Electroencephalography in Neuropsychiatric Disorders: Microstates, LORETA, and Mismatch Negativity – Homage to Dietrich Lehmann

Toshihiko Kinoshita

Kansai Medical University, Department of Psychiatry, Moriguchi, Japan

One of the most important milestones in the noninvasive study of human brain function took place in 1929 with the publication of the human electroencephalogram (EEG) by the German psychiatrist Hans Berger. At that time, practically all the research was mainly of a descriptive and phenomenological nature. Initially, the main information provided by the EEG consisted of the observed brain waves, in normal subjects and in some pathologies, such as epilepsy.

It took a rather long time to make significant advancements that changed the use of the EEG as an empirical clinical tool into a well-established quantitative method for studying brain function. The main development consisted of recognizing the spatial organization, i.e., the scalp topography, of the electric potential differences, now popularly known as EEG topographic maps. The introduction of the quantitative analysis of topographic maps radically changed the field, by modeling the EEG in all its glory, providing spatiotemporal information on brain function.

One scientist whose fundamental contributions paved the way for this second milestone was Dietrich Lehmann, who passed away in 2014, at the age of 84. Since almost 50 years ago, Dietrich Lehmann had already been performing source localization, where he pioneered in one of the first dipole fitting studies. At a later time, he contributed to the development of the LORETA methods, now widely used in imaging of cortical electric neuronal activity.

In more general terms, he was developing novel ways to analyze multichannel EEG recordings. To this day,

those contributions are still regarded as being among the most advanced, cutting-edge methods of EEG analysis. The spatial representation of the EEG in the form of scalp maps, and the necessity of using the average reference in achieving spatial representations that are independent of the choice of reference, underlie all modern analyses. It is worth noting that the early statistical analyses of topographic maps preceded and influenced the development of statistical parametric mapping as used today in functional brain imaging.

However, perhaps the most important contribution of Dietrich Lehmann was the discovery of how the spatial patterns of the EEG change with time, described by microstates, which implement the “atoms of thought” in his theory of consciousness. On the one hand, this model gives a quantitative description of the spatial and temporal aspects of the EEG, in the form of a small number of microstate topographies, and their transitions, which follow a Markov process. On the other hand, this model hypothesizes that human consciousness is implemented discretely and discontinuously in time and where the microstates correspond to the different brain resources being used.

Building on this basis, and in homage to Dietrich Lehmann, we collect in this special issue novel results in the study of pathologies such as schizophrenia, migraine, and OCD, using measurements of microstate theory parameters, connectivity, source localization, and genotypes.