

Polysomnographic (PSG) Recording in Humans

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This document describes the use of a PowerLab 400/410 with four Bio Amp front-ends, together with Chart software, to record electroencephalogram (EEG), electromyogram (EMG) and electrooculogram (EOG), necessary for the standard physiological recording of human sleep (polysomnograph). The software package “Chart” provides an inexpensive, yet powerful and adaptive interface to the PowerLab recording unit for doing anything from basic polysomnographic (PSG) recording (as described here) to clinical and research investigations of sleep disorders such as sleep apnoea.

Introduction

As human beings, we spend approximately one third of our lives asleep, yet we know very little about how or why sleep occurs.

Essentially, as we drift off to sleep, our overall brain activity slows down. This is reflected in a general slowing of the frequency of electrical activity of the brain. Depending on the net frequency of our brain’s electrical activity, we are classed as either “awake” or “asleep”. This frequency also indicates our “stages” or depth of sleep, with slower brain frequencies indicating slow-wave sleep stages or “deeper” sleep.

For obvious reasons, we cannot investigate human neural activity using intracellular recording. Another way of investigating neural activity is through the use of external electrodes that measure electrical activity at the level of the scalp. This is known as the Electroencephalogram or EEG. The main advantage of this technique is that it allows non-invasive human studies to be conducted. The method is often referred to as open-field or far-field recording, because the site of the recording electrode on the scalp is receptive to electrical fields from many neurons and is not located at the internal site of any one particular neuron or groups of neurons.

Sleep Recording

Electroencephalogram (EEG)

When two electrodes are attached to the surface of the human scalp and connected to an amplifier, the output of the amplifier reveals variation in voltage over time. This variation in voltage is known as the EEG. The EEG is considered to reflect the sum of many cortical neurons firing independently. The amplitude of the normal EEG can vary between approximately -100 and +100 μV , and its frequency ranges up to about 40Hz.

Originally, sleep was viewed as a passive unitary state. It was assumed that as the brain was deprived of sensory input, it was unable to sustain the wake state. Sleep was simply viewed as the absence of waking, and both states were considered to be externally regulated. German Physiologist, Hans Berger's pioneering measurement of the electroencephalogram (EEG) in the 1930's was accepted as genuine evidence of brain activity when EEG frequency and amplitude changes were consistently correlated with vigilance, drowsiness and sleep periods.

Electrooculogram (EOG)

It was not until 1954, when Aserinsky and Kletman published a physiological description of sleep did modern sleep research gain its current coherence. They showed that polygraph devices could measure electrical changes around the eyes associated with spontaneous eye movement activity together with the EEG electrical changes on the scalp associated with sleep. These researchers found that during sleeping EEG states, sudden eruptions of eye movement activity occurred periodically throughout the night. When subjects were awakened from these periods of sleeping eye movement activity, they reported dreams much more frequently than from periods devoid of this activity. This form of sleep is now known as Rapid Eye Movement (REM) sleep.

Electromyogram (EMG)

From animal work done in the late 60's, Jouvet (1967) and Morrison (Hendricks, Morrison & Mann, 1982) were the first researchers to show that bilateral electrical lesions to the pontine tegmentum area of the brainstem of cats produced a unique consequence during sleep, which was called "Oneiric Behaviour" or "REM Sleep Without Atonia" (REM-A). During EEG & EOG defined REM sleep, cats with such lesions showed behaviors such as, locomotion, jumping, attacking and grooming. This led these researchers to suggest these animals were possibly acting out their dreams! Thus, the role of this part of the brain in animals was proposed to inhibit motor activity during REM sleep, hence the name "REM sleep atonia". In humans, excessive movement during sleep (or REM sleep behaviour disorder) is thought to be related to the functioning of this region of the brainstem.

In standard sleep polysomnography, external electrodes placed at the masseter region measure the electrical activity of jaw muscles. This measurement aids in the detection of REM sleep, as net muscle activity or muscle tone normally decreases during REM atonia. It also acts as a useful indicator of bruxism.

Sleep Stages

After a series research endeavors aimed at polygraphically describing sleep using EEG, EOG and EMG measures, a universally agreed classification of sleep was established. This classification involves five stages: four depths of sleep (Stages 1 to 4) together with REM sleep (Rechtschaffen and Kales, 1968).

When a person closes his or her eyes and relaxes, the EEG characteristically shows a regular pattern of 8-12 vibrations per second (hertz; Hz); these are known as alpha waves. As the individual drifts into Stage 1 sleep, the EEG becomes slower and less regular and is reduced in amplitude with little or no alpha. Stage 2 is characterized by the appearance of spindles, which are short runs of rhythmical EEG waves of 12 to 16 Hz. This stage is also characterized by K-complexes. These are EEG waveforms

lasting about 0.5 second and have a well-delineated negative sharp wave (12-14 Hz) which is immediately followed by a positive component. Stages 3 and 4 are characterized by slow EEG waves (1 to 2 Hz) which are known as delta waves. REM sleep is characterized by an EEG pattern similar to Stage 1, except, in addition, rapid eye movements appear on the EEG record and EMG recordings are of low amplitude. Stages 1-4 are often collectively known as non-REM (NREM) sleep. These stages alternate throughout the night. The deeper stages (3 and 4) tend to disappear in the second half of the night as REM becomes more prominent (Hartmann, 1976). A thorough description and guide to the scoring of sleep stages can be found in Rechtschaffen and Kales (1968).

The following exercise is designed to investigate the physiological changes in EEG, EMG and EOG that can occur during a daytime nap in humans.

Equipment

- PowerLab unit with at least 4 channels
- Chart software
- 4 ML132 Bio Amps with MLA1340 Bio Amp cables
- MLA1090 Electrode cream
- 7 MLA WBT-9 EEG/EMG recording electrodes
- 1 MLAIMÉ earclip earth electrode
- 1 three-way earth-link electrode
- 70% Alcohol preparation & Cotton wool
- surgical tape
- tissues
- water based marker
- a quiet room with a comfortable recliner chair or bed

Setting up the equipment

Ensure all equipment is turned off. Ensure the PowerLab is connected to your computer as outlined in the users manual. Connect the Bio Amps to the PowerLab unit as outlined in the users manual.

Method

EEG Electrode Placement - The 10-20 System

Electrode placement positions are mostly described with reference to the 10-20 system (Jasper, 1958). In this system, the location of an electrode is specified in terms of its proximity to particular regions of the cortex (F-frontal, C-central, P-parietal and O-occipital) and of its bilateral location (odd numbers for left side, even numbers for the right side and 'z' for midline). Thus, 'Pz' defines a midline electrode location over the parietal lobe, while 'F₃' defines a left frontal site. Although these electrode descriptions refer to particular brain areas, it is important to note that activity recorded at any particular scalp site is not necessarily attributable to activity in brain regions in close proximity to that site. This is because the brain acts like a big conductor, meaning that electrical activity generated in one area can be detected at distant locations. See Figure 1

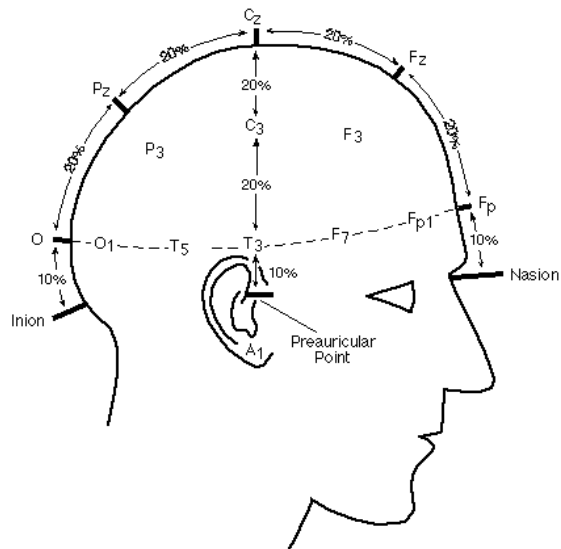


Figure 1. The 10-20 system of electrode placement.

The electrical measurements taken when measuring EEG are known as *differential*. This is because the electrical signal measured is the difference between electrode sites. The differential electrode sites commonly used for sleep recording are A_1 / C_4 or A_2 / C_3 . An earth is also connected to offset 50Hz electrical interference. This electrode is often placed as an earclip on the opposite earlobe.

1. Measure and mark the positions A_1 / C_4 with a marker.
2. Place EEG paste in the electrode cups.
3. Clean each site with 70% alcohol solution, then fix the electrodes with medical tape to A_1 / C_4 and fix the earth to the earlobe.
4. Connect the subject to the patient lead. Ensure the earth electrode is plugged in the green socket marked "earth" on the patient lead.
5. Ask the subject to relax and avoid moving as much as possible.

EOG Electrode Placement

Standard electrode placement for EOG involves placement at the cheek bone toward the outer canthi of each eye, with a common reference at the Fp location as described in the 10-20 system. See Figure 2.

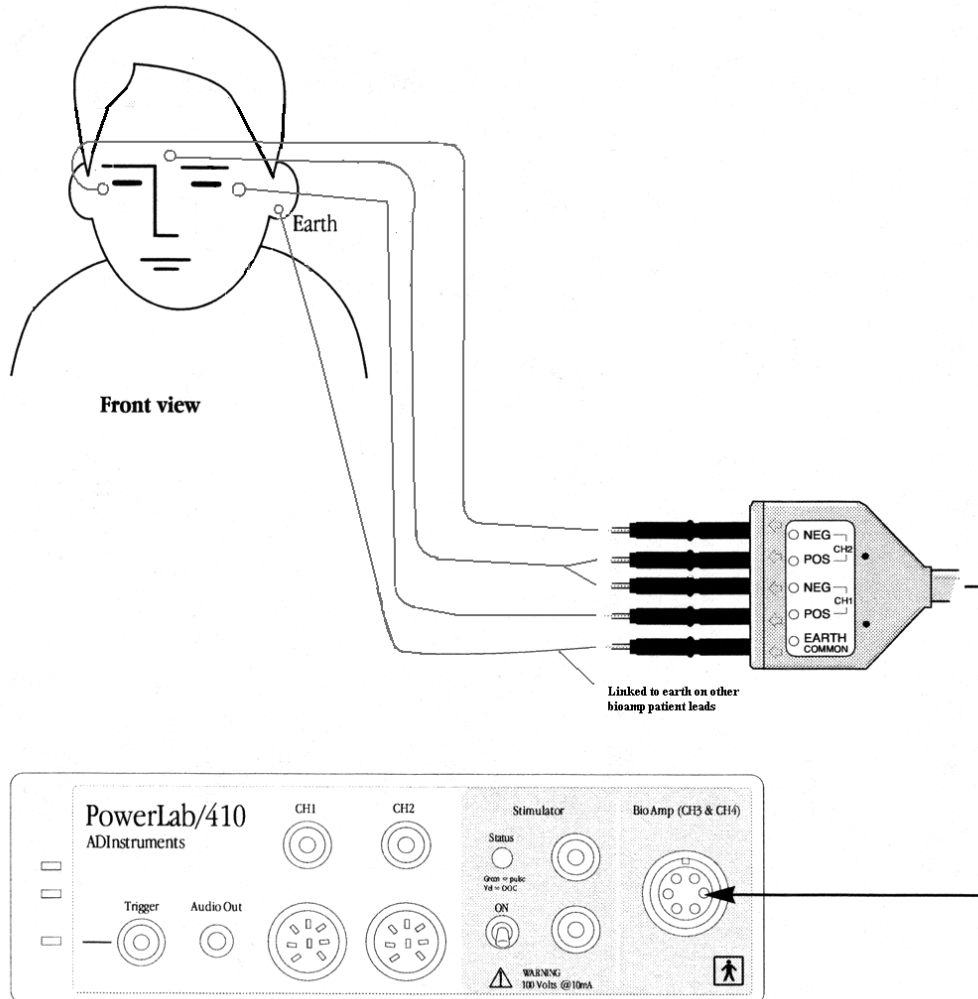


Figure 2. Standard electrode placement for EOG.

EMG Electrode Placement

Standard electrode placement for EMG involves placement near the masseter musculature of the lower jaw. You can distinguish where to place these electrodes by asking your subject to clench their jaw repeatedly. A bulge in musculature along their jaw line will denote best electrode placement site. See Figure 3.

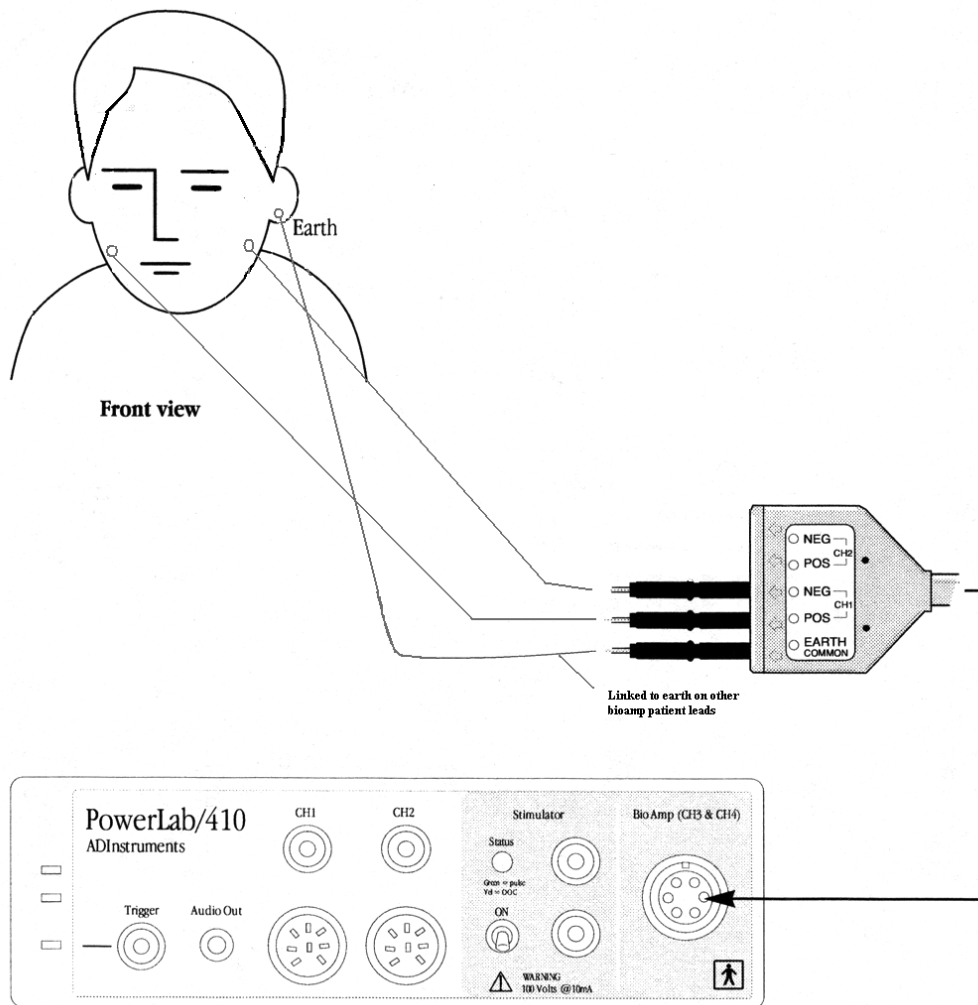


Figure 3. Standard electrode placement for EMG.

Safety

The Bio Amp is specially designed to have no direct electrical connection from the patient to ground. Thus, protecting your subject from any electrical faults. To maintain this patient-isolation, NEVER connect your subject to anything other than the patient lead, which must only be connected to the Bio Amp

Chart Settings

Turn on the sound amplifier, PowerLab unit and computer, in that order. Open Chart. You now need to set up Chart for sleep recording using the Bio Amp. The recommended settings for the Bio Amp are shown in Figure 4.

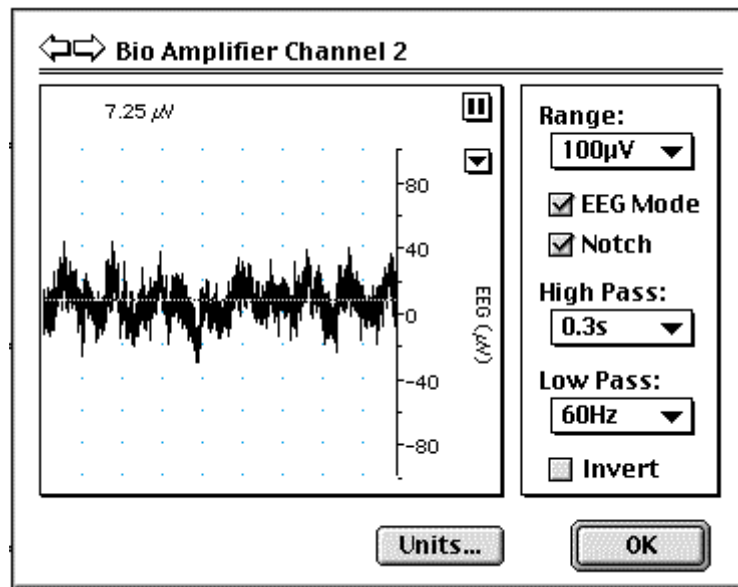


Figure 4. The Bio Amplifier dialog box.

The Bio Amp should have a recording range of 100 μV . Click the Bio Amp button. You are now looking at the ongoing EEG of your subject. Ensure the Notch filter and EEG Mode are selected. A recording range with High Pass at 0.3 sec and Low Pass at 60Hz is best. However, if your signal is noisy (most likely due to a poor connection of electrodes to the subject), you can set the Low Pass filter to 30Hz and still achieve a useful recording. For EMG and EOG, use the same filter settings, but make the recording range wider for EOG (200 μV) and smaller for EMG (50 μV).

Under the ‘Setup’ menu, choose ‘Channel settings’. Set the number of recording channels to four. Set the recording ranges as above. You can label each channel under the ‘Title’ heading. Ensure the sample rate of EEG is at least 400/s and the others are at least 20/s. You can set the colour of each trace under the “Colour” heading. See Figure 5.

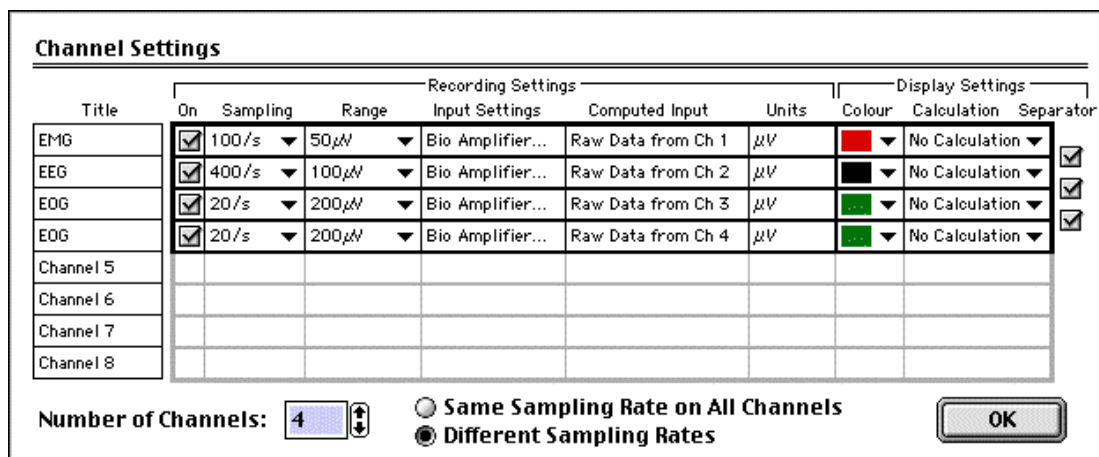


Figure 5. The Channel Settings dialog box.

With a 14” monitor, the clearest display for sleep scoring is with the Chart display set at a ratio of 10:1. This adjustment is made in the bottom-right corner of the Chart

recording window. This setting gives about 12 secs of recording display at any one time, with 0.5 sec dotted chart divisions. But primarily it gives a display of approximately 10mm = 50 μ V (vertical) and 10mm = 1 second (horizontal). These dimensions are equivalent to those used in the Rechtschaffen & Kales (1968) scoring manual. If you have a different sized monitor, you will have to adjust the display settings in chart to best approximate this display scale.

With your subject set up with electrodes to record, EEG, EMG & EOG, and your Chart software set up to record sleep data from your PowerLab, you are now ready to record human sleep.

Sleep Recording using Chart

1. Provide the most quiet and sleep-conducive environment as possible. Ideally, you and your computer equipment will be outside the room where your subject is sleeping. Therefore, a long USB or SCSI lead between the PowerLab unit and the computer is recommended.
2. Click 'Start' on the bottom right hand corner of the Chart screen.
3. To confirm you have connected your subject correctly, it is best to do some simple calibration procedures. First, ask your subject to move their eyes from left to right. You should see clear changes in your EOG recording denoting eye movements. Ensure the eye movement traces are recording in opposite polarity. This is so you can later distinguish between true eye movements and EEG artifact on the EOG trace. Next, ask your subject to clench their jaw repeatedly. Clear activation of the EMG trace should be visible on the 'Chart' record.
4. Ask your subject to relax, lay down and try to sleep. Ask him/her to try to ignore the wires as much as possible. Figure 6 is an example of the EMG, EEG and EOG recording, with opposite-polarity EOG traces and EMG jaw activity.

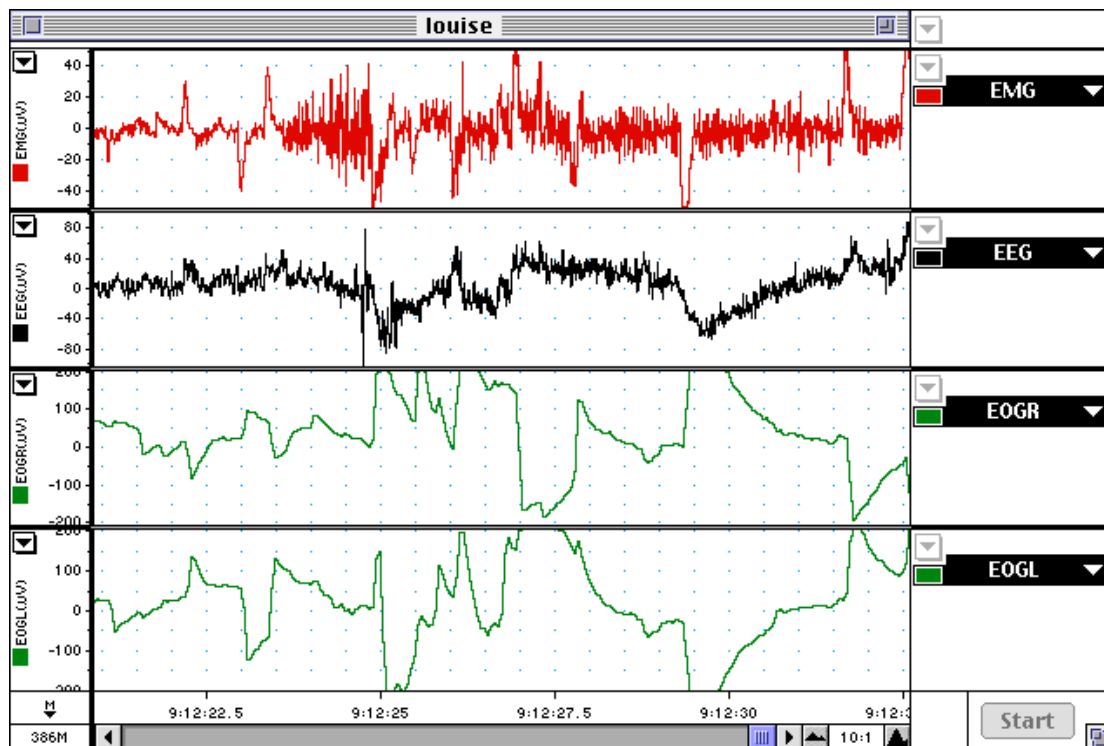


Figure 6. PSG of an awake subject with EMG jaw activation and eye movements.

Examples of PSG Sleep Records

As a person closes their eyes and begins to relax, alpha frequency EEG (8-12 Hz) dominates the awake EEG record (Figure 7).

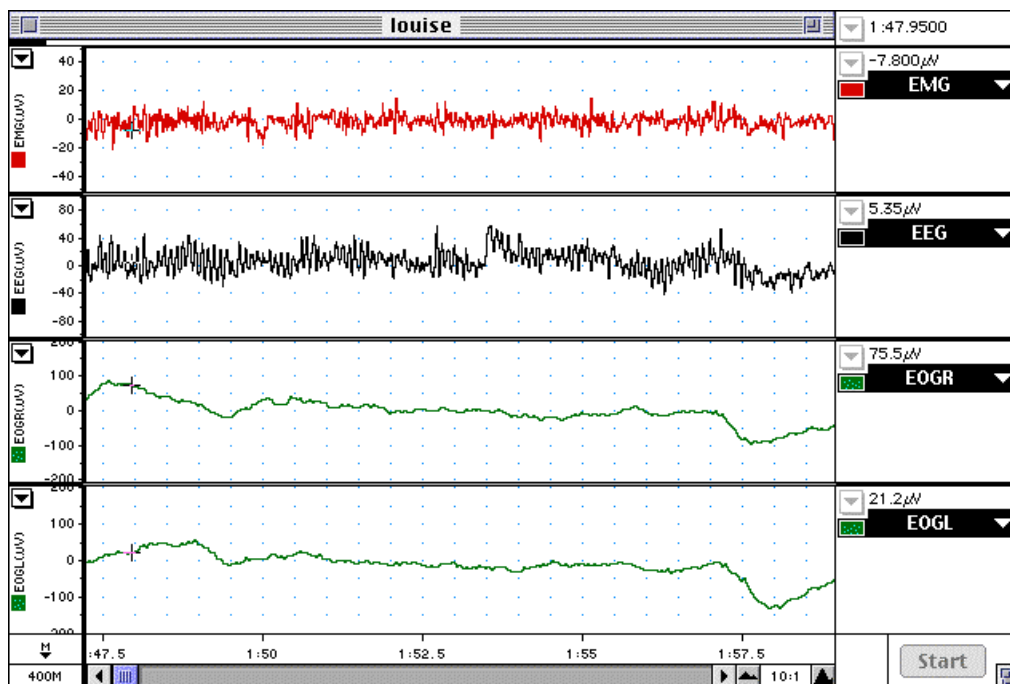


Figure 7 – Awake. Eyes closed and drowsy. Alpha frequency dominates the EEG record.

As the individual drifts into Stage 1 sleep, the EEG becomes slower and less regular and is reduced in amplitude with little or no alpha. Slow rolling eye movements can often be seen on the EOG record. (Figure 8).

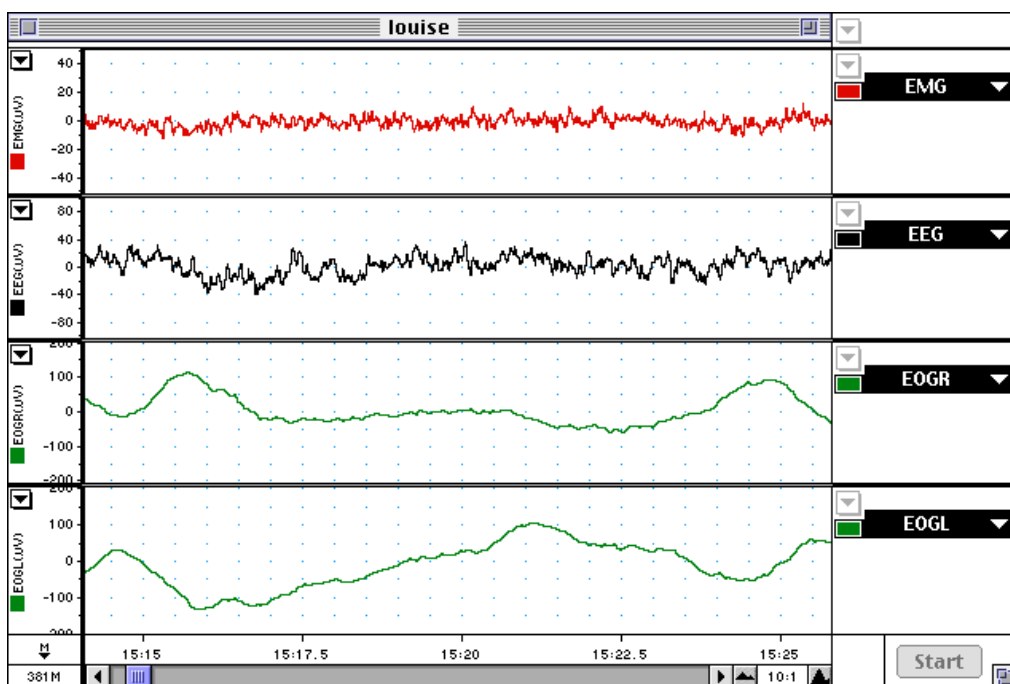


Figure 8 – Stage 1 sleep. Alpha frequency EEG is no longer present. The EEG is now a lower frequency and amplitude than when awake. Slow rolling eye movements can be seen

on the EOG traces.

Stage 2 is characterized by the appearance of spindles, which are short runs of rhythmical EEG waves of 12 to 16 Hz. This stage is also characterized by K-complexes. These are EEG waveforms lasting about 0.5 second and have a well-delineated negative sharp wave (12-14 Hz) which is immediately followed by a positive component. A K-complex followed by spindle activity is highlighted in Figure 9.

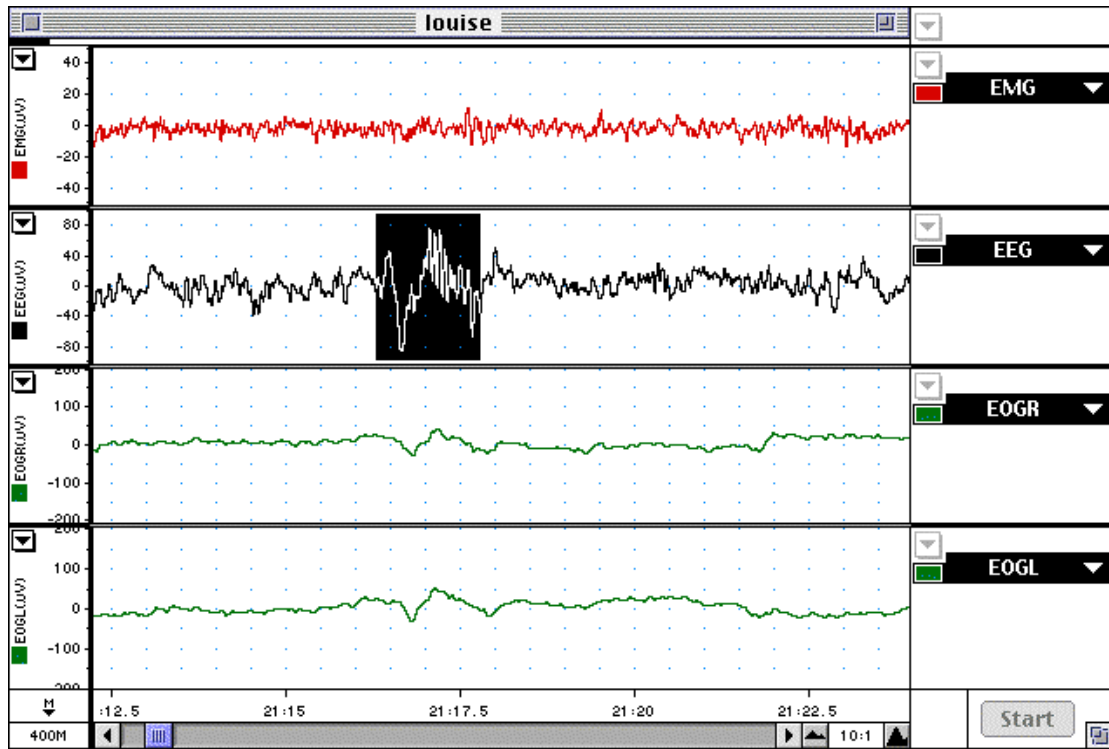


Figure 9 – Stage 2 sleep. K-complexes and spindles now appear on the EEG record (highlighted).

Stages 3 and 4 are characterized by slow EEG waves (1 to 2 Hz) which are known as delta waves. Stage 3 has at least 50% of a 30 second record denoted by delta waves, whereas Stage 4 requires at least 75% of the record to be delta activity. These stages are shown in Figures 10 and 11, respectively. Notice the EOG artifact occurring in synchrony with the delta activity. The EOG trace will often record the high amplitude synchronous EEG activity as artifact. However artifact is easily distinguished as parallel traces, whereas binocular eye movements are calibrated to record as opposite polarity traces (cf. Figure 6 to Figures 10 & 11).

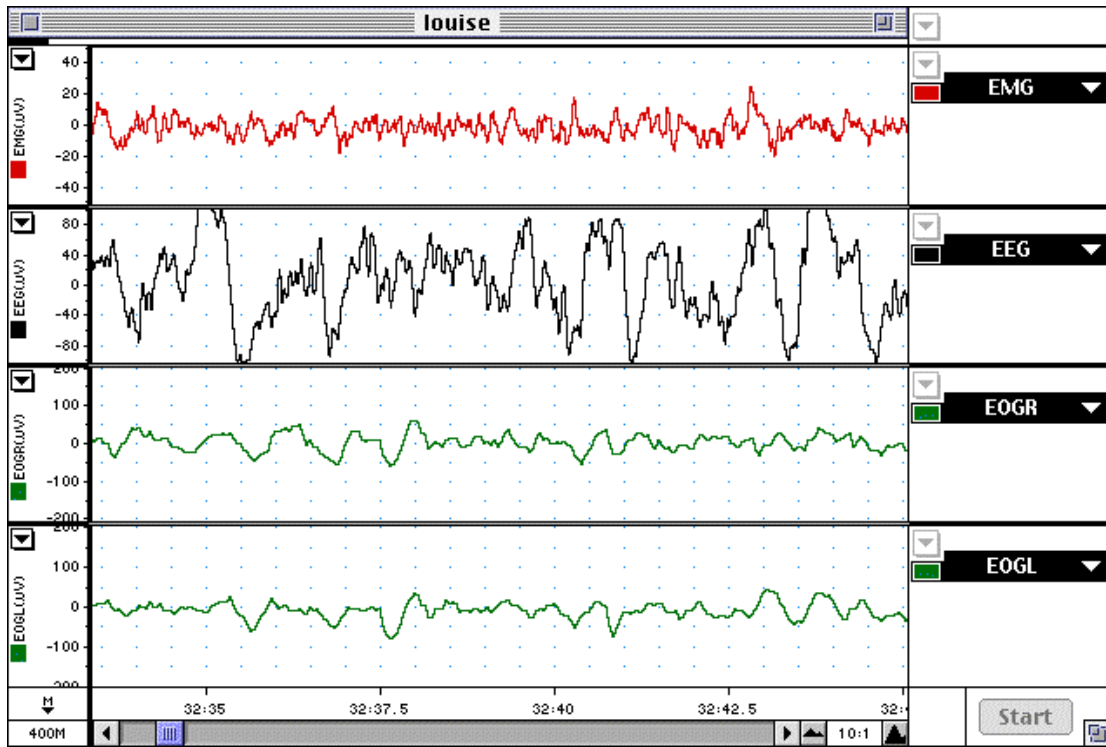


Figure 10 – Stage 3 sleep. Delta waves (1-2 Hz) now represent at least 50% of the EEG trace. Parallel EOG traces represent EEG artifact.

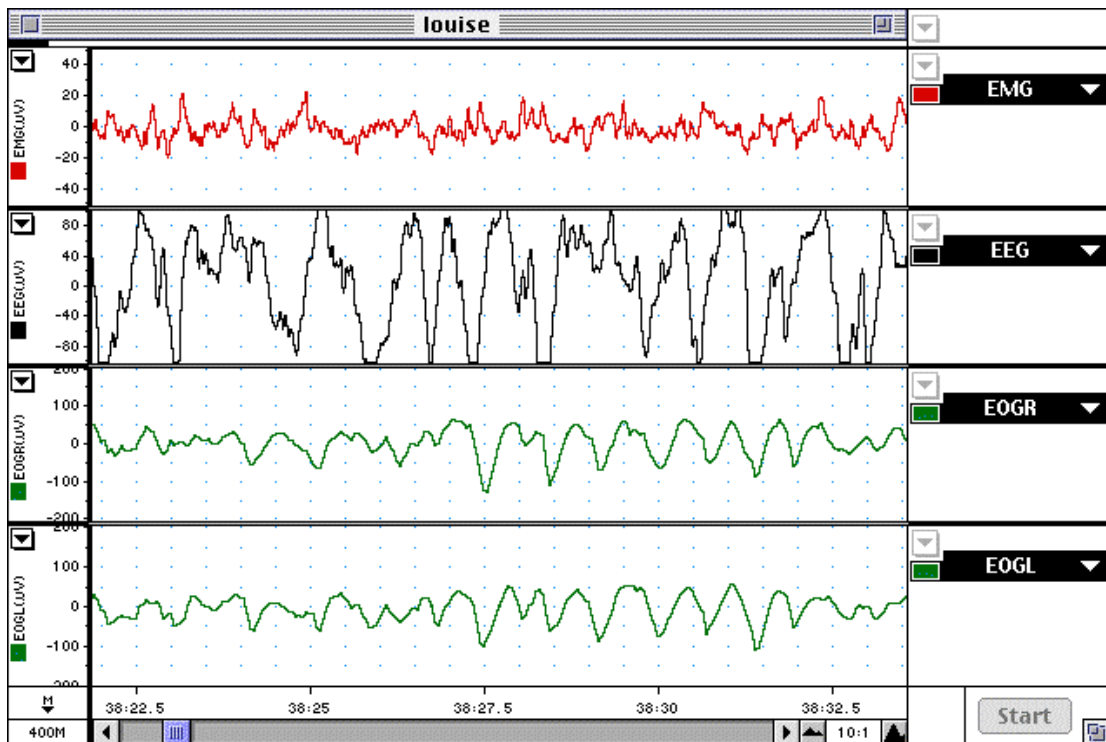


Figure 11 – Stage 4 sleep. Delta waves (1-2 Hz) now represent at least 75% of the EEG trace. Parallel EOG traces represent EEG artifact.

REM sleep is characterized by an EEG pattern similar to Stage 1, except, in addition, rapid eye movements appear on the EEG record and EMG recordings are of low amplitude. See Figure 12.

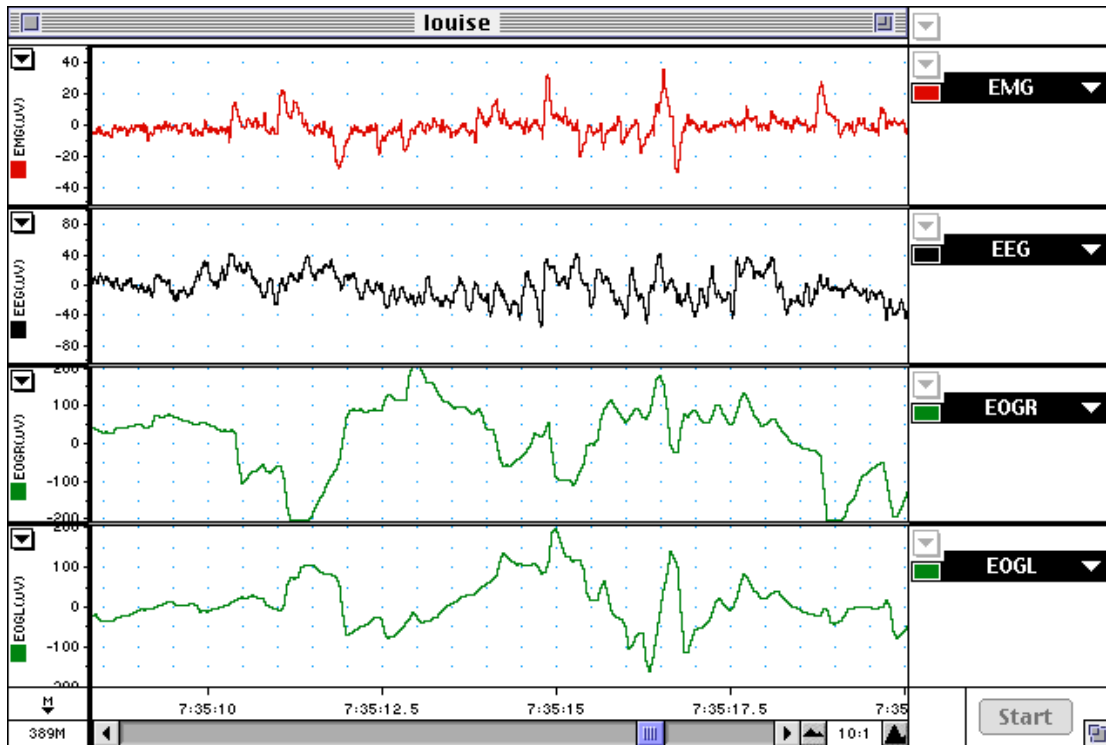


Figure 12 – Rapid Eye Movement (REM) sleep. REM sleep is characterized by an EEG pattern similar to Stage 1, except, in addition, rapid eye movements appear on the EEG record and EMG recordings are of low amplitude. In this trace, large EMG muscle twitches are prominent.

Spectral Analysis

Another useful feature of 'Chart' for sleep PSG is the 'Spectrum' program extension. This allows Fast Fourier Transform (FFT) spectral analysis of the EEG data you collect. Figure 13, below is a spectral analysis of a waking period from sleep. Note the peak in EEG alpha frequency range (8-12 Hz) indicating arousal.

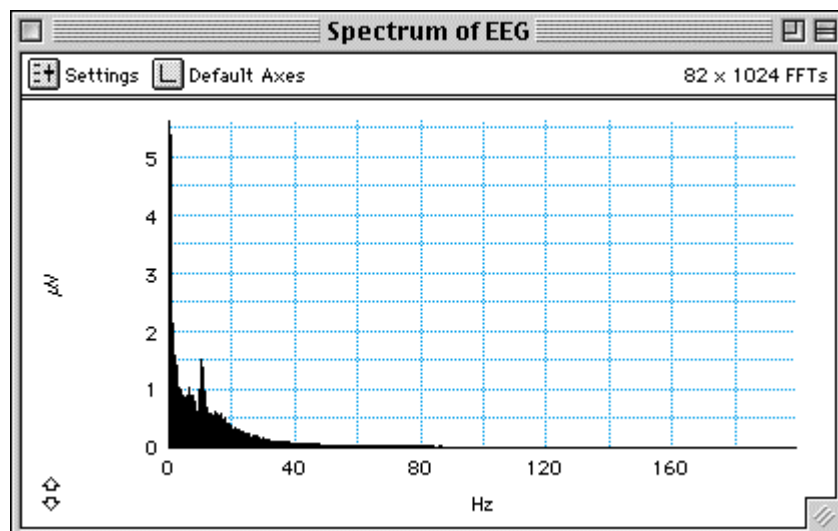


Figure 13. A spectral analysis of a waking period from sleep.

Further Investigation

Dreaming: Try waking your subjects from REM sleep versus other stages. You should observe vivid dream reports, mainly from REM. Subjects woken from Stage 2 will often be quite adamant that they were awake!

Sleep and aging: Compare the amount of REM sleep in older and younger subjects. REM sleep declines with age (Hartman, 1967).

Other physiological measures: If you are lucky enough to have more channels (PowerLab S-Series: 8s or 16s), you can also measure a variety of other physiological variables. Pulse, Blood Pressure and temperature variation during REM can be measured using the MLT1010 pulse transducer, ML117 BP Amp and MLT409 skin temperature transducer. GSR eruptions during Stage 3 & 4 sleep can be measured using ML116 GSR Amp.

Sleep Apnea: Try to collect overweight, male subjects over 40, who snore and have daytime sleepiness. You can measure abdominal / chest respiratory effort during sleep using the MLT1132 piezo respiratory transducer, airflow with the MLT415 nasal airflow transducer, and respiratory gasses using the ML205 gas analyser with spirometer kit (MLA140). People showing Obstructive sleep apnea (OSA) will show a flattening of the nasal airflow trace with decreasing O₂ and respiratory effort still present. People with central sleep apnea will show a flattening of respiratory effort and airflow with O₂ fallout. If you do observed sleep apnea in a subject (and chances are you will in overweight males over 40 who snore), refer them to their local general practitioner.

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