



# Methodology for EEG and Reference Values of the Software Analysis

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## Abstract

**BACKGROUND:** EEG is a way of graphically recording the electrical potentials of the brain. The main parameters of the EEG are related to the ratios between the individual frequency components, their amplitude and characteristic waveforms.

**AIM:** The aim of the study was to develop and describe a consistent and detailed methodology for the technical conduct of an EEG study, as well as to find the reference values of some of the most frequently derived average values of parameters from the software analysis of modern EEG equipment. TOOLKIT: The EEG office of the Medical Faculty at Trakia University is equipped with a multifunctional 31-channel digital EEG/EP device with a sampling frequency of 1000 Hz.

**METHODOLOGY:** Unification of the technical implementation is necessary so that the results can be compared with the maximum cleared probability of statistical error due to controllable factors. The outlined sequential steps can serve any technical contributor.

**RESULTS:** Electroencephalographic study of 100 clinically sound participants and determination of the reference values of the indicators. We have created a table with the mean values of the EEG Software Analysis.

**CONCLUSION:** The frequency composition of the EEG signal includes four types of waves or rhythms: delta/0.5–3.5Hz/, theta/4–7.5Hz/, alpha/8–12Hz/, and beta/13–30Hz/. The amplitude of the EEG under physiological conditions ranges from 15 microvolts/low-amplitude/to 150 microvolts/high-amplitude/. Average limits are between 30 and 80 microvolts.

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## Introduction

Electroencephalography (EEG) is a way of graphically recording the electrical potentials of the brain. It is performed with a special device - an electroencephalograph. It has the ability to detect, amplify, and register the deviations of the total electrical potentials that are generated in the process of the functioning of the nerve cells of the cerebral cortex. The rhythmic deviations of the total potentials reach as a very weak signal to the surface of the head, where they are detected by electrodes. The signals are conducted from the electrodes by means of cables to the electroencephalographic apparatus, amplified many times, and filtered from noises. The main parameters of the EEG are related to the ratios between the individual frequency components, their amplitude, and characteristic waveforms. The frequency composition of the EEG signal includes four types of waves or rhythms: delta/0.5–3.5Hz/, theta/4–7.5Hz/, alpha/8–12Hz/, and beta/13–30Hz/. The amplitude of the EEG under physiological conditions ranges from 15  $\mu$ V/low-amplitude/to 150  $\mu$ V/high-amplitude/. Average limits are between 30

and 80 microvolts. The dominant activity in the EEG recording is referred to as background/main activity/ and depends on the functional state of wakefulness, sleep, etc. Alpha and beta rhythms are an expression of the normal activity of the cerebral cortex, as during sleep they disappear and the slow theta and delta waves appear. When they are not carried away during sleep, they are an expression of brain disease, except in early childhood, when they are a normal predominant rhythm. Modern EEG equipment provides averaged numerical data of a number of parameters obtained through software analysis of the recording values. The technical specifications and the literature lack data on the reference values of some of them. Furthermore, a detailed and developed methodology for the technical conduct of the research is not found.

## Aim

The aim of the study was to develop and describe a consistent and detailed methodology for the technical conduct of an EEG study, as well as to find the reference values of some of the most frequently derived average values of parameters from the software analysis of modern EEG equipment.

## Toolkit

### Technical specifications

The office of electroencephalography of the Medical Faculty at Trakia University is equipped with a multifunctional 31-channel digital EEG/EP device, with the following minimum and mandatory characteristics: Channels for EEG and long-latency EP: 25; Bipolar polygraphs channels (EEG, ECG, EOG, EMG, and EP): 6; Built-in channel impedance meter with indication on the front panel of the device for the state of the electrodes in the registration process; ADC: 24 bit; frequency range for EEG channels: 0 Hz–600 Hz; Sensitivity for EEG channels: 0.01–10000000  $\mu\text{V}/\text{mm}$ ; possibility of cascading the channels with an additional amplifier of the same type sampling rate: 1000 Hz.

## EEG Methodology

Unification of the technical implementation is necessary so that the results can be compared with the maximum cleared probability of statistical error due to controllable factors. The outlined sequential steps can serve any technical contributor. The study is carried out in an electrophysiology laboratory [1]. The following preparation and implementation is required. Notifying the patient about the upcoming examination and mental preparation; providing a patient information application and an informed consent form [2]. Restful sleep of the patient is ensured, except in cases where sleep deprivation is necessary. On the day of the examination - washed hair with soap to reduce the resistance of the contact surface. Placing the patient on the couch or in the chair and sedating to relax; explaining that it won't hurt; familiarization with the helmet and technique; we instruct him to cooperate during the whole study and the challenge samples. Fitting the helmet - well tightened so that the electrodes do not move during the recording. Clearing the hair and placing the electrodes pre-soaked in physiological solution in standard places according to the international 10/20 system connecting the electrodes to the cables from the EEG device. Enter the passport part in the system and record it in the laboratory journal. Measure the electrode impedance and ensure that it is within the allowable limits. During the examination, the patient is in a soundproof, darkened room with closed eyes. Spontaneous or background activity is recorded first. To activate changes in brain biocurrents, the following methods are applied: hyperventilation, photo stimulation, opening and closing eyes, recording during sleep deprivation, recording during natural sleep, mind counting; recording duration of at least 20 min with artifact-free epochs at 15–30 mm/s. During the recording, the patient is actively monitored, the quality of the recording is also monitored, and if there are problems, the recording is interrupted until they are eliminated, and then continued. In the event of a

provoked epileptic seizure, secure airways and protect the patient from injury; AEM is made by appointment. Factors changing the quality of the EEG recording and the most common errors: broken or tangled cables; poor contact of the electrodes with the scalp; dirty hair or oily scalp; poor relaxation of the patient, blinking of eyes, clenching of teeth, shaking of the head; wide smearing of the contact gel or the physiological solution, which turns the electrodes into one electrode.

## Results

Electroencephalographic exam of clinically sound controls and determination of the reference values of the indicators. After a campaign to recruit and study healthy controls for the purpose of health prevention, the conduct of the studies thus planned according to the design described above was started. Each healthy participant included in the database was informed in advance about the benefits and risks of EEG and have signed an informed consent. A total of 100 clinically sound participants were studied, and the summary mean results of their variables are presented in Table 1.

**Table 1: Reference values of electroencephalography variables from the software analysis**

Mean amplitude of the alpha rhythm in the left hemisphere in $\mu\text{V}$	11.2	* / . 1
Mean amplitude of the alpha rhythm in the right hemisphere in $\mu\text{V}$	12.4	* / . 1
Interhemispheric asymmetry of the alpha rhythm in %	15.9	$\leq 45$
Dominant frequency of the alpha rhythm in Hz	10.2	* / . 2
Mean amplitude of the low - frequency beta rhythm in $\mu\text{V}$	7.5	* / . 3
Mean amplitude of the high - frequency beta rhythm in $\mu\text{V}$	7.2	* / . 3
Mean amplitude of the delta rhythm in $\mu\text{V}$	6.1	* / . 3
Dominant frequency of delta rhythm in Hz	2.6	$\leq 3,5$
Mean amplitude of theta rhythm in $\mu\text{V}$	6.3	* / . 3
Dominant frequency of theta rhythm in Hz	4.91	* / . 1
Decrease in the alpha rhythm index in EO in %	55.6	$\geq 30$
Decrease in the alpha rhythm index in HV in %	23.1	$\leq 30$

## Discussion

The frequency composition of the EEG signal includes four types of waves or rhythms: Delta/0.5–3.5Hz/, theta/4–7.5Hz/, alpha/8–12Hz/, and beta/13–30Hz/. The amplitude of the EEG under physiological conditions ranges from 15  $\mu\text{V}$ /low-amplitude/to 150 microvolts/high-amplitude/. Average limits are between 30 and 80 microvolts.

The alpha rhythm is the predominant activity, with an occipital maximum, in the awake state with eyes closed. It has a frequency of 8–13 Hz. Alpha rhythm is the name applied to a certain type of alpha frequency activity with certain characteristics. The morphology of the alpha rhythm is usually sinusoidal. More often, the amplitude on the right side is higher. The disappearance or blocking of alpha activity with eye opening, stimulation, or even mental concentration is known as reactivity. In some patients,

alpha activity disappears with eye closure and reappears with eye opening. This is known as a paradoxical alpha rhythm and has no pathological significance. Absence of alpha activity is also not an anomaly.

Beta activity is greater than 13 Hz. Most beta activity is between 15 and 25 Hz. It is often found in the frontal and central regions in awake individuals. Beta activity is usually of low amplitude, often  $<20 \mu\text{V}$ . Benzodiazepines, barbiturates, and other sedatives cause an increase in the amplitude of beta activity, thus making it more prominent. A particular type of beta activity, the fast alpha variant, is noted in the occipital region and is a normal variant.

Theta activity involves frequencies between 4 and 7 Hz. Theta activity in the 6–7 Hz range can be seen in the awake state in the frontocentral region in young individuals. This activity is present in states of heightened attention or alertness. Transient theta activity can be observed in individuals over 60 years of age. This activity can occur as a single wave or for a short time. Like the alpha rhythm, temporal theta activity responds to eye opening and stimulation. Such periodic transient theta activity is normal except when it is persistent and of large amplitude.

Delta frequencies are  $<4$  Hz. They are less common in the normal EEG recording of an adult. These delta waves should be of the same amplitude as the alpha rhythm, appear as single waves, and occupy  $<1\%$  of the recording. If delta waves are more frequent or of greater amplitude, they represent an abnormality.

The mu rhythm is an arcuate activity observed in the central or centroparietal regions. Its frequency is similar to the alpha rhythm, 8–11 Hz. The mu rhythm is asymmetric and asynchronous for the two hemispheres and is often interspersed with beta activity. Mu activity is blocked when the subject is asked to move the contralateral limb. A paradoxical mu rhythm is when this activity occurs with contralateral limb movement. Sometimes the apical phase of the mu rhythm may resemble spikes, especially when there is an adjacent cranial defect.

Lambda waves are seen in the tooth shape with positive polarity observed in the occipital region. They are typically between 160 and 250 ms in duration and  $<50 \mu\text{V}$  in amplitude. Lambda waves are bilaterally synchronous, although they can occur asymmetrically and mimic sharp waves. They appear when a person scans a complex visual image and can be eliminated when asked to look at a blank white sheet of paper.

#### *Low voltage EEG*

In some individuals, no clear alpha rhythm can be identified. Instead, their background activity is low-amplitude beta, alpha, or theta activity. The amplitude of this activity is usually  $<20 \mu\text{V}$ . A low-voltage EEG is seen more often in older individuals than in children and

is not considered abnormal unless a previous EEG in the same patient shows a clear alpha rhythm. When the total activity is  $<10 \mu\text{V}$ , it may be abnormal.

With hyperventilation for 3–5 min, hypocapnia and the resulting cerebral vasoconstriction and hypo perfusion are thought to be responsible for the changes that occur. The normal response consists of a gradual increase in theta frequencies, followed by rhythmic delta bursts and finally generalized, continuous, rhythmic delta activity. Sixty to ninety seconds after hyperventilation stops, slow activity begins to subside. The hyperventilation-induced delay is more prominent if the individual's blood sugar is low (a long time after the last meal) or if significant cerebral ischemia occurs. Abnormal responses to hyperventilation include generalized spike-and-wave discharges and focal spikes. For these reasons, hyperventilation should not be performed in patients with significant cardiopulmonary disease, acute stroke, sickle cell disease, or pregnancy.

Photo stimulation consists of short bursts of light applied at frequencies from 1 to 30 Hz. Light creates a visual evoked potential that can be recorded best in the occipital region. The likelihood of seeing such a reaction may increase when the eyes are closed and the stimulator is  $<30$  cm from the patient. A photo paroxysmal reaction consists of spikes and sharp waves that can lead to a seizure.

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## Statement of Ethics

This study protocol was reviewed and approved by Local Ethics Committee of Trakia University - Stara Zagora city, Bulgaria, approval number 14/02 OCT 2020. All participants voluntarily signed an informed consent form before inclusion in the study.

## Authors Contributions

Christiyan Naydenov – constructing and processing the research; writing, revising and releasing the article; exam the patients, taking the ICF, processing the EEGs; Antoaneta Yordanova - creating the database and processing the statistics; language edition; Velina

Mancheva – scientific supervisor, team coordinator; final approval.

## Data Availability Statement

The datasets generated and analyzed in the current study are available from the corresponding author on reasonable request.

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