A New Hands-on Laboratory Course for Teaching Neurosciences Using the Students Electrophysiology Signals

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Abstract

Neuroscience is a rapidly growing field, helping to create new drugs and technologies to cope with an aging population and understand neurological diseases and processes. New innovative, affordable teaching tools are required to train a new generation of researchers for these high-tech 21st Century jobs. An innovative Neuroscience laboratory course was developed to integrate wireless electrophysiology systems with a hands-on learning approach where the students can evaluate their own neurological signals. It allows Neuroscience programs to rapidly expand laboratories to accommodate larger incoming class sizes, with minimal staff training and without new facilities. A personal computer and the lab course kit are the only needed equipment, minimizing the requirements on the department. The compact, wireless system can turn any setting into a laboratory.

Introduction

The **National Science Foundation** recently reported that engineering education should include "integrative laboratory experiences that promote inquiry, relevance, and hands-on experience" [1]. The **Tulane BME study** reported that students preferred to receive information visually (preferred by 88% of the student sample) rather than verbally, focus on sensory information (55%) instead of intuitive information, process information actively (66%) instead of reflectively, and understand information globally (59%) rather than sequentially [2]. This course was designed to incorporate all of these learning preferences.

With bioinstrumentation hardware and transducers, students are educated on instrumentation, neuro-electrophysiology and clinical applications. Labs are designed for both undergraduate and graduate students and are available in both English and Spanish. Students perform each lab using the wireless 12-channel data acquisition monitor, sensors and transducers, and included software. The monitor self-programs appropriate gains, resolutions, and sampling rates for each lab to simplify student setup. Real-time or saved data can be output to MATLAB, LabVIEW, ASCII, Excel, or other third party applications for custom analysis.

CleveLabs is a third generation teaching tool, taking the experiments off the lab bench and putting them into real life. The monitoring device is small, wearable, battery powered, and wireless, making the student untethered, replacing the artificial scenario of monitoring a person sitting at a desk with real-world monitoring, and allowing students to monitor themselves while participating in physical activity (Fig 1). A database of seizure activity allows the student to view abnormal signals as well as normal EEG data. Clinical labs provide hands-on experience that will help them become researchers and medical facility technical leads.

CleveLabs provides 31 laboratory sessions.
Schools may present or omit selected sessions to fit their curriculum. (*2007 new labs in italics.*)

Basic Data Principles	**Advanced Physiology**
Data Acquisition Basics	Blood Pressure
Digital Signal Processing	Electromyography II
Statistical Analysis	Electrocardiography II
Image Processing*	Electroencephalography II
Wireless Medical Telemetry	Polysomnography
Breadboard Circuit Design	*Pressure Based Airflow*
Accelerometry	*Pulse Oximetry*
Post-Processing Toolbox	Speech Recognition
	Spirometry
	Biomechanics
Basic Physiology	**Clinical Applications**
Biopotential Basics	Alertness Detection
Electrocardiography	Biofeedback
Electroencephalography	Environmental Controls
Electromyography	Gait Pattern Recognition
Electrooculography	Heart Rate Detection
Respiration	Motor Control
	Student Designed Lab

*Available as an option

CleveLabs provides 15 neuro laboratory sessions.
This list provides the recommended one semester Neuro Lab Curriculum (15 labs)

Basic Data Principles	**Advanced Physiology**
Data Acquisition Basics	Electromyography II
Digital Signal Processing	Electro-encephalography II
Post-Processing Toolbox	Polysomnography
Basic Physiology	**Clinical Applications**
Biopotential Basics	Alertness Detection
Electro-encephalography	Environmental Controls
Electromyography	Gait Pattern Recognition
	Motor Control
	Student Designed Lab

Methods

Fifteen neurological labs are available for teaching a three-hour laboratory course for one or two credits. **Data Basics** are taught in four labs: Data Acquisition Basics, Digital Signal Processing, Statistical Analysis, and a Post-Processing Toolbox that the students use to process saved data. **Basic Physiology** is taught in three labs: Biopotential Basics, Electroencephalography I, and Electromyography I. **Advanced Physiology** also has three labs: Electromyography II (EMG versus force), Electroencephalography II (seizure analysis), and Polysomnography (PSG, sleep testing). Finally, five **Clinical Applications** labs include: Alertness Detection, Environmental Controls, Gait Pattern Recognition, Motor Control, and a Student Design Capstone Lab. The PSG lab acquaints students with electrocardiogram (ECG), electro-oculogram (EOG), airflow, respiration effort, and oximetry. Sixteen other labs (for a total of 31) are also included.

A. Advanced device design

Increased home monitoring and the ubiquity of tiny untethered medical devices are changing the world of medicine.

The CleveLabs physiological laboratory course utilizes the BioRadio® 150, a lightweight, wireless physiological monitor with **12 physiology channels**:

- 8 programmable channels for **EEG**, **EMG**, **EOG**, **ECG**, & **respiratory effort**
  - Programmable for
    - input range,
    - sampling rate,
    - resolution,
    - AC or DC coupling
- Pulse oximetry
- Airflow
- Accelerometry (2-axis)
- Slow DC input

Subject worn unit amplifies, digitizes, and telemeters data to a computer located up to 100 feet from the subject. Computer unit connected to the student computer via a USB port receives the telemetered data. This hardware platform exposes students to state-of-the-art technology vs. traditional rack/table mounted equipment.

The BioRadio's wireless design removes cumbersome tethered leads and increases the flexibility of potential locations and applications (Fig 2). Previously, only a 900 MHz. system was available. New this year, a **2.4 GHz Bluetooth** system allows CleveLabs to be used in Europe, Asia, and Africa. Furthermore, the new BioRadio 150 can use a 4 GB SD removable memory card to allow days of data to be recorded and viewed at a later time. This allows the student to monitor himself or herself during a marathon, round of golf, football match or similar activities that are out of the traditional lab, ward or home use of the device. This can be particularly exciting for students when conducting their "Student Designed Capstone Lab" at the end of the course. Using devices that have the same look and feel of clinical devices is extremely important in providing a valuable education (Fig 3).

B. Databases of abnormal data prepare students to identify diseases

The EEG II lab shows different seizures. The ECG II lab shows arrhythmias such as atrial fibrillation and flutter; ventricular tachycardia, bigeminy, trigeminy, and flutter; sinus bradycardia and others. This allows the student to view these abnormal conditions and compare them to their own heart signals.

C. Experience in real clinical applications made simple

Providing a significant focus on the diagnosis and treatment of disease allows health sciences students to prepare for a career in the medical field (Fig 4). Giving the students a laboratory experience in diagnostic techniques on growing new fields such as biofeedback, gait analysis, alertness, motor control, and biomechanics gives the students an advantage when entering the job market.

Figure 2 The BioRadio is easy to take outside for sports analysis or even to teach classes outdoors.

Figure 3 BioRadio (left) provides training that makes the use of the Crystal Monitor, SleepScout, and Sapphire learning seamless.

Discussion

The CleveLabs system has been implemented at dozens of universities around the globe, from Malaysia to the UK. Many universities, including the **University of Southern California**, the **University of Toronto**, **Case Western Reserve University**, and **Lake Forest College** have used the labs to teach students from an introductory level to the 600 graduate level. A Spanish version is also available for Spanish-speaking countries.

Positive feedback was obtained after the course was integrated into the curriculum at several universities. Students enjoyed being able to move around while monitoring themselves. The modular format provided course flexibility. Additional flexibility was achieved by using the BioRadio 150 drivers for third party software development (**MATLAB**, **LabView**) to create new labs (Fig 5).

The flexibility of the course allows it to be used from high school to graduate school. Upper level students are expected to design detection and control algorithms to gain experience in problem solving and troubleshooting.

Finally, the BioCapture and BioCapture Pro products provide additional research grade software, allowing the CleveLabs BioRadio 150 hardware to be used for research, precluding the need for repurchasing similar equipment for other projects.

Figure 1 The CleveLabs lab course and BioCapture research tool provide all the hardware, software, and accessories the university needs to start non-invasive human neurological tests.

Results

Wide-ranging laboratory topics introduce students to several basic scientific principles, physiological basics, advanced physiology, and clinical applications. Initial laboratory sessions introduce physiological mechanisms underlying the recorded signal, teach students how to acquire data from themselves, and demonstrate effective signal processing. Intermediate sessions introduce abnormal clinical signals. Later sessions apply the signal in a clinical application. Each laboratory incorporates detailed setup instructions and user-friendly features for saving, analyzing, and reporting results. Students process and analyze signals both in real-time and offline. The laboratory course minimizes overhead time associated with hardware setup, equipment troubleshooting, and data management, while maximizing the time spent critically analyzing and applying data. Finally, the course integrates learning styles shown effective for most BME students including active, sensing, visual, and global learning [2].

Conclusion

The CleveLabs Health Science Laboratory Course allows universities to provide hands on lab instruction allowing the students to view their own neurological signals in real world situations. It does not require any special laboratory facilities. It is designed to provide everything the instructor needs, requiring no additional training. The manual has all the labs ready to go "straight out of the can."

Figure 4 CleveLabs prepares students for careers in the medical field.

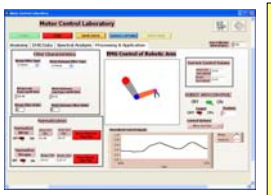

Figure 5 Labview software makes the data easy to visualize and manipulate, and allows the experiment to be easily modified to meet the needs of individual university programs.

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