Event-Related Synchronization and Desynchronization of Alpha and Beta Waves in a Cognitive Task

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Together with the discovery of alpha waves in human scalp electroencephalograms (EEG) by Berger (1930), blocking was reported in response to a light stimulation. Triggered by the pioneering research of Berger, other groups focused on blocking or desynchronization of alpha and beta waves after visual afferences as well as after somatosensory stimulation or movement (Jasper and Andrews 1938; Jasper and Penfield 1949; Gastaut et al., 1952; Chatrian et al., 1959). Besides these findings of alpha or beta wave attenuation after sensory stimulation or with voluntary movement, there were also reports of an enhancement of alpha band activity as a response to visual stimulation (Morrell, 1966; Creutzfeldt et al., 1969) and tactile stimulation (Kreitman and Shaw, 1965).

Sensory stimulation affects not only the spontaneous EEG within the alpha and beta bands but can also evoke 40-Hz oscillations in the visual cortex (Eckhorn et al., 1988; Gray et al., 1989) or fast somatoparietal rhythms over the posterior parietal cortex (Rougeul et al., 1979).

The terms "event-related desynchronization," or ERD, and "event-related synchronization," or ERS, are used in this chapter to describe the ability of neural structures to generate more or less coherent oscillating potentials. ERD describes the attenuation or blocking and ERS (actually the negative ERD) is the enhancement of oscillating potentials within the alpha and beta bands. The ERD (ERS) can be quantified by measuring the power decrease or increase in event-related EEG trials. Time-dependent quantification of the ERD in the alpha and beta bands was first reported by Pfurtscheller and Aranibar (1977) and Pfurtscheller (1981).

The ERD is a topographically localized phenomenon of short duration (phasic) and not identical with the diffuse and tonic EEG desynchronization reported by Moruzzi and Magoun (1949) after reticular formation stimulation resulting in a "flat" EEG spectrum. ERD was reported during visual stimulation (Aranibar and Pfurtscheller, 1978), voluntary movement (Pfurtscheller and Aranibar, 1979, Pfurtscheller and Berghold, 1989), and cognitive activity (Sergeant et al., 1987; Pfurtscheller and Klimesch, 1989; Klimesch et al., 1990a).

Reports about rhythmic activity within the alpha band differentiate between alpha waves and alpha spindles (Lopes da Silva et al., 1973b). Alpha spindles are transient phenomena dominant over the anterior brain regions and are characteristic of the transitional period between waking and sleeping. Alpha

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waves can be long-lasting and are dominant over the posterior region in the awake state during rest. Andersen and Andersson's (1968) publication on alpha rhythms concentrates on the generation of alpha spindles. A paper recently published by Steriade and Llinas (1988) is also based on the genesis of spindle oscillations. They found that the major factors accounting for the appearance of spindle oscillation are the involvement of reticular thalamic neurons within the thalamocortical system. The alpha waves could be explained as a result of the filter properties of neural networks when submitted to random input (Lopes da Silva, 1973a). A modulation of these "alpha filters" can result in a more synchronized or desynchronized pattern.

In this chapter we focus not on the neural substrate of alpha waves and alpha spindles, but only report some examples of synchronized and desynchronized alpha and beta rhythms during different processing states of the brain.

Data Acquisition Processing and Topographical Display

A modified "electro-cap" with either 29 or 30 electrodes was used for EEG recording. Of these electrodes, more than half were placed according to the international 10–20 system, while the others were assigned to additional points in between (Fig. 1). The EEG was amplified with a 30-channel amplifier system (frequency response 1.5–30 Hz) and sampled by a PDP 11/73 computer. The EEG data were sampled at a rate of 64/s, using stimulus-synchronous epochs of some seconds, with 2 or 4 s (dependent on the type of experiment) before the stimulus. The individual trials were displayed on-line on a monitor

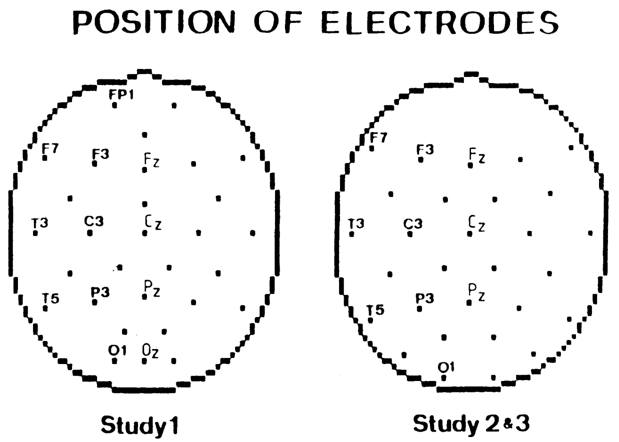

Figure 1. Position of electrodes used in the three studies. The electrode scheme used in studies 2 and 3 was also used for the movement experiment.