

EEG and Brainwaves

Introduction to EEG:

Electroencephalography (EEG) is a non-invasive method to record electrical activity of the brain along the scalp. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time, as recorded from multiple electrodes placed on the scalp.

The brain's electrical charge is maintained by billions of neurons. Neurons are electrically charged (or "polarized") by membrane transport proteins that pump ions across their membranes. Neurons are constantly exchanging ions with the extracellular milieu, for example to maintain resting potential and to propagate action potentials. Ions of similar charge repel each other, and when many ions are pushed out of many neurons at the same time, they can push their neighbours, who push their neighbours, and so on, in a wave. This process is known as volume conduction. When the wave of ions reaches the electrodes on the scalp, they can push or pull electrons on the metal on the electrodes. Since metal conducts the push and pull of electrons easily, the difference in push or pull voltages between any two electrodes can be measured by a voltmeter. Recording these voltages over time gives us the EEG.

The electric potential generated by an individual neuron is far too small to be picked up by EEG. EEG activity therefore always reflects the summation of the synchronous activity of thousands or millions of neurons that have similar spatial orientation. If the cells do not have similar spatial orientation, their ions do not line up and create waves to be detected. Pyramidal neurons of the cortex are thought to produce the most EEG signal because they are well-aligned and fire together. Because voltage fields fall off with the square of distance, activity from deep sources is more difficult to detect than currents near the skull.

Scalp EEG activity shows oscillations at a variety of frequencies. Several of these oscillations have characteristic frequency ranges, spatial distributions and are associated with different states of brain functioning (e.g., waking and the various sleep stages). These oscillations represent synchronized activity over a network of neurons. The neuronal networks underlying some of these oscillations are understood (e.g., the thalamocortical resonance underlying sleep spindles), while many others are not (e.g., the system that generates the posterior basic rhythm). Research that measures both EEG and neuron spiking finds the relationship between the two is complex, with a combination of EEG power in the gamma band and phase in the delta band relating most strongly to neuron spike activity.

For more information refer to following links:

1. <https://en.wikipedia.org/wiki/Electroencephalography>
2. <http://www.nhs.uk/Conditions/EEG/Pages/Introduction.aspx>

About Brainwaves:

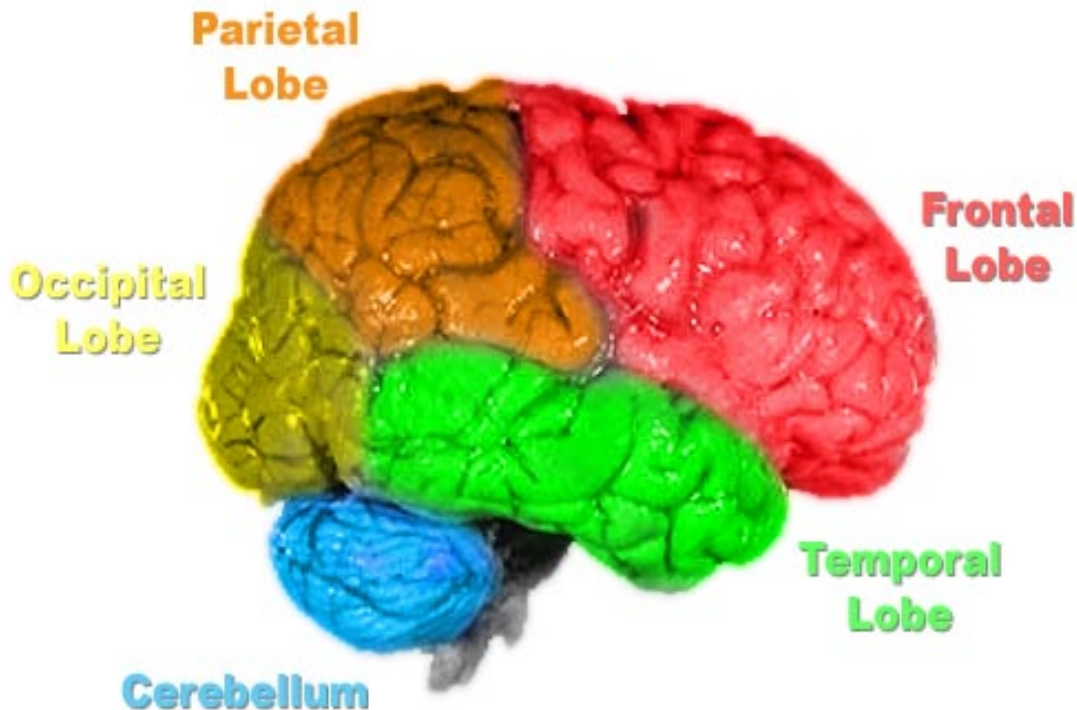
1. What are Brainwaves?

Your brain is made up of billions of brain cells called neurons, which use electricity to communicate with each other. The combination of millions of neurons sending signals at once produces an enormous amount of electrical activity in the brain, which can be detected using sensitive medical equipment (such as an EEG), measuring electricity levels over areas of the scalp.

The combination of electrical activity of the brain is commonly called a brainwave pattern, because of its cyclic, "wave-like" nature.

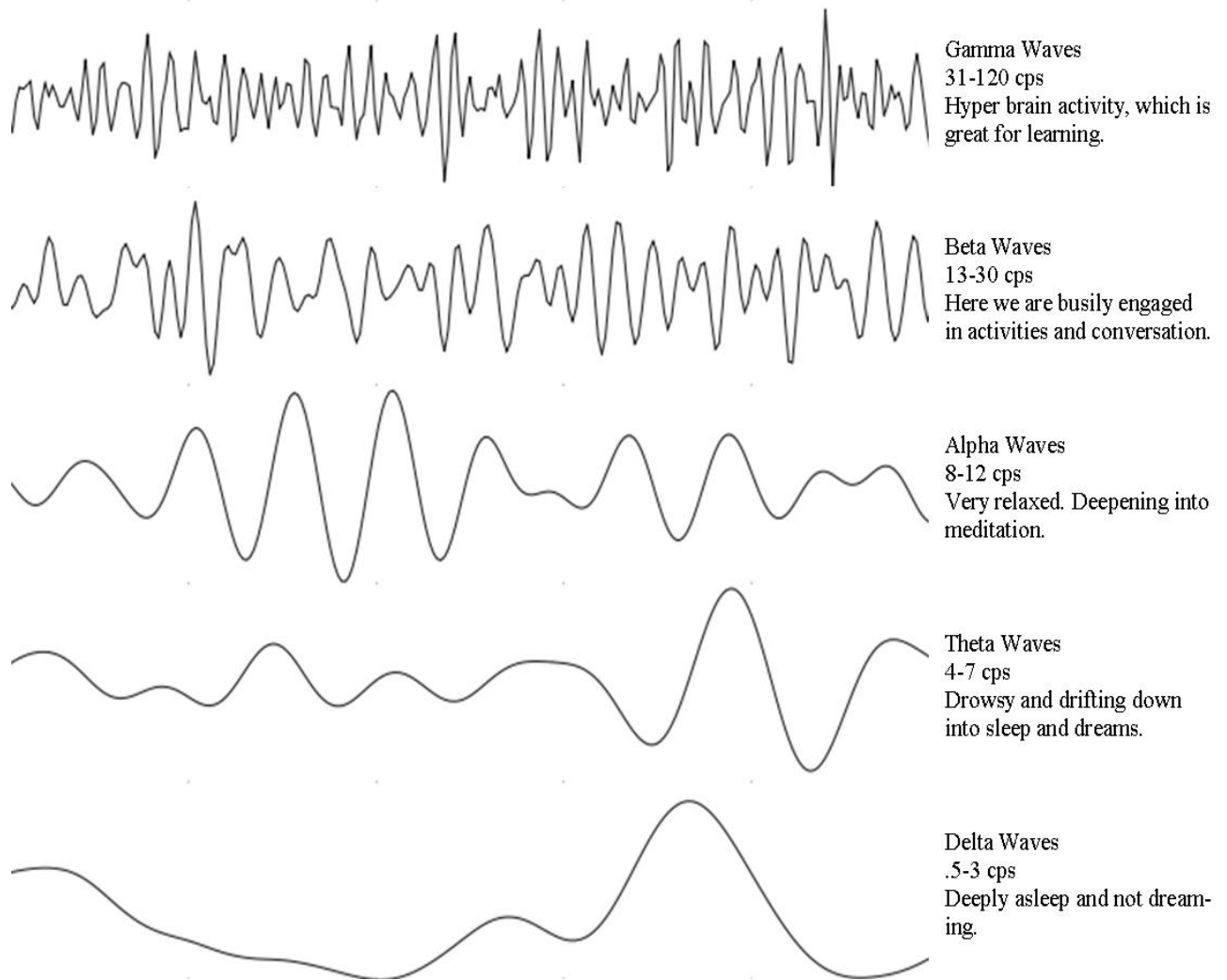
With the discovery of brainwaves came the discovery that electrical activity in the brain will change depending on what the person is doing. For instance, the brainwaves of a sleeping person are vastly different than the brainwaves of someone wide awake. Over the years, more sensitive equipment has brought us closer to figuring out exactly what brainwaves represent and with that, what they mean about a person's health and state of mind.

Fsg 2. Various Brain lobes



- (a) Gamma waves are oscillating waves with frequencies around 40 Hz, although they can be as high as 100 Hz and as low as 24 Hz. These originate from the thalamus (buried deep in the centre of the brain) and are responsible for states of high attention and concentration.
- (b) Beta waves are between 12 and 30 Hz and are the states associated with normal waking consciousness. These are emitted from the motor cortex, a region of the cerebral cortex, which is the outermost layer of tissue on the brain. Beta waves are split into three sections: Low Beta Waves (12.5-16 Hz, Beta 1 power); Beta Waves (16.5-20 Hz, Beta 2 power); and High Beta Waves (20.5-28 Hz, Beta 3 power).
- (c) Alpha waves originate at the Occipital lobe and have a frequency of 8-12Hz. These are most present when you are awake but are very drowsy or relaxed.
- (d) Theta waves are oscillating waves that are located in the Hippocampus and are associated with dreaming. They are in the 4-7Hz range.
- (e) Delta waves are associated with very deep, dreamless sleep cycles and are high amplitude waves, which have a 0 to 3Hz frequency. These waves emit from both the thalamus and the cortex.

Brain Waves Graph



2. The Significance of Brainwaves:

You can tell a lot about a person simply by observing their brainwave patterns. For example, anxious people tend to produce an overabundance of high beta waves while people with ADD/ADHD tend to produce an overabundance of slower alpha/theta brainwaves.

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Table 1. Here is a table showing the known brainwave types and their associated mental states:

Wave	Frequency	Associated Mental State
Gamma	27 Hz and up	Gamma is associated with the formation of ideas, language and memory processing, and various types of learning. Gamma waves have been shown to disappear during deep sleep induced by anesthesia, but return with the transition back to a wakeful state.
Beta	12hz - 27hz	Wide awake. This is generally the mental state most people are in during the day and most of their waking lives. Usually, this state in itself is uneventful, but don't underestimate its importance. Many people lack sufficient beta activity, which can cause mental or emotional disorders such as depression and insomnia. And low SMR production (a sub-range of beta at 12-15hz) may be related to insomnia. Stimulating beta activity can improve emotional stability, energy levels, attentiveness and concentration.
Alpha	8hz - 12hz	Awake but relaxed and not processing much information. When you get up in the morning and just before sleep, you are naturally in this state. When you close your eyes your brain automatically starts producing more alpha waves. Many studies monitoring the EEG activity of experienced meditators have revealed strong increases in alpha activity. Alpha activity has also been connected to the ability to recall memories, lessened discomfort and pain, and reductions in stress and anxiety.
Theta	3hz - 8hz	Light sleep or extreme relaxation. Theta is also a very receptive mental state that has proven useful for hypnotherapy, as well as self-hypnosis using recorded affirmations and suggestions.
Delta	0.2hz - 3hz	Deep, dreamless sleep. Delta is the slowest band of brainwaves. When your dominant brainwave is delta, your body is healing itself and "resetting" its internal clocks. You do not dream in this state and are completely unconscious.

Gamma Brain Waves

Frequency Range	Mental State
27 to 100hz	 Wide Awake

What are gamma brain waves?

Your brain is made up of billions of cells called neurons, which use electricity to send signals and communicate with each other. An enormous amount of electrical activity is produced in the brain, because millions of these signals are sent simultaneously. This combined activity is commonly described as a "brain wave" because it rises and falls like a wave.

Gamma waves are one category of this activity, and like all brain waves, their appearance is directly connected to what a person is doing, thinking or feeling. Gamma waves are the highest frequency wave type, and are known to be broadly associated with cognition, information processing, attention and memory

Discovery- gamma brain waves can be stimulated!

Hans Berger invents the EEG, using it to confirm the existence of brain waves and perform the first tests to determine their function. ¹



1930

Following Berger's discovery of brain waves, multiple studies found that it was possible to use a wide variety of stimuli, including sound and light, to deliberately alter brain wave patterns. One such study conducted by Dempsey and Morison even found that tactile stimulation could induce changes in brain wave activity. ²

Among the earliest evidence for the existence of gamma waves is published, after they are detected in the recordings of electrical activity from electrodes implanted in the visual cortex of awake monkeys. ³

1941

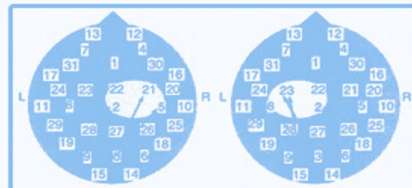
A publication in *Nature* highlights the discovery that gamma may be associated with learning, memory, linguistic processing and other cognitive abilities (Image below is from the *Nature* article, showing data from electrodes, indicating increased gamma activity during associative learning). ⁴

1964



Ongoing research suggests that gamma waves may be significantly related to consciousness. ⁵

1999



2000

New research is continually being conducted, as brain wave stimulation continues the transition from a neurological curiosity to an important tool with practical and beneficial applications. The following are some of the benefits found in published, peer-reviewed studies.

Beta Brain Waves

Frequency Range

12 to 27hz

Mental State



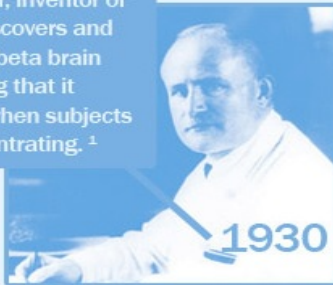
Wide Awake

Your brain is made up of billions of cells called neurons, which use electricity to send signals and communicate with each other. An enormous amount of electrical activity is produced in the brain because millions of these signals are sent simultaneously. This combined activity is commonly described as a "brain wave" because it rises and falls like a wave.

What are beta brain waves?

Beta waves are one category of this activity, and like all brain waves, their appearance is directly connected to what a person is doing, thinking or feeling. For example, a person producing lots of beta waves is probably feeling wide awake

Hans Berger, inventor of the EEG, discovers and names the beta brain wave, noting that it appeared when subjects were concentrating.¹

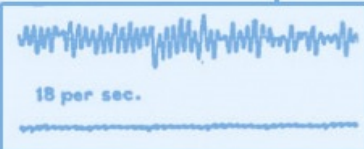


William G. Walter publishes a landmark study showing that photic stimulation changes brain-wave activity significantly enough to change one's mental state. He writes "The rhythmic series of flashes appear to be breaking down some of the physiologic barriers between different regions of the brain."³

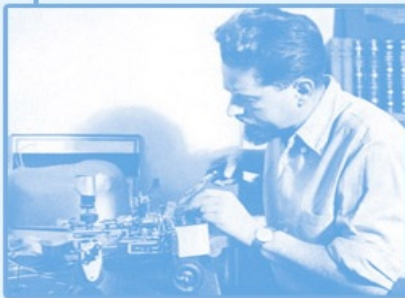
Discovery- beta brain waves can be stimulated!

Lord Edgar Adrian sets out to disprove Berger's findings, but his research only confirms what Berger discovered regarding brainwaves. Adrian also finds that brain wave activity is affected by photic stimulation. His published results trigger a flurry of interest in brainwaves and the EEG.²

1934



1949



The first device for stimulating beta activity is made available to the public. The "Brain Wave Synchronizer" spurs even further clinical studies on brain wave stimulation.⁴

1959



1960 - Present

Brain wave stimulation continues the transition from a neurological curiosity to an important tool with practical and beneficial applications. The following are some of the benefits found in published, peer-reviewed experimental studies where beta wave activity was stimulated.

Alpha Brain Waves

Frequency Range

8 to 12hz

Mental State



Awake/Relaxed

Your brain is made up of billions of cells called neurons, which use electricity to send signals and communicate with each other. An enormous amount of electrical activity is produced in the brain because millions of these signals are sent simultaneously. This combined activity is commonly described as a "brain wave" because it rises and falls like a wave.

What are alpha brain waves?



Alpha waves are one category of this activity, and like all brain waves, their appearance is directly connected to what a person is doing, thinking or feeling. For example, a person producing lots of alpha waves is probably feeling relaxed and calm.

Discovery- alpha brain waves can be stimulated!

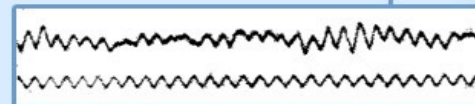
The Grecian scientist Ptolemy observes that watching flickering sunlight through the spokes of a spinning wheel can lead to a euphoric feeling.¹



200 AD

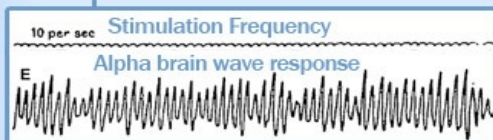
German psychiatrist Hans Berger invents the electroencephalogram (EEG), and creates the first depictions of the alpha wave.²

1929



Researchers Adrian and Matthews discover that photic (light) stimulation can induce alpha wave activity.³

1934



W. Gray Walter (who once visited Berger's lab) publishes the results from studies with thousands of subjects, showing the changes in mental state produced by photic stimulation.⁴


1956



1960 - Present

Brain wave stimulation continues the transition from a neurological curiosity to an important tool with practical and beneficial applications. The following are some of the benefits found in published, peer-reviewed experimental studies where alpha wave activity was stimulated.

Theta Brain Waves

Frequency Range	Mental State
3 to 8hz	 Relaxed/Light Sleep

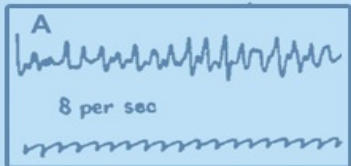
What are theta brain waves?

Your brain is made up of billions of cells called neurons, which use electricity to send signals and communicate with each other. An enormous amount of electrical activity is produced in the brain because millions of these signals are sent simultaneously. This combined activity is commonly described as a "brain wave" because it rises and falls like a wave.

Theta waves are one category of this activity, and like all brain waves, their appearance is directly connected to what a person is doing, thinking or feeling. For example, theta waves are linked to deep relaxation or early stages of sleep.

Discovery- theta brain waves can be stimulated!

Drs. Adrian and Mathews discover that electrical activity in the brain can be deliberately altered with flashing light, and produce the first EEG image (shown here) demonstrating theta activity driven by photic stimulation.¹



1934

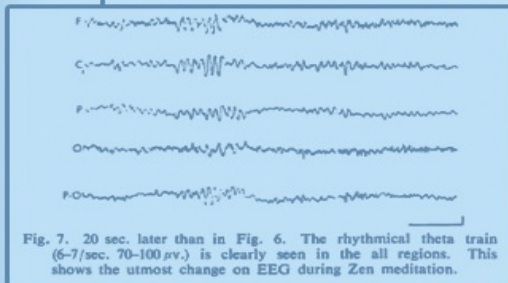
Inspired by his observations of radar operators falling into trance-like states due to steady flashing light exposure, Sidney Schneider produces the Brainwave Synchronizer. It is the first publically available device for brain wave stimulation, and is used in early studies on hypnotic induction.²

Dr. Kasamatsu conducts the first of many studies wherein enhanced theta brain wave activity is observed in EEG data gathered from active meditation practitioners.³

1957



1966




2006

Stanford University hosts a symposium dedicated to brainwave stimulation. The ability of theta stimulation to aid in anxiety reduction is one of multiple applications highlighted during the proceedings.⁴

Present

Ongoing research provides further evidence that brainwave stimulation is an important tool with practical and beneficial applications. The following are some of the benefits found in published, peer-reviewed experimental studies involving theta wave activity.

Delta Brain Waves

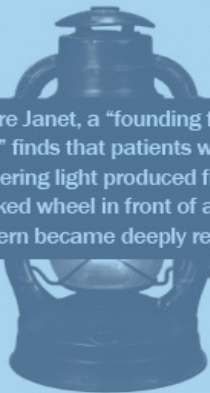
Frequency Range	Mental State
0.2 to 3hz	 Deep Sleep

What are delta brain waves?

Your brain is made up of billions of cells called neurons, which use electricity to send signals and communicate with each other. An enormous amount of electrical activity is produced in the brain because millions of these signals are sent simultaneously. This combined activity is commonly described as a "brain wave" because it rises and falls like a wave.

Delta waves are one category of this activity, and like all brain waves, their appearance is directly connected to what a person is doing, thinking or feeling. For example, a person producing lots of delta waves is deeply asleep.

Pierre Janet, a "founding father of psychology," finds that patients who gazed into the flickering light produced from a spinning spoke wheel in front of a kerosene lantern became deeply relaxed.¹



~1900

Discovery- delta brain waves can be stimulated!

Hans Berger is the first to describe human brain waves, creating the first recording of brain wave activity (pictured below) using his newly invented electroencephalogram-otherwise known as an EEG.²

1934



W. Gray Walter tests the effects of an electronic strobe on thousands of subjects using advanced EEG equipment, and proves rhythmic flashing lights can quickly alter brain-wave activity, resulting in states of profound relaxation.³

1949



Gian Emilio Chatrian discovers that audio stimulation can also affect brain waves, noting changes in brain wave activity in response to clicks at a frequency of 15 per second.⁴

1959

1960 - Present

Brain wave stimulation continues the transition from a neurological curiosity to an important tool with practical and beneficial applications. The following are some of the benefits found in published, peer-reviewed experimental studies where delta wave activity was stimulated.

Reference:

1. <http://www.transparentcorp.com/products/np/brainwaves.php>
2. <http://www.brainworksneurotherapy.com/what-are-brainwaves>
3. <http://mentalhealthdaily.com/2014/04/15/5-types-of-brain-waves-frequencies-gamma-beta-alpha-theta-delta/>