I. **INTRODUCTION**

The brain is encased by the cranium, bones of the skull which immediately cover and protect brain surfaces. A thin cover of skin, called the scalp, covers most of the cranium. The largest part of the brain immediately beneath the bones of the cranium is the cerebral cortex. The cerebral cortex is composed of nerve cells (neurons) many of which are functionally connected to each other, and connected to other parts of the brain. Electrical activity in the form of nerve impulses being sent and received to and from cortical neurons is always present, even during sleep. In a biological sense (as well as a medical or legal sense,) absence of electrical activity in the human cerebral cortex signifies death.

Functions of the cerebral cortex include abstract thought, reasoning, voluntary and involuntary control of skeletal muscle, and the recognition and differentiation of somatic, visceral, and special sensory stimuli. Specific regions of the cerebral cortex process or generate various kinds of information. For example, the occipital lobe processes visual information while the parietal lobe processes somatosensory information such as cutaneous pain or temperature (Fig. 3.1).

![Fig. 3.1 Regions of the brain](image)

The sensory information is relayed from the periphery through lower centers in the brain, and then the information is sent to various regions of the cerebral cortex. Since the cerebral cortex is just under the cranium, electrodes placed on the scalp above the various regions of the brain can detect the electrical activity associated with functioning neurons. The recording of the brain’s activity obtained by using electrodes is called electroencephalogram or EEG (electro = electrical, encephelo = brain, gram = record).

An EEG electrode will mainly detect the activity in the brain region just under it. Nevertheless, the electrodes receive the activity from thousands of neurons. In fact, one square millimeter of cortex has more than 100,000 neurons. Since each region of the cerebral cortex of an alert person is busy receiving, integrating, and sending many impulses, this activity is detected in the EEG. (For more information about waveforms, see the Orientation chapter.)

It is only when the input to a region is synchronized with electrical activity occurring at the same time that you begin to distinguish simple, periodic waveforms in an EEG.

In 1929, an Austrian physician named Hans Berger discovered that electrodes placed on the scalp could detect various patterns of electrical activity. After verifying that the recordings were indeed recording from the brain, and were not artifacts of muscle or scalp, scientists began to study these “brain waves.” Today, the EEG is still a medically useful recording for brain function. In medical and basic research, the correlation of particular brain waves with sleep phases, emotional states, psychological profiles, and types of mental activities is ongoing.

Four simple periodic rhythms recorded in the EEG are alpha, beta, delta, and theta. These rhythms are identified by frequency (Hz or cycles/sec) (Table 3.1). The amplitudes recorded by scalp electrodes are in the range of microvolts (µV or 1/1,000,000 of a volt).
II. EXPERIMENTAL OBJECTIVES

1) To record an EEG from an awake, resting subject with eyes open and eyes closed.
2) To identify and examine alpha, beta, delta, and theta components of the EEG complex.

III. MATERIALS

- BIOPAC electrode lead set (SS2L)
- BIOPAC Disposable Electrodes (EL503,) 3 electrodes per subject
- BIOPAC Electrode Gel (GEL1) and Abrasive Pad (ELPAD) or Skin cleanser or alcohol prep
- Lycra® swim cap (such as Speedo® brand) or supportive wrap (such as 3M Coban™ Self-adhering Support Wrap) to press electrodes against head for improved contact
- Biopac Student Lab System: BSL 4 software, MP36, MP35 or MP45 hardware
- Computer system (Windows 8, 7, Vista, XP, Mac OS X 10.5 – 10.8)

IV. EXPERIMENTAL METHODS

A. SETUP

**FAST TRACK Setup**

1. Turn the computer ON.
   - If using an MP36/35 unit, turn it OFF.
   - If using an MP45, make sure USB cable is connected and “Ready” light is ON.

2. Plug the equipment in as follows:
   - Electrode Lead Set (SS2L)—Electrode Check (MP3x only. For MP45, plug into CH 1.)

3. Turn ON the BIOPAC MP36/35 unit.

...Setup continues...

Detailed Explanation of Setup Steps

![SS2L connection diagram](image)

**Fig. 3.2 MP3X (top) and MP45 (bottom) hardware connections**
7. Get Subject in proper seating position (Fig.
6.5).
8. Wait five minutes to allow Subject to
relax, and for electrodes to establish proper
contact.

Subject should be seated and relaxed. Ideally, the room should be
reasonably quiet to help Subject mentally relax.

Fig. 3.5 Positioning

9. Start the Biopac Student Lab Program.
10. Choose “L03 – Electroencephalography
(EEG) I” and click OK.
11. Type in a unique filename and click OK.

12. Optional: Set Preferences.
   * Choose File > Lesson Preferences.
   * Select an option.
   * Select the desired setting and click
     OK.

END OF SETUP

If your lab is using multiple MP hardware types, choose the appropriate
BSL program (shortcut icon contains MP number).

No two people can have the same filename, so use a unique identifier,
such as Subject’s nickname or student ID♯.
A folder will be created using the filename. This same filename can be
used in other lessons to place the Subject’s data in a common folder.

This lesson has optional Preferences for data and display while
recording. Per your Lab Instructor’s guidelines, you may set:

   * Grids: Show or hide gridlines
   * Lesson Recordings: Specific recordings may be omitted based on
     instruct or preferences.
C. DATA RECORDING

FAST TRACK Recording

1. Prepare for the recording.
   - **Subject** remains seated, relaxed and still, with eyes closed.
   - Review recording steps.

2. Click **Record**.

   - **Subject** remains seated, relaxed and still, with eyes closed.
   - Record for 20 seconds.
   - **Director** presses F4 and cues **Subject** to open eyes.
   - Record for an additional 20 seconds.
   - **Director** presses F5 and cues **Subject** to close eyes.
   - Record for an additional 20 seconds.

3. Click **Suspend**.

4. Verify recording resembles the example data.
   - If similar, click **Continue** and proceed to the optional recording section, or click **Done** to finish.
   - If necessary, click **Redo**.

Recording continues...

**Detailed Explanation of Recording Steps**

This lesson will record the "raw" (full bandwidth) EEG while the **Subject** is relaxed with eyes closed, eyes opened, and eyes closed again. The alpha, beta, delta and theta channels are simultaneously recorded, but are hidden by default. Hidden channels may be displayed during the recording by holding down the "Alt" (PC) or "Option" (Mac) key when clicking on the channel button.

To work efficiently, read this entire section before recording, or review onscreen **Tasks** to preview recording steps in advance.

**Hints for obtaining optimal data:**

- **Subject** should be seated and relaxed to keep muscles still, especially facial muscles. (Do not talk.)
- **Subject** must try not to blink during “Eyes Open” portion of recording.
- **Subject** should try to relax mentally; i.e. think of a relaxing place.

**Note:** Display > Autoscale Waveforms and Autoscale Horizontal are available DURING recordings to allow scale changes if necessary.

The **Director** instructs **Subject** to change the eye condition for 20-second intervals, and inserts an event marker at each change.

**First 20 seconds (secs. 0 – 20)**

- **Subject** is relaxed, with eyes closed for the first 20 seconds.

**Next 20 seconds (secs. 21 – 40)**

- **Director** presses F4 to insert a marker labeled “Eyes Open” and cues **Subject** to open eyes and try not to blink for the next 20 seconds.

**After another 20 seconds (secs. 41 – 60)**

- **Director** presses F5 to insert a marker labeled “Eyes Closed” and cues **Subject** to close eyes for the next 20 seconds.

**Fig. 3.8 Example data**

Verify recording shows variation between the “Eyes Open” and “Eyes Closed” recordings.

**Note:** To check the data, it may be necessary to show one or more of the hidden frequency bands. To activate, hold down the Alt (PC) or Option (Mac) key when clicking on the channel button.
V. DATA ANALYSIS

FAST TRACK Data Analysis

1. Enter the Review Saved Data mode.

   - Note Channel Number (CH) designations.
     Channel  Displays
     CH 1  EEG (hidden*)
     CH 40  alpha
     CH 41  beta
     CH 42  delta
     CH 43  theta

   - Note measurement box settings:
     Channel  Measurement
     CH 40  Stddev
     CH 41  Stddev
     CH 42  Stddev
     CH 43  Stddev
     SC  Freq

2. Set up your display window for optimal viewing of the channels 40 – 43.

3. Use the I-Beam cursor to select the first “Eyes closed” data.

   A

Data Analysis continues...

Detailed Explanation of Data Analysis Steps

If entering Review Saved Data mode from the Startup dialog or lessons menu, make sure to choose the correct file.

Fig. 3.9 Example data

The EEG channel is hidden but can be easily brought into view. (See Step 2.)

The measurement boxes are above the marker region in the data window. Each measurement has three sections: channel number, measurement type, and result. The first two sections are pull-down menus that are activated when you click them.

Brief definition of measurements:

   Stddev: Standard deviation is a measure of the variability of data points. The advantage of the Stddev measurement is that extreme values or artifacts do not unduly influence the measurement.

   Freq: Converts the time segment of the selected area to frequency in cycles/sec.

The “selected area” is the area selected by the I-beam tool (including endpoints).

Useful tools for changing view:

   Display menu: Autoscale Horizontal, Autoscale Waveforms, Zoom Back, Zoom Forward
   Scroll Bars: Time (Horizontal); Amplitude (Vertical)
   Cursor Tools: Zoom Tool
   Buttons: Overlap, Split, Show Grid, Hide Grid, +, -
   Hide/Show Channel: “Alt + click” (Windows) or “Option + click” (Mac) the channel number box to toggle channel display.

This is the data from the time 0 to the first event marker.

Fig. 3.10 First Eyes Closed data
ELECTROENCEPHALOGRAPHY I

• **EEG I**

DATA REPORT

Student's Name: ________________________________
Lab Section: ________________________________
Date: ________________________________

I. Data and Calculations

Subject Profile

Name: __________________________ Gender: Male / Female
Age: ____________ Heigh: ____________ Weight: ____________

A. EEG Amplitude Measurements from Standard Deviation measurements

<table>
<thead>
<tr>
<th>Table 3.2 Standard Deviation [Stddev]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhythm</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Alpha</td>
</tr>
<tr>
<td>Beta</td>
</tr>
<tr>
<td>Delta</td>
</tr>
<tr>
<td>Theta</td>
</tr>
</tbody>
</table>

B. EEG Frequency Measurements from first ‘Eyes closed’ data

<table>
<thead>
<tr>
<th>Table 3.3 Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhythm</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Alpha</td>
</tr>
<tr>
<td>Beta</td>
</tr>
<tr>
<td>Delta</td>
</tr>
<tr>
<td>Theta</td>
</tr>
</tbody>
</table>

II. Questions

C. List and define two characteristics of regular, periodic waveforms.

D. Compare and contrast synchrony and alpha block.
III. OPTIONAL Active Learning Portion

A. Hypothesis

B. Materials

C. Method

D. Set Up

E. Experimental Results

End of Lesson 3 Data Report
E. Examine the alpha and beta waveforms for change between the “eyes closed” state and the “eyes open” state.

i. Does desynchronization of the alpha rhythm occur when the eyes are open?

ii. Does the beta rhythm become more pronounced in the “eyes open” state?

F. The amplitude measurements (Sddev) are indicative of how much alpha activity is occurring in Subject. But, the amplitude values for beta do not truly reflect the amount of mental activity occurring with the eyes open. Explain.

G. Examine the delta and theta rhythm. Is there an increase in delta and theta activity when the eyes are open? Explain your observation.

H. Define the following terms:

i. Alpha rhythm

ii. Beta rhythm

iii. Delta rhythm

iv. Theta rhythm
4. Repeat Step 3 using "Eyes open" data.

5. Repeat Step 3 using the second "Eyes closed" data.

6. Zoom in on a 3 – 4 second section of the first "Eyes closed" data.

7. Use the I-beam cursor to select an area that represents one cycle in the alpha wave (Fig. 3.11).

8. Repeat Step 7 for two other alpha wave cycles.

9. Repeat Steps 7 – 8 using the beta wave data.

10. Repeat Steps 7 – 8 using the delta wave data.

11. Repeat Steps 7 – 8 using the theta wave data.

12. Answer the questions at the end of the Data Report.

13. Save or Print the Data Report.

14. Quit the program.

END OF DATA ANALYSIS

This is the data between the first and second event markers.

This is the data between the second event marker and the end of the file.

Accurate Frequency calculation requires a selected area of only one cycle.

![Fig. 3.11 Selected area shows one cycle of the alpha wave.](image)

Make sure you stay in the first "Eyes Closed" data region.

Click the cursor/pointer into the beta wave region to select this channel for "SC" measurements. (Channel label will darken.)

Click the cursor/pointer into the delta wave to select this channel for "SC" measurements.

Click the cursor/pointer into the theta wave to select this channel for "SC" measurements.

An electronically editable Data Report is located in the journal (following the lesson summary,) or immediately following this Data Analysis section. Your instructor will recommend the preferred format for your lab.

END OF LESSON 3

Complete the Lesson 3 Data Report that follows.
If recording does not resemble the Example Data
- If the data is noisy or flatline, check all connections to the MP unit.
- If there is excessive baseline drift or large spikes:
  - Check that electrodes are making good contact with the scalp, cap or wrap is snug and that the cables are not pulling on the electrodes.
  - Subject must remain as still as possible.
  - Try relaxation techniques, such as slow breathing or relaxing muscles.

Click Redo and repeat Steps 2 – 4 if necessary. Note that once Redo is clicked, the most recent recording will be erased.

With this lesson you may record additional data by clicking Continue following the last recording. Design an experiment to test or verify a scientific principle(s) related to topics covered in this lesson. Although you are limited to this lesson’s channel assignments, the electrodes may be moved to different locations on the Subject.

Design Your Experiment
Use a separate sheet to detail your experiment design, and be sure to address these main points:

A. **Hypothesis**
   - Describe the scientific principle to be tested or verified.

B. **Materials**
   - List the materials you will use to complete your investigation.

C. **Method**
   - Describe the experimental procedure—be sure to number each step to make it easy to follow during recording.

Run Your Experiment
D. **Set Up**
   - Set up the equipment and prepare the subject for your experiment.

E. **Record**
   - Use the Continue, Record and Suspend buttons to acquire as many recordings as necessary for your experiment.
   - Click Done when you have completed all of the recordings required for your experiment.

Analyze Your Experiment
F. **Set**
   - Set measurements relevant to your experiment and record the results in a Data Report.

If choosing the Record from another Subject option:
- Continue the entire lesson from Setup Step 4.

5. After clicking Done, choose an option and click OK.

6. Remove electrodes.

END OF RECORDING
B. CALIBRATION

The Calibration procedure establishes the hardware’s internal parameters (such as gain, offset, and scaling) and is critical for optimal performance. **Pay close attention to Calibration.**

**FAST TRACK Calibration**

1. Subject remains relaxed with eyes closed during Calibration.

2. Check Electrode Impedance. (Optional*)

*Only functional if your MP hardware is compatible with the Electrode Check feature. If your MP hardware is not compatible, this feature will not be available. Please contact BIOPAC Technical Support for more information on how to enable Electrode Check functionality.

**IMPORTANT**

Certain subjects may not fall below the 10 K ohm reading. This reading is subject to individual variations in skin conductivity and electrode placement.

3. Click Calibrate.

4. During Calibration Subject must:
   - Remain seated, relaxed and still, with eyes closed.
   - Wait for Calibration to stop.

5. Verify recording resembles the example data.
   - If similar, click **Continue** and proceed to Data Recording.
   - If necessary, click **Redo Calibration**.

**Detailed Explanation of Calibration Steps**

*This step is optional and not applicable to MP45 hardware.*

Use **Check Electrode Impedance** to check the Subject's skin conductivity. This opens the Electrode Checker panel and displays skin resistance in k ohm.

<table>
<thead>
<tr>
<th>File</th>
<th>Display</th>
<th>Lessons</th>
<th>Help</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Check Electrode Impedance panel

<table>
<thead>
<tr>
<th>9.89 kΩ</th>
<th>9.87 kΩ</th>
</tr>
</thead>
</table>

To use:

- Make sure the SS2L is plugged into the MP unit's Electrode Check input.
- Click Check Electrode Impedance button.
- Ideally, both readings should be similar and below 10 k ohm. (See Fig. 3.6.)
- When finished, be sure to remove the SS2L from the Electrode Check input and plug into the CH 1 input before continuing (right).

Calibration lasts eight seconds.

The baseline should be relatively stable around 0 uV.

![Fig. 3.7 Example Calibration data](image)

If the data shows excessive baseline drift or large spikes, make sure the electrodes are making good contact with the scalp and that the cables are not pulling on the electrodes.

Click **Redo Calibration** and repeat Steps 3 – 5 if necessary.
4. Position electrodes on the scalp. Fig. 3.3 shows a sample configuration.

**IMPORTANT**
Good electrode contact with scalp is crucial for obtaining a meaningful EEG recording.

**Guidelines for electrode placement:**
- The placement of the scalp electrodes can vary (within limits) depending on your instructor's or Subject's preference.
- Keep the electrodes on one side (right or left) of the head.
- The third electrode is the ground electrode and is placed over the Mastoid region (behind the ear).

**Hints for obtaining optimal data:**
- As much as possible, move (part) the hair away from the electrode area to ensure the electrode makes contact with the scalp.
- Gently abrade skin at the electrode sites.
- Apply a drop of gel to the electrode.
- Apply pressure to the electrodes for about 1 minute after the initial placement.
- Subject must remain still. Blinking and other movement will affect the recording of all four rhythms.
- Despite your best efforts, electrode adhesion may not be strong enough to record data; try another Subject or different electrode placement.

The pinch connectors work like a small clothespin, but only latch onto the nipple of the electrode from one side of the connector.

Drape the electrode cables over the head so that they are not pulling on the electrodes.

The cap or wrap should be snug but not uncomfortably tight.

5. Clip the Electrode Lead Set following the color code in Fig. 3.3.

6. Place cap/wrap on Subject's head to press electrodes into scalp (Fig. 3.4).

**Setup continues...**

Place a Lycra® swim cap or supportive wrap on Subject's head to press the VIN+ and VIN-electrodes against the scalp with a constant pressure. Subject should not press electrodes against scalp.
Table 3.1 Typical Frequencies of Synchronized Brainwaves

<table>
<thead>
<tr>
<th>Rhythm</th>
<th>Typical Frequencies (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>alpha</td>
<td>8-13</td>
</tr>
<tr>
<td>beta</td>
<td>13-30</td>
</tr>
<tr>
<td>delta</td>
<td>1-5</td>
</tr>
<tr>
<td>theta</td>
<td>4-8</td>
</tr>
</tbody>
</table>

Alpha

The four basic rhythms have been associated with various states. In general, the alpha rhythm is the prominent EEG wave pattern of an adult who is awake but relaxed with eyes closed. Each region of the brain has a characteristic alpha rhythm but alpha waves of the greatest amplitude are recorded from the occipital and parietal regions of the cerebral cortex. Results from various studies indicate that:

* females tend to have higher mean frequencies of alpha waves than males
* alpha wave amplitudes are likely to be higher in “outgoing” subjects
* alpha wave amplitudes vary with a subject’s attention to mental tasks performed with the eyes closed

In general, amplitudes of alpha waves diminish when subjects open their eyes and are attentive to external stimuli although some subjects trained in relaxation techniques can maintain high alpha amplitudes even with their eyes open.

Beta

Beta rhythms occur in individuals who are alert and attentive to external stimuli or exert specific mental effort, or paradoxically, beta rhythms also occur during deep sleep, REM (Rapid Eye Movement) sleep when the eyes switch back and forth. Notice that the amplitude of beta rhythms tends to be lower than for alpha rhythms. This does not mean that there is less electrical activity, rather which the “positive” and “negative” activities are starting to counterbalance so that the sum of the electrical activity is less. Thus, instead of getting the wave-like synchronized pattern of alpha waves, desynchronization or alpha block occurs. So, the beta wave represents arousal of the cortex to a higher state of alertness or tension. It may also be associated with “remembering” or retrieving memories.

Delta and Theta

Delta and theta rhythms are low-frequency EEG patterns that increase during sleep in the normal adult. As people move from lighter to deeper stages of sleep (prior to REM sleep,) the occurrence of alpha waves diminishes and is gradually replaced by the lower frequency theta and then delta rhythms.

Although delta and theta rhythms are generally most prominent during sleep, there are cases when delta and theta rhythms are recorded from individuals who are awake. For example, theta waves will occur for brief intervals during emotional responses to frustrating events or situations. Delta waves may increase during difficult mental activities requiring concentration. In general, the occurrence and amplitudes of delta and theta rhythms are highly variable within and between individuals.

Electrode positions

Electrode positions have been named according to the brain region below that area of the scalp: frontal, central (sulcus,) parietal, temporal, and occipital. In the bipolar method, the EEG is measured from a pair of scalp electrodes. The pair of electrodes measures the difference in electrical potential (voltage) between their two positions above the brain. A third electrode is attached behind the ear as a point of reference, ‘ground’, of the body’s baseline voltage due to other electrical activities within the body.

In today’s lesson, you will record an EEG using the bipolar method.