Brain Rhythms and Sleep

Introduction

Cyclic variations occur in our environment and in our body. Here we focus on cyclic variations in our brain activity and behavior.

The Electroencephalogram

The electroencephalogram (EEG) is a measurement of the generalized activity of parts of the cerebral cortex. The human EEG was first described by Hans Berger in 1929.

Recording Brain Waves

Electrodes are taped to the scalp and voltage fluctuations between pairs of electrodes are recorded. The voltages are very small, in the order of 10s of microvolts (μV). Typically about two dozen electrodes are attached in standard positions.

- The EEG measure the synaptic excitation of the dendrites of pyramidal cells of the cerebral cortex.
- The neural signals are very small and a measurable EEG depends on the summation of hundreds if not thousands of membrane potentials.
- The amplitude of the recording depends, in part, on how synchronous the activity of the underlying neurons is.

EEG Rhythms

- EEG recordings vary in amplitude and frequency:
  - Beta waves have a frequency faster than 14 Hz and signal an activated cortex.
  - Alpha waves have a frequency between 8-13 Hz and are associated with quiet, waking states.
  - Theta waves have a frequency between 4-7 Hz and occur during some sleep states.
  - Delta waves have a frequency slower than 4 Hz , are large in amplitude, and occur during deep sleep.
- EEG show some general pattern:
  - High frequency, low amplitude rhythms are associated with alertness and waking or the dreaming states of sleep.
  - Low frequency, high amplitude rhythms are associated with non-dreaming sleep or the state of coma.

Mechanisms and Meanings of Brain Rhythms

The Generation of Synchronous Rhythms

- Synchronous rhythms maybe generated in two major ways:
  - They may generated by a central clock (a pacemaker method).

  - They may share or distribute the timing among themselves by mutually exciting or inhibiting one another (a collective method).
- Within the mammalian brain, rhythmic, synchronous activity is usually coordinated by both of these methods.
- Some thalamic neurons have the ability to act as pacemakers.
  - Individual neurons have special voltage gated ion channels that respond to repolarization rather than depolarization.
- The rhythmic activity of each thalamic pacemaker cell than becomes synchronized with many other pacemaker cells by a collective method.
- The coordinated activity of the thalamic neurons is then passed to the cortex by thalamocortical axons.
- Some rhythms of the cerebral cortex do not depend on the thalamus, but are generated by a collective method amongst them.

Functions of Brain Rhythms

The functions of the rhythms of the cerebral cortex are largely a mystery.

The Seizures of Epilepsy

In a seizure, neurons in the affected area fire with a synchrony that never occurs during normal behavior.

- Epilepsy is more a symptom of a disease than a disease itself.
- Epilepsy is often causes by tumors, trauma, metabolic dysfunction, infection, and vascular disease.
- Epilepsy can also be caused by genetic disorders of ion channels, transporters, receptors, and neurotransmitters.
  - Decreased GABA actions can cause seizure.
  - Increased glutamate actions can cause seizures.

Sleep

Sleep is a readily reversible state of reduced responsiveness to, and interaction with, the environment.

The Functional States of the Brain

- Awake
  - Low voltage, fast EEG
  - Vivid, externally generated sensations
  - Logical, progressive thought
  - Continuous, voluntary movement
  - Rapid eye movements
- Non-REM sleep
  - High voltage, slow EEG
  - Dull or absent sensations
  - Logical, repetitive idling thought
  - Occasional, involuntary movement
  - Few if any rapid eye movements

- REM sleep
  - Low voltage, fast EEG
  - Vivid, internally generated sensations
  - Vivid, illogical, bizarre thought
  - Muscle paralysis; movement commanded by the brain but not carried out
  - Rapid eye movements

The Sleep Cycle

- Roughly 75% of total sleep is spent in non-REM and 25% in REM.
- A non-REM – REM cycle take about 90 minutes.
- The quantity of REM increases as sleep proceeds.
  - About half of REM occurs in the last third of sleep.
- During non-REM sleep:
  - Metabolism is low
  - Parasympathetic activity is increased
  - Most sensory input cannot reach the cortex
- During REM sleep
  - Metabolism is high
  - Sympathetic activity is increased
  - Sensory input reaches cortex

Why do we Sleep?

It is generally thought that sleep is for the brain. However, it is not clear why we sleep.

- For restoration of certain brain regions, such as cerebral cortex.
- An adaptation for conserving energy?

Functions of Dreaming and REM Sleep

The body seems to crave REM sleep.

- REM sleep and dreaming may be involved in the integration of experiences or consolidation of memory

Neural Mechanisms of Sleep

- Neurons critical for control of sleep and waking are part of the diffuse modulatory neurotransmitter systems.
- Brain stem modulatory neurons using NE and 5HT fire during waking and enhance the awake state.
  - Some neurons using Ach are active during waking.
  - Other neurons using Ach enhance critical REM events.
- The diffuse modulatory systems control the rhythmic behaviors of the thalamus.
  - Slow, sleep related rhythms apparently block the flow of sensory information up into the cortex.
- Descending branches of the diffuse modulatory systems are also involved.
  - Signals to spinal motor neurons inhibit movement during REM and dreaming.

Wakefulness and the Ascending Reticular Activating System

- Several sets of neurons increase their firing in anticipation of waking and during arousal.
    - Norepinephrine neurons of the locus coeruleus.
    - Serotonin neurons of the raphe nuclei.
    - Many acetylcholine neurons of the brain stem and basal forebrain.
    - Histamine neurons of the midbrain.

Falling Asleep and the Non-REM State

- Several sets of neurons decrease their firing when falling asleep and going into non-REM sleep.
    - Norepinephrine neurons of the locus coeruleus.
    - Serotonin neurons of the raphe nuclei.
- Some neurons increase their firing when falling asleep and going into non-REM sleep
    - Some acetylcholine neurons of the brain stem and basal forebrain.

Mechanisms of REM Sleep

- Several sets of neurons <u>decrease their firing markedly</u> with onset of REM sleep.
    - Norepinephrine neurons of the locus coeruleus.
    - Serotonin neurons of the raphe nuclei.
- Some neurons <u>increase their firing sharply</u> with onset of REM sleep.
    - Acetylcholine neurons of the pontine nuclei.

Sleep Promoting Factors

Adenosine appears to be a sleep promoting chemical messenger.