to do with the treatment.¹²⁴

The electroshock device imported its own time structures and material flows into life in the camp. Treatments occupied a certain period of time and legitimated visits to the infirmary building for a number of weeks. With an electroshock treatment as a pretext, prisoner visits could be organized

123 *Ibid.*, pp. 163f. When precisely and how exactly the apparatus in Auschwitz was employed cannot be gathered from his report. Makowski (1978) confirms Drohocki’s construction of an electroshock and electroanaesthetic apparatus and mentions that he worked from January 1944 to January 1945 as a detainee doctor in Monowitz.

124 Drohocki 1975, p. 164.

between different divisions of the camp and a small news exchange could be set up. In a situation in which rapid success primarily meant new vital risk, contact to the apparatus became central. It seems as if the camp world made especially visible that social embedding of a scientific technology which usually disappears behind the production of knowledge and other application effects.

In a text that could be called complementary, Ludwik Fleck processed his own experiences as a detainee in the concentration camp at Buchenwald, where he was deployed as typhus specialist in a vaccination laboratory. For Fleck this laboratory represented an extreme case of his sociology of knowledge:

I had the rare opportunity to observe for almost two years the scientific work of a collective that exclusively constituted laymen. The findings of these observations clear up some problems in philosophy of science much better than speculative discussions. [. . .] In erroneous, just as in true knowledge, the view forms not by logical calculation of any particular elements but by a complicated stylizing process. There is no observation that is not prejudiced by directed and limiting preparedness for thought.¹²⁵

Drohocki did not make any reflections about sociology of science and yet his report supplements Fleck's considerations where he retraces precisely the relations occasioned by the apparatus:

Electroshocks very quickly became an attraction drawing interested persons from other divisions of the hospital as well as from among the camp elite, SS-members, etc. I was bombarded with questions, each had his own comments about those seizures, each had his own theory, his own explanation. I was given suggestions, among other things, various projects such as for the removal of inconvenient persons.¹²⁶

New options for action not only came from curious bystanders but also arose from the circumstances of the application situation. For lack of therapeutic alternatives, Drohocki used his apparatus, for instance, for the treatment of asthma attacks. Furthermore, because there was a shortage of narcotics, the unconsciousness attendant to shock suggested specific utilization of the device for short surgical interventions. Initial trials ended up in a project to develop other apparatus specifically for this electronarcosis: "For that, it was a matter of constructing new apparatus, trying them out, carrying out new calculations, and enlarging the number of collaborators—in a word: Out of the electroshock idea there emerged ad hoc an institution of

125 Fleck 1983, pp. 134 and 140; cf. Borck 2004a.

126 Drohocki 1975, p. 164.

the character of an enterprise.”¹²⁷ The electroshock device and the research on other apparatus allowed Drohocki to attract the camp leadership’s attention and barter “scientific research” for a reprieve on his life. Important Nazi visitors to the concentration camp got demonstrations of Drohocki’s apparatus, and he wrote reviews for individual SS physicians. Drohocki was able to save his own life but not that of his wife, who was killed in Birkenau. When the Auschwitz-Monowitz camp was being dissolved, he was relocated via Buchenwald to its subdivision Dora, in order to conduct further experiments on electronarcosis, but it never came to that.

Drohocki’s devices were unquestionably materializations of biopolitics. Under camp conditions, they were presumably only able to organize such an extensive network because of their propensity to signify the trademark of a neuropsychiatric biopolicy. At the center of biopolitics, their own concept becomes blurry and loses its potential for differentiation. If the camp is the “biopolitical paradigm of modernity,” then reports and analyses such as those by Drohocki and Fleck show that it indicates scarcely more than one perspective in looking at the dynamics and heterogeneity of bioscientific practices.

127 *Ibid.*, p. 165.

6 Designing, tinkering, thinking

What is hidden inside the EEG?

In twenty years of international research, a sensational method to observe the electrical activity of the live brain became established as a diagnostic procedure worldwide. This innovation in diagnostics is indebted to the regular curve pattern that Berger already noted in his first communication on the EEG. Following a canon of clearly defined EEG characteristics, the “normal science” easily registered within its research agenda deviations from this pattern which proved to be secure diagnostic indicators of a series of clinical issues.¹ This anchoring of the EEG in clinical diagnostics left its institutional mark during the first postwar decade with the founding of international professional societies, specialized journals and congresses, with international standardization of recording practices, the publication of manuals and textbooks, as well the industrial production of EEG devices.²

The initial enthusiasm about Berger’s discovery circulating in German newspapers during the summer of 1930, and the charged suspense among the assembled physiologists in Cambridge on 12 May 1934 as the EEG of the electrical activity of Adrian’s brain doing mental arithmetic was being recorded, drew on entirely different expectations, however. A parameter was measured in the EEG that showed a clear dependence on processes of the psyche. What would have been more obvious than to suppose that the EEG

1 On the concept of a normal science, see Kuhn 1979, esp. pp. 49–56.

2 By the end of the 1940s national EEG societies had already formed in the USA, Great Britain, France, Scandinavia, and Italy, which united as the International Federation of E.E.G. Societies after the first International EEG Congress in London in 1947 and brought the *EEG Journal* into being; see Cobb 1985. In 1949 the first textbook in English on *Clinical Electroencephalography* appeared (Cohn 1949). Grass Model III devices set the international recording standard. Serial production of EEG devices in Germany began at the end of the 1940s by the company *Elektrofrequenz Schwarzer* in close cooperation with Kornmüller; see the correspondence with Fritz Schwarzer among the Kornmüller papers, MPG-A, III/16. *Siemens* put its own instrument on the market only toward the end of the 1950s. I thank Ms. Doris Vietinghoff of the Siemens Archiv Medizintechnik, Erlangen and Mr. Jürgen Neubert from the company Schwarzer GmbH in Munich, for access to the extant documents.

was the key to the psychophysiology of humans? Not everyone would have immediately thought of “candid letters in brain script,” that is, of a perfect fusion between the world of the mind and physical processes which encompassed even the arbitrary and ambivalent symbol systems of human communication. But the blockage of alpha waves during intellectual exertion at least promised rapid deciphering of electrophysiological functions of the nervous system involved in psychic processes. What else might one look forward to, with such a conspicuous and promising connection revealed right at the beginning of work by the new method? This hope was not fulfilled. Electroencephalography rather proved to be surprisingly obtuse. The brain presented itself as surprisingly resistant to that bombardment of kilometer-long scrolls of EEG graphs from thousands of examinations. Jasper again pinpointed the mood when he demanded in 1948 that the “promotion of large-scale, mass-production, brain-wave factories” finally give way to a “new attack on some of the most important problems of human behavior, the neuronal mechanisms underlying processes of awareness, thought, and action.”³ The physiology of the recorded curves in the EEG; the incongruity between those comparatively slow but continuous oscillations and the abrupt activity of individual nerve cells singled out by cellular neurophysiology; and the conspicuous relation between EEG alterations and psychic processes: all remained largely unresolved. But just these open questions and urgent issues extended far beyond diagnostics which the EEG had been established as. Which electrophysiological processes was electroencephalography depicting? And what was their psychophysiological importance? These questions provoked a search for hidden signs in the EEG that left its mark in new analytical procedures just as much as in new interpretations. The EEG seemed to indicate, above all, that something still needing to be recovered was hidden behind the regularity of its curves.

In this pointed and multiply staggered constellation, the EEG operated as a “theory inspiring tool” in Gerd Gigerenzer’s meaning.⁴ In view of the obstinacy with which the findings gathered by electroencephalography manifested psychophysical regularities that resisted arrangement within neurophysiology, experimental practice alone already suggested that the new method should be elucidated in many directions in search of conspicuous findings; the registration techniques should be transformed or refined in various ways;

3 Jasper 1948, pp. 343 and 346.

4 Gigerenzer (1991) formulated this as a heuristic principle to make accessible to analysis in the philosophy of science the “context of discovery” next to the “context of justification” (in Reichenbach’s distinction). About the examples offered by Gigerenzer himself for acknowledged psychological theories, such as the computer model in cognitive science (Gigerenzer 2000, pp. 26–43) or the process of statistical conclusion as a metaphor of the mind, this principle seems to me fruitful also for an epistemological analysis of open constellations in which theories could claim only temporary validity. I take as a basis Rheinberger’s (2000) analysis of scientific tinkering (*Bastelei*).

and the findings should be elaborated by existing representational and analytical procedures. Gigerenzer's open tool concept permits one to bundle together almost all forms of work about and using EEG curves aimed at a theory of brain function or at a psychophysiology of brainwaves, and it delimits them at the same time from diagnostic descriptive procedures with which the curves are handled—to borrow Pauline Davis's words—“just as an artist looks at a human face.”⁵ The brain theories that emerged out of the technical research on EEG curves not only document the close interlocking between experimental practice and theory development, which has so often been emphasized by the actors themselves. These theories also demonstrate how technical science literally makes one think. The current fluctuations recorded in an EEG put thought and psychic activity in a new light; but the halting of “big” and regular electrical activity at the instant of mental activity was itself hardly more than a challenge to continue the technical and theoretical work.

EEG curves called for tinkering around with ideas about processes in the brain as locations of thought. Refined methods of amplification and recording, special analytical procedures, or new representational techniques would enhance, reshape, and differentiate the already discovered cerebral currents, in order to reveal those connections between current and mind, psyche and brain process, supposed ever since the initial findings. A cascade of new epistemic things thus stepped up alongside the scientific object “brainwave” constituted by the EEG. New apparatus registered variations in the EEG, accentuations of individual segments, or delivered an analysis of the recorded currents. An ensemble of technical media was engaged to remold the EEG plots and to unlock them further until the hidden thing inside the EEG would finally be found. Cerebral research operated here in the zone that Martin Heidegger presented as typical of modern technical science:

The recovery that prevails in modern technical science has the character of a stance, in the challenging sense. This happens in that the hidden energy in nature is unlocked, what has been unlocked is remolded, what has been remolded is stored, what has been stored is redistributed, and what has been distributed is re-engaged. Unlocking, remolding, storing, distributing, re-engaging are all manners of recovery.⁶

Heidegger's famous example is the power station set in a flowing current. Just as the Rhine river was already a flowing current without the power station, current fluctuations existed in the brain without the EEG. But it was

5 Pauline Davis 1940a, p. 714.

6 Heidegger 1954, p. 20; on the following see also the talk “Bauen Wohnen Denken,” *ibid.*, pp. 139–156.

only by the EEG that the brain became a producer of rhythmic current oscillations; EEG curves were the window opening onto a particular perspective on brain processes. The recording technology set in motion an ultimately endless process of transformations that made new things apparent. But because none of the theories on psychophysical brain functions that were postulated in this connection could prevail, this example manifests the constructivism of theoretical experimental research. One does not need to follow Heidegger's existential philosophy to whittle the constructivism of modern brain research down to the question of whether the theoretical frameworks that were generated in their technically instructed experimental practice arrive at "habitable" forms of thought.

Rapid vibrations of thought

Press reporting about the EEG is a good indicator that the new method of recording immediately suggested a very specific association. The EEG counted as an instrument for reading thoughts because by this method the human brain could be observed while thinking. The metaphor of writing, already so avidly employed by Marey for the graphic method, allowed the inscription of cerebral currents to become the electric script of thoughts in a code that only needed to be deciphered. The associated anxiety that it might now be feasible to monitor intellectual life by the new technology could already be gathered from some letters to Berger. The theory was thus already finished, it was already in the air and was only waiting for an apparatus that could be linked to it. However, this link was not nearly so easily performed as one would imagine. For example, up to World War II only one paper in which the EEG was tested as a lie detector—evidently without much success—was published.⁷ The writing model for the inscription of brainwaves demarcates the conceptual counterpart to Gigerenzer's heuristic technique. Here technology was deployed to let a particular theory become reality. At least one research program was started with the explicit aim of "finding specific electric potentials for different experiential contents," therefore to make out of an EEG a genuine detector of psychic states.⁸ Its analysis shows how in this case experimenting developed a life of its own that is in bad accord with the concept of theory-testing in the philosophy of science.

7 Obermann 1939. On the history of the instrumental transfer of lying, see Bunn 1997. A series of papers did report about EEG signs of different forms of attentiveness (e.g., Adrian 1938, Martinson 1939, Burrow and Galt 1945), and in 1948 a "kappa burst" was announced in *Science* as equivalent to thinking (Kennedy, Gottsdanker, Armington, and Gray 1948).

8 This at least is how the Austrian psychologist Hubert Rohracher described the point of departure of his EEG researches in a late autobiographical text (1972, p. 265). It is likely that he embarked on his experiments with this preconceived plan. Berger, too, had started off with strong psychophysical basic assumptions, and his experimental system remained unproductive for years from overly strong theoretical guidance, but he never got far enough along to ascribe different mental contents to his EEG curves.

Tinkering rather seems central, even for a theoretically conceived research agenda. Just as tinkering can lead to a new theory, so also the concept of brain script led to tinkering.

On 4 April 1935 Berger received a letter with astonishing EEG observations by a psychologist he had never heard of before. Hubert Rohracher first described his confirmation of alpha waves from resting-state recordings and then continued:

Furthermore, it was revealed that upon intellectual activity and upon sensory stimulation (calculation and light flashes) extraordinarily frequent oscillations arise—up to 1500 per sec—some of which also presented during the registrations of the resting state, which, of course, never can be complied with in an ideal way by test persons.⁹

At that time Berger had not yet published anything about his experiments on rapid oscillations; and after taking a critical look at the enclosed curve samples, he answered with paternalistic admonishment that “there are still too many secondary oscillations in it which do not arise cerebrally but have come in some other way.” But the writer of the letter would not be dissuaded about his idea of tracing mental activity to rapid rhythms in the EEG and differentiating the variants of these rhythms by individual forms of work. In his first EEG paper Rohracher published a ranking of different mental activities by registered brainwave frequencies, where mental arithmetic took the lead with over 1000Hz, and spelling even came to 500Hz.¹⁰

The fastest invisible oscillations as carriers of psychic events evidently were present right at the start of Rohracher’s electrophysiological research projects. Even prior to his EEG investigations, Rohracher had attempted to detect electromagnetic waves with a coil wrapped around the head—therefore, to receive radio signals of the mind.¹¹ Rohracher began with his EEG experimentation right after Berger’s first summarizing account of the EEG in *Zeitschrift für Psychologie*.¹² Those experiments initially yielded no results useful to him because the postulated rapid oscillations were completely unidentifiable in the curves. So he had an amplifier arrangement from the department on remote signaling at the Viennese polytechnic specially constructed for his purposes, with which oscillations up to 3000 Hz

9 Hubert Rohracher to Hans Berger dated 4 April 1935, folder “Rohracher,” Berger papers.

10 Rohracher 1935.

11 Rohracher 1972.

12 Berger 1932b. At that time Rohracher held a position as research assistant at the psychology department of the University of Innsbruck. He conducted the first experiments together with Agostino Gemelli in Milan. In 1938 his teaching license was revoked for having made anti-Nazi statements, and in 1939 he was deployed in the military as a psychologist. However, in 1942 he received an appointment as extraordinary professor of psychology at the University of Vienna. After the war he was promoted to full professor of psychology at Vienna in 1947.

were recordable by oscillograph. In spring 1935, hence at the same time as the first international researches on the EEG, Rohracher's experimental system began to deliver results along the lines of his starting hypothesis:

[Beta oscillations] are the electrical effect of those brain actions which occur in our brain during psychic processes; beta waves thus become apparent, as the experiment demonstrates, primarily during intellectual exertion and upon sensory stimulations. They are unusually irregular and, insofar as they are countable at all from the unsurveyable variety of their forms, exhibit frequencies of up to 1000 oscillations per second. These properties agree with the notions that we must have about brain processes forming the basis of psychic events: The unusually complex cooperation between extraordinarily many cortical cells required by the simplest of psychic processes, allows one to expect as an electrical effect a very intricate curve with relatively rapid variations in potential.¹³

Like Berger, Rohracher distinguished between alpha and beta waves as two fundamentally different wave types,¹⁴ but in his case this typology found its instrumental correlate in the technical application of two separate amplifier systems, each for just one wave type. That way, Rohracher could represent cerebral currents to suit exactly "the notions that we must have about brain processes forming the basis of psychic events." Thus his recording device was already constructed theory.

Rohracher's application of Fourier analysis to EEG curves is equally instructive about the interplay between tinkering and theory in this experimental system. Although his full attention was directed at the rapid oscillations in the EEG, it is remarkable that Rohracher did not use this method, as others did, to figure out hidden harmonic oscillations in the EEG curve, that is, rapid frequencies. This mathematical analysis of the curves was not supposed to supply evidence for his hypotheses but to stabilize the experimental system at a phase when Rohracher's theory had fallen into a marginal position, because the mainstream, primarily in American EEG research, were working on brainwaves against the backdrop of neurophysiological issues or with the aim of characterizing alpha waves. Rohracher's Fourier analyses drove at singling out his approach as mathematically exact, scientifically extremely conscientious experimentation.¹⁵ Because the analyses showed that his recording apparatus had recorded alpha waves as sinus waves with hitherto unattained clarity and free from interferences, he contended that the

13 Rohracher 1938b, pp. 362f.

14 Albeit, Rohracher preferred rapid oscillations as the substrate of mental work from the outset, even before Berger officially changed over to this interpretation.

15 Rohracher twice published a Fourier transform of alpha waves (1937, 1938a). His paper on sources of error and control methods in EEG examinations (1939a) in particular provides references to this strategy.

rapid frequencies questioned by other researchers should also be recognized as “genuine” biological or psychophysiological phenomena. With these investigations Rohracher did, in fact, succeed in establishing himself as a specialist in alpha-wave registration.¹⁶

In Rohracher’s hands the abstract mathematical method of Fourier analysis, which transformed complex EEG curves into more or less regular spectra, removed from alpha waves that hidden specificity which he had been looking for in the EEG. Because the Fourier analysis revealed them as uniform sinus waves, alpha waves fell away as carriers of spontaneous mental activity. According to Rohracher, they should most likely be regarded as the expression of purely physiological processes in the nervous system. At the same time, in this elaboration of his approach, beta waves slipped increasingly out of grasp as a subtle complex of oscillations of the psychically active cortex. Beta waves were not some artifact from interference. Rohracher viewed them as electrophysiological representations of psychic events. Their very elusiveness from mathematical analysis made these smallest instantaneous variations in potential stand out as transitional phenomena between psychology and physiology. This might well have been the reason why Rohracher never subjected beta waves to Fourier analysis. Their ephemeral nature did not prevent Rohracher from constructing far-reaching theories of the brain and the memory based on beta waves, however, with which he came very close to a concept of electrophysiological memory retention, which has normally been associated with Donald O. Hebb.¹⁷

The intention behind Rohracher’s electrophysiological investigations was to figure out a scientific foundation for psychology, without reducing it to electrophysiology. His brain theory was supposed to bridge the gap between the most advanced scientific application in electrotechnics and the greater cultural history of the West. This context is breathtakingly depicted in one popular account (Figure 43). A report on Rohracher recording brainwaves was published in large double-page format in the National Socialist propaganda magazine *Koralle* on 8 August 1943. Half a year after the defeat of Stalingrad and while the Allies were already conducting daytime air raids on larger German cities, *Koralle* was publishing EEG curves of “inner calm” or “strenuous brain work” framed by Giorgione’s *Sleeping Venus* and Dürer’s *Melencolia*, which latter is described as follows:

Untiringly pondering, ceaselessly probing, the human mind—Albrecht Dürer suggests it by the figure of this picture—delves into the problems

16 Reviews widely praised his synthesis in book form and it appeared in an expanded second edition just a year later (Rohracher 1941).

17 Hebb 1949. See Rohracher 1939b; this “attempt at a brain theory” appeared in a second, revised edition in 1948 in which he also discussed Hebb. In 1953 and 1967 it appeared under the title *Die Arbeitsweise des Gehirns und die psychischen Vorgänge* [The way the brain works and psychic processes].



Figure 43 EEG research between intellectual history and technical torture. A popular report from 1943 on Hubert Rohrer’s experiments and his brain theory: The Brain “Writes” Wave Lines.

of the surrounding world. One sees in the figure’s face and attitude the permeating tension of thinking. Nowadays the energetic foundations that form the basis of mental activity can be made visible in “brainwave images.”

Another picture shows Rohrer lifting the lid of a coffin-like iron chest, inside of which lies a test subject with his head turned to the side like the reclining Venus depicted above, “as if all thought had been extinguished” (caption). The thick iron plates were a direct consequence of Rohrer’s powerful amplification of weak beta waves, which necessitated special shielding of the experimental arrangement. At the same time, they let Rohrer appear as the modern Frankenstein, since nowhere else had such a radical shielding been chosen for the same technical reasons.

The EEG was supposed to be a bridge between the soft and hard sciences; but keeping open this perspective on the EEG curves encouraged fantasies of surveillance and remote control with respect to Rohrer’s projects. The photograph of Rohrer standing in front of the chest with the locked-in test person unintentionally delivered an illustration of his secret war research. Although his first experiments on radio signals from the head had yielded no results, he continued to pursue them in parallel to his EEG studies. An engineer friend of his gave him the tip to experiment with densely wound small receiver coils, with which he did in fact capture unexplained

radio signals.¹⁸ At the same time he conducted some experiments on himself to see whether the brain was also a receiver organ for radio signals:

I conveyed by means of electrodes attached to the forehead and the back of the head alternating currents through my head at a frequency in the range of 5,000–10,000 oscillations that was raised stepwise, first by 10 and then by 100 Hertz; the intensity was augmented so much that the current was just barely tolerable (up to 7 milliampère). Apart from subjective light effects and the familiar tingling sensations, there wasn't the slightest thing noticeable. If organs really were present in the brain that respond to electric oscillations, these relatively powerful currents would have induced clear effects; as there failed to be any effect at all, it cannot be assumed that the extremely weak fields emitted from the human brain could exert any kind of action on other brains.¹⁹

Although Rohracher publicly announced the failure of these stimulation trials, he secretly continued to work on this project. In March 1944 the Reich Research Council (*Reichsforschungsrat*) approved a research commission on “influencing psychic states by electromagnetic fields,” assigning it the high urgency level SS.²⁰ The goal of these investigations was the capability to put the crews of enemy bombers in a state of fear by remote control, by broadcasting powerful radio waves tuned to EEG states typical of fright and confusion. In the course of his wartime research, Rohracher transformed himself into that brain engineer of “physiological problems of the future” envisioned ten years before.

Rohracher's EEG research on brain theory and his psychoactive electrotherapy marked the extreme variant of a spectrum of ways to get cerebral currents to oscillate by metaphorical connection to existing theoretical structures. By its rapid establishment the EEG could claim terrain for itself, which owing to the technical demands and expertise was less accessible to interferences by outsider methods and popular concepts than the various electropsychological projects of the 1920s. But this does not mean that the upswing in brain-current curves did not animate others to use them for their own purposes. Ernst Henßge, for instance, an electrotherapist at the famous sanatorium *Weißer Hirsch* in Dresden, added so-called “action current therapy” (*Aktionsstromtherapie*) with brainwaves to his copious repertoire of biophysical therapy methods from 1937 on. Treatments with currents at alpha-wave frequency were supposed to have a beneficial effect particularly

18 Rohracher's first book after the war was devoted to this phenomenon (Rohracher 1949).

19 Quoted from the *Koralle* issue dated 8 August 1943; see also Rohracher 1941, p. 66.

20 “Beeinflussung psychischer Zustände durch elektromagnetische Felder,” BA, R 26/III, vol. 1; see Schaefer 1986, p. 105. Hans Schaefer evidently purposely mentioned no names when he described this project in his autobiography but described the applicant as a “full professor of psychology” and a “renowned and otherwise very capable colleague.”

on strokes, cerebral sclerosis, and paresthesia.²¹ The ophthalmologist from Bottrop, Johannes Ohm, who for decades had been studying nystagmus, an occupational disease of miners, and had already put forward in 1925 a voluminous work bearing the title *Augenzittern als Gehirnstrahlung* (Ocular Jittering as Brain Rays), suspected that the fine muscles of the eye intercepted the rhythmic potentials of deeper layers of the brain like small radio receivers and converted them into oscillatory eyeball movements: “Why should the irradiations of the brain stop at the nerves and muscles? Who supplies us with the fine apparatus to receive them ‘wirelessly’?”²² Berger also chose as the motto for his last publication the poem *Geheime Wellen* by Heinrich Anacker:

*Wie seltsam, daß geheime Wellen gehen
Von Mensch zu Mensch, weit über Land und Meer;
Daß einer Seele Ruf wie Flügelwehen
Uns nächtlich streift, kaum ahnen wir woher.
[. . .]
Und in derselben Stunde kann's geschehen,
Daß unterwegs uns schon die Antwort fand—
Ein Wunder strahlt; geheime Wellen gehen
Von Mensch zu Mensch, weit über Land und Meer.*

Secret Waves

How strange that secret waves move
From person to person, far over land and sea;
That the call of a soul, like the flutter of wings,
Brushes us by night, we hardly know whence.
[. . .]
And in the same hour it can happen
That along the way the answer has already found us—
A marvel shines; secret waves move
From person to person, over land and sea.²³

On the penultimate page of his *Psyche* he divulged that he had been inspired by Rohrer's views to conceive his never-realized project on rapid waves, meaning to check Cazzamalli's radio brain, until he “distanced himself from such experiments at the urgent advice of savvy electrophysicists.”²⁴

21 Henßge 1937, 1939. Henßge's book from 1952 shows that this was certainly not an outsider to electrotherapeutics.

22 Ohm 1925, p. 318; see Ohm 1935. Ohm first presented his wave theory of brain function 1922 at the annual meeting of the *Deutsche Ophthalmologische Gesellschaft* in Jena, which Berger inaugurated because he happened to be the officiating dean then. Later Berger repeatedly noted down papers by Ohm in his journals as interesting reading.

23 Berger 1940, p. 3. Berger had found this poem in the 18 October 1936 issue of the newspaper *Deutsche Allgemeine Zeitung*.

24 Berger 1940, p. 31.

For lack of serviceable EEG apparatus, Berger began at this time together with his wife to conduct experiments on telepathy.²⁵ Rohracher's rapid oscillations of thought, Ohm's brain rays, or Berger's experiments on thought waves signify attempts to make the EEG speak or sound within the cultural resonance space of telepathy. Instead of arriving at operationalizable brain theories by technical engineering, these researchers were looking in EEG curves for messages by concepts and models already predetermined at the outset.

The concert of cerebral currents

Here we have finally arrived at the place to introduce Richard Jung's EEG investigations. He got around to formulating a theory of brain function inspired by the EEG only indirectly, because his habilitation thesis fell through, presumably due to envy and malevolence. As a medical student in Berlin Jung by chance witnessed one of the first intraoperative EEG recordings, in February 1934, which is how he became interested in this research. Thanks to an equally chance encounter with Alan Gregg while he was writing his doctoral thesis under Hugo Spatz 1934/35 at the *Deutsche Forschungsanstalt für Psychiatrie* in Munich, Jung obtained a Rockefeller fellowship with which he gathered training in the modern methods of electrophysiology and electrical brain-stem stimulation in 1936 from Adrian in Cambridge and Walter Rudolf Hess in Zurich.²⁶ With this training he came in spring 1937 for his second fellowship year to the KWI for Brain Research in Buch near Berlin, where Spatz had just taken over. There he and his friend Ewald Weisschedel began, in Kornmüller's physiology department, an ambitious electrophysiological research program with electric recordings from the subcortical brain regions taking Hess as their model.²⁷ In addition to this reorientation in the research hitherto committed to Vogt's cyto-architectonics, Jung also immediately joined Kornmüller in building up application of the EEG in clinical diagnosis there.²⁸ This one year sufficed

25 See laboratory journal on 9 March 1941 (VI, p. 244): "Yesterday I performed the first experiment with U. in re thought transmission, albeit with negative outcome; it is probably a matter of practice. I also don't feel comfortable enough yet."

26 Jung later quoted the wonderful characterization of different research styles combined by Hess: "Here you come now from England and believe in the *facts* of physiology. My opinion differs on that: 'Facts' mean nothing to me or very little; just the interconnections are important in research. Physiology needs theory too. One must first have understood the systemic order in the nervous system, then one's experiments can be planned. You will realize that here, all right. And one more thing, don't come to me with too much anatomy. They've become too anatomical over there at the Monakow institute, and that's why we don't get any further with them anymore" (Universitätsarchiv Freiburg: Jung papers, C 92/227).

27 Weisschedel and Jung 1938, Jung and Weisschedel 1938.

28 The work evidently made rapid progress. Already in January 1938 Jung and Kornmüller reported at the *Berliner Gesellschaft für Psychiatrie und Neurologie* on electrical

for Jung to record enough EEG conductions from epilepsy patients, in addition to the experimental brain-stem stimulations on animals for his planned habilitation thesis at Freiburg.²⁹

This belated beginning of clinical electroencephalography in Germany did not produce any “Kornmüller-Jung school,” however, but a quarrel of almost unbelievable proportions that loomed over the establishment of electroencephalography in Germany until far into the postwar period.³⁰ Kornmüller evidently felt cheated by Jung of “his” EEG and for that reason claimed the epilepsy topic as his own. With his next collaborator, Rudolf Janzen, he published papers about the epilepsy EEG in rapid succession, thereby torpedoing Jung’s habilitation thesis.³¹ In this situation, Jung rearranged his new Freiburg EEG laboratory into a polygraphy laboratory where he recorded different physiological and bioelectrical signals synchronously by a method he had developed. These recordings included the EEG, ECG, EMG, respiration, fluid pressure, and eye movements (which later separated out into its own research area called electronystagmography).³² With this arsenal of representational procedures, Jung aimed for an electrophysiological characterization of the autonomous nervous system, with its

conductions from various regions of the brain stem; and again in summer 1938 at the International Congress of Physiology in Zurich. See Jung and Kornmüller 1938a, 1938b, and 1938c.

29 Jung described their quarrel in a letter to Kornmüller dated 11 August 1938 as follows (Universitätsarchiv Freiburg: Jung papers, C 92/140): “The situation is clear, I think. During my stay in Buch at the end of last [year] and the beginning of this [one], I began with conductions from patients in the epilepsy area at your laboratory, after you had been wishing to do so for years already upon completing your experimental analyses on animals, but, as you said, could not do for lack of a collaborator with a clinical interest as well as training in electrophysiology. In working out a satisfactory recording technique and choosing the patients, as you will recall, I did the principal work. You knew that I would be continuing to occupy myself with these recordings from epileptics in Freiburg and that, as long as I have no opportunity to conduct experimental analyses on animals, this is the only fruitful application of electrophysiological methods to the C[entral] N[ervous] S[ystem] open to me, therefore also the area in which I would initially like to work and publish. You wrote me, furthermore, on May 20th that you were continuing to occupy yourself, together with Janzen, on ‘occasional human recordings,’ but that you did not want to publish anything about it before reaching agreement with me about it. It was clear that it would have to annoy me when later, in July in Buch, you put before me a finished manuscript by ‘Kornmüller and Janzen’ about these examinations, some of which even concerned the same case that I had examined in your laboratory.”

30 The foundation of the German EEG society had to take place in Kornmüller’s absence because Jung was to be elected for its presidency. Kornmüller was only elected in 1958 as the 5th president of the *Deutsche EEG Gesellschaft*, after Jung, Duensing, Schütz, and Janzen. Jung, in turn, was blanked out of the memory of Kornmüller’s team; a list of publications from 1968 included all the papers of former co-workers of Kornmüller, without mentioning a single paper by Jung from his time in Buch (MPG-A III/16/371).

31 Kornmüller 1938, Kornmüller and Janzen 1939a, 1939b, and 1939c, Janzen and Kornmüller 1939a, 1939b, and 1939c.

32 Jung 1939a, 1939b, 1939c, and 1939d.

manifold interweavings with the central nervous system, to which he had become introduced under Hess. The different recording methods did not fuse very well into a coherent research program, however, rather ending up in a wild jumble of graph inscriptions. Nevertheless, by 1941 he had assembled enough curves on tremor forms from Parkinson patients to finally habilitate in Freiburg after all.³³

Perhaps this forced occupation with the diverse graphs from his own laboratory implied special attention to the patterns of graphic recordings irrespective of what specifically was being registered. In any event, Jung found curves printed in *Pflüger's Archiv* that to him appeared similar, even though they depicted the motion pattern created by a centipede's legs.³⁴ The paper was by Erich von Holst, a zoologist who was at that time intensely studying the complex rhythmic animal movements not executed by central organization. Apart from studying the coordinated motions of centipedes, von Holst also analyzed many other phenomena in the animal kingdom known as "relative coordination," such as the fin movements of fish or the wing movements of birds (Figure 44). He interpreted rhythmic coordination as an autonomous action of spinal ganglia or of the spinal cord not traceable back either to a centralized control center nor to firm stimulus-reaction chains. Its guiding principle was, rather, generated in the rhythmic activity itself.³⁵ Jung's tremor curves manifested similar coordination phenomena and thus suggested that in principle this approach could be applied to the human nervous system. In light of von Holst's observations, the EEG curves documented the functional cooperation between individual brain regions. They were the result of a superpositioning of thousands of individual nerve currents and simultaneously an image of their autonomous organization by just this mutual electrical influence. The rhythm of the signal conveyance within a unit triggered resonance effects or discharge effects in neighboring or connected areas; this was the key to a flexible functional organization of the central nervous system. When Jan Friedrich Tönnies, his friend from their common time at Buch near Berlin, returned from New York, Jung reported to him in a letter about his new interpretational approach for rhythm phenomena and phase relations in the EEG.³⁶

33 Jung 1941.

34 Jung himself portrayed his encounter with Holst's theories as a resonance effect of visual thinking (1992, p. 496).

35 Holst 1934, 1936, 1937, 1939.

36 Jung 1941. Others had also examined phase relations in the EEG, of course. Berger had repeatedly pointed out the broad synchrony among alpha waves deflected from the cortex as a whole and saw this as a central argument for his holistic interpretation of the EEG; whereas Jasper, for instance, carried out intensive studies on the potential distribution over the cortex. However, Jung and von Holst first formulated a brain theory out of these observations. If anything, a similar idea lay behind the Fourier analyses of EEG curves by Gibbs and Grass, since Gibbs was looking for pace-making centers of the EEG, and the radio amateur Grass surmised that the brain functioned as a system of coupled oscillators,

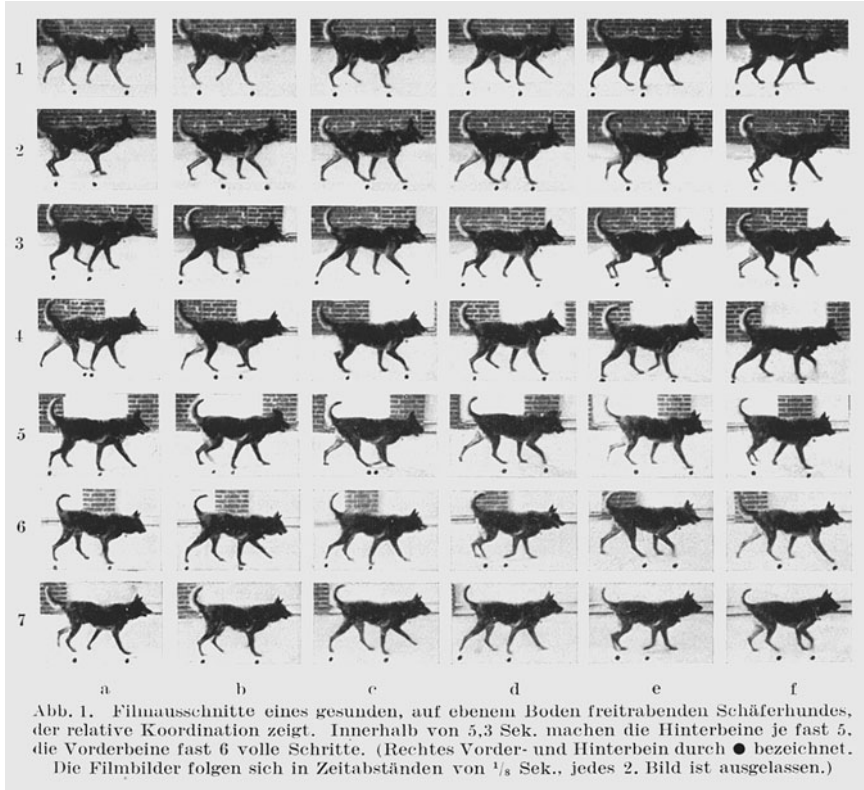


Figure 44 The phenomenon of “smooth coordination,” according to Erich von Holst a universal principle of control, illustrated here by a loping German shepherd dog. The original caption reads: “Film clippings of a healthy German shepherd loping freely on flat ground presenting relative coordination. Within 5.3 secs the hind legs each make almost 5 full strides, the forelegs 6. (Right fore- and hind legs are indicated by a ●. The film strips follow in a temporal sequence of $\frac{1}{8}$ sec; every 2nd image is omitted.)”

I believe, though, that these things are important and fundamental to the functioning of the central nervous system and that this way a series of individual phenomena that English and American neurophysiology has mostly also seen but scarcely drawn into relation and evaluated, can be integrated. Above all, it seems to me important in this way to draw classical reflex physiology into relation with the newer studies on the rhythmic-automatic activity of the central organ. I arrived at all of this

in analogy to frequency modulation in a radio (see Gibbs 1937, or RAC, RG 1.1, series 200A, box 86, folder 1040).

from the tremor analyses [. . .] and the parallels arising out of it with the notions by von Holst about relative coordination.³⁷

In three brief years between his initial contact with von Holst in 1938 and his being drafted for military service in 1941, Jung looked systematically for physiological or pathological phase relations by means of multi-channel EEG recordings; and in cooperation with von Holst formulated a theory of self-organization of brain function by autonomous rhythm control:

From the various forms of electrical activity of the cerebral cortex, neither can an argument be derived against any “holistic theories” of the C[entral] N[ervous] S[ystem], nor does the common influencing of the entire cerebral cortex constitute any contradiction to localization theory. The EEG is rather more suitable to indicate the legitimacy of both points of view, the holistic view and the differentiating localizational view. The central nervous system and the cerebral cortex is not a rigid mosaic of individual structures or a shapeless plastic entity, but [. . .] a functional unit constructed of partial actions with a differentiated organization. This organization proceeds in a hitherto only incompletely clarified way, aided by factors of smooth coordination. We basically still know very little about the individual physiological processes forming the basis of the phenomena of smooth coordination, as generally also about the manifestations of excitation, inhibition, and synchronization in the central nervous system.³⁸

The war and Jung’s conscription prevented further research on these questions and hence also a more detailed neurophysiological elaboration of this brain theory. Similar phenomena of electrophysiological feedback supplied Norbert Wiener just a few years later with the decisive conceptual inspiration to formulate his theory of cybernetics. After the war had ended Jung and von Holst did, in fact, take up the concept of smooth coordination (*gleitende Koordination*) again, using cybernetic vocabulary. Together with Horst Mittelstädt, von Holst reformulated his guiding idea as a “principle of reafference,” and Jung worked together with Tönnies on “feedback as a principle of function.”³⁹ All the same, only in retrospect does what von Holst and Jung had jointly developed read like a private prelude to postwar cybernetics. Notwithstanding Jung’s and von Holst’s enthusiasm about a new unifying principle to integrate physiology, biology, and gestalt psychology, their

37 Jung’s letter to Tönnies dated 6 September 1939, Universitätsarchiv Freiburg, Jung papers, C 92/242.

38 Jung 1941, p. 110; see Hugger 1941. With a view to the present trend in favor of Wolf Singer’s *Bindungstheorie* as a neurophysiological basis for complex brain functions, remarkable parallels do strike the eye (Singer 2003).

39 Holst and Mittelstädt 1950, Tönnies 1949, Jung and Tönnies 1950.

conception remained on this side of the epistemic break to cybernetics. At least for von Holst, the theory of smooth coordination was proof of the transferability of holistic and vitalistic assumptions in scientific investigations against inadequate machine theories:

A development triggered by the first exact experiments on sensory and neural physiology of the past century, culminating in the theories of tropism and classical reflexes—according to which an animal is directed and compelled puppet-like by external stimuli, while his movements are mechanically rigorously composed of reflex chains of elemental individual stimulus reactions—was thus terminated and closed by the findings of diverse and entirely independent branches of research. Standing in the middle between these individual fields: the physiology of the lower centers, electrophysiology, and pathology of the brain, the theory of animal behavior, gestalt psychology, and finally also the physiology of the heart; in a unique intermediary role there are phenomena of relative coordination connecting relational fibers from here to there and making possible first groping steps in this great new problem: the play of autogenous forces in the central nervous system.⁴⁰

What was supposed to be developed here was not an abstract and universal control theory, but a theory of the specific, vital functionality of the brain. Obviously, Jung and von Holst belong to a cultural history of German cybernetics, with its beginnings reaching back into the period of National Socialism.⁴¹ However, cultural connotations seem to have influenced their analyses more than did war-defined constraints. Part of the complexity of this cultural history of cybernetics is that Jung's opponent Kornmüller, who during the war built EEG instruments for mechanical control of the brain, would shift his focus after the war to an esoteric theory of brain control by glial cells.⁴²

40 Holst 1940, p. 807. Von Holst's coordination theory explicitly rejected mechanical models of the live organism, even though he was probably among biology's most skilled model-builders. Similarly, Jung did not see the special advantage of this systemic approach for the abstract description of neuron processes; he only saw its deficiency—namely, it lacked a connection to cellular neurophysiology.

41 Dittmann 1995. In 1944 the engineer Hermann Schmidt received the first German chair for control engineering at the Berlin polytechnic. Under the motto: "Control whatever is controllable and make the uncontrollable controllable," Schmidt (1941, p. 88) conceived a "perfecting of the technical world" in which "the categories of the natural sciences, to which belong foremost the concepts of magnitude and causality, meet under a higher unity with the categories of the humanities, foremost among them the concepts of form and finality."

42 In this theory he attributed to glial cells the decisive share in the control of neuron processes; he supposed of them neurohumoral, endocrinal activity (Kornmüller 1947).

A German physiologist's lofty flights

World War II is considered a transitional phase in the history of science that brought new forms of interdisciplinary collaboration, broad dissolution of the barrier in research between applications and fundamental questions, and a hitherto non-existent close interlocking of the state with science.⁴³ How the mobilization of science and scientists shifted the existing research fields and opened up new research prospects will be followed here using just one example drawn from EEG research—namely, Kornmüller's researches on high-altitude physiology. Out of an analysis of EEG frequencies emerged the project to design a mobile oxygen-deficiency warning device.⁴⁴ Slow EEG waves had already been correlated with consciousness problems, but the ascent of air combat to heights not compatible with human life changed the appreciation of this observation. Air warfare wrote new signs into the EEG.

Mitchel Ash spoke of a "three-fold disinhibition" of wartime scientists in their treatment of nature, other people, and themselves.⁴⁵ This applies especially and to an especially brutal degree to high-altitude physiological research in Germany. The massive support of aviation and the enormous ideological load it bore produced a viciously competitive climate that radicalized these researches in Germany to a literally murderous degree. The technical upswing in aviation and aeromedicine helped high-altitude physiology initially to establish itself as a specialty discipline on adapting the human body to extreme environments. This produced a race between experimental arrangements and developments in aircraft technology that rapidly went beyond what the body could handle and the race was physically run by the "test men" in the Dachau concentration camp in spring 1942. This disinhibition of scientists occurred on many tracks at once and should not be seen only from this one perspective of a trend toward liquidation.⁴⁶ It must also be understood as a wearing down of barriers and differentiations between nature, technical engineering, and human life. The total disinhibition by the involved scientists in their treatment of people viewed as having no rights obscures another disinhibition along that vein in the same research

43 Science turned into "big science," prototypically realized in the Manhattan Project or the Apollo Program in US space flight; see Mendelsohn, Smith, and Weingart 1988, Galison and Hevly 1992, Pickering 1995. At first sight the EEG and neuropsychiatric research might seem far removed from "big science," as its endeavors continued to be on behalf of individual patients or clinical pictures. Nevertheless, the changes in the neurosciences related to the war period are analogously structured, even without the development of big-science institutions.

44 This example is obviously not representative. In the actors' eyes and the Nazi administration's view, it was, rather, top-priority quality research, even throughout the periods of shortages; it had high urgency certification and was continued up to the final phase of the total-war deployment.

45 "dreifache Enthemmung" (Ash 1996).

46 The way Karl-Heinz Roth (2000) reconstructs these experiments.

context with consequences that remain to be explored. Already at the beginning of the 1940s, concepts about the hybridization of man and machine formed, at the intersection between technology, clinical and physiological research, for which years later the term “cyborg” would be coined.⁴⁷ The oxygen-deficiency monitoring device is an example of a technically implemented guidance model aimed at a hybridization of man and machine. Here it was no longer research at the absolute limits of the human body’s pathophysiology in unnatural environments, but the behavior of a complex biotechnical module that was supposed to be optimized physiologically and technically through the development of automated guidance systems. The exploration of biological feedback control systems was transferred onto an investigation of artificial man-machine systems. Put in terms of the National Socialist vision for the “new human” (*der Neue Mensch*), a hybrid between flying machine, human body, and electronic feedback loops was formed in its place.

During World War II the KWI for Brain Research in Buch, in close cooperation with the Aeromedical Research Institute of the Reich Ministry of Aviation in downtown Berlin, performed systematic EEG experiments on hypoxia at high altitudes. The KWI enjoyed a kind of monopoly on electroencephalography in Germany. Having a share in prestigious aviation research gave hope of securing new state subsidies and the department’s continued operation during the war years.⁴⁸ In summer 1940, therefore at the beginning of the air war against England, Hubertus Strughold from the Aeromedical Research Institute started a cooperation with Kornmüller at the KWI to study the EEG at high altitudes, as new German combat aircraft were able to fly at heights above 7,000 meters, which repeatedly led to dizziness and altitude sickness, that is, to conditions of dazed euphoria or unconsciousness. That was why special training and selection programs for flight crews were intensively sought. The fundamentals from high-altitude physiological research were needed.

47 Manfred E. Clynes and Nathan S. Kline: “Cyborgs and Space,” *Astronautics*, Sep. 1960, pp. 26–27 and 74–75, quoted from Gray 1995, pp. 29–33.

48 In 1940 EEGs were being registered regularly probably only in Buch within the German Reich. Berger had emigrated, and the neurograph at Vogt’s institute in Neustadt in the Black Forest seems to have seldom operated. Jung used it temporarily in spring 1940 to examine soldiers with brain injuries in Karl Kleist’s field hospital for reservists in Frankfurt. In Vienna and/or Innsbruck, Rohracher and Holzer started initial routine EEG examinations. Thus more EEG instruments were in operation in Allied Europe than in the German Reich. The KWI for Brain Research was able to continue almost all of its research during the war years, because immediately at the outbreak of war a military administrative structure was created that allowed the scientists to be called up to perform their military service at their own workplaces. Kornmüller used his collaboration with Strughold and others to suggest serial production of an EEG device to Siemens. Although the project did not advance beyond the designing of a prototype, he did manage to obtain start-up funding in the amount of 12,300 reichsmarks from the DFG; see BA R73/12337.

Strughold's team contributed the apparatus for producing the special oxygen-nitrogen mixture to simulate mountain air, the psychological experimental method (known as Lottig's number-writing test), and cinematographic recording of the tests. Kornmüller's team supplied the Tönnies neurograph, which was why the experiments initially were performed at Buch where the instrument was permanently installed. The synergy between experts in respiratory physiology and electrophysiology produced a technical surplus of new observation methods. For example, the test person's writing plate and pen were connected to an electrical recording circuit that registered exactly the phases of writing or writer's cramp. The experiments were additionally recorded on film with the aid of a number of mirrors so that the camera could record on a single image the behavior of the test person's writing hand, with the EEG appearing simultaneously in the other half of the display, the way it was recorded by the neurograph (Figure 45).⁴⁹ At the beginning of December 1940, Kornmüller, Palme, and Strughold submitted their first joint paper to *Luftfahrtmedizin*, in which they asserted that it was indeed possible to diagnose every phase of altitude sickness exactly by the EEG. The experimental system indicated "the degree of oxygen-deficit effect momentarily, second by second in an objective way."⁵⁰ On the basis of already available reports on EEG changes from consciousness disorders,

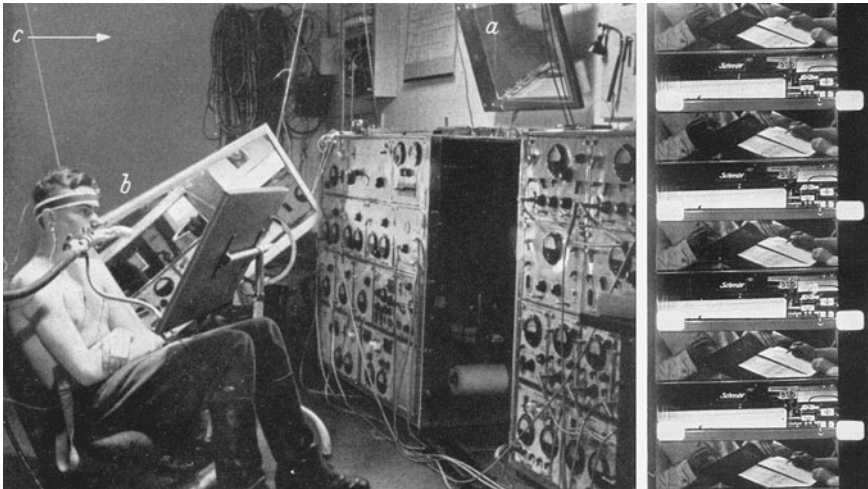


Figure 45 The experimental set-up for EEG examinations of high-altitude physiology at the KWI for Brain Research during World War II. A mirror arrangement permitted synchronous filming of the test person's hand movements with the neurographically plotted EEG curve.

49 Thus the so-called "split-screen display," now routine in epilepsy diagnostics.

50 Kornmüller, Palme, and Strughold 1941, p. 161.

such a finding certainly could have been expected. Here, however, a rearrangement of the research culture is signaled at the same time: The experiments sought to evaluate the EEG, measured against the established standard of the psychological number-writing test method; but its result was an evaluation of the examined organ: “The cerebrum can be regarded as the most promptly reacting announcer of impairments in capability from hypoxia.” This strange wording of the cerebrum as an “announcer” marked a trend that itself “announced” something else. Here the brain was transformed into a detection system whose signal alterations only needed to be evaluated in a suitable way. This sentence sketched the path that would later be taken by this research.

At first the yield of these trials remained within surveyable scope, despite the supplementary technical equipment. At the first typical signs of altitude sickness, the researchers observed slow waves of 2 to 3 Hz instead of physiological rhythms of 10 to 20 Hz. Thus far the results merely represented, “second by second,” the objectivization of brain-function disturbance. A research report drawn up in August 1941 opened up a new prospect:

The frequencies of 8–6 Hz indicate stepping beyond the breakdown threshold for the cerebral cortex, particularly for the frontal lobe, whereas 3-Hz oscillations are to be evaluated as the expression of severe impairments of the entire cerebrum. One could also denote the first 7- and 6-Hz oscillations as the theoretical breakdown threshold. Objectively we do not notice any substantial changes in the behavior of the t[est] m[en] yet from oxygen deficiency that would impair the tm’s physical and psychic fitness; but the cerebral bioelectric picture already shows us clear impairments to the cerebral cortex. At greater heights the occurrence of the first 3–2-Hz oscillations would then coincide with the practical breakdown threshold. There we detect clear alterations also in the subjective and objective manifestation. The power to make decisions and the will is more and more inhibited and with continued increase in hypoxia gives way to general apathy and lack of drive even for life-saving actions.⁵¹

This new observation endowed a definition to altitude sickness supported by technical data, distancing it somewhat from psychic findings and

51 Beigel, Haarstrick, and Palme 1943, p. 316. At this time Kornmüller’s projects were experiencing an upswing on many fronts. Kornmüller also launched an incursion into the ideological battle at the same time. Because the imminent “taking of Moscow could be counted on,” he proposed to confiscate there Lenin’s brain, which had been examined cytoarchitectonically by Vogt, in order to retroactively turn that “athlete in association” into a syphilitic, “objective establishment of which would be valuable at least propagandistically” (Kornmüller to de Crinis dated 11 October 1941, BA R 4901/alt R 21/11.065, sheet 144).

subjective symptoms. The brain-plus-EEG device system had proved to be a far more sensitive measurement instrument than the number-writing test or introspection. It produced disruption signals in the form of an alteration in the curve even before psychic signs of altitude sickness became manifest. This conceptually decisive step coincided with a notable spatial and practical reorganization of the experimental system. Palme no longer performed these experiments with Kornmüller's gas-bottle respiration at Buch but in the low-pressure chamber at the Aeromedical Research Institute. Because the neurograph could not be brought there, he modified a conventional ECG instrument to record the weaker brain currents. Thus the technical and epistemic preconditions were set to turn the EEG into a mobile early-warning system for altitude sickness and thereby to have the brain deployed in the war as a measuring instrument.⁵²

Now one could think about developing a miniaturized EEG device that specifically indicated the appearance of slow waves in the EEG of a crew member inside an airplane, or one that reacted to the appearance of such waves by signaling an alarm:

Such a filter could be set, e.g., to waves of 6 to 7Hz. Then it would indicate such waves, but not normal waves. [. . .] During the war we tested such instruments at the Kaiser Wilhelm Institute for Brain Research at Buch near Berlin. [. . .] We worked thus by placing one electrode at the forebrain and a second one at the ear. As electrodes we used artificial sponge that through galvanization had acquired a fine metallic coating. [. . .] We affixed the artificial sponge inside the aviator hat in such a way that a strip of the electrode material lay against the forehead inside the hat fitted on the head, and a second strip lay against the ear. Slow waves also occur instead of α waves during fatigue and sleep, so it could be considered whether to use the device to indicate tiredness states as well (e.g., in an automobile).⁵³

Kornmüller's technical measurement design drafted a feedback loop between the brain and the mind. Thus the brain, the apparatus, and the pilot were supposed to be connected together in a feedback control system so that the pilot could react to a signal by his brain before his body realized the threatening brain condition, that is, before he lost control of the airplane from the consequences of altitude sickness. Making this idea a reality turned

52 Low-oxygen warning devices already existed previously. All those devices monitored the oxygen content in the breathing air, not the functional state of the brain; see, e.g., Tobias and William 1947.

53 "Signalisierung der langsamen Wellen des EEG im Sauerstoffmangel," typescript by Kornmüller dated 15 November 1945, MPG-A III/16/41; Kornmüller had presumably already drafted such a measurement procedure in 1941, see Kornmüller 1961, p. 440, and Noell 1950, p. 302.

out to be difficult, however. Kornmüller and the KWI were not able to construct a deployable measurement instrument, because its excellent technical department under Tönnies' direction had been practically dissolved by the time his successor Johannes Schaefer was called up to war duty. Kornmüller's team's first apparatus for frequency analysis was built by the short-wave engineer Johannes Prast.⁵⁴ Kornmüller subsequently arranged for the manufacture of the miniaturized EEG-wave sensor, in cooperation with *Deutsche Telephonwerken (DeTeWe)* in Berlin, which supposedly managed to bring a prototype to the stage of experimental testing by 1944 when production had to be halted.⁵⁵ At war's end these investigations greatly interested the American occupiers.⁵⁶ Prast's and Kornmüller's assistant, Werner Noell, was invited to continue their developmental research at the Heidelberg Aero Medical Research Center, where the Americans assembled those high-altitude physiologists from Germany whom they brought back to the USA not long afterward, under Operation Paperclip. Prast and Noell apparently continued to work on the sensor over there.⁵⁷

Kornmüller's "cigar-box sized" sensory prosthesis was supposed to offer the flying occupiers feedback to their brains, in order to keep the activity of flying brains within the tolerance limits required for maneuverability. Airplane, brain, and signaling device together formed a cybernetic machine in exactly the same way as Wiener had conceived his anti-aircraft predictor.⁵⁸ The psychic or mental functions of the brain certainly could not be foreseen in combat deployment, but their functioning could be technically anticipated. Kornmüller's alarm device was hardly a reified brain theory for him; rather, it emerged out of tinkering research, along the tracings of conspicuous curve patterns. Kornmüller never did publish anything about the function or physiology of slow waves, for instance. After the war he did not pursue these investigations anymore either, preferring instead to withdraw, in order

54 One of Kornmüller's doctoral students used a similar form of this filter 1942/43 for a paper on EEG-frequency analysis; see Kornmüller's referee report on the dissertation by Bruno J. Franek, "Über eine Frequenzanalyse des Elektrenkephalogramms" dated 2 December 1944, MPG-A, III/16/38.

55 This device built by *DeTeWe* presumably involved an electronic filter that, based on the principle of electric resonance, filtered out only a narrow range of oscillations from the spectrum of brainwaves. Thus it differed from the two methods by Gibbs and Walter for EEG-frequency analysis then commonly in use, which could not be used inside an airplane because the analysis periods required took too long and they were too susceptible to shaking.

56 Leo Alexander also spoke with Kornmüller during his interviewing in preparation for the Doctors' Trial at Nuremberg, and the USA presumably found out about this project that way; see his report "Neuropathology, Neurophysiology, Including Electroencephalography, in Wartime Germany" dated 20 July 1945.

57 Prast and Noell 1948. I cannot tell whether this device was ever tested in an airplane under real deployment conditions, as Kornmüller claimed in 1961 (p. 440) as a successful aftermath of his wartime research.

58 See Galison 1994.

to find new theoretical impetus for his research in the endocrine activity of cellular ganglia. It was left to others to formulate out of EEG curves and cybernetic feedback control systems a theory of the brain as an electrical machine.

The brain as a cybernetic machine

“This electrical brain—the Computer—thinks of everything”—was the slogan of Western Electric, the American producer of communications electronics, on full-page advertisements of their new automatic anti-aircraft guidance computers in 1944.⁵⁹ During the nineteenth century, the term “computer” usually denoted the profession of the (mostly female) employees for ongoing calculation tasks at observatories or weather stations. Now it was transferred onto machines. Electrical machines took over a human task and entered into competition with human brains. The computer mentioned in the advertisement—still capitalized even in English—was obviously not yet one in the modern definition of the word but merely an automated calculator capable of implementing a few fixed operations. But, as is known, plans for programmable automated calculators were drawn up, in direct connection with this war research, which were supposed to process mathematically formulatable problems by the model of Alan Turing’s universal machine.⁶⁰ And within a few years, these projects had assumed such concrete forms that in 1950 Turing was able to propose his now legendary, strikingly simple test for the simulation of human intelligence. (His tragic death prevented his participation in the further development of computers.) In the same context, Turing predicted that in the year 2000 one would be commonly speaking about thinking computers without protest. At that time, he was quite perfectly situated in the contemporary thinking: In 1944 the *New York Times* still carried the critical headline: “Harvard’s Calculating Machine Can Do Wonders But Is Not a ‘Super-Brain’,” whereas six years later the third generation of these “thinking machines” led to the famous *Time* cover with an automated calculator ably typing away on a typewriter (Figure 46).⁶¹

At first glance, the computer thus seems to connect directly to the technical modelings of the 1920s, continuing the line from the “thinking iron,” radio brains, or weak cerebral connections. The special dynamics that were developed by this new model of the brain distinguishing it from the preceding modelings must, however, be sought in that they went beyond structural analogies, such as, for instance, those between neuronics and electrical switches, to refer to functional identity. With its switchboard plants and

59 See the advertisements in *Life* dated 7 February and 12 June 1944.

60 Turing 1936; see Hodges 1983, or, on the history of computer development Campbell-Kelly and Aspray 1996, Spufford and Uglow 1997.

61 *New York Sunday Times* issued on 13 August 1944, p. E9; *Time* issued on 23 January 1950.

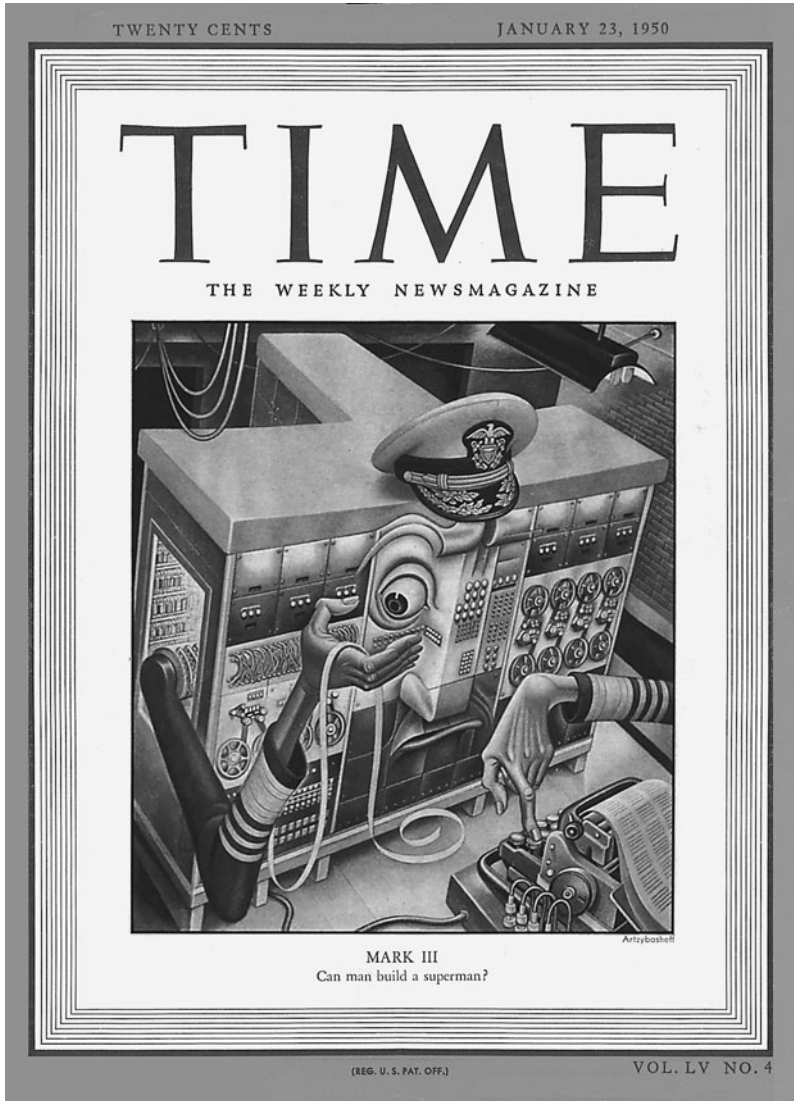


Figure 46 Harvard's supercomputer as a typewriting American officer, cover illustration from 1951.

media engineering, electrotechnics of the 1920s offered a broad fund for electrotechnical brain models. The thesis of a functional identity between the computer and the brain took recourse less in concrete implementations, such as the telegraph, switchboards, radio, or automated calculators, than in the principle of data processing in media technology. This change over from structural analogies to functional equivalence was directly related to

the contemporaneously forming area of cybernetics. Discussions about the comparability of computers to brains were embedded in cybernetics theory from the start. Brain research or brain theories were one of the central themes of early cybernetics. More precisely speaking, cybernetics was itself a product of a new definition of the relationship between causality and finality which was running parallel to the shift in accent from structure to function.

Around the same time that Jung and von Holst were working out their brain theory of smooth coordination and Kornmüller reconceptualized the brain as an “announcer,” the Macy Foundation organized a meeting of neurophysiologists and social scientists in New York on the topic “cerebral inhibition,” which became the model for the later Macy conferences and thus the germ of cybernetics.⁶² There Arturo Rosenblueth, who had been working with Walter B. Cannon for a long time on homeostasis, reported about a new distinction between “purpose and teleology” as exact scientific concepts:

We have restricted the connotation of teleological behavior by applying this designation only to purposeful reactions which are controlled by the error of the reaction—i.e., by the difference between the state of the behaving object at any time and the final state interpreted as the purpose. Teleological behavior thus becomes synonymous with behavior controlled by negative feed-back, and gains therefore in precision by a sufficiently restricted connotation.⁶³

The concept of negative feedback allowed one to describe by a unifying and scientifically precise term such different things and processes as homing torpedoes, machines with servomechanisms, purposeful conduct, or neurological clinical pictures, which easily explained these as overshooting or failed feedback. Unlike von Holst, Rosenblueth was not aiming at overcoming the machine paradigm but at a transdisciplinary analysis of guidance processes applicable equally to technical systems or organic ones. Thus arose the fascinating possibility to interrelate the most disparate sciences at the current state of technical development. Margaret Mead later reminisced that she was so absorbed that it made her oblivious even to pain: “I did not notice that I had broken one of my teeth until the Conference was over.”⁶⁴

When in March 1946 the Macy Foundation reassembled the circle convened earlier in 1942 for a meeting on “feedback mechanisms and circular causal systems in biology and the social sciences,” an extremely productive research area had already formed between guidance theory, computer design, brain theory, and neurophysiology. In the four years between the

62 On the history of cybernetics in the USA, see Heims 1980, 1993.

63 Rosenblueth, Wiener, and Bigelow 1943, p. 24.

64 Mead 1968, p. 1, quoted here from Heims 1993, p. 15.

“Cerebral Inhibition Meeting” and the first Macy cybernetics conferences, the “electrical brains” of anti-aircraft weapons systems had already been construed and Norbert Wiener had developed the basic assumptions of his cybernetics from the problem of guiding these air-defense systems. Besides conceiving control loops between man and machine, he had also conducted physiological studies together with Rosenblueth on feedback processes in muscular control. John von Neumann’s “first draft” of a programmable computer had appeared with many borrowings from neuroanatomy; and the neuroanatomist Rafael Lorente de Nó had identified histologically in circular nerve connections the central nervous foundation of intelligent calculation operations.⁶⁵ But above all, Warren McCulloch and Walter Pitts had designed in 1943 an abstract logical description of neural networks with which they declared brains to be Turing universal machines, logical automats.⁶⁶ McCulloch and Pitts argued that the brain and its mental activities could be described by binary logic, because the logic was implemented in the anatomy of neural networks and the physiology of their binary operation mode. The presupposition of their argumentation was, of course, that intellectual activity could be conceived primarily as the solving of logical mathematical problems. Logical automats, such as “thinking machines,” “thought,” in the sense that thinking could be successfully reduced to algorithmic processing of symbols.⁶⁷ Precisely because of this reductionalism, “a logical calculus of the ideas immanent in nervous activity” could become a central point of reference for the reintroduction of mind and thought into neurophysiology, which throughout the years of focusing on cellular potentials had granted them little more than “ghostly status.”⁶⁸

The program of the first Macy conference pinpointed the convergence of brain research and computer technology and allowed the electrical brain to become the conference’s guiding theme. The entire first day was dedicated to its double exposition: In the morning von Neuman reported about “computing machines,” and Lorente de Nó introduced their “biological exemplification.” In the afternoon, Wiener spoke about “goal-seeking devices” and Rosenblueth offered further “biological exemplifications.”⁶⁹ It is self-evident

65 Wiener 1985, Neumann 1973, Lorente de Nó 1932, 1943, 1947.

66 McCulloch and Pitts 1943.

67 See Mackenzie 1996, Wilson 1996. What a “universal machine” would still have to achieve becomes vaguely apparent when robots must stop their movements in open space after just a few steps upstairs. The science exhibition “Sieben Hügel—Bilder und Zeichen des 21. Jahrhunderts” (Seven hills—images and symbols of the twenty-first century), Berlin’s millennium project, began with a welcome by a robot that could only execute an exactly pre-determined series of steps at that moment of the opening ceremony.

68 Kay 2001.

69 The second day was devoted to the fields of psychology and psychiatry, thus positioned somewhat at the transition between the days devoted to the theoretical core and application, because the reviewers were not even mentioned by name. See the program sent out to the participants and the summarizing report by McCulloch. I thank Claus Pias for this material.

that all the participants knew about the great differences between brains and computers. Nevertheless, the central reports aimed to show their similarity in functional respects (Wiener and Rosenblueth) as well as structurally (von Neumann and Lorente de Nó), where circuit-like switches in the brain were identified with the storage and memory systems in a computer.⁷⁰ The obvious differences between brains and computers were, in their view, evidence of the very strength of the new theory; because the principle of negative feedback, the reduction of the difference between target value and value of the given state, was universally applicable.⁷¹ The price of this integration of fields of knowledge so disparate as psychiatry, economics, and electrotechnics, was of course a de-differentiation in the design of theory, if little more resulted from application of the basic model of negative feedback than a reduction of the scope of each topic to cybernetic machine theory. The reduction of difference was the underlying intent of cybernetics at the annual convention of the American Psychological Association, for example, which in 1948 carried the promising title “human beings as servo-mechanisms.”

The reductionism of contemporary brain theories is perhaps most extremely demonstrated in the thermostat model of the brain developed by W. Ross Ashby. An apparatus of four mutually controlling servomechanisms sufficed for him as a model of an adaptive intelligent system, since the “homeostat” not only regulated its state with the aid of feedback circuits within predetermined limits, but also adapted to new environmental conditions: It was “able to learn.” The thermostat model had already yielded the *Design for a Brain*, as Ashby titled one work in 1952. In the model, the feedback circuits only controlled a couple of electric potentials, but in that already lay the possibility of outstripping human intelligence by machines, if thinking was calculating, and learning was an adaptive servomechanism. As early as 1948, Ashby prophesied machines that would supply practicable instructions for a rational world order, even when its sense remained incomprehensible to the people carrying them out:

The world’s political and economic problems, for instance, seem sometimes to involve complexities beyond even the experts. Such a machine might perhaps be fed with vast tables of statistics, with volumes of scientific facts and other data, so that after a time it might emit as output a vast and intricate set of instructions, rather meaningless to those who had to obey them, yet leading, in fact, to a gradual resolving of the political and economical difficulties by its understanding and use of principles and natural laws which are to us yet obscure.⁷²

70 On the influence of neuroanatomy on computer design, see Schmidt-Brücken 1998 and Abraham 2002.

71 Bowker 1993.

72 Ashby 1948, p. 383. On Ashby, see Pickering 2010.

To Ashby, cybernetics were simply “the eye to see”; and consequently a few years later he extended his repertoire of designs with an “intelligence amplifier.”⁷³ Thus equipped, Ashby began the attempt in 1959 to lead the Burden Neurological Institute according to cybernetic principles; but the world of research institutions did not resemble any machine and Ashby failed as the *central processing unit* because his co-workers perceived his control strategies as rigid surveillance measures.⁷⁴

His American model, Wiener, was more adept at introducing himself as a cybernetic machine—by means of computer-supported EEG analysis.⁷⁵ Wiener regarded the EEG as the hidden key to the central functioning principle of the brain; and he wanted his analysis to show that the brain worked like a computer. Against the background of his communications and information theory, an EEG curve was like a disturbed radio signal whose message could be filtered out of the interferences by statistical data analysis. A so-called autocorrelation of the current oscillations registered in the curve ought to transform the EEG into a graph of the rate of specific frequencies. Albeit, the corresponding analysis of just a second-long segment of the EEG required many days, owing to the many computational steps involved. That was why Wiener’s project of a mathematically exact frequency analysis of EEG curves could only be realistically performed at MIT by the newly designed high-performance computing machines (Figure 47).⁷⁶ In his digital EEG analysis he, not immodestly, suspected he would find “the Rosetta Stone of electroencephalography,” because the EEG’s script was, after all, only a distorted representation of the true language of the brain, which was retrievable thanks to technical analysis:

[Brainwaves] speak a language of their own, but this language is not something that one can observe precisely with the naked eye, by merely looking at the ink records of the electroencephalograph. There is much information contained in these ink records, but it is like the information concerning the Egyptian language which we had in the days before the Rosetta Stone, which gave us the clue to the Egyptian script. [. . .] When

73 Ashby (1956b) chose this abbreviation for his *Introduction to Cybernetics* (“I to C”) in the second edition of *Design for a Brain* (1960). On the intelligence amplifier, see Ashby 1956a.

74 See Cooper and Bird 1989.

75 Wiener had already heard of the EEG from Rosenblueth at the end of the 1930s but had evidently initially not attached any ambitions to it, especially considering that at that time Rosenblueth as a homeostasis researcher was not participating in the EEG experiments at Harvard. Wiener seems to have drafted an EEG project only subsequent to their joint neurophysiological studies on the control of heart activity, muscular clonus, and forms of tremor.

76 Independently of Claude Shannon (1948), Wiener had developed together with Julian Bigelow a statistical concept for information and so-called time-series processes (see Wiener 1949). At the beginning of the 1950s Wiener conducted studies together with Mary Brazier of Massachusetts General Hospital. They reported about it at the 3rd International EEG Congress in 1953; see also Brazier and Casby 1952, Brazier 1973, Barlow 1997.

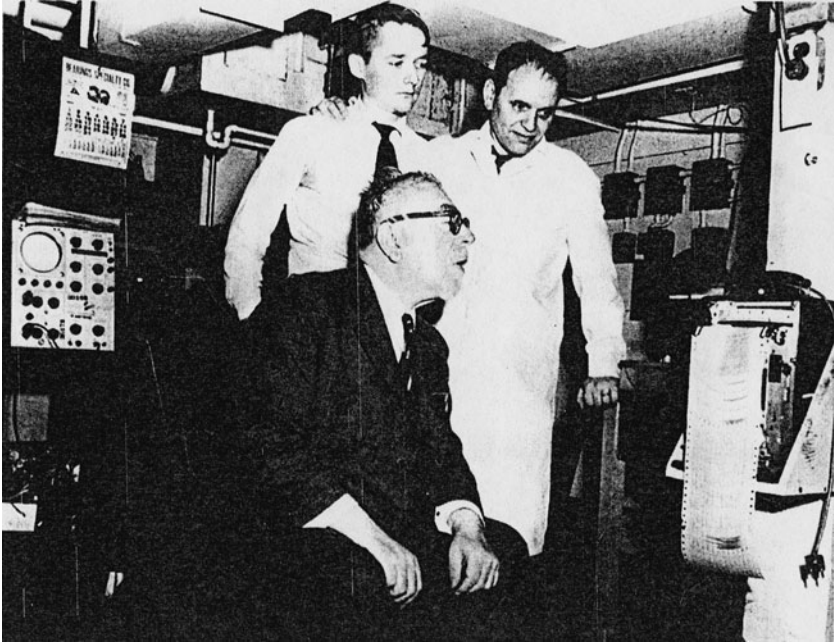


Figure 47 Norbert Wiener observing, in 1955, together with John Barlow and Walter Rosenblith, an MIT computer compiling an autocorrelation analysis of his EEG.

the crude original records of brainwaves are transformed by the autocorrelator, we obtain a picture of remarkable clarity and significance, quite unlike the illegible confusion of the crude records which have gone into the machine.⁷⁷

The result of this transformation was an astonishing curve. It showed no interference, only the desired agreement between brain and computer in the form of a clear frequency maximum at exactly 9.05 Hz:

Note that a sharp frequency line is equivalent to an accurate clock. As the brain is in some sense a control and computation apparatus, it is natural to ask whether other forms of control and computation apparatus use clocks. In fact, most of them do.⁷⁸

77 Wiener 1956, p. 289.

78 Wiener 1961, p. 197. Wiener's friend and colleague Grey Walter was certainly among his sharpest critics. Of all places, in a memorial volume in honor of Wiener (Walter 1969, p. 95), he wrote that the sharp peak at 9.05 Hz was sheer fiction: "We are left with the impression that the explanation of an imaginary spectrum is supported by an imaginary experiment."

The brain resembled a computer not only because it conducted computing operations but it seemed to function by the rate of the same mechanisms. The computer was a tool supplying brain research with a new paradigm. The computer represented a technical reification of certain functioning principles that inspired one, for instance, to look for signs of similar processes in the EEG.

A central computing rate of alpha waves fit into Wiener's brain theory for a second reason as well. It also yielded a direct link to the mechanism proposed by McCulloch and Pitts on gestalt perception and the processing of symbols. During the third Macy conference in spring 1947, when Wiener's statistical concept of information was also discussed, the two of them showed diagrams that they later elaborated in an article "How We Know Universals."⁷⁹ Their basic idea was that the brain did not process sensorial data from the eyes and ears *en bloc* but serially, similar to how a television composes a picture line by line. Geometrical forms, for example, would not be recognized by the brain as such but would be computed from point relations on different lines, which, first, are describable as a series of logical operations by neural networks and, second, made pattern recognition largely independent of the optical distortion of observed forms almost always occurring in reality. The scanning mechanism was somewhat the complementary piece from gestalt psychology to McCulloch's and Pitts's paper from 1943 on the logical description of neural networks.⁸⁰ Wiener then regarded his autocorrelograms as empirical confirmation of such a scanning mechanism: "We may suspect that this alpha rhythm is associated with form perception, and that it partakes of the nature of a sweep rhythm, like the rhythm shown in the scanning process of a television apparatus."⁸¹

Wiener's brain-theory postulates were in reciprocal relation to his experiences in electroencephalography. When the autocorrelation analysis did not show in all cases the same prominence of alpha peaks in the EEG spectra, but rather individual discrepancies, these individual differences motivated him to speculate about the meaning of a particularly precise alpha rhythm. He suspected the regularity of the alpha rhythm was a mirror of intelligence, which along the lines of his cybernetic revolution immediately demanded a central control station for the taking and evaluation of EEG correlograms, including intelligence testing and career counseling—and he set a good example by doing so himself.⁸² In a rapidly conducted research program in 1950 at Massachusetts General Hospital, the frequency rates in

79 Pitts and McCulloch 1947.

80 When the neuroanatomist Gerhardt von Bonim saw these diagrams, he did not consider them mathematically logically produced systems but images of the visual cortex. This was the kind of productive interdisciplinary interaction that made the Macy conferences so legendary; see Wiener 1961, pp. 22f.

81 Wiener 1961, p. 141.

82 Wiener 1985, pp. 320–330.

the EEGs of Norbert Wiener, John von Neumann, and Albert Einstein were compared:

Thinking processes—especially those of geniuses—may be better understood through studies of brain waves that are under way here at the Massachusetts General Hospital. [. . .] “Brightness and originality, creative and abstractive thinking, might be associated with—or facilitated by—certain different scanning mechanisms,” he declared. According to the theory, this scanning mechanism switched from one group of brain cells to another during the thinking process, much like a radar scanner. Very active brains, such as Dr. Einstein’s while he was thinking of his theory of relativity, for example, achieved this scanning very rapidly.⁸³

For a brief moment everyone was talking about scanning mechanisms and the EEG of intelligence, but the great cyberneticists did not benefit from that so clearly; it was not Wiener but Einstein who received more publicity. *The New York Times* and *Life* ignored Wiener and published in spring 1951 a photo only of Einstein lying on the EEG cot (Figure 48). This study on the



Figure 48 Einstein undergoing EEG recording. The EEG was not published.

83 *New York Times* dated 24 February 1951, p. 9. The Peruvian psychiatrist quoted here, Alejandro P. Arellano, presented his findings at the meeting of the Eastern Association of Electroencephalographers in December 1950 in New York; see Arellano 1951. The published abstract identified none of the test subjects by name, however.

genius EEG evidently garnered one more time the full power of fascination of the electrophysiological spirit of enlightenment, although on a new level compared to the first popular responses to cerebral currents of 1930 and 1935. The mobilization of complicated machines to coax a mysterious organ into writing was no longer in the foreground, it was rather the machine-like form of the brain. Even its functional mechanism seemed not to be a mystery anymore, although virtually none of its readers could make anything of the described scanning mechanisms. But, as Roland Barthes asserted, ultimately the reason why Einstein's knowledge had become so popular was that it could be expressed by a simple but cryptic world formula. This analysis in cultural history has not lost any of its actuality. Barthes was one attentive reader of the newspaper reports about Einstein's EEG on the other side of the Atlantic like the one just quoted:

Paradoxically, the mind of greatest intelligence supplied the picture of ultimate mechanics. [. . .] A photograph shows him laid out, his head surrounded by much electrical wiring. The waves of his brain are being registered while he is asked "to think about relativity theory." (But what does "think about" ... actually mean?) The intention surely is to make us think that the seismograms will be especially hefty because relativity theory is a hard topic. [. . .] This Einstein mythology makes him into so unmagical a genius that one speaks about his thinking as if it were some functional task, like the mechanical production of sausages, the milling of grain, or the crushing of ore.⁸⁴

Einstein's EEG was the construed intersection between electrical brains and cybernetic machines. Today the mythologizing effects of science can certainly be extended to cybernetics and its dream of rational universal control wanting to illuminate the world by automatic computer systems and logical calculus.

Brain theories out of the model building-block box

Tinkering is a central component of research in laboratory science. An analysis of the heuristic function of techniques and apparatus is just as profitably transferrable onto experimental practice. The laboratories of EEG scientists were zones of a symbiosis between humans and machines, in which machines were routinely employed to produce data. At the same time, experimentation prompted the construction of specialized apparatus to generate new kinds of data or to model particular functions. And occasionally in this practice machines were developed that united these functions. This technical productivity of experimentation can be exemplified by an analysis of Grey Walter's EEG researches. Machines and models of brain research were created there

84 Barthes 1964, pp. 24f.

as in no other laboratory, which gradually led to a man-and-machine symbiosis itself becoming the goal of research on the brain.⁸⁵

A brief anecdote about the first meeting between Walter and Wiener in Boston in 1946 spotlights the contrary ways of working of these two cyberneticians. While Wiener at MIT was still looking for a mathematically exact automatization of Fourier analysis of EEG curves, Walter had already installed, next door at Massachusetts General Hospital, his comparatively simple but extremely practical frequency analyzer:

I had, empirically and intuitively, hit on an electromechanical method of frequency analysis which generated a rough approximation to a Fourier Transform; and the parameters and characteristics coincided almost exactly with those recommended by Wiener on purely theoretical grounds. I was quite put out to hear Wiener holding forth about the theory and principles of frequency analysis applied to brain waves as if this were a novel and difficult concept, when my machine was ticking away almost next door, reeling off brain wave spectra automatically, every ten seconds, hour after hour. Wiener was more than a little affronted, too, because he had not been told what we were doing and when I gave my account [. . .], he fell asleep at once—his habitual defence against competition.⁸⁶

This confrontation could hardly have been the reason for Walter's invitation to America. Most probably, it had simply been due to dissatisfaction about the analysis procedure already installed there.⁸⁷ Gibbs and Grass had been working for almost ten years on partly automated Fourier transformations of EEG curves, the heart of which was a "general radio wave analyzer." But EEG signals could not simply be fed into the apparatus. Many intervening steps were required with passages between media and cut-and-paste work literally with scissors and glue.⁸⁸ Compared to mathematical calculation of a

85 The following section is indebted to essential ideas from a protracted discussion with Rhodri Hayward. See Hayward 2001a and 2001b.

86 Walter 1969, pp. 93f.

87 Mary Brazier, who had transferred from Golla in England to Robert Schwab in the EEG laboratory at Massachusetts General Hospital in summer 1940, mobilized the Rockefeller Foundation to have her former colleague Walter and his apparatus appear at Mass General's "Ether Dome" in Boston in November 1946. Perhaps there was some reckoning of accounts from other quarters as well. Robert Schwab wrote on 7 June 1946 to Robert A. Lambert of the Rockefeller Foundation (RAC, RG 1.1, series 224A, box 1, folder 5): "Since there is some disagreement as to what method of automatic analysis is feasible, Dr. Frederick Gibbs of Chicago has done considerable amount of work in this field, we thought the way to handle it was to get the subject thrashed out in an international meeting of this sort." On this meeting see Barlow 1997.

88 To transform the conventional EEG into a frequency signal, it was not inscribed as an ink trace on paper but exposed on film in silhouette. These strips were glued together into loops

frequency spectrum by hand, the analyzer reduced the work of many days to a few hours, but the procedure remained inconvenient and involved. Their Fourier analysis of the EEG is not only an example of the enormous amount of work that could be invested in an EEG project but it is also an instructive study on the interlacings between “tinkering and thinking,” on *Bastelei* in research.⁸⁹ This *bricolage*, hand-crafting, by media technicians was so complex that Gibbs had three-dimensional wooden models specially built for their visualization.⁹⁰

Instead of supplying complete EEG spectra, Walter’s apparatus only provided the rates of a few frequency ranges. Nevertheless, it was constructed to process the electric signals of the EEG in real time and record their evaluations underneath the curves while EEG registration was still in progress.⁹¹ This analyzer was likewise a hybrid of various media technologies. The core piece was the rotary switch of a telephone exchange system that ran through a cascade of storage registers with rising resonance frequency like a “scanner” and recorded the stored oscillations graphically as a frequency-specific peak. With Walter’s apparatus no Fourier transformations could be performed to seek as yet unknown waves or ones not visible in the original curve. The analyzer was designed to indicate the relative occurrence rate of frequencies in the alpha-wave range (Figure 49).

The driving force behind the British analyzer was a psychophysiological research project by Frederick Golla, who recruited Walter to London from Adrian’s laboratory especially for these EEG studies.⁹² In a number of psychophysiological studies, Golla had tried to filter out by parameters such as respiration, pulse, and skin resistance, personality types with mainly acoustical or mainly visual ways of processing.⁹³ The EEG afforded a method

and projected as endless film on the narrow slit of a photocell whose frequency signal could then be transmitted to the radio analyzer which finally recorded the frequency spectrum of the film strip as a graph; see Grass and Gibbs 1938. The enormous work involved can be gathered from the fact that even the “simple method” of converting the conventional line EEG into a silhouette EEG was deemed worthy of publication in *Science* (Gibbs 1943).

89 See Rheinberger 2000.

90 See Gibbs and Grass 1939, Gibbs, Lennox, and Gibbs 1941, Gibbs and Knott 1949.

91 See Walter 1943.

92 Frederick Lucien Golla, the “father of psychophysiology” born in 1878 (Bird 1996), was not only in the same generation as Berger but as a psychiatrist pursued a research program that was similar in many respects with its focus on “attendant physiological effects” of mental processes. Unlike Berger, his research was not conducted on the side in a small private laboratory. He headed the only research department on experimental psychiatry in Great Britain during those years, the Central Pathological Laboratory at Maudsley Hospital in London.

93 Golla 1921, 1935, Golla and Antonovich 1929a, 1929b. Walter later occasionally alleged (e.g., Walter 1950, p. 67) that while the experiments were ongoing in 1929, the just-published first EEG paper by Berger came up in conversations at London, whose observations he summarily declared were artifacts but Golla wanted to have them checked. Brazier, however, who at the time was not merely a guest as Walter was but a member of Golla’s team, contradicted this account; see Cobb 1981, p. 59.

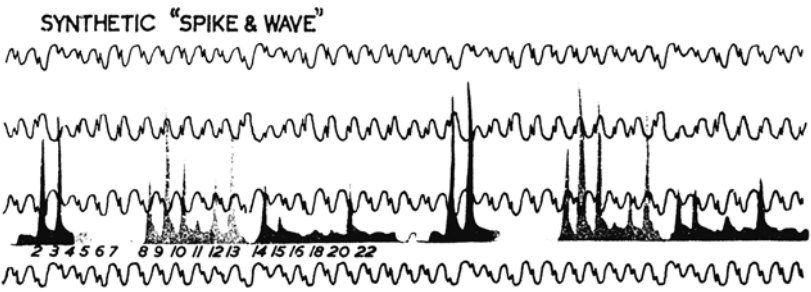
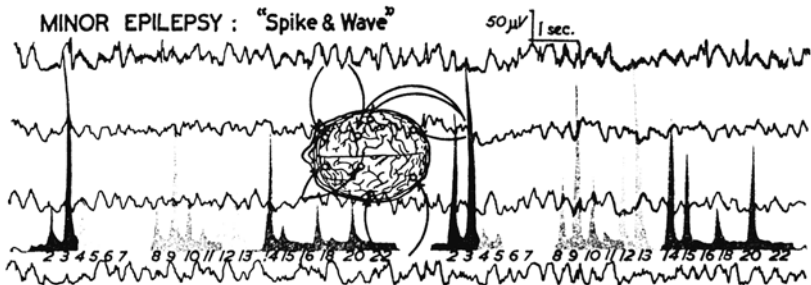
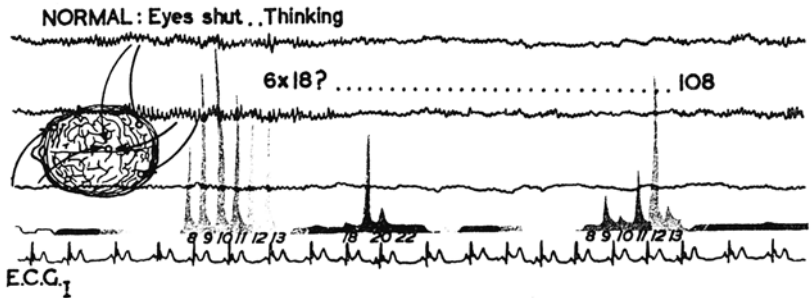
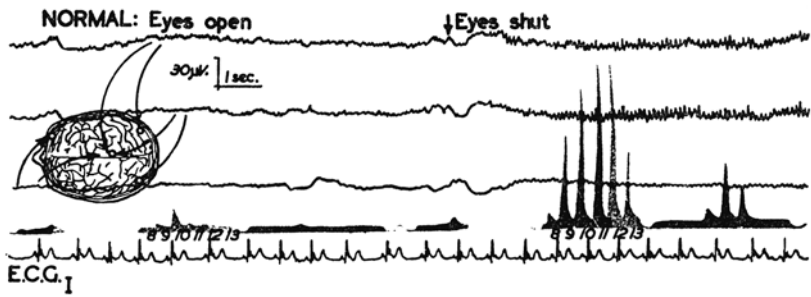


Fig. 4. Analysis of typical Electroencephalograms. The brain diagrams show the points from which the records are taken. The analysis is of the upper record in each case.

Figure 49 Examples of typical EEG patterns and spectra using Walter's resonance filter for frequency analysis from 1943.

of examination for this, even though up to that point no typical EEG patterns for visual or acoustical thinking had been described. In the first study in which the British analyzer device was implemented, Golla and Walter observed that the persons they had postulated to be the visual-thinking type on the basis of their already established method, belonged to the group of those from whom they had difficulty conducting any alpha waves.⁹⁴ The test repeatedly applied by almost all EEG scientists for alpha-wave blockage in the EEG upon visual stimuli, all at once offered a simple grid for personality diagnostics, with far-reaching implications.

Walter advertised the method with astonishing success as an objective measure of thinking style. With the analyzer one could rapidly and simply distinguish between three groups: “R” (responsive) types, who while resting presented a good alpha rhythm that was blocked during mental activity. With reference to Golla’s theory, Walter considered these to be members of a group able to use visual notions without having constantly to rely on visual activity, because the visual system at rest produced alpha waves as a sign of its inactivity. “M” (minus) types, from whom alpha waves could not be registered even in the resting state. They ought to possess a strongly visualizing style of thinking because their visual system never indicated inactivity. “P” (persistent) types, from whom an alpha rhythm was permanently registered, even during mental exertion and illumination. He considered these abstract thinkers who engaged the visual cortex only for specifically visual tasks. Walter perceived the consequences of this classification as even extending into private life:

At breakfast Petra and Michael receive a party invitation and have to decide whether they want to go or not. Let’s assume Petra is an outright P type and Michael an outright M type. Michael pictures for himself a set of lively images, how he and she are going to the party, the party itself, the people they meet, etc. [. . .] But Petra, who is a P type that can’t use visual notions so quickly and easily, has a more abstract way of thinking. She considers the pros and cons of going, weighs the duties and other obligations against the pleasure of going out. [. . .] Michael’s efforts to make her see his pictures annoy and irritate her, while he gets bothered in the same way by her attempts to make clear to him her deeply felt abstractions. [. . .] It is not as if one of the two is more egocentric than the other [. . .]. Their language, their mental accents, so to speak, don’t match.⁹⁵

One might ask how Petra and Michael had gotten together at all, if the differences in their styles of thinking set them so much apart. Grey Walter

94 Golla, Hutton, and Walter 1943.

95 Walter 1963, pp. 175f. Our translation.

and his wife Vivian Dovey, by contrast, had the luck of being able to understand each other almost telepathically and, of course, must share the same type of thinking as well.

How much sorrow might a simple EEG consultation possibly be able to prevent? The example of couple counseling by style-of-thinking diagnostics bore a potential of veritably global proportions: "It may even be that serious crises between nations [. . .] have arisen because the negotiators have different types of imagery and can only talk at cross-purposes."⁹⁶ Walter literally addressed the world; he was writing to the general public, the scientific community, or UNESCO. More important to him than controlling styles of thinking was the related insight about the many different kinds of human brains. Walter's personality diagnostics was not aimed at hierarchical classification but at difference: "To me differences between people are the most exciting and fun discoveries. [. . .] We must hope and work toward having the application of this finding spread and complete the appreciation people have in one another."⁹⁷ That is why Walter continued to stand by his personality typology, even after it turned out that he had long been living with a woman of opposite style of thinking. This did not place his theory in question, or even argue against the sense of electrophysiological personality analysis. It simply proved the attraction between opposite vibes, if one knew about the differences and understood how to live with them.

Walter's brain research was conceived as a practical guide to happiness and for that reason emphasized technology. The apparatus and machinery that Walter constructed in his laboratory constituted an electrotechnical self-enlightenment of humanity in that they illustrated its variety and at the same time related it according to simple technical principles. Walter's apparatus thus served as a visualization of the living brain in the dual sense of display and modeling. Hence Walter developed, on one hand, a completely new kind of EEG representation especially to demonstrate the variety of electrical activity, the "spinning topography," and on the other hand, a whole series of electrotechnical models of psychic behavior, the most famous of which were the electrical tortoises. The toposcope showed landscapes of electrical brain activity in the form of oscillation vectors on small round picture tubes. In this brain television a "display unit" of up to twenty radar screens visualized the complex electrical activity of the brain as a constellation of synchronous, phase-shifted or asynchronous activation patterns (Figure 50).⁹⁸ The toposcope certainly did not just illustrate EEG waves but was itself a brain theory built out of tubes and radar screens. It illuminated

96 Walter 1968, p. 184.

97 Walter 1963, p. 13. Our translation.

98 Walter 1951, 1953b.

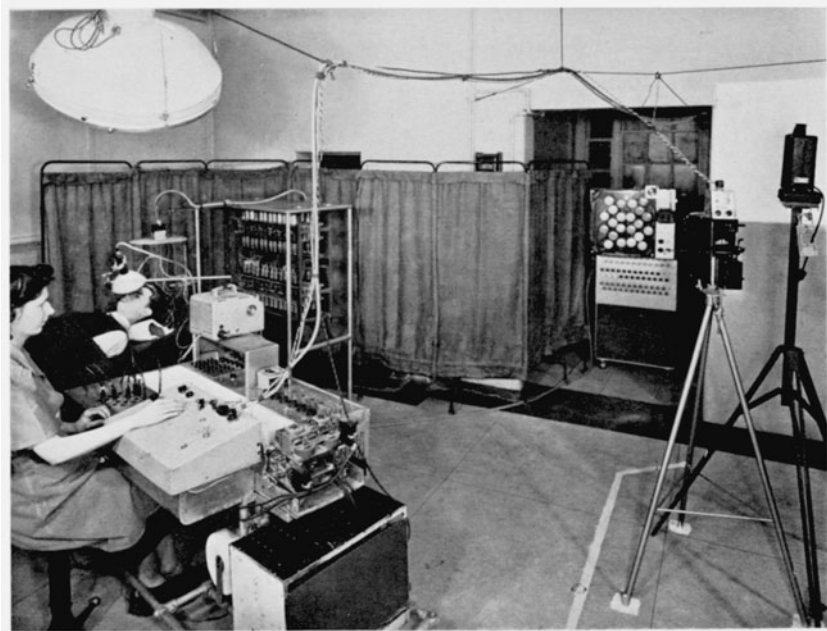


Figure 5

“In this way is projected a moving panorama of the brain rhythms.”

Figure 50 EEG visualization as a brain television, 1953. The test subject lies on the examination cot on the left under a stroboscope lamp for influencing the EEG rhythms. On the right inside the niche in the back is the toposcope with twenty radar screens, arranged as a brain monitor; at the front on the right is a camera to film the events on the radar screens, on the left, a unit for conventional EEG registration and the control panel for coordinating the light stimuli and the resonance frequencies in the toposcope and for operating the camera.

the brain as an occult alpha-wave radar system, to which frequency the screens of the display were tuned:

The way in which the pattern of alpha rhythm is altered or suppressed by imposed mental or visual patterns can be followed in EEG recording; it can be watched with greater dramatic effect in the toposcope where the dominant pattern can be seen taking possession of the visual projection and association areas. When flicker is used, the display given by the toposcope comes near to being a moving picture of a mind possessed in quite another way. [. . .] The behaviour of the spontaneous and artificial rhythms in these conditions is strictly in accordance with the effects to be expected from a scanning mechanism. The interference of flicker with a normal process of scanning would be shown on a television screen by illuminating the television studio with a flickering light. The effect of

this on the picture would be most unpleasant, indeed hard to bear; blobs of light would dart giddily about the screen. Similar confusion in the brain is seen in our records and toposcopic observations.⁹⁹

The toposcope augmented the EEG because it depicted a particular way of working by the brain and, precisely in that way, allowed something else to become apparent. The complex patterns, recalling flower arrangements, that the brain drew on the toposcope's television screens "corresponded to the theoretically expected effects"—and they showed a dominant, differentiating activity that took possession of the brain as chaos. The toposcope operated with the "intervals and interludes of a non-objectivizable brain, where it would mean being creatively active to penetrate in there in searching them out." In this way, in their quest for creative brain research, Gilles Deleuze and Félix Guattari only had to borrow the toposcope as a model: "It would be a little like tuning a television screen, with its intensities making visible that which escapes the objective power of definition."¹⁰⁰

Parallel to this composed chaos in brain television, Walter also designed electromechanical creatures, as comparatively simple models of apparently inexplicable mechanisms of life, such as curiosity or power of judgment. In Bristol a cyborg zoo formed out of machines that moved and learned by themselves. The tortoises "Elmer" and "Elsie," for example, combined a rotating spotlight as a "scanning mechanism" or a radar beam with one more or less sensitively reacting photocell as sensor switch, that controlled its motor drive. As soon as the photocell received a reflection of the spotlight off a bright object, it steered the tortoise toward it. Sensor, motor, and scanner in a simple circuit sufficed to produce behavior that seemed intelligent. This sensory circuit permitted the modeling of a stereotypical gender difference in a simple way, since Elsie, coded as female with her red housing and a more sensitively set photocell, responded much more hectically to light stimuli than her "male" partner. The tortoises were supposed to demonstrate the functionality of a technically simple scanner model, in order to prove that complex achievements, such as are made by the human psyche do not necessarily have to be connected to complex physiology. Walter's media-technical stagings of his brain theories transported electrophysiology literally into the animation stage. His models were built to participate in human life. At conventions Elmer moved around on his own among the public and steered toward the lighter legs of the ladies. Elsie belonged to the family, and luckily little Timothy Walter treated his electromechanical sister with care (Figure 51). In such symbiotic stagings it was not just the closeness to life of technical models that was supposed to become manifest. Walter confronted himself and his audience with the "motility of brain activity," in

⁹⁹ Walter 1953a, p. 72.

¹⁰⁰ Deleuze and Guattari 2000, p. 249.



IN THEIR COUNTRY HOME NEAR BRISTOL, THESE PARENTS HAVE TWO CHILDREN: ONE IS ELECTRONIC.

Vivian Dovey and Grey Walter have two offspring: Timothy, a human baby and Elsie, the tortoise, of coils and electronic valves. Timothy is very friendly with his mechanized sister.

Figure 51 Grey Walter's staging of his family life, with an electric tortoise as the second child.

order by this confrontation with a technical alter ego to exploit the scope of the "plasticity and adaptability of brain functions." Walter's illustrations of the living brain were laboratory creations for the world outside so as not to let human brains deteriorate in the treadmill of modern civilization, but to

open up to a new future. In anticipation of as yet unimagined brain worlds, Elmer and Elsie participated in the living brain: "The machines that are now flashing and ticking in our laboratories are the first forms of the extended life of the living brain, the first attempts at total human understanding, just as Gutenberg's first printing presses were the precursors of the Reformation."¹⁰¹ Modern brain research was like a media-technical revolution with the outcome still open. Walter's "practical instructions for a better life" recommended creating scope for the brain, literally, in its symbiosis with technical engineering.

The tinkering with radar screens, spotlights, engine drivers, vacuum tubes, flicker lamps, scanning mechanisms, and frequency analyses in Bristol allowed the models of the brain and the way it operated tendentially to take the place of a unified theory of the brain. Tools transformed Walter's laboratory into a model workshop whose measure of success gradually became constructive productivity itself rather than the establishment of a theory. This productivity seems to me to carry more weight than the decision about whether Walter's machines reflected the live brain in a magical or distorting mirror.¹⁰² In the wonder worlds of these machines, the code to Rohracher's experiential contents was nowhere to be found; neither were the EEG zigzags deciphered as a symbolical order, although Walter shared with other cyberneticists the optimism of finding inside the EEG the way the mind works. Walter's machines were a medium of communication by the human *with* his brain. Mirrored by these machines, self-description or self-deception were two sides of one and the same interminable process. Walter's recovery of brain functions had the "character of a stance, in the challenging sense." The psychophysiological regularities of the EEG count now, as before, as the unclarified core of the EEG. This history of attempts at elucidation demonstrates not that the EEG is a puzzling parameter of the brain but that it is a way to represent brain functions that cannot be separated historically and epistemologically from the technical processes by which the curves are produced.

101 Walter 1963, pp. 220f. Our translation.

102 Meyer-Drawe 1996, p. 23. On the following, see Meyer-Drawe 1997.

7 Conclusion

Plea for an open epistemology

In all probability, the progressive miniaturization of technical engineering in the twenty-first century will make the coupling of intelligent machines to the human body more and more inconspicuous. Based on miniaturization strategies, this vision of a technological command of life no longer forebodes a regime of robots and machines demoting people into slavery or technical servitude. The development of “smart” technology has dismissed this opposition between technical science and life. Do we now stand at the beginning of a new technologization of life? This vision, as technically implemented biopolitics, aims to penetrate life with technical artifacts engineered to be invisible. The American electrophysiologist Alan Gevins, for example, considers it likely that a portable EEG device will be developed that is so comfortable and easy to use that the apparatus will become normal apparel:

It’s only a matter of a few years before you won’t even notice that there’s an EEG machine there at all since the electrodes and amps may be built into a baseball cap. No wires will connect the EEG machine to a computer. You and your brain will be like a wireless modem, beaming data about your state of alertness and level of attention and mental effort directly into the computer.¹

At first glance, the construction of this “personal brain scanner” seems only to depend on the development of more or less sophisticated methods to make the recording of electrical brain activity so matter-of-course that it could proceed largely unawares. The personal brain scanner is supposed to be deployed in everyday life and should therefore not get in the way of routine tasks and physical activity. It seems to Gevins to be beyond question that in future the laboratory situation and the day-to-day will increasingly mingle until the current normal separation between clinical diagnostics and daily life is eliminated. At core, Gevins forecasts that the future of the EEG

1 Gevins 1997, pp. 114f.

lies less in brain research than in daily applications, where the data contained in the EEG will be individually utilizable by each user personally to maximize his personal profit.

The time for such a transferral of the EEG into an everyday appliance seems not to have come yet, though, if Gevins still suggests that the gadgetry be concealed inside a baseball cap. Maybe a residual resistance by people against their technical subversion must first be overcome, until usage of an EEG by this technique shapes a part of routine life. A naturalization of technical science, the biological tactic of mimicry, ought to help it into conventional usage. Nevertheless it seems to be established that the opposition of man and technical science now already involves the ideology of a romanticizing opposition, which misses the specifics of the new brain technologies. How antiquated this ontology has become is evidenced by the semantic confusion in the usage of the personal pronoun in the quote: "You and your brain will be like a wireless modem, beaming data about your state of alertness and level of attention and mental effort directly into the computer." The ego and its brain are supposed to be fused into one technical thing, in order to convey physical data to a computer via a third entity that is referred to as "you." Its ontological status is complicated even more in that the informational content of this data is assessed by the computer but can evidently only be actualized by the ego. Ego, brain, scanner, and computer are connected together in a feedback loop that presumes technical psychobiological methods of knowledge that blur any clear sundering lines between knowledge, life, and technology. Moreover, the efficiency of this feedback loop is not gauged by its capacity to overdrive the subject but by the subject's continued ability to act autonomously throughout critical situations. The personal brain scanner aims at limited technical influence on its user.

Gevins's personal brain scanner technically represents a modern variant of Kornmüller's signaling device—albeit with a nontrivial difference in the application setting. Gevins is not thinking of perfecting man-machine hybrids for air warfare, which cannot do without the technical fusion of man and machine in an airplane, to start with. His idea is, rather, technically mediated improvement of human *performance* in daily life, which at least up to now has largely refrained from such hybridizations. The usefulness of such an EEG-directed feedback loop between the ego and the brain still derives from the military project of securing survival: The ego must be kept inside the curve. During a long car drive, for example, the wearer of such a baseball cap could protect herself from dropping off to sleep and therefore from coming off the road. Another option connects the ego and the curve in a more metaphorical way. The wearer of the personal brain scanner could plan vital decisions, tests, or public appearances so that they coincide with a high "level [. . .] of mental effort" rather than with a valley in the performance curve. The easy-to-wear EEG device does not propose to substitute or undermine the autonomy of the acting subject by artificial intelligence

but to extend it by technical aids held close to the body. The technically extended ego should take the place of an apparently given pretechnological self. The maxim of psychoanalytical enlightenment would thereby have entered into the era of its technical reproducibility. Where there was once a cerebral ‘it,’ should come a digital ‘ego’: constant control by the psychic apparatus in the sobering light of technically generated knowledge.

Will this hybridization of human and technical engineering allow the old dream of scientific enlightenment via the subject to come true? Take Ivan Pavlov’s formulation at the Congress of Physiology in 1932, for example, where Max Heinrich Fischer had presented EEG research from Berlin-Buch without generating any ascertainable resonance:

I am convinced that presently an important new step in human thought is approaching, upon which the physiological and the psychological, the objective, and the subjective really will unite, will *in fact* merge into each other. Then the time will also have come when the agonizing contradictions and disjunction between my consciousness and my body will entirely naturally dissolve or simply fall away. Truly!²

Physiologists, psychologists, and research engineers have, in fact, been working on a fusion between machine and organism since the 1930s and 1940s. The first cyborgs appeared during the war, and cybernetics after it. In retrospect, however, a precarious ambivalence of the EEG emerged more clearly than at the time of the cybernetics euphoria. This ambivalence differed from cellular neurophysiology or Pavlovian reflex physiology in that the nervous system was conceivable not as a calculable machine but as a spontaneously active, unpredictable unit. Cyberneticians had set their stakes on solving such unclear ontologies at the threshold between the organic and the inorganic with control theory or information theory. Warren McCulloch—certainly the most philosophical mind among cyberneticians—has gone so far as to declare neurophysiology as the fundamental science of an “experimental epistemology,” making explicit reference to Helmholtz’s projected physiological theory of knowledge:³

We have an algorithm to determine from anatomy those functions of its inputs that a given neuron can compute. These are sufficiently well substantiated for us to attribute one of the four shape functions, that

2 Pawlow 1953, p. 213. Our translation, original emphasis.

3 His article coauthored with Jerome Lettvin, Humberto Maturana, and Pitts, “What the Frog’s Eye Tells the Frog’s Brain” (Lettvin et al. 1959) described the frog’s eye not as a perfect camera but as a selective filter of visual information relevant to its survival and constitutes the founding document of the theory of autopoietic systems. See McCulloch’s summary: “A Historical Introduction to the Postulational Foundations of Experimental Epistemology,” in McCulloch 1965, pp. 359–372.

we know are computed by ganglion cells in the frog's eye, to each of four kinds of ganglion cells. The projections to the brain preserve spatial relations. Whitehead's cognizance by adjective and cognizance by relation are thus anatomized. We have theories, perhaps wrong in details, to account for the perception of universals like squares and triangles as mediated by mammalian brains. [. . .] In short, the central problem of experimental epistemology seems in principle to be soluble along lines sufficiently well verified to reduce every particular question of physiology of knowledge, however intricate experimentally, to a strictly parochial problem.⁴

McCulloch's "nervous theory of knowledge," basing physiology itself as an epistemology, was by no means unique around the mid-twentieth century. Self-basing theories formed in other scientific fields as well, such as Jean Piaget's genetic epistemology or Konrad Lorenz's evolutionary epistemology. McCulloch's project differed from these endeavors by a technical constructivism that linked his theory to computer development. As stimulating as this approach was, its focus on logical operations now appears limited. Issues that have meanwhile come under intense discussion, such as intentionality or emotional intelligence, were simply omitted in this functionalistic approach. The early constructivism, oriented toward the electrical brain, was successful essentially because of its reduction to phenomena declared as relevant. Experimental epistemology set cybernetics on the basis of a program explained by physiology and thereby stayed blind to the constructive productivity of experimental systems.

It was hardly chance that Grey Walter was unable to find any hint of a central metronome for the calculational beat of the brain in his frequency analyses of EEG curves, even though, just like Norbert Wiener, he had speculated about feedback loops and scanning mechanisms. To Walter, music was literally at play:

We know that within the brain, a great many electric processes can be identified, each with its own quite limited domain, some apparently independent, others interacting with one another. We must accept that in the EEG we are dealing essentially with a symphonic orchestral composition, but one in which the performers may move about a little, and may follow the conductor or indulge in improvisation—more like a jazz combination than a solemn philharmonic assembly.⁵

To a certain extent his constructivism went in the opposite direction: He constructed more and more complex models of brain function until in the

4 McCulloch 1965, p. 371.

5 Walter 1961, p. 17.

end he arrived at purely metaphorical images to describe how the brain worked. In the 1960s jazz improvisation lay definitely beyond the range of activity of electrical brains. Compared to McCulloch's experimental epistemology, Walter was executing a research project that could be characterized as *negative* epistemology: "The important difference is that the brain is not a logical machine at all."⁶ Against the backdrop of reductionist theories by Wiener, Ashby, or McCulloch, Walter's objection looked entirely plausible. But what does it actually mean to say the brain is "not a logical machine"? Can science determine an organ's function as illogical? And can a brain cognize itself as illogical by the scientific notions processed within it?

Georges Canguilhem provides a double historical perspective on the noted confusion between the brain and thought. He traces its genesis back to Descartes and the brain research initiated with phrenology in the early nineteenth century guided by Cartesianism:

Before the formation of phrenology, Descartes was considered a thinker, an author responsible for his philosophical system. According to the account of phrenology, however, Descartes is the bearer of a brain that thinks in the name of René Descartes. Because Descartes is identical to his brain, which contains "possibility," he perceives *cogito* ["I think"] within himself. [. . .] In short, from the image of Descartes's skull, the phrenologist draws the conclusion that Descartes in total, his biography and his philosophy, were inside a brain that is indisputably *his*, namely, Descartes's brain; as, it does, of course, contain the propensity to perceive actions that are inside *it*. But what is this *it* exactly? [. . .] How can *it*, which the modern physiologist as successor to the phrenologist establishes and describes—how can this *it*, namely the brain, arrive at an *I think*?⁷

To this accusation of mixing up thought with organ functions, Canguilhem attached a harsh critique of modern brain research and its automat theory of thought. The "stale metaphor of the brain as a computer" applies only to logical operations of the brain. According to him, the computer perhaps demonstrates a model of particular achievements of thought but simultaneously the human capacity to transcend such achievements of thought. As long as research on the brain does not regard language in its semantic dimension and therefore as part of human culture, it supplies at best a physiology of speech production and for that reason could not instruct philosophy either. Philosophy must, rather, take into account its critical potential against a naturalization of the mind, in order to preserve thought as a form specific to human life. Philosophy should "oppose every foreign incursion

⁶ Walter 1970, p. 53.

⁷ Canguilhem 1989, pp. 15–17.

into the brain that aims to take away from thought its power to reserve final authority.”⁸ Almost thirty years later, we can scarcely add anything to these words by Canguilhem. They formulate with emulable clarity the aporetic situation of brain research and its ambitious projects in cognitive science.

But what about the personal brain scanner, which seems to presuppose and at the same time undermine the Cartesian disjunction between brain and mind? With his brain prosthesis Gevins wants to *strengthen* thought’s “power to reserve final authority.” Doesn’t the scanner generate out of this constraint, foremost, phenomena that—in Gaston Bachelard’s words—demand “open, recurrent doubt in a past of secure knowledge”?⁹ In view of this example, it seems as if Canguilhem was too quickly setting thought in opposition to computer, while Gevins’s scanner has long since been operating in Bachelard’s zone of a non-Cartesian epistemology. When Canguilhem sharply divides the roles: “The physiologist is master of his house, but the philosopher pokes his nose in everywhere,”¹⁰ should one not then retort that the philosopher’s role does not nearly make him master of the house everywhere?

One must give credit to Canguilhem, though, for not pleading a convenient division of labor among the sciences, with the authoritative status of reflection being awarded exclusively to philosophy. Canguilhem’s criticism of a machine theory for the organism was precisely not aimed at an essential difference between technical science and life. Not long ago, Ian Hacking reminded us that as early as 1946, hence exactly within the context of the genesis of cybernetic theories, Georges Canguilhem pointed out the irresolvable historical and philosophical interweaving of concepts of machine and organism.¹¹ Accordingly, Canguilhem had conceived a relationality between organism and machine that led him close to postmodern cyborg theoreticians. Instead of too quickly establishing conceptual difference, one should rather seek their relatedness.¹² This is why the intention of this analysis is to sketch an *open* epistemology of the man-machine couplings in brain research.¹³ Canguilhem’s remarkable characterization of creative thinking supplies a first track here. It describes surprisingly exactly the reaction to information from the brain scanner in a significant way: “What kind of a state of thinking is it, in which one can eye what one does not see at all?”¹⁴ Independent of how the claim to knowledge by the neurosciences should be evaluated, their experimental arrangements evidently provoke creative

8 Ibid., p. 37.

9 Bachelard 1988, p. 163.

10 Canguilhem 1989, p. 18.

11 Hacking 1998.

12 Canguilhem 1975.

13 By this is meant an epistemology that reflects equally the historical shapability of the objects of research as well as that of knowledge processes. On the concept of *offene Epistemologie*, see Gumbrecht and Pfeiffer 1991.

14 Ibid., p. 22.

thinking. Two projects of reflexive EEG experiments that are located exactly within the zone that Gevins's scanner barely touched, can serve as the guiding thread.

In a brief account of his EEG researches, Adrian recalled in 1971 how at the public demonstration of the EEG in 1934 in Cambridge, he had been able to judge the success of the demonstration while the experiment was still in progress by the reaction of the audience, without himself observing the EEG and without his alpha waves being disturbed by such secondary thoughts. In front of the astonished assembly of physiologists, he succeeded in doing what had failed for Berger in his private laboratory: self-observation of the EEG, which was more effective the more consistent Adrian was about eliminating from the test situation all effects of this self-observation. And exactly at this point (if one may believe Adrian's reminiscence, at least) a thought of trickery arose in his mind:

I was the subject, I was unable to see the alpha waves from my head being written out on the screen when I closed my eyes, and ceasing when I was required to solve problems in mental arithmetic, but I could tell from the general hush in the audience and the scratching noise of the pen that the demonstration was going well. [. . .] I do recall that several members of the audience asked for short lengths of the ink-writer record which had covered the floor of the theatre as the demonstration progressed. In fact it had gone so well that I began to wonder whether I had not unconsciously trained myself to produce the result by some kind of trick movement.¹⁵

But who is tricking whom here? And what could it actually mean to have "trained" one's mind? Don't Adrian's doubts rather document the trap of a too modest epistemology, because he had not managed—in Canguilhem's words—"to alienate [sufficiently] the naive objects of his vital questions in order to earn scientificness"?¹⁶ Ultimately, the success of the experiment lay in that the public was able to follow, from the registration by the device, when the Nobel laureate's brain began to solve an arithmetical problem and when it was finished. The perfect functioning of the brain in interaction with the recording apparatus aroused the suspicion that this was just the result of a manipulation on the part of a hidden ego whose activity was being registered in the experiment simultaneously as well. The apparatus inscribed a trace of the activity by Adrian's psyche, the value of which he began to doubt by virtue of the registration's psychophysical precision. Because he realized how accurately his mind was keeping inside the curve, Adrian thought of an intricate form of self-deception by which the brain was somehow tricking

15 Adrian 1971, pp. 1A-9f.

16 Trans. from Canguilhem 1979, p. 153 ("Zur Geschichte der Wissenschaften vom Leben seit Darwin").

itself. “Nothing is [. . .] more terrifying than a thought beyond one’s control, as fleeing ideas that barely sketched vanish again, already [. . .] plunging into others over which we have equally little command.”¹⁷ Wouldn’t the lack of a response by the EEG in the case of his self-doubting also have had to give Adrian occasion to doubt his brain or the recording method? Adrian’s self-doubts illustrate exemplarily Canguilhem’s diagnosis that the special problem of the life sciences is not the use of experimental concepts but the forming of concepts in the experimental way, because in the life sciences insight and technical means are combined in a way that the objects of knowledge act back upon the constitution of the knowledge.¹⁸ Self-reflexive research on the brain operates in the aporetic situation, on one hand, of first constituting its object experimentally, and on the other hand, of employing an anticipatorily cognizing subject in this experimental arrangement.

Hardly any other EEG researcher has explored more thoroughly than the American performance artist and composer David Rosenboom how the “theoretical experimental processing of knowledge”¹⁹ puts object and observer together into a new position. From the material wastes of electroencephalography and computer technology he started a project on subject constitution, the “brain music machine” from 1974.²⁰ Similar to the personal brain scanner, brain music is based on an EEG analysis. It is, in a way, a musical performance by the EEG and the brain. The constellation is the same as for Gevins or for the brain researchers at Buch who wanted to monitor the brains of pilots: The EEG device is linked with a synthesizer for acoustical data output and in a feedback circuit interconnecting the brain, the ear, and the ego. The EEG device converts the brain’s resting oscillations into an audible tone that, in turn, influences the situation of the EEG conduction because the test person, in this instance the artist, hears the tone, but his brain makes those resting oscillations vanish at the very moment that he concentrates on the acoustical impressions.

“Ego or brain?” is hence the wrong question to ask to gain insight into the epistemological confusions of the previously sketched projects. The tone of the brain music machine is an expression of the artist’s intentionality. He designed a machine that, as a knowledge construction of neurophysiology, sounds its effect on his brain activity. Each change in the tone is an expression processed by the machine of an altered state of the brain, which, in turn, can be influenced by the artist in real time. But this is where the confusion starts,

17 Deleuze and Guattari 2000, p. 238.

18 Canguilhem 2001.

19 Canguilhem 1979, p. 145.

20 David Rosenboom’s concert instrument from 1974 was a set of head electrodes, a simple amplifier for EEG signals, and a synthesizer whose output was modulated by the conducted EEG signals. A custom-made model of this device was built for Earl Bakken and is now, together with a description of the device, located at Bakken Library and Museum of Electricity in Life, Minneapolis. On Rosenboom’s project, see Rosenboom 1976 and Büscher 2000.

because the tones are not representations of a notion of sound, a concentration on a particular tone, but quite the contrary, the result of *disregarding* the tone, because any concentration suppresses the alpha waves that had generated that tone. A tone only sounds at mental rest. Non-concentration generates the sound, which the artist then hears and which he must then *disregard* if he does not want to interfere with it and make it vanish. In a certain respect with his machine the artist is acting against himself. It is an arrangement to outsmart the brain/ego.

The performance aims directly at the contradictory nature of this attempted trickery; it lives on the paradox of the set-up. Where Berger landed up at a dead end because his curiosity disrupted the curve, and Adrian turned away in irritation because his brain had deceived him and emitted signals no more substantial than those of a diving beetle; where Wiener wanted to outbid the puzzle of electric waves with analysis engineering; Rosenboom staged pure feedback between brain and machine which generated new phenomena. The brain music machine initially looks like a media effect. Just because knowledge and brain-research technology are indebted to media is why it is so effectively dramatizable in this performance as a media effect. On this point one could also ascribe a critical potential to brain music: The performance makes mediality of brain research visualizable, or acoustically experienceable, which is not treated within science because it is embedded in the research practice as a reality construct. Such a criticism from media theory about the representationalist approach of brain research might well be sound but it falls short as long as it projects a difference between representation and presence.

The intrinsic sense of Rosenboom's brain music machine rather lies in that it itself subverts this critique model. The tones of its performance seem to be a representation of a particular EEG activity and the expression of an individual artistic achievement, but at the same time they dodge the clear attribution of representation and brain process. The ego, the machine, and the brain are connected together in such a way that any form of autonomy is foiled. Neither the brain nor the ego nor the machine controls the situation. One could rather say that they mutually keep each other in check. The performance much rather seems to suggest Deleuze and Guattari's noted exploration of chaos and brain, because what it describes "is not a brain behind the brain but an initial flyover state close to the ground, a flyover on the self." Rosenboom's performance does not expose any deeper truth about the brain behind scientific EEG research and forges no unity between science and art, only unrest.

The critique at the beginning of modern medicine was that its experimental methods necessarily examine artificial states of life, because "the conditions of laboratory analysis set the living being in a pathological situation from which, paradoxically, conclusions can be drawn supposedly with the validity of a norm."²¹ Rosenboom did not reiterate this critique but allows this

21 Prus 1825, quoted from Canguilhem 1974, pp. 97f.

dependence to become productive in an unpredictable way. The lively activity expressed by the produced tones is irresolvably interlaced with the knowledge of neurophysiology and the technology of electroencephalography. The performance uses, stages, and demonstrates this interlacing in a way that thwarts all attempts to resolve the triad of knowledge, technical engineering, and life toward one of its poles. The technical logic of circuitry, the singular mindedness of the live brain, and the individuality of the artist are permanently cross-checking each other, without any primary normativity becoming effective. They stand in a mutual relationship of stimulation and simulation. Rosenboom's brain music machine points to a relational productivity of research on the brain, in which the materiality of objects is constrained within their epistemic dimension and the activities of life. Thus it indicates how modern cerebral research acts in that interstice which Paul Valéry had already outlined in his *Cahiers* over fifty years ago: "In the *interior* of thinking, and behind that there is no thinking."²² As long as electroencephalography seeks the signs of the mind inside the curve, it applies to its object a division between mind, brain, and technology, by which it disregards the epistemological dynamics of its research. Its experiments operate beyond the difference between technical science and life in a region that is no longer describable by an ontology that permits life and machine its anchoring. Where scientific reflection ends in aporias, art performs what has escaped experimentation.

Electroencephalography opened to research on the brain a new, fascinatingly ambivalent knowledge space. On one hand, the method seemed "exceedingly simple," because the repeatedly confirmed and typical alpha waves could be easily and quickly registered along with their inhibition, provided the required recording devices were available. On the other hand, it was "exceedingly complex," because even with the most difficult instruments and most sophisticated research designs, it was not possible to find a plausible explanation for those highly regular, surprisingly slow, and astonishingly rhythmic electrofluctuations. This tension spurred on the investigations for many years, especially considering that the important successes in neuropsychiatric diagnosis quickly secured broad clinical applicability for the new method. Special techniques for curve registration were supposed to explain the genesis of electric waves; and complex models were supposed to present the functional principles of electrical brains. And yet, despite the production of an enormous amount of data and despite multiple modelings, the brain stubbornly eluded all attempts at electrical interpretation. It remains an open question how the present-day methods of electrophysiology in the neurosciences will draft a physiology of the mind, since cerebral research is, as Heinz von Foerster has formulated it, a "Wissenschaft des Unwißbaren"—a "science of the unknowable."²³

22 Trans. from Valéry 1989, p. 142 (*Cahiers* V, IX, 124).

23 Foerster 1994.

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