A LabVIEW™-Based Ergonomics Workstation to Monitor the Mental Workload of Performing Surgery

by
Warren D. Smith, Ph.D.¹, Yi-Hung Chung, M.S.², Ramon Berguer, M.D.³
¹Coordinator, Biomedical Engineering Program
²Biomedical Engineering Program, California State University, Sacramento
³Department of Surgery, University of California, Davis Medical Center

Category:
Biomedical

Products Used:
LabVIEW 5.0
DAQCard™ 700

The Challenge:
Modern minimally invasive surgical techniques are better for the patient but are physically and mentally demanding on the surgeon. Ergonomic studies of surgeons at work are needed to develop surgical instruments and methods that reduce the workload of performing minimally invasive surgery.

The Solution:
We used LabVIEW 5.0 on a laptop computer with a DAQCard 700 to develop a portable ergonomics workstation to monitor skin conductance, forehead electroencephalogram, electromyogram, and electrooculogram activity as indicators of mental workload. We then used the workstation at an international conference to study 28 surgeons as they performed surgical tasks.

Abstract
Modern minimally invasive surgical techniques are better for the patient but are physically and mentally stressful for the surgeon. We used LabVIEW on a laptop computer to create a portable ergonomics workstation to monitor the mental workload of performing surgery. The workstation monitors skin conductance, forehead electroencephalogram and electromyogram activity, and the electrooculogram. The workstation displays and saves the raw waveforms and the results of FFT-based power spectral analysis. We used the workstation to study 28 subjects while they performed simulated surgery. We found that the mental workload of minimally invasive surgery is significantly greater than that of traditional surgery.

Introduction
Modern, minimally invasive video-endoscopic surgery (VES) techniques reduce patient discomfort and recovery time. However, VES, with its awkward instruments and limited video image of the operating field, is physically and mentally demanding on the surgeon.¹ Ergonomic studies are needed to learn how to reduce the stresses on the surgeon.² We are utilizing the versatility and power of LabVIEW (Laboratory Virtual Instrument Engineering Workbench) and National Instruments™ data acquisition hardware to create custom virtual instruments (VIs) to investigate the ergonomics of performing surgery.³-⁵ The present study describes the development and application of a new LabVIEW-based ergonomics workstation for the study of surgeons’ mental workload.

Methods
We constructed a portable, ergonomics workstation to monitor the mental workload of performing surgery by using LabVIEW 5.0 software (National Instruments, Austin, TX) on a 5300c PowerBook laptop computer (Apple Computer, Cupertino, CA) equipped with a DAQCard 700 PCMCIA acquisition card (National Instruments). The system measures a subject’s tonic skin conductance level (SCL) as an indicator of mental stress level and electrooculogram (EOG) and frontalis electroencephalogram (EEG) and electromyogram (EMG) activities as indicators of mental concentration level.
We use custom-built, battery powered, electrically isolated analog circuitry to prepare the physiological signals for the DAQCard. To measure SCL, we apply a stimulus current limited to 10-A between a pair of self-adhesive silver/silver chloride Physiotrode electrodes (Futurehealth, Trevose, PA) gelled with K-Y Jelly (Ortho Pharmaceutical, Raritan, NJ) on the ulnar edge of the subject’s right palm. We then feed signals proportional to the electrode current and voltage to two channels of the DAQCard 700. We measure combined frontalis EEG and EMG activity between a differential pair of self-adhesive, pregelled, silver/silver chloride electrodes (Multi Bio Sensors, El Paso, TX) on the forehead at the Fp1 and Fp2 sites of the 10-20 electrode system, referenced to electrically joined earlobe electrodes. We measure EOG activity differentially between the Fp2 electrode and another Multi Bio Sensors electrode over the right zygomatic bone, again referenced to the earlobes. We amplify (gain of 40,000) and filter (-3 dB at 1 Hz and 40 Hz) the EOG and frontalis signals and feed them to two additional channels of the DAQCard 700.

The LabVIEW VI samples each of the four channels at 200 Hz and displays 1-s updates of the signals for quality control. The VI computes SCL values (in micromhos or Siemens) as the ratio of peak-to-peak values of current to voltage. The VI also computes and displays the power spectral density (PSD) versus frequency of the frontalis signal for 3-s epochs and extracts PSD band powers for the delta (1.0-3.7 Hz), theta (4.0-7.7 Hz), alpha (8.0-13.7 Hz), and beta (14.0-29.7 Hz) frequency bands. The VI displays trend plots of the frontalis band powers (3-s update interval), raw EOG (200-Hz update rate), and SCL (1-s update rate). The VI saves all raw data and computed SCL and PSD band power values to disk.

With approval from the California State University, Sacramento Committee for the Protection of Human Subjects, we used the LabVIEW ergonomics workstation to study 28 volunteer surgeons at the international conference of the Society of American Gastrointestinal Endoscopic Surgeons (SAGES) in San Antonio, TX, March 24-27, 1999. We asked each subject to tie suture (Ethicon, Somerville, NJ) knots for 2 min. using traditional open surgery techniques and then using VES techniques. For the latter, the subjects used a VES station (Olympus America, Melville, NY) with an endoscopic video display, a laparoscopic trainer box (Karl Storz Endoscopy - America, Culver City, CA), and laparoscopic needle drivers (Karl Storz Endoscopy - America). We asked each subject to self-rate the levels of mental concentration and stress. We counted the number of knots tied and eye blinks and computed average values of SCL, the frontalis band powers mentioned previously, and a gamma band power (30.0-39.7 Hz). We made statistical comparisons using the two-sided Wilcoxon matched pair signed-rank test at a level of significance of 0.05 without Bonferroni correction.

Results

Figure 1 shows the LabVIEW VI ergonomics workstation in use at the 1999 SAGES conference. A surgeon at left is standing at the VES station and patient simulator trainer box. The VES monitor at left displays the endoscopic video camera view of the operating field inside the “patient.” The ergonomics workstation electronics and laptop computer are on the table in the center. A large computer monitor at right displayed the front panel of the VI for viewing by conference attendees. Figure 2 shows a surgeon, with recording electrodes attached, using VES techniques to tie suture knots. Figure 3 shows a portion of the LabVIEW VI front panel with 2-min. trend plots of PSD band powers (upper two charts), EOG (third chart), and SCL (bottom chart) during knot tying. The figure shows increases in frontalis and EOG activities and SCL during the task.

In the SAGES study, we found significant increases in skin conductance level, number of eye blinks, and frontalis activity for VES compared with open surgery techniques, indicating significant increases in the surgeons’ levels of mental stress and concentration. Significant increases in the subjects’ self-ratings of stress and concentration with VES techniques confirmed these findings.
Conclusions
We found that with LabVIEW and the National Instruments DAQCard 700, we could rapidly convert a commercial laptop computer into a portable, yet sophisticated ergonomics workstation that let us carry out a study of the mental workload of performing surgery at an international conference. The workstation was quick to set up and convenient to use. We collected a large amount of meaningful ergonomic data in a short time because of the workstation’s custom design and power and because we could take it to a site where there were many willing surgeon subjects.

Figure 1. The LabVIEW VI Ergonomics Workstation in Use at the 1999 SAGES Surgery Conference.

Figure 2. A Surgeon Using VES Techniques to Tie Suture Knots at the 1999 SAGES Surgery Conference.
References