8. Event-Related Oscillations in the Brain

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8.1 Induced Rhythms: A Widespread, Heterogeneous Class of Oscillations

It is one of the leitmotifs or core hypotheses of the present book that the brain-evoked potentials are an ensemble of oscillations.

Başar (1980) suggested the definition of evoked potentials as the superposition of “evoked rhythms”. Bullock (1992) introduced the broader term “induced rhythms.” In the present book, the still broader term “event-related oscillations” will be used frequently, as recently proposed by Karakaş (1997).

What are event-related oscillations? In the experimental-analytical chapters of this book EPs and/or ERPs are decomposed (or dissected) into oscillatory responses by using digital filters or by means of wavelet analysis. In interim explanations in several chapters of the present volume it is shown that these oscillations are not artificially created components. The oscillations that followed the stimulation are, as a rule, real responses of the brain. The expression “real response” was used by Başar (1980) in a preliminary way and will be excellently demonstrated in Chap. 18.

We use the expression “event-related” in general to express that every EP is triggered also by an event. A simple auditory or visual stimulation is in a number of cases an “event” containing also behavioral or cognitive inputs to the CNS, and every stimulation is not just a physical or sensory excitation, it is an event. The expression “oscillation” now replaces the expression “rhythm,” since the evoked rhythm is less appropriate: A rhythm is an oscillatory behavior with some duration. The evoked oscillations usually have a damped oscillatory character lasting for 500 ms (which may be extended to approximately 1 s in the case of the P300 delta response). The oscillations have in simple cases only 2–4 oscillation.

Accordingly, the use of the expression “event-related oscillations” is more tenable from the physiological and cognitive viewpoints. In the spontaneous EEG itself there are several event-related oscillatory states with longer duration and resembling a spindle activity. These activities may also be called “internal event-related oscillations” coming from yet hidden sources.
8.2 Induced Rhythms – The View of Bullock

Gray et al. (1992) described the core philosophy of measuring induced rhythms as follows: “Place an electrode on the surface or in the depth of nearly any neuronal structure in the brain of either vertebrates or invertebrates. Record the fluctuations of voltage produced by the flow of current, and what you are likely to observe is an irregular sequence of rhythmic changes of potential having a multitude of frequencies (Bullock and Ba§ar 1988). If your electrode happens to be within one of many structures responsive to sensory stimuli, the presentation of a stimulus will in many cases evoke a sustained rhythmic fluctuation of potential outlasting the stimulus. This propensity for neural structures to generate oscillatory waves of activity has come to be termed an ‘induced rhythm’. It is a general property of sensory as well as many other neuronal networks that is expressed during periods of activation”.

One of the most striking examples of sensory-induced rhythms in the brain was originally described by Adrian (1942, 1950) who introduced the term “induced waves” for oscillations caused by odor stimuli in the olfactory bulb of cats, rabbits, and hedgehogs, distinguishing these events from intrinsic, spontaneous waves.

Gray et al. (1992) point out that Adrian ... recorded the activity of individual olfactory neurons as well as the macroscopic local field potential. He then stimulated the olfactory receptor sheet with an odorant mixture that evoked a brisk neuronal response at short latency. Associated with this response he observed a pronounced rhythmic wave of activity in the field potential recording that occurred at roughly the same latency and outlasted the presence of the stimulus. This oscillatory response, having a frequency of 30 to 60 Hz, he termed the “induced wave” (Adrian 1950). Induced waves were observed in the olfactory bulb and pyriform cortex of a variety of mammalian species (Bressler and Freeman 1980; Freeman 1975). They were seen in amphibian and fish as well as in humans (Hughes et al. 1969; Libet and Gerard 1939; Thommesen 1978) ....

Experimental evidence for the synchronization of rhythmic activity was abundantly available from investigations in the olfactory system (Freeman 1975, 1978; Freeman and Schneider 1982). When recorded at multiple locations in the olfactory bulb or pyriform cortex, the induced waves were found to be synchronized with little or no phase lag. These synchronous interactions were transient (i.e., 100–200 ms in duration) and were later found to be stimulus specific (Bressler 1988; Vianna Di Prisco and Freeman 1985).

Von der Malsburg (1981, 1986) predicted that by selectively synchronizing the rhythmic activity of neurons responding to features in an image a sensory