Behavioral Electroencephalography

Behavioral Electroencephalography

By

Gerald Ulrich

Cambridge
Scholars
Publishing

Behavioral Electroencephalography

By Gerald Ulrich

This book first published 2023

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-9260-X
ISBN (13): 978-1-5275-9260-5

CONTENTS

PREFACE

Electroencephalography (EEG) was introduced with great hopes, but work soon came to a standstill. During the introduction of psychopharmacology in the Sixties to Seventies of the last century the EEG played a central role as a tool for psychiatric research. Nevertheless, a steady, and for the past three decades almost rapid loss of importance for clinical neurosciences, especially concerning psychiatry cannot be denied. In this situation it seemed highly appropriate to precede the book with an analysis of the causes. Its purpose is to prove that this deficiency of importance is not result of an inadequate the handling of the method but rather of a cornucopia of flaws and shortcomings. Time-functions are sequences consisting of oscillations with a certain Frequency (measured in cps or Hz) and Amplitude (measured in Microvolts). Although nobody knew up to now what these measures could tell, it seemed clear-cut to anybody that these measures as well its mathematical handling represented the key to the long-sought EEG code. As a precondition the morphological differences between the single waves were considered. Thus, one distinguishes EEGs without any theoretical justification according to their visual resemblance of the composing single waves with Greek letters e.g, gamma, lambda, my, rho, pi, si, sigma and zeta-waves, trying to associate doubtful EEG-pictures with neuropsychiatric disorders (Kugler J., 1981).

With the general availability of the FFT in the seventies of the last century the original conviction of an understanding of the cortical oscillations by mathematical quantification seemed to come to fulfillment. This conviction found its expression in a sheer magical significance “computer assisted EEG” being immune against any questioning. It was taken for granted that only by spectral analysis via FFT (Fast Fourier Transform) one would reach scientifically satisfying target variables.

Ever since the beginning eighties the clinical EEG, especially in psychiatry turned out to be a failure. This major disappointment has been scanty concealed by a booming tendency of imaging techniques.

The reason is the just as popular as anti-science slogan “only matter matters” or with other words: science has to be data-driven instead of theory-based.

To renounce epistemology from science is tantamount to an abandonment of the question of about the meaning of an item and inevitable leads to vague assumptions, deceptive intuitions and unprovable ideas. The gravest flaws resulting from are theory-free science are:

- Exclusion of any dynamical information - checkable
- Statistical comparison of averaged spectral parameters instead of using a single case design
- Using non-checkable commercial software
- Non-consideration of the basic non-stationarity
- Non-consideration of the basic nonlinearity
- Non-consideration of the nonexistent isomorphism between Function and Behavior
- Non-consideration of the pathomorphological or “paradoxical” SR-EEG in healthy subjects’ statistical comparison of averaged spectral parameters instead using a single case design

CHAPTER 1

ON THE PHILOSOPHICAL FOUNDATION OF THE EXACT AND THE BIOLOGICAL SCIENCES

Physicalism claims a data monism independent of the object of knowledge. In the case of psycho-physical entities like man, however, a data dualism in the sense of a categorial distinction between physical and mental data as well as their mediation is mandatory in order to avoid aporias. Philosophers like *Ernst Cassirer* and theoretical physicists like Werner Heisenberg and Erwin Schrödinger agree that the world of exact natural sciences lacks everything that is meaningful for the *life world.* According to *Cassirer,* the language of natural sciences is not able to convey something like meaning which is why a scientific dialogue about worldviews is impossible. Meaning is a social performance generated by attribution. As such it cannot be located in the brain. The brain contains only materially-objective, life worldly meaningless functions. Thus, the epistemic opposition of Function and Behavior/Performance is an indispensable prerequisite for any anthropological progress in knowledge. A reversible clear assignment of Function and Performance exists only in artificial, but not in man-made systems. Gustav Fechner's statement from 1860 is still valid, according to which the question of the effect-relations between the physical and the mental cannot be the subject of a pragmatically oriented natural research. Nothing else says the mill simile from Leibniz' Monadologie published in 1704:

> *"Suppose there was a machine whose structure allowed to think, to feel and to have perceptions, one could imagine it so proportionally enlarged that one could enter into it like into a mill. Provided this, one will find by visiting it from the inside only parts which push each other, and never something which could explain a perception".(„Angenommen, es gäbe eine Maschine, deren Struktur zu denken, zu fühlen und Perzeptionen zu haben erlaubte, so könnte man sich diese derart proportional vergrößert vorstellen, daß man in sie eintreten könnte wie in eine Mühle. Dies vorausgesetzt wird man, indem man sie von innen besichtigt nur Teile finden, die sich gegenseitig stoßen und niemals etwas, das eine Perzeption erklären könnte", (transl. from German).*

To mention only a few names, among the philosophers Immanuel Kant and Max Weber adopted this view, among the physiologists Emil Du Bois Reymond as well as the founders of a scientific psychiatry, Wilhelm Griesinger, John Hughlings Jackson, Henry Head, and Henri Ey, as well as the logician and metamathematician Kurt Gödel. As opponents to the mill simile and closer to the modern self-understanding David Hilbert as well as the numerous representatives of the „Philosophical Functionalism“ of Anglo-American provenance are to be mentioned. The biological natural sciences must do justice to all natural conditions, the material-physical as well as the processual-psychical. This condition is fulfilled only by Aspectual dualism or Epistemic dualism, as Baruch (Benedict) Spinoza propagated it as complementary entanglement of the physical and psychological experience. The paradigm of the physical is represented by Newton’s theory of colors, whereas the paradigm of the psychological is experienced by Goethe’s theory of colors. Heisenberg placed the latter as undergoing recognition („erlebendes Erkennen“) on an equal footing with the former as abstract recognition („abstraktes Erkennen“). According to Schrödinger the physics of abstract recognition (physikalisches Erkennen, transl. from German) - could only be constructed at the price that the self and with it everything subjective was removed from it. In the biological natural sciences or "life sciences" and here especially in medicine such a labeling would be fatal. Here today it is above all a matter of reintroducing the subject eliminated in the name of progress and with it the first-person perspective. The commitment to physicalism and objectivism is considered the epitome of progress in modern biological sciences, including medicine. No distinction is made between physical and psychical data. However, an object of knowledge, such as the psycho-physical unity of man, requires a dualism of physical and psychological data as well as their mediation. This mediation refers to the thing-world of the physical and the life-world of the socio-cultural i.e. the methodological paradigms of Physiological Function and Behavior/Psychological Performance. Since Fechner’s Psychophysical Parallelism, empirical research has been attempting to sum up the psycho-physical unity of the human being in different terms. The same means the concept of Vigilance (**V**) published almost 100 years ago by the English neurologist Henry Head (1922). Head’s Vigilance was inspired by Jackson’s Doctrine of Concomitance. The constant actuality of Head’s **V** is expressly underlined by an annotation of the psychologist U. Laucken (2005) who quoted Cassirer’s remark to Head’s **V** in his "Logic of Cultural Studies" (1942): “He understood this as a transversal concomitance of mental and physical phenomena („ …als transversale Konkomitanzbeziehung von psychischen und physischen Phänomenen“, transl. form German). The

philosopher Cassirer agreed with the physicist Schrödinger that the world of exact Galilean natural sciences lacks everything that is meaningful in the life-world. Accordingly, the language of the natural sciences is neither able to transport meaning nor, in general, mental performances. Therefore, it makes no sense to conduct a scientific dialogue about diverging worldviews, because the medium of conversation does not exist in the scientific cosmos. He spoke aptly of the "semantic blindness" of physiological psychology or neurophysiology. Thus, we can contrast a meaningless neurophysiology belonging to the physical cosmos and a psychophysiology generated in the psychic cosmos. Neurophysiology deals with Behavior and Experience. The categorial distinction between Function and Behavior/ Performance/Experience is not a semantic quibble, but an indispensable prerequisite for any anthropological progress in knowledge. In order to expand our psychophysical horizon, it is necessary to "bridge" the epistemically incommensurable gap between the realms of physical and mental phenomena. This is also manifested in the fact that there exist two different languages (e.g. E. Laszlo, 1972). The neurophysiological brain functions are described in brain language, the psychological performances/behaviors in mind language. The philosophical direction of Functionalism, on the other hand, demands a reversible unambiguous assignment between the Mind (the realm of Performances/Behavior/Experience) and the Brain (the realm of Functions). The founder of Functionalism, Hilary Putnam (1988), however, soon distanced himself from this by following the insight that our experience cannot be translated into the semantic language based on a dictionary of words, syntax and grammar which are arbitrary human conventions. In contrast to artificial systems, brains as living systems are in a permanent transaction with their environment. Because of this the correlation between Function and Performance/Behavior/Experience never remains the same. A reversible and unambiguous correlation demanded by Functionalism can only exist in artificial systems, since only these have just a unique state specified by an external operator so that Function and Performance fall into one. This conception, also known as Fechner’s Principle, is found for the first time in his main work "Elements of Psychophysics" from 1860. According to Fechner, the question of effects between the physical and the mental could not be the subject of a pragmatically oriented natural research. Among the supporters of Fechner’s principle were above all the proponents of data dualism. The fact that it had enabled psychology to coexist fruitfully with the field of physical phenomena for many years was remarkably emphasized by Albert Einstein (1922). By the way, the "Fechner Principle" can be found in the "Croonian Lectures" from 1884 by Jackson (1835-1911). His follower H. Head (1861-1940) adopted Jackson’s concept of a

hierarchically ordered Cerebral Global Function (CGF) with higher (inhibitory) and lower (excitatory) states of order. In order to do justice both to the aspect of Function and to the aspect of Behavior, Head also strove for a conception of nervous and mental energy, integrating Function and Behavior, for which he coined the novel, often misunderstood meta-theoretical concept of Vigilance (**V**). Head's **V** can be understood as a „measure" of the currently realized quantitative level of central nervous integration (functional level) and at the same time as a qualitative indicator of the currently achievable behavior. A strict separation of Function and Performance, which used to be taken for granted, seems to be mostly no longer understood today or dismissed as a linguistic quibble. This is especially true for the conviction, which cannot be shaken by any argument in discussions with colleagues from the Anglo-American language area, that artificial systems do not differ inevitably from natural systems by the degree of their intricacy, but rather by their complexity. By establishing correlations/correspondences between the incommensurable descriptive realms of the physical (or the neurological) on the one hand and the psychologically (mental, or spiritual) on the other hand, the hiatus between both realms is bridged. Not to be misunderstood: the concept of bridge between the physical and the psychic presented here does not appeal to an exploration of the transition from material to psychic phenomena or vice versa. Such a transition can be excluded. It is rather a pure theoretical concept, or construct, or explanatory principle as well as a regulative idea in the sense of Immanuel Kant. A key role in the dissemination of Fechner's principle was played by the neurobiologist Emil Du Bois Reymond. In his memorable Leipzig speech to the Society of German Natural Scientists and Physicians in 1872 which earned him the accusation of scientific pessimism, he stated: "Whether we will ever comprehend spiritual processes from material conditions is a question quite different from whether those processes are the product of material conditions."(Ob wir die geistigen Vorgänge aus materiellen Bedingungen je begreifen werden ist eine Frage ganz verschieden von der, ob diese Vorgänge das Erzeugnis materieller Bedingungen sind"). On this point he contradicted his friend Hermann von Helmholtz, who insisted on the general validity of the mechanistic paradigm within natural science:

> *"But if motion is the primordial change underlying all other changes in the world, then all elementary forces are forces of motion, and the ultimate goal of the natural sciences is to find the motions underlying all other changes and their driving forces, that is, to dissolve into mechanics." („Ist aber die Bewegung die Urveränderung, welche allen anderen Veränderungen in der Welt zugrunde liegt, elementare Kräfte oder Bewegungskräfte ist das*

Endziel der Naturwissenschaften die allen anderen Veränderungen zugrunde liegenden Bewegungen und deren Triebkräfte zu finden, also sich in Mechanik aufzulösen.",(transl. from German).

Wilhelm Griesinger (1862), one of the fathers of scientific psychiatry, took a position that from today's point of view can still be considered progressive, in that he opposed both a one-sided brain-centered psychiatry that excluded soul-states („Seelenzustände") and an equally one-sided psychiatry that was not interested in the brain. It was also self-evident for him that the *states of the soul* are not reducible to functional disorders of the brain. Almost simultaneously with Du Bois Reymond, he wrote in the 2nd edition of his textbook of 1862:

"*If we also knew everything what is going on in the brain during its activity ... what use would it be? All oscillations and vibrations, everything electrical and mechanical is still no state of soul, no mental representation*".

In addition to neuroscientific theorizing and its application in explaining clinical phenomena, Head's **V** concept also provides a viable foundation for electrophysiological research. The French authors Lairy & Dell (1957) were the first to see in the electroencephalogram a macro-indicator for Head's **V**, i.e. the *Global Cerebral Function* (GCF) of the brain as well as of the quality of the associated *Adaptive behavior.* Other authors - among them my teacher Dieter Bente - tried to expand this theory in the direction of a psychophysiological or psychiatric EEG, following in the footsteps of the Jena psychiatrist Hans Berger, who in 1929 had succeeded for the first time in recording the brain electrical activity in the human. The fact that the EEG - despite the promising start - could not develop its generally expected heuristic potential, can be blamed in retrospect on a failed methodology. For further development as a macro-indicator of GCF, a gradually ordered differentiation of oscillations would have been necessary. In this early stage of development only the method of visual pattern recognition was available. Although shortly after Berger's discovery two American groups of neurophysiologists of the Harvard Medical School under the direction of H. Davis and A. L. Loomis had described in the EEG - recorded under spontaneous resting conditions (SR-EEG) - a more or less regular sequence of distinguishable spatiotemporal wave patterns between full wakefulness and falling asleep the further development stagnated for various reasons. An EEG pattern, for instance can only be recognized as such if it can be distinguished from the rest of the EEG or other patterns, for instance artefacts. Instead of facing these difficulties, one thought to reach the goal, if one regarded the EEG as a stationary random process in the manner of a "*bio-electrical accompanying music*" of the neurotransmitter chemistry.

Thus, the initial apparent *via regia* was finally replaced by impassable paths, which became more and more impenetrable due to the general availability of digital computers. Finally, the EEG was almost completely in the hands of mathematicians and pharmacologists who excelled in the calculation of data driven target variables without any supporting theory concerning their behavioral relevance. Besides the philosophically founded neuroscientists Fechner and Du Bois Reymond, theoretical physicists like Erwin Schrödinger, Werner Heisenberg, and Niels Bohr, as well as numerous philosophers, of whom pars pro G. W. Leibniz, F. W. J. Schelling, M. Weber, E. Cassirer and H. Jonas shall be mentioned, have made essential contributions to the staking out of a thematic framework This enabled an extension and completion of the epistemic foundations of the exact natural sciences in the direction of the biological natural sciences. Leibniz already saw this in his *Monadologie* (1707), when he spoke of the „unconscious perceptions" (*unmercklichen Perzeptionen)*. Some decades later, he expanded on his intuitively gained insight in his *New Treatises on the Human Understanding*":

> *"All this justifies the conclusion that also the noticeable perceptions arise gradually from those which are too weak to be noticed" and further "In a word, the belief that there are no perceptions in the soul other than those it becomes aware of is a great source of error ... It is not easy to imagine that a being can think without realizing that it is thinking. (Leibniz, 1765) ".*

All conscious experience results from a developmental process that leads from diffuse ambiguity towards clear unambiguity. From a certain degree of unambiguity and stability on, experience no longer appears to us as mere imagination or illusion. John Hughlings Jackson, about 140 years ago, spoke of *faint images* - hints of images - that we can admit or reject, as opposed to *vivid images*, which impose themselves on us as independently existing facts of the external world. It seems to us, therefore, that this kind of fully differentiated experience emerges causally from the physical or neural. If, on the other hand, we question our physical thinking functions and therewith the law of conservation of energy of thermodynamic physics, then we get the answer that the emergence of the psychic is mere self-deception. In fact, in Jackson's faint- and vivid-images we are not dealing with different categories, but only with gradations. This is equally true of terms firmly rooted in psychiatric terminology such as *illusory misperceptions* and *hallucinations*. Both are perceptions, which as such are always subjective in nature and at best can only be explained and distinguished by the concomitant certainty of reality. By physical measuring of the material one arrives at life-worldly irrelevant quantities, but never at life-worldly significant *qualia.* Every attempt to objectively represent sense perceptions

by measuring from the corresponding material/functional into physical quantities is doomed to failure. If we strive for statements about the objectively given objects of our environment, we are obliged to *introspectively* sweep for the images of the objects inevitably appearing only in the first-person perspective, by using our mind's eye. Intersubjective reliability is admittedly excluded in this procedure. That we are dealing here with a central methodological problem of the neurosciences is a crucial part of Jackson's "*Doctrine of Concomitance*" (1884). Half a century later, Alfred Prinz Auersperg, member of the Heidelberg school of neurologists around Viktor v. Weizsäcker, designated the same as *coincidential parallelism* („Koinzidentialparallelismus").

The fact that in science we are basically dealing with two logically incommensurable "worlds" can be seen in the controversy that is still going on about the truth or scientificity of Goethe's or Newton's chromatics. It was the physicist and philosopher Werner Heisenberg who recognized the two concepts as complementary to each other as well as equally "scientific". Without Goethe's conception, which rests on the ground of experiencing there would be - according to Heisenberg - no color perception and thus no physical chromatics. Thus, the primacy indisputably lies with Goethe's psychological qualities of the color spectrum as perceived by a subject from the first-person perspective. Newton's physical chromatics, on the other hand, begins only from the third-person perspective with the measurement of electromagnetic oscillations of the color spectrum. All statements from the first-person-perspective are necessarily pre-scientific and therefore non-binding for a researcher sworn to the objective third-person-perspective. Heisenberg contrasted Goethe's chromatics as physics of undergoing experiencing with Newton's theory on an equal footing as physics of abstract recognition. The scientific equivalence of the physical or the mental form of thinking corresponds to the two complementary, epistemically as well as logically incommensurable „worlds". The question of the "true" world can be traced back to our innate causality thinking and is therefore of equal rank with the question of the priority of matter or spirit. As with other "hard problems" we have to do here with one of the pseudo-problems which, according to Max Planck, necessarily result from false premises. A proposal, such as that of the New-Kantian Windelband, for a unified methodological dualistic science, which would have removed the ground from the fruitless controversy between Newton's abstract and Goethe's experiential natural science, was not taken up by the mainstream. Physicalism and the "Life Sciences" that is classified today as "Natural sciences" is based on the model of physics, whose subject is the physical cosmos. More and more the so-called life sciences claim the role of the

leading discipline within this broad field. A psychic cosmos complementary to the physical cosmos, however, remains largely invisible. In a systematics of that which has being, the psychic cosmos could be understood as identical with the topos of the Phenomenological philosophy in the sense of Husserl. In the middle of the 19th century the physicist Hermann von Helmholtz formulated an empiricist theory. A central role is played in this theory by the hitherto unused concept of *sensations*, under which Helmholtz functional states of the body was to be understood. Furthermore, he distinguished *images* and *signs,* as well as *sensations* and *perceptions*. He considered *sensations* as abstract *signs* produced according to the laws of physical optics and not as images isomorphic to objects. *Perceptions* were considered to him as conscious mental ideas, resulting of an interpretation of the *unconscious sensations* by the *mind* according to the laws of thinking: "*Sensations are signs for our consciousness, whose meaning is left to our intellect to learn to understand"*, Helmholtz, 1867; *„Die Empfindungen sind für unser Bewusstsein Zeichen, deren Bedeutung verstehen zu lernen unserem Verstand überlassen ist", transl. from German).* By reformulating the physiology of perception as applied physics, Helmholtz destroyed the trust of people in the truth of the „sensory world". His theory is basically just such an *Information processing approach* as all following ones (e.g. Shannon & Weaver, 1949), which are all in need of an „interpretative homunculus". If it should have been Helmholtz's endeavor to kill off the *homunculus* in a semantic way, then he was not successful. A *homunculus*, however, becomes superfluous in the nativist theory of perception advocated by Hering. In the spirit of Occam's principle of parsimony, Hering restricted himself to the smallest number of rationally possible assumptions - namely a single one. Accordingly, every actual act of perception, being possible only once, is accompanied by quite specific physiological processes. Since we have excluded in principle an unambiguously reversible assignment of Function and Meaning and thus the original Putnamian *Functionalism*, Hering's so-called *nativist theory of perception* can only claim validity for the biographically unique senso-motoric acts of our mind.

CHAPTER 2

CEREBRAL FUNCTION AND ORGANISMIC BEHAVIOR

A steady, and for the past decades almost rapid loss of importance cannot be denied. In this situation it seemed highly appropriate to precede the book with an analysis of its causes. Its purpose is to prove that this loss of importance is not the result of the unproductiveness of the method itself but of an inadequate handling of the method.

Hardly anyone remembers today the promises of prominent EEG experts in the early Seventies that the increased availability of powerful digital computers would result in significant breakthroughs in psychiatry turned out through quantification. And who of the younger colleagues still knows that the German psychiatrist Berger was in search of energies being unknown in physics that should be responsible for mental disorders?

In order to avoid an obvious misunderstanding, it has to be emphasized that we are dealing here with the EEG as a behavioral means to scrutinize psychiatric disorders and not with an outdated procedure formerly used for neurological exclusion diagnostics. Nevertheless, the most psychiatric hospitals have still an unneeded room designed as “EEG lab”. Instead of admitting after decades of searching in vain for the proverbial needle in the haystack, the indefatigable search seems to continue.

First research results came from two neurophysiological working groups from the Harvard Medical School in the early thirties (Davis et al, 1937; 1938 and Loomis et al. 1938) The matter was such new that one was unsure about the source and the meaning of the sinusoidal oscillations to be recorded from the scalp by electronic amplifiers. A majority of physiologists suspected the “waves” as artefacts of unclear origin. It was not before 1946 that Lord Adrian who excelled in peripheral neurophysiology stated a cortical origin. First research results were published by the collaborating working groups of Davis and of Loomis. Anyway, it soon became undeniable that the *Graphoelements* (Jung, 1950, transl. from German) were

unique concerning its temporal resolution but one did not guess a particular purpose for it. Some saw in it a method to connect the material brain and of the immaterial mind. Opponents of a Behavioral EEG consider up to now the *Grapholelements* wholesale as "drowsiness patterns" (e.g. Thatcher et al. 1999) and therewith as artefacts to be averted by applying acoustic stimuli during the recording procedure or by "*alerting tasks*". Unfortunately, the promising begin of Behaviorally Psychiatric EEG research was abandoned after a short blooming in favor of the missed doctrine of "*microprecise causality*". If we draw a preliminary balance, then we cannot help but notice that the thesaurus of behaviorally relevant EEG-knowledge is exhausted in a structurally unconnected conglomerate of non-replicable single facts. As Dondey & Gaches (1977) stated in a psychiatric handbook article, clinical EEG findings for the most part do not meet scientific requirements. To put it more bluntly, the Behavioral EEG lacks a rational foundation.

After the advent of digital revolution which made the Fast Fourier Transform (FFT) generally available, mean value spectra became the undisputed target parameters without further discussion. A lonesome exception was Dieter Bente who adhered undeterred to the primacy of principally meaningful morpho-dynamic qualities. But he had no idea how to quantify qualities. Nevertheless he stated that the validity of any quantitative transformation depended decisively on the re-translatability of the numerical values into the original qualities. Furthermore, he stressed that the spontaneously generated morphological structures of the EEG belong to the realm of biology since they emanate from the sphere of the living.

Great physicists have repeatedly emphasized that such a self-imposed limitation to the "*efficient cause*" is not only unsatisfactory but also a source of contradictions and aporias. Max Planck has pointed out that all natural processes are targeted which implies a "*final cause*". Since Behavior cannot be conceptualized in terms of an elementary characteristic of interacting neuronal assemblies, "Brain physics" needs to be extended by this very aspect in order to complete it. According to Werner Heisenberg (1935) any biological research question has to begin by "undergoing recognition". The following quotations of the great physician complete what was said above:

> *"The treatment of biological phenomena with the thought forms of classical mechanics means to miss the object, i.e. "life"*

and further

> *"... even the simplest biological experiences teach us that living beings have a degree of stability which complex structures cannot have due to physical and chemical laws. Therefore, something must be added to the physical law before we can fully understand the biological properties" (Heisenberg, 1935).*

This implies the growing together of neuroscientific basic research understood as *Function* and clinical utilizations understood as *Behavior*. Such a terminology exactly corresponds to the antinomy between Function and Adaptive Behavior.

> *Around 1915 physicists showed that the assemblies of particles dealt by thermodynamics was beyond the terminology of physics. By analogy, Niels Bohr stated that "brain physics" is just as complementary to brain physiology as atomic dynamics to thermodynamics (Treder, 1983).*

Accordingly, a "*crisis of brain physics*" had been stated, at least for a "*brain physics*" that limits itself to exact classical mechanics. By experiments performed with rabbits W. J. Freeman (1975) showed that the "*behavioral qualities*" of olfaction are coded in "*global patterns of neural assemblies*" or by functional states to be described quantitatively". Therewith, he complemented the "*Functional*" with the "*Behavioral*" and brought the first ground of comparative psychophysiology which involves Behavior in addition to Function. Any biological natural science that embraces the two logically incommensurable but epistemologically complementary domains of Function and Behavior requires a strategic reorientation. In an article dealing with Jackson's Croonian Lectures (1884) "Hughlings Jackson's Hirnpathologie*",* Otto Sittig, then spokesman of the medical faculty of the German University Prague wrote:

> *"It can be taken for granted that nobody except Jackson has thought more profoundly about the theoretical foundations of our discipline. It is wise to follow his traces. Jackson's teachings are not the teachings from today but from tomorrow" (transl. from German)"*

and

> *The topicality of the thoughts of this veracious great visionary becoming visible only today is underscored by a remark of the medicine historian Jacyna (2011) which appeared exactly 100 years after Jackson's decease in "Brain": "The kind of philosophy to which he was evidently most drawn possesses a distinctly modern aspect."*

About 30 years after the beginning of his work on the human EEG and 5 years after the first publication of his Alpha-Rhythm in 1929, Berger's

discovery found official approval as a brain physiological phenomenon by one of the leading neurophysiologists and Nobel Prize laureate Lord E.A. Adrian (1934). The working groups of the Harvard Medical School (see above) concurrently described a total of 5 clearly discernible Spatio-temporal activity patterns, which they assigned to different states of consciousness, three of them in the waking state (A, B, C) and two in sleep (D, E):

> *"We can distinguish several fairly well-defined steps in the approach and onset of sleep" ... "We have now investigated the finer details of the A and B stages, and are able to relate alterations of the electrical pattern of the brain to signals given by the subject which are based upon changes in his state of consciousness. Such a correlation is of great interest from the point of view of psychophysiology, for it unites subjective with an objective aspects of brain function." (Davis et al. 1938).*

These findings still apply today as they did 80 years ago. Thus, the hitherto unanswered question arises as to why this sensational finding did not result in research programs but, on the contrary, were almost completely forgotten in the following decades. In trying to give an answer it has to be noted that the brain-physiology of those years dealt almost exclusively with the peripheral nervous system. It had been assumed as self-evident that the same functional principles of a linear relationship underlie both to the peripheral and the central nervous system. Accordingly, the analysis of brain function had to start out from the fact that brain function analysis had to take into account an unimaginable number of synaptic and dendritically mediated interactions of nerve cells. But it became soon apparent that the observable regularity of the morpho-dynamic patterns as well as the time-structure of the whole EEG were incompatible with such premises. Therefore, one preferred to ignore the EEG for the time being. But after Adrian, Berger's Alpha rhythm had been approved as a scientific fact, one had to deal with it for better or for worse. This left room for popular-scientifically camouflaged speculations. There was talk of "*Brain Script*" as a code that had to be decoded. This assumption was in line with the interpretation of a direct registration of the time-course of physiological processes, such as the heart (electrocardiogram, ECG), which became possible in those years. Some physiologists were convinced that nature communicates itself directly in its own language through the recording devices, thus opening up a direct access to the phenomena of life (Borck, 2007; 2008). The sequence of waves was regarded as direct film-like pictured signatures of natural phenomena that would be transformed into observable material objects through the "*inscription*" of physical quantities such as force and energy. It was the father of cybernetics N. Wiener (1954) who explicitly excluded the possibility of translating the *brain script* into a colloquial language being

based on semantic conventions. It seemed more likely to him that the EEG depicted functional processes taking place in the brain. But he had no idea what the distinctiveness of a Handful different brain-electric oscillations, then commonly denoted as "*brain script*", could mean if they did not concern encoded semantic information. But such an assumption raises the even more awkward question what on earth the brain could have say to the rest of the organism. Others viewed the "*brain script*" as the physical materialization of the immaterial mind (see above) and thus as the "*missing link*" to the solution of the body-mind problem. Introduction and broad acceptance of the "*graphic method*" as such cherished the opinion that the sequence of waves represented "*mechanical objectivity*", which made an interpretation by a human observer subject superfluous. The more the neurophysiologists dealt with the EEG, the more clearly the differences between the functional mode of the peripheral and the central nervous system became conspicuous.

Lord Adrian (1946) stated 12 years after his approval of the Alpha-rhythm that the brain functions were completely different than one would expect from a more complicated machinery of "highly integrated reflexes". This opened the door to further popular scientific speculation. In analogy to the "Stone of Rosetta", which had made possible the deciphering of the Egyptian hieroglyphs, the naive notion of a translatability of the brain-specific code into colloquial language became topical again. More plausible is a general socio-psychological explanation, which we owe to the Polish microbiologist L. Fleck (1935). The title of his book, published in German is: "The emergence and development of a scientific fact. Introduction to the doctrine of thought style and thinking collective." Fleck's performance consisted in pointing out on the crucial importance of an irrational refusal of objectively proven findings as scientific facts. A substantial analogy between the example used by him and the problems dealt with in his book justifies a comprehensive description of Fleck's work. Fleck's motivation came from the physical bias of contemporary biology, which he realized as a serious obstacle to scientific progress. Such obstacles could be avoided by a common framework overarching biology and physics. His argumentation revolves around the terms *thought style* and *thought collective* ("*Denkkollektiv*") that he introduced. The style of thinking is considered to be the product of a collective of like-minded people. It is consolidated by positive feedback and leads to isolation, narrowing of the horizon of experience as well as to an illusionary harmony of the collective of thought. The characteristic feature of a thought style is the maintenance of unprovable assumptions even against rationally approved convincing empirical facts. Thought collectives are extremely conservative by their

nature because they oppose our evolutionary ability to recognize the novel. Thought styles and thought collectives develop as a rule parallel to the introduction of new technologies. As an example, he cites phenomena coming only into being by making them visible. Without our ability to distinguish qualities by making use of our senses, no questions could be posed for a subsequent rational validation by measuring them in a physical sense.

> *"In order to see, one must know what is essential and what is not; if one must be able to distinguish the background from the image, one must be oriented towards what category the object belongs to. Otherwise we look, but we do not see, in vain we stare at the all too numerous details, we do not grasp the observed gestalt as a definable wholeness. So it is not only under the artificial conditions of the experiment that we have just carried out, but at each of the simplest and the most complicated "perception".*

CHAPTER 3

THE INDISPENSABILITY OF HENRY HEAD'S THEORETICAL CONSTRUCT OF VIGILANCE (V)

Fleck's contribution is excellently suited to explain the errors and confusions, as well as the diverging lines of development, which no longer seem to have any common basis and stand in the way of a prosperous further development. Fleck's efforts, directed against the imminent drifting apart of the *exact natural* and the *impure biological* sciences have to be seen in the light of the currently dominating zeitgeist. Thus, the theoretical physicist Heisenberg (1935) pointed out that the real or imagined distinction of qualities is the indispensable prerequisite of any natural science, even or precisely those which understand themselves as "*exact*". The distinction of qualities requires a specific mode of undergoing recognition/experiencing ("*Erlebendes Erkennen*", transl. from German) as opposed to the physical mode of "abstract recognition" ("Abstraktes Erkennen") which is the domain of the exact or pure natural sciences. Thus, we have at our command not just one mode of recognition but two of them. A complete description of the facts and circumstances of any phenomenon requires the complementarity of both modes. On the one side, the primary measurements of physicists need to be supplemented and validated by a reference to the real-existing material qualia as prerequisite of an intersubjectively comprehensible distinction of qualitative differences being meaningful for our lifeworld. On the other side the vital experience due to pure sensorial observation has to be quantitatively supplemented. Therewith our empirical knowledge is validated both as a prerequisite of ensuring and the formulation of novel working hypotheses. Heisenberg exemplified his distinction between the two complementary modes of recognition by means of the infertile, emotionally led controversy about the understandings of the scientific doctrines of color vision by Newton and v. Goethe. It goes without saying that Heisenberg's aspiration for the *biperspectivism* cannot be practiced simultaneously. It rather requires a data-related prioritization. Starting from naturally given patterns, we have to be aware of the pitfalls of our phylo- as well as ontogenetically acquired ability to distinguish patterns. Only in a second step meaningful physical measurements which have to be

based on theoretical arguments resulting from the preceding qualitative observations will become possible. As already pointed out it is precisely the other way round if we start from the numerical values that can only be obtained by primary measurement, because their life-world significance is only revealed by the recognition mode of "*undergoing experiencing*". Anyone who is talking about EEG as a method of "*measuring*" brain-electrical activity discloses his one-sided physically coined "*thought style*" that makes him a member and defender of the corresponding "*thought collective*". To repeat it again with other words, a neurophysiological research which restricts itself to the "*thought style*" of "*abstract recognition*" can never go beyond a life-worldly meaningless brain-physical functional analysis. A careless synonymous use of "*neurophysiology*" and "*psychophysiology*" is obviously related to this. Karl Jaspers (1929), psychiatrist and philosopher, expressed the same sentiments from the viewpoint of psychopathology:

> *"What leads away from vital experiencing and intuition without returning to it builds an imaginary world in the infinite" and further: "The sciences (also) have the tendency to conceal the "sein" through the sheer mass of detailed knowabilities and to paralyze the view of phenomena and with the fixed elements of perception as a result of much learning and knowledge". (Jaspers, 1946).*

It is amazing that within half a century of quantitative EEG research the crucial question about the dynamics of the recording remained unnoticed. The only explanation for this gap is that the EEG did not provide relevant information. Checking the literature one may only find certain passages in an article by Lairy & Dell (1957) who construed Henry Head's theoretical term of **V** as inferred from the EEG. Since the EEG does not support or exclude the diagnosis of a disease, the question arises whether behavior might be addressed by that method. In case of affirmation, the further question of the special kind of the addressed behavioral ensues. It has to be pointed out that up to now studies concerning the behavioral relevance of the spectral power values do not exist. This applies for instance with view to Berger's early assumptions about positive correlations between psychomotor relaxation and Alpha-power, psycho-motor activation and Beta-power and drowsiness and Theta-/Delta-power. It deserves attention that Berger's dubious as well as time-honored assumptions have not been verified till now by modern technology. Only Lairy & Dell (1957) had pointed to certain passages of Head's article of 1923.The theoretical impact of Head's **V**, especially on EEG research, was neglectable low in the following decades. The main reason that prevented neuropsychiatrists to take advantage of this epochal inspiration was the undue use of **V**. This was

partly owed to ambiguities with Head's original writings, and all the more to a conceptual confusion being caused by the secondary literature. **V** became an empirical term as sustained attention (Mackworth, 1949) and was thus bereaved of its heuristic potential. Such being the case, the call to dispense with this inconsistently used term altogether or to replace it with a supposedly more precise one such as "arousal" was only too understandable (e.g. Oken et al. 2006). However, that **Arousal** instead of **V** well-nigh counteracts Head's intention can be proven by his verbalizations (see below). Accordingly, **V** is just not a pure condition of raised excitability or an enhanced reaction to stimuli. But it rather deals with efficiency. A high level of **V** is associated with looking out of the unexpected and the unusual. In our opinion, it should be important for every conceptual exegesis whether there exists a rationally acceptable definition for it or not. The decisive point is rather whether the term is indispensable for the explanation of a certain phenomenon. A decision on this can only be made on a careful study of the original literature as well as experimental studies. The common restriction to the secondary literature or only adopting the opinion of others bears the danger of perpetuating errors. One basic error is the widespread view that Head had in mind the sheer quantity of brute force or energy. In contrast, all relevant definitions given by Head clearly prove that he was primarily and basically concerned with Behavioral Physiology. This seems important to us, since if **V** is understood as an empirical term being ascertained by plain physical measurement it fails Head's intentions from scratch. It still took a while until Head was understood by a few neuropsychiatrists as significant for their subject (Lairy & Dell, 1957). Moreover, Dell (1958) remarked that for the formally complete description of living beings a theory was needed which made it possible to grasp the organism together with its environment as an entirety in the sense of Jakob v. Uexküll (1905; 1920; v. Bertalanffy, 1977; etc.). The following citations are given because hardly any user of **V** is aware of Head's intentions:

> *"It is true that a tissue which gives a large response can often be activated by a weak stimulus; but there is no invariable correlation between the value of the threshold stimulus and the size of response (Head, 1923)" and "The extent to which the activities exhibit at any moment signs of integration and purposive adaptation indicates its **V**" (Head, 1926).*

The vexing problem was that no linear stimulus-effect relation could be determined. It was not only physical exhaustion or tiredness which influenced the actual state (level) of V but a wide range of known, but also unknown factors. From the given citations it becomes clear that Head's **V** indicated not only the level of the organism's sensorimotor integration but

also the quality of an actually given transactional connection between an organism and its environment. It becomes further clear that Head's **V** implies a priori non-linear systems' dynamics. Whereas with simple linear system dynamics the exact physical characterization of the input allows for an exact prediction of the output, this is not valid with non-linear systems. Here, in addition the actually given state of the stimulated system is decisive for the outcome. Convincing examples for the importance of the existence of different CGF states of order are so-called paradoxical drug effects. They are no longer paradoxical if one replaces the inappropriate premise of a linear-deterministic input-output relation by the principle of "chaotic determination" being valid with all complex or living systems.

As a theoretical term Head's **V** does principally not refer neither to material nor to immaterial conditions but only to the relations between such naturally given realities. Semantically they belong to the domain of metaphysics. It was Head's forgotten or never understood intention to bridge the categorical gap between the physical and the psychological level of description. Therefore, it can be designated as a bridging principle in the sense of the philosopher Hempel. He who forbids using metaphysical terms would no longer be able to see the wood for the trees. Not only Head's **V** belongs to metaphysics, but also all basic terms of physics as there are material, energy, time, gravity etc. They have in common to be creations of the human mind. As such they cannot be brought into question or defined. Nevertheless, they are needed to explain quite another naturally given reality. Without them any material natural condition would remain enigmatic because nothing is self-explaining. Anything is by its nature context-dependent and thus ambiguous. A scientific term, in contrast, has to be non-ambiguous. The non-reflected use of colloquial words within a scientific article is a source of contradictions and aporias. There are a lot of papers where the authors demand to abandon the use of **V** altogether on account of the term's inconsistency instead of the meticulous read of Head's original publication.

The increasing poverty of the formerly highly esteemed ability to read and understand a scientific content or to begin reading again or reading between the lines seems the tribute in return for the inevitable acquisition of the occupational appreciation of the normative internet-slang. Therewith, biology does more and more lose the extant residues of its biological thought style (Fleck. 1935). Simultaneously the exact Galilean sciences, especially those which are characterized quite rightly by their physicalistic thought style will more and more lose their complementary life-worldly meaningful biologic counterpart.

Over years a substantial number of publications have accumulated, dealing with EEG-correlates of different psychological constructs such as fear, concentration, absentmindedness, excitement, insecurity, wide-awakeness, alertness, approach/- withdrawal behavior, to mention just a few (Low, 1987). But it is hardly possible to clarify the contextuality of the observed EEG-effect, either under physiological nor psychological circumstances.

If today we assume however, that the scalp-recorded SR-EEG is the result of a partial synchronization of extended cortical substrates then it is very unlikely that specific psychological processes, not to mention specific contents, can be distinguished by this method. It seems much more plausible that the EEG allows the distinction of a limited number of functional states that show a closely related but not an invariant connection with certain psychological constructs such as those mentioned above. For psychiatry, we can conclude from this that for isolated psychopathological phenomena EEG-correlates cannot be expected. But the real question that preoccupies many researchers is, whether the psychiatric pictures can be differentiated through the EEG. This question, however, can only be posed if a specific pathophysiology can be associated with psychiatric pictures. Following Kraepelin's postulate of *Dementia praecox* as a disease entity – the empirical proof is not yet confirmed – and the majority of researchers assume to this day that there exist real mental diseases that are just as real as for instance diabetes mellitus. However, the numbers of those are growing who point to the decades-long inability to validate psychopathologically distinct psychiatric syndromes and demand a re-evaluation of the research strategies, since plain hypotheses could not do justice to the complexity of the psyche (e.g. Maas & Katz, 1992). Like wooden paths that start out wide and open. Such approaches so far always ended in an impenetrable thicket. The reason for the continued attractiveness of "*transmitter psychiatry*" being erroneously denoted as a "*biological*" one, lies probably in the fact that a majority of psychiatrists is contented with partial hypotheses, persevering in bustling modesty, never raising their eyes to the complex whole that might cause feelings of insecurity. As could be expected from the beginning the quantitative EEG (qEEG) had maneuvered into a neurophysiological impasse. Moreover, its proponents had been inaccessible for rational arguments. As repeatedly stated there exists a deeply rooted and long-lived but also unfounded conviction that the frequency-band and the averaged spectral-power values are of behavioral relevance. Furthermore, it seems to be blocked out that the mathematical transformation of the EEG from the time- into the frequency-domain may result in very different power-value spectrograms. A further massive adulteration of the original signal consists in the elimination of dynamic information by simple averaging or artefact-editing. Moreover, it is

disregarded that the EEG represents a highly individual quality. A reference to "normality" is excluded just like a subject's facial play, gait or tone of voice. By abandoning "normality" any and all requirements for making use of parametric methods whatsoever expire. Left out of consideration is also that the recording of the EEG is not a measuring technique. To measure means to compare with a physically defined and standardized quantity. Phenomena of empirical reality however are qualities which cannot be measured nor reckoned. But they allow a transformation at the ordinal scale level. On the whole one may state that any research, based on erroneous assumptions will always deliver results which are in line with the speciousness of false premises. The most important obstacle for clinically relevant EEG research is the *linearity assumption* (see below). We forget all to easily that "*linearity*" is not suggested by the EEG signal. Rather we are inclined inherently to await *linear causality*. Self-deceptive linearity implies Gaussian normal distribution and is responsible for a wealth of methodical artefacts, e.g. the "*Law of large numbers*". With the advent of digital technology in the early Seventies we boomed an upsurge of the quantified EEG within clinical psychiatry. *Methodically competent engineers and mathematicians suddenly dominated the research agenda. Although being unable to formulate meaningful questions concerning human* ***Behavior*** *they wasted no opportunity to promise the earth. At the very beginning of this hype one could read*:

> *"The advantages of this technique are sufficiently clear that in a few years its routine clinical usefulness may well be evident "(Hughes, 1987),*

or

> *"...these results are the first independent validation of clinical nosology" (John et al. 1990).*

Shortly afterwards the "American Psychiatric Association" (APA, 1991)

stated:

> *"Because qEEG itself contributes only limited information of direct clinical significance, persons otherwise not qualified to perform differential diagnoses, are not qualified to make diagnoses with qEEG. The ability of qEEG to help in the diagnosis of non-organic disorders (such as schizophrenia or depression) is not yet established. At this time, the ability of any qEEG procedure to make psychiatric diagnosis or to discriminate between various groups of psychiatric patients and normal subjects is not well established. Unfortunately, advertisements and promotional material from some manufacturers of qEEG instruments have gone beyond the existing scientific evidence to make claims of diagnostic utility."*

Plainly, what has hindered the clinical exploitation of the SR-EEG to date is its inherent complexity in connection with particular methodological specifics. Since the dependence on unfavorable external circumstances prevent, the creation of the necessary base of experience came to a standstill from the beginning, the demand for the development of a genuine psychiatric EEG could only be met with rejection, disbelief or, at best, skepticism's. All too often the clinical EEG- interpreter with an unfortunate limitation of experience- and knowledge horizon and the clinical psychiatrist with similar deficits did not coincide. Both sides wanted to protect their territory. The fact that certain software, such as "Neurometrics", "Neuroguide", "CEEG" etc. are protected by patents should be indication enough for significant commercial interests involved. As already stated it is considered normal that in clinical EEG research engineers and statisticians are leading the way. Analysis of the EEG has almost entirely the concern of researchers who operate within the models of physical thought. The results have been relative barren and sparse from the standpoint of the clinicians. Whereas the lab-scientist searches for generality, the clinician is searching or what makes his particular patient unique. He is interested in immediacy. Presently, the research laying the groundwork for neurodynamical models is taking place largely without the involvement of psychiatrists and outside of the psychiatric journals. Moreover, without any proof or argument, it was stated apodictically by psychiatrists with dubious clinical experience:

> *"…Abnormality profiles" are distinct for different disorders" (E. R. John et al. 1977; 1988; 1990). This is aggravated by the fact that the term "Abnormality profiles" results from a statistical comparison with "Normative Data Bases" (NDB) consisting of isolated EEG characteristics without any scientific support but instead patented and purchased with great success. The "Neurometrics" model (John et al.) claims to be valid for all other psychiatric disorders than only schizophrenia. This is all the more amazing as there exist since long the generally accepted fact that no EEG correlates exist with intellectual or mental impairments (La Veck & de la Cruz, 1962). Kiefer et al., (2002) examined a large number of mentally defective people (subjects 17 to 72 years of age) with enlarged ventricles, diagnosed as "**L**ong standing **O**vert **V**entriculomegaly in **A**dults (LOVA) due to a slowly developing chronic occlusive hydrocephalus with amazing low behavioral impairments, if at all). 34 % subjects of the sample showed a "normal" EEG including the most severe cases of idiocy. Such a discrepancy between Cortex thickness (reduced cortex thickness between 2 and 3 cm up to a minimum of 1,5 cm) pertains also the other way round. Contrary to expectations no statistical correlation could be found between amount and intensity of behavioral impairment. A shunt-surgery did not influence the clinical state.*

Thus, even under spontaneous resting conditions, it is by no means rare to find conspicuous EEG images in completely healthy and capable test persons which differ considerably from an ideal type and suggest a cerebral dysfunction. Depending on the applied standard of the interpreter, a frequency of about 5 % can be expected. An important argument against the assumption of a pathological change is the stability of the abnormalities in repeated recordings under identical conditions with intervals of weeks and months (Ulrich, 2021). If at all, such EEG pictures are called *norm variants* and are evaluated as *paradoxical* phenomena. Some experts see in it an indication of an increased vulnerability to certain noxa or a deficit of functional brain maturation. However *paradoxical phenomena* are ignored by clinical research if they are not in line with the prevailing paradigm. Out of consideration, however, is an obvious methodological interpretation that can be traced back to the *induction problem* of the Scottish philosopher David Hume (1711-1776). This problem still plays an important role in *Applied mathematics* as the *Inverse problem*. Such problems arise as soon as one wants to infer the underlying causes from observed effects of a system. They are usually difficult or impossible to solve. Commonly *Inverse problems* have several mathematically correct solutions. But without contextual information it is not possible to decide which one is preferable. It is easy to see that most problems in medicine, and in particular in imaging techniques, are *Inverse problems*. The opposite is represented by the comparatively much easier to solve *forward problems*. To come back to the genesis of the *paradoxical EEG phenomena*, it is to be reminded of the principle, according to which each empirical determination of a physical quantity is afflicted with unknown randomized measurement errors, which are subject to the laws of statistics. As a quintessence it follows that every theory must be falsified or verified by experience, whereby according to K. Popper the falsification has the primacy since one single negation is enough. Strictly speaking there exists no induction and therewith no paradoxical EEG phenomenon. It was the endocrinologist J. Selye who called attention to the neglected fact that diseases are not only characterized by specific symptoms. They also have in common a syndrome consisting of non-specific symptoms which he summarized as "*General Adaptation Syndrome*" (*GAS*). *GAS* was considered responsible for general malaise and to see a doctor. As underlying mechanism, a disturbance of the HPA-axis was detected. The HPA-axis is a complicated set of relationships and signals that exist between the hypothalamus, the pituitary gland and the adrenals. Selye conceived GAS as an unexploited field of scientific insights, provided that this issue was investigated from a hitherto unusual point of view. It was his very theory of the non-specific which laid the foundations for an end to the