

Chapter 15

Human Mastication Project Laboratory

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Introduction

The human mastication exercise has traditionally been the last of three modules which comprise a one-semester Neuroscience Project Lab designed for juniors interested in doing independent undergraduate research and considering entering a Ph.D. program. The class meets for 5 hours twice a week. The purpose of the project is to provide a structured experience in which students can design and implement a set of experiments. Each student is also asked to write an NIH-type research grant. The students are charged with selecting a research project that falls within the area of the neural control of chewing. The repetitive pattern of jaw movements during mastication is fairly simple so that it lends itself to both a kinematic and an electromyographic analysis. Of equal import, the familiarity of the behavior makes it easier for the students to generate creative questions.

At the beginning of the course, some 10 weeks before the module begins, each student is handed several background review articles, a full NIH RO1 proposal packet, and required to take a 1-hour course in the medical school library which qualifies them to use the National Library of Medicine (NLM) on-line reference database. Dates are set for discussing possible projects with the instructor and for submission of a draft of each section of the grant. The beginning of the human mastication module is the deadline for turning in all sections of the proposal with the exception of the “Progress Report/Preliminary Studies.” During the first session each student gives a 10-minute oral presentation (followed by class discussion) describing their proposed project. At the end of the module students resubmit their proposal with a completed Preliminary Studies section based on the findings obtained during the five weeks of the project. Students are encouraged not only to add the new section, but to update the rest of the proposal in light of their actual methodology and results.

All final proposals are copied and distributed to each student for a “mock” 3-hour session modeled after an NIH Study Section. The study section, which is the last class meeting, is an important component of the module. As the students prepare and then verbalize their formal critique of classmates’ projects, they tend to also identify strengths and weaknesses in their own work.

To fulfill the specific aims of the research projects, the general objectives of most students include the identification and quantification (EMG amplitude, frequency and phase) of jaw opening and closing muscle patterns during mastication. This data is directly linked on a frame-by frame basis to videotaped kinematic data of jaw movements using the Mac/LabView virtual instrument system. Specifically, the students are able to display on the computer monitor any part of the EMG record and by clicking a button on the screen have the computer directly access the correlated video record with an accuracy of 1/30 of a second. Conversely, students can use the Mac/LabView interface to move through the video record and, at any desired point on the videotape of jaw movements, simply “call up” the correlated EMG record. Tools built into the LabView interface facilitate parametric analysis of the masticatory cycle and provide a means for storage of data files for subsequent statistical analysis.

Note: While the program has been designed to acquire correlated EMG and kinematics, it is possible to run the Human Mastication Project Lab software without video capabilities and thus substantially decrease setup costs. In fact, the goals of the lab can be fulfilled using *any* available equipment capable of recording surface EMGs and following the Project Schedule as presented in the Student Outline.

Materials

Recommended materials for each two student station:

Macintosh computer (must have two available Nubus slots)
 National Instruments NB-MIO16X series data acquisition board
 National Instruments DMA board and RTSI bus cable
 National Instruments BNC adaptor board
 LabView software
 Custom LabView “virtual” instruments (available from the author)
 Four-channel differential amplifier
 Oscilloscope (optional)
 Surface EMG electrodes (9)
 Disposable electrode adhesive collars (200)
 Redux paste
 BNC cables

If you plan to use correlated video:

NEC PC-VCR SVHS video recorder with computer interface
 Video camera and tripod
 Video monitor
 Strobe light
 Squib
 High-gain DC amplifier
 Videotapes, T-120 S-VHS (blank) (2)

If you plan to use split-screen video add:

Second video camera and tripod
 Video distribution amplifier
 Video split-screen generator

Student Outline

Introduction

The purpose of this module is to design a set of experiments and thus gain experience with each step of the scientific enterprise from background library research, to outlining a feasible project, to writing a grant proposal, through data collection, analysis, and final presentation of results. Your project will focus on some aspect of the neural control of chewing in humans.

Mastication is controlled by a central pattern generator (CPG). That is, there is a network of neurons within the central nervous system (CNS) that produces and coordinates the activation of jaw muscles during chewing movements. While the basic pattern or rhythm of CPGs can be produced in the absence of sensory feedback, sensory information plays an important role in shaping and refining the motor output. Motor patterns controlled by CPGs are also subject to modification by other ongoing behaviors and physiological functions.

You will be provided with equipment to record electromyographic (EMG) activity from up to four jaw muscles and to correlate this muscle activity with videotaped records of jaw movements during chewing. If the project you design requires additional equipment, be sure to talk to your instructor well in advance of the module's start date. As soon as possible, you should start studying the provided review articles and sample research papers (see Appendix A) to get your "feet wet."

How do I pick a project? The two things you will need to pick a project are your brain and the library. Think about mastication. What is actually happening when you chew? As you chew your food, is the pattern of mastication changing over time? Does the placement of food in your mouth change as you chew it and what factors influence food positioning? Do you always chew the same way? If not, what conditions cause your pattern of chewing to change? Do you chew the same way your roommate chews? Once you have thought about chewing, identify a set of questions that are of interest to you, that is, "I wonder why (if) when we chew....." To help get you started, you will be provided with some samples of past projects (Appendix B).

Now, with question in hand, head for the library and see if somewhere in the 20,000 journal articles submitted to the National Library of Medicine (NLM) database per month, you can find an answer to your questions. If you can't, you are on your way to identifying your project. Look for related studies and topics, and, using these studies as a model, begin to formulate a *testable* hypothesis. But, what if you find a research study that answers your question? *Congratulations!* Isn't answering questions what science is all about? Instead of being depressed that someone beat you to the punch, use the study as a starting place. Critique the paper carefully and see how the study can be improved or extended. Most good scientific studies not only answer questions, but they suggest new avenues of inquiry.

Project Schedule

Note: You should be preparing for the Human Mastication Lab while the first two modules are running. The Project Schedule listed below is in addition to assignments for these sections.

Week 2: One-hour lecture on "CPGs and Mastication" followed by an equipment and software demo. Also a 1-hour class taught by med school library staff on the use of the NLM Database (time to be announced).

Week 3 and 4: Arrange private appointments with instructor to discuss ideas for research project.

Week 5: Be prepared to hand in a one-page paper clearly stating your project's hypothesis and outlining experimental design.

Week 6: First draft of “Research Design and Methods” section due. All requests for special equipment should be submitted *no later* than the end of this week.

Week 8: First draft of “Specific Aims” and “Background and Significance” sections are due.

Week 9: First draft of “Abstract” due. Make appointment to review first draft of submitted sections with instructor.

Week 10: Second draft (all sections except “Progress Report/Preliminary Studies”) due.

Week 11: Human Mastication module begins. Be prepared to give a 10-minute oral presentation on your project to your classmates during the first lab session. Each presentation will be followed by class discussion.

Week 12: You should aim to finish *all* data collection by the end of the week. This will allow you 3 weeks for data analysis and any additional or repeat experiments found to be necessary.

Last day of lab (end of week 15): Final Proposal (all sections) is due. Twenty-four hours later, you may pick up copies of each of your classmates proposals in the lab.

Weekend after last lab (time and place to be announced): “Mock” Study Session. Be sure to bring your evaluations of each of the projects. Expect to give a 5-minute oral presentation followed by class discussion. Dinner will be served following the Study Session!

Data Acquisition

Electrode Placement

1. Placing EMG electrodes on your subject will be the first step in the experiment. If you are not sure where the muscles you wish to record from are located, you can open up the program “Main Menu” and refer to the anatomical diagrams in the “Help” window (Figure 15.1).
2. For each desired channel of EMG you will have to use a pair of electrodes. The center-to-center distance should be about 2.5 cm (1"). Reducing this spacing tends to limit the area of the muscle from which you are recording. Increasing the distance can result in picking up electrical activity from other muscles.
3. You must prepare the site on the skin prior to placing the electrodes by vigorously rubbing the surface with the abrasive Redux paste. This is done to lower skin resistance by removing dead skin and protective oils.
4. Once the skin is prepared, place an adhesive collar on each of the electrodes and fill the center well with a small glob of Redux paste making sure there are no air pockets.
5. Gently remove the backing from the other side of the adhesive collar (being careful not to remove the paste from inside the well) and affix the electrode to the prepared skin site on your subject.
6. The tip plugs at the end of the two electrodes should be attached to the input of one of the channels of the AC amplifier.
7. While viewing the oscilloscope, ask your subject to chew to verify electrode placement and to make sure you are getting a good recording.

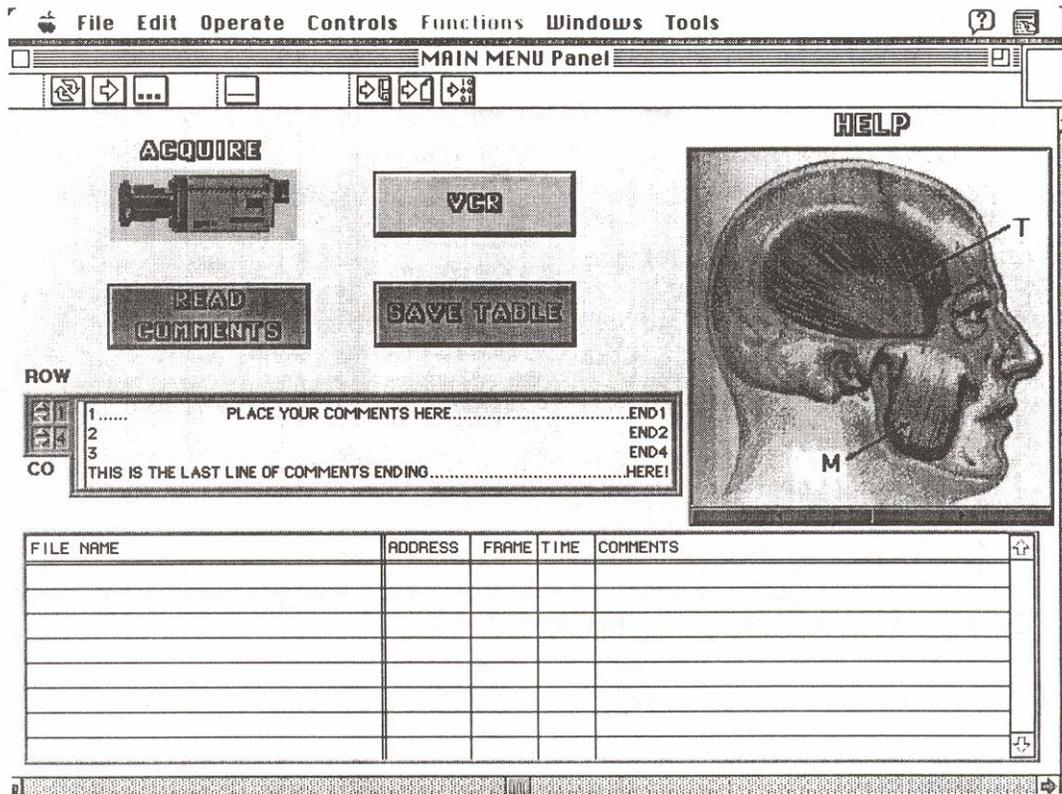


Figure 15.1. Main Menu used to control acquisition of EMG and video data. A “Help” window contains several drawings to facilitate localization of the major masticatory muscles.

8. Be sure to note in your lab book which muscle is connected to which AC amplifier channel!
9. You will also need to put a single (not a pair) electrode on a remote site such as the earlobe to act as a ground. The tip plug end of this electrode should be connected to the black binding post on the BNC adapter board sitting next to your computer.

Preflight Checklist and Using the Software

1. You are now ready to start your experiment. Do I need to remind you to make sure the power has been turned on for all the equipment?
2. On a more serious note, do be sure the VCR is set to “Channel L” and that the correct tape has been loaded. Also be sure that the strobe is positioned (aimed at subject) so that the flash will be seen in your video recording.
3. If you have not already done it, launch the program “Main Menu” and start it by clicking on the arrow icon of the menu bar.

4. To begin recording, click on the picture of a camera labeled “Acquire.”
5. The first time you do this a new window will open called “Scan2 Driver Interface A Panel.” If your experiment does not call for EMG recordings from four muscles, this panel can be used to turn off unwanted channels and thus reduce the size of your data files. If all channels are to be used, simply press continue.
6. Now, a window will open and give you the following prompt: “Create new file or modify existing one?.” You should click on “New” and then select the title of your data file and its destination using the Standard Mac Save Dialog Box which will appear.
7. We are getting close. You will now see a new box called “Comment Box Panel” in which you can add comments. You will also see a reminder to make sure your Squib is armed (red LED light should be glowing). When comments have been entered and the Squib armed you are ready to go.
8. Once you click on the blue “Finished” button, the computer will take control of the VCR, open a new window called “Get EMG Panel” and about 10 seconds later cause the strobe to flash and begin recording EMG activity. You will know when data is being recorded because the computer will continuously beep at you. Don’t forget to tell the subject when to start chewing!
9. When you are ready to end the recording simply click on the red “Stop” button.
10. You will now return to the “Main Menu” panel and should notice a new entry in the bottom table with the following data from the run you just completed: File Name, Address, Frame, Elapsed Time, and Comments.
11. To start a new experimental trial simply click again on the “Acquire” button.

Cautions and Comments

What should I look for? What can go wrong? During an experimental trial, data is streaming to your hard disk. If during data collection you run out of hard disk space, the trial will be prematurely terminated (before you hit the “Stop” button). If this happens you will get an error message, but you will not lose the data collected before the error. To continue, you must make more room on your hard disk by moving some data files to the NeuroLab Server.

You can also interfere with the sequence of the program if you click on anything besides the designated buttons. Each step of the program waits for a button to be pressed, if you click anywhere else on the computer screen, you may bring a background window to the foreground and obscure the window you need. If this happens, ask an instructor or TA for help or simply restart the program (restarting the program or if necessary rebooting the computer is often a useful solution to the “this computer hates me syndrome”).

If you are using correlated video records, there are a few extra things you must monitor. If the “Get EMG Panel” opens and the computer begins collecting data (you hear the beeping) but the strobe light does not flash or if new values for “Address” and “Frame” do not appear.....*stop collecting data*. Check to make sure VCR and strobe are on, that the correct tape is in the machine, and the Squib is enabled. If all these things were okay, try one more time and if it still does not work ask your TA or instructor for help.

One final comment, if your data analysis calls for measuring EMG amplitude, it would be very wise to do a short pretrial for each individual to make sure that the EMG recording is not saturating due to an electrode placement which results in a very large electrical signal. This will cause

clipping of the top of the EMG bursts and make it impossible for you to get quantitative amplitude measures. To test for EMG saturation, record activity and then follow the directions given below for using the program “Graph EMG” to display stored data. If the peaks of your EMGs are not clipped you can go ahead with collecting the data for your subject. If the peaks are clipped turn down the gain setting for that channel on the AC amplifier (say, from 1000X down to 100X).

Good luck and don’t forget that a computer is not a safe substitute for keeping complete and accurate notes in your lab book!

Data Analysis

Quantifying EMGs

How do I quantify my EMG data? Figure 15.2 indicates that the four basic ways of looking at EMG data are in terms of burst frequency (bursts/second measured in hertz), burst amplitude, burst duration, or duty cycle (burst duration divided by duration of the chewing cycle), and phase relationships between bursts from different muscles.

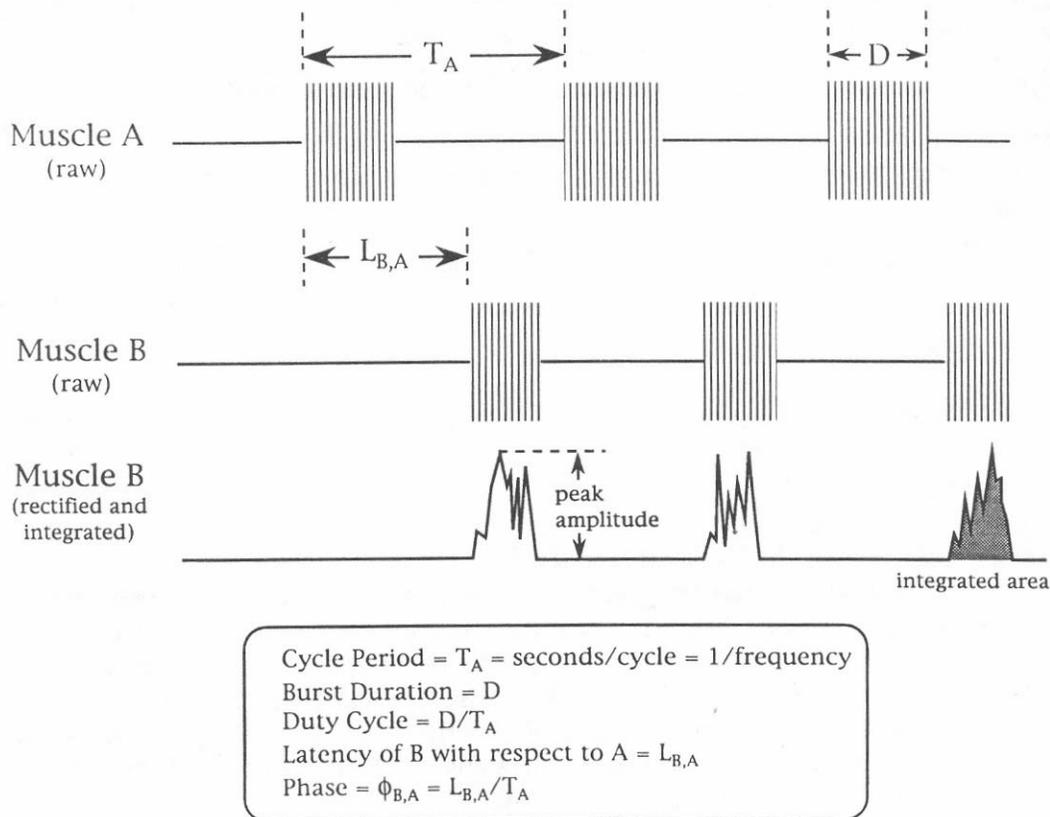


Figure 15.2. Methods for quantifying raw and rectified/integrated EMG. See text for more details.

A burst is defined as that time during the chewing cycle when there is a rapid increase in EMG (that is, the muscle is active—most masticatory muscles have one burst of activity per chewing cycle). The duration of the chewing cycle is typically measured as burst or cycle period; that is, the time from the beginning of an EMG burst to the beginning of the next recorded EMG burst. Period

is the inverse of instantaneous frequency. If each muscle active during chewing fires one burst per chewing cycle, it should not matter which you use to measure cycle period.

Phase is a way of quantifying the timing or pattern *between* muscles. To measure the phase of Muscle B with respect to Muscle A, on a cycle-by-cycle basis you would get the latency from the beginning of the EMG burst in A to the beginning of the EMG burst in B and divide that value by the cycle period for EMG A.

Comparing Data for Different Subjects

Which values you choose to measure will depend on your project and what questions you are asking. It is also *very important* to know when it is valid to compare data between subjects. It is appropriate to compare burst frequency, and phase relationships across subjects, but it is not valid to compare burst amplitude (and burst duration is questionable). Think about why it is not safe to compare the amplitude of EMGs between Subject A and Subject B. The amount of electrical activity you measure from surface electrodes is very dependent on positioning and the resistance of the path from skin to electrode. These factors will be different from subject to subject, and in fact, will change if you have to replace electrodes during an experiment or if you retest the same subject on another day.

Therefore, it is only valid to compare the amplitudes between experimental and control trials for a single subject and then *only* if electrode placement has not been changed! While a little more subtle, the same considerations apply to burst duration. Since different regions of the muscle may be recruited into activity at slightly different times, electrode placement can influence results.

So how do I compare subjects? One approach is to normalize. That is, instead of relying on absolute amplitude in millivolts, deal with percent change at a given recording site between control and experimental trials. For example, say that Variable 1 caused a 20% increase in EMG amplitude in Subject A. This could be directly compared with the per cent increase/decrease from control in Subject B when confronted with the same variable.

Since EMGs are complex interference patterns (with both positive and negative peaks) reflecting the sum of activity recorded in many different muscle fibers, it is best to rectify and integrate the raw EMG before you measure amplitude (Figure 15.2). Remember that amplitude can be measured as either a peak value or as total activity (area under the curve).

Displaying Your Data

1. Enough you say, “Just show me how to plot the neat data I just got.” Okay, here we go! Open the application called “Graph EMG” (Figure 15.3). Once opened, you can leave both “Main Menu” and “Graph EMG” running at the same time. Switching between the programs is done via selection from the “Window” pull-down submenu of the LabView menubar.
2. Once the “Graph EMG Panel” window is opened, you start the program by clicking on the arrow icon. This will immediately cause a Standard Mac Open Dialog box to appear with the following prompt, “Select Stream To Disk Data File.”
3. Find your data file and open it. It is important to note that if you forget to click the arrow to start the program and instead just select “Open” from the “File” pull-down submenu of the LabView menubar you will not be able to find or display your data. The program must be running.

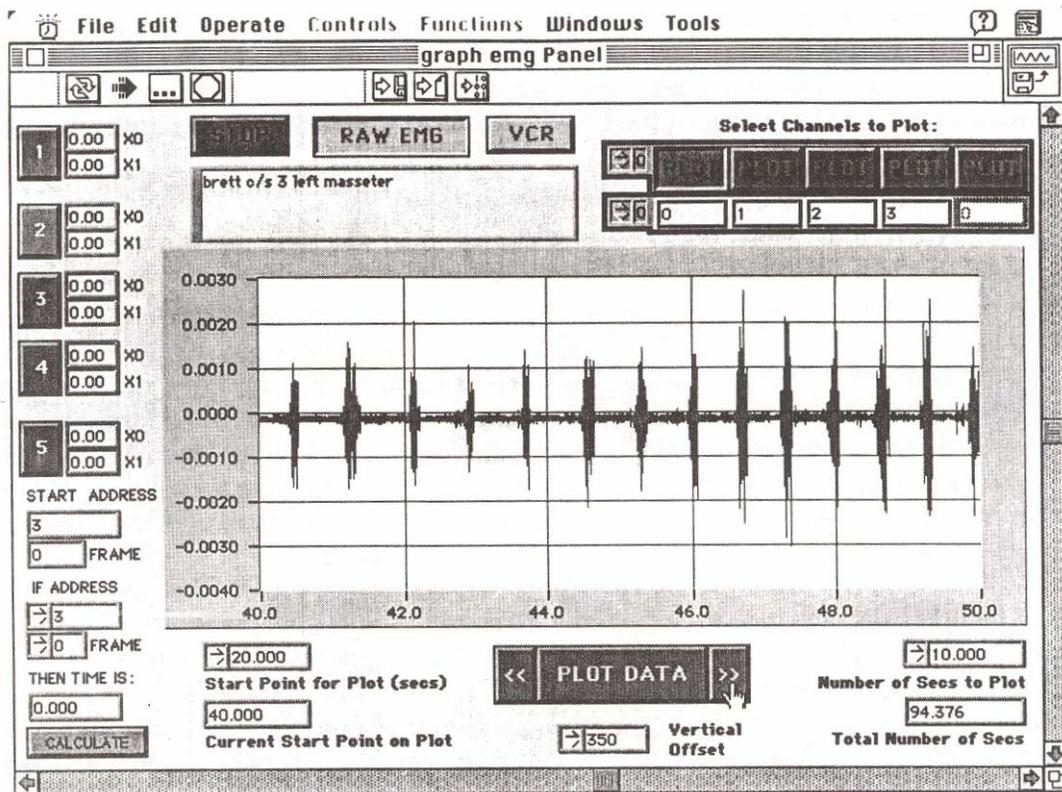


Figure 15.3. “Graph EMG” displays either raw or rectified/integrated EMG. One channel of raw EMG is shown.

4. Once you have selected a data file, you will see a new window called “Master VCR WINDOWgraph Panel” (Figure 15.4). If you are correlating video and EMG, use the controls in this window to find the exact frame and address on the videotape in which the strobe light flashed, and enter these values in the indicated boxes.
5. Once you have done this, or if you are not correlating EMG and video, click on the green “Continue” button. Notice that the “Graph EMG Panel” window will come to the front of your computer screen and following a short delay you will see that the value in the bottom right hand box “Total Number of Secs” is updated with the appropriate time for your data file.
6. You should now use the buttons on the top right to select the channels you wish to plot. If EMGs were not recorded in a particular channel, that button will be “grayed out.”
7. Next select whether you want to display your data as raw (Raw EMG button yellow) or rectified/integrated (Raw EMG button grey). If you display integrated data, all channels will be integrated but only the first channel selected will be rectified.

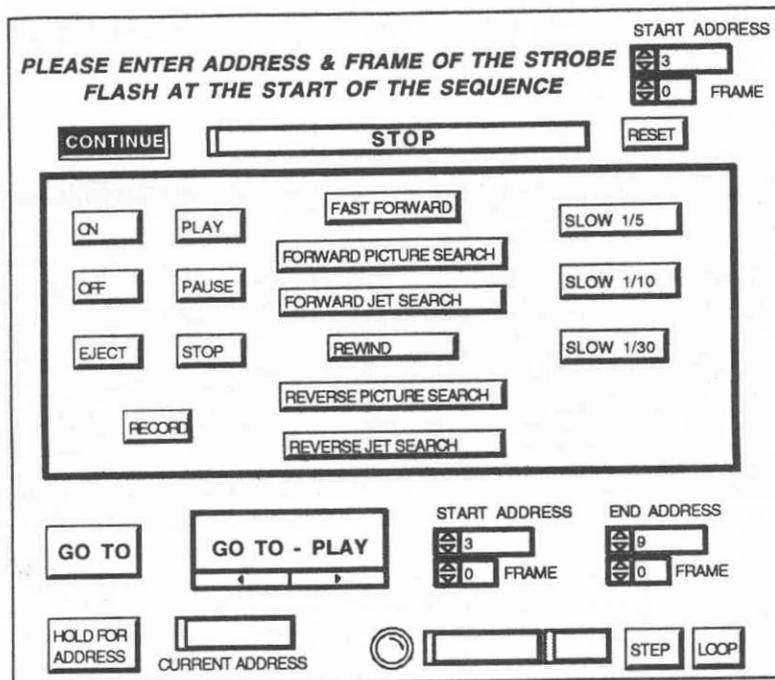


Figure 15.4. The “Master VCR Window” allows interactive computer control of video data stored on the SVHS tape recorder.

8. If you plan to display raw EMG data be sure that the value in the box called “Number of Secs to Plot” times the number of channels you are displaying does not exceed a value of 10 seconds. If a larger value is selected, when you go to plot you will get the dreaded “choo-choo” cursor indicating you are out of memory and requiring you quit LabView and start all over again.
9. Now you are ready to pick the starting point for plotting and then all you have to do is click on the bar labeled “Plot Data.”
10. Once the data are displayed, you can scroll forward or backwards in time slices equivalent to the value in the box “Number of Secs to Plot” by simply pressing the left or right arrows flanking the “Plot Data” bar. If you repress the bar you will go back to the original start point or to whatever value is entered in the “Start Point for Plot” box.
11. To change the spacing between EMGs from different channels adjust the value in the box labeled “Vertical Offset.”

Measuring Your Data

1. Quantification of EMG can in many cases be aided by selecting one of the five buttons numbered from “1” to “5” along the left side of the window.

2. If you wish to analyze Channel #1, press that button and a new screen called “Cursor Control Panel” will open and display the same segment of data that had been shown on the previous screen (Figure 15.5).

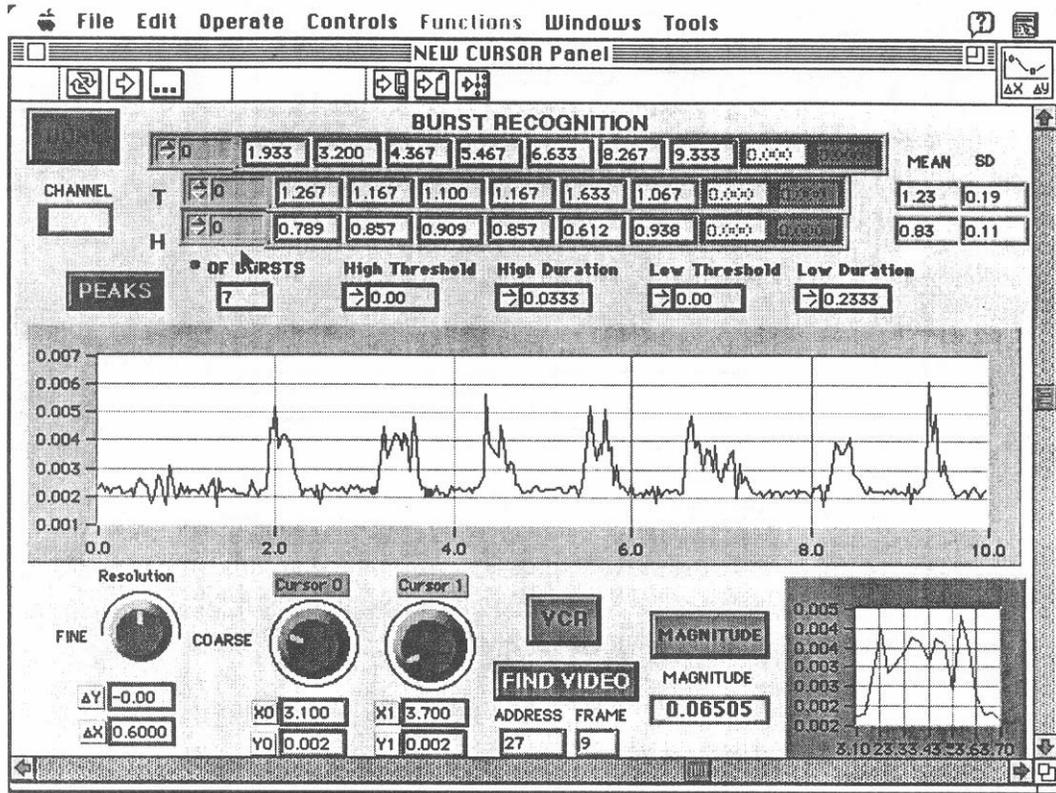


Figure 15.5. The “New Cursor Window” provides the interface for detailed measurements of EMG properties and for precise correlation of video and EMG records.

3. You will now have the ability to move two cursors back and forth through your data and directly read values for X, Y, delta X or Y, and the frame of videotape which would be equivalent to the red cursors position on the displayed EMG. Furthermore, you can then press the “Find Video” button and the VCR will automatically display that video image.
4. When displaying rectified/integrated EMG, if you position the red cursor at the beginning of a burst and the blue cursor at the end of a burst and click on the “Magnitude” button, the designated burst or peak will be drawn in the small graph at the bottom right of the window and the area under the curve will be computed and displayed in the box called “Magnitude.”
5. Finally, you can enter values for low and high thresholds and durations, press the button called “Peaks,” and have the program automatically recognize each burst, compute period and frequency, and determine means and standard deviations. This function is a little tricky and it is suggested that you ask the TA or instructor to give you a hand in determining the proper threshold values.

6. When you have squeezed your data dry, press the “Done” button to return to the “Graph EMG Panel” window. Notice that the positions at which you left the red and blue cursors will be remembered and will appear as “X01” and “X1” values. This feature can be useful for measuring phase relationships between muscles.

Printing Your Data

Printing your data is easily accomplished by selecting “Print” from the LabView file menu. You will get a high quality (300 dpi) copy of whatever is on your computer screen. A text window has been provided so that you can enter comments which will appear on the hardcopy. You should be sure that “Page Setup” has been set for landscape not portrait orientation. Once you have given the print command be careful to select “Black and White” and *only* check the “Front Panel” box (all other boxes at the bottom of the “Print Dialog Box” should be unchecked). Be patient, it can take several minutes to print a front panel on a Laserwriter IIg. When you are done viewing and printing a data file press the “Stop” button and you are ready to start again.

Caution and Comments

A few final comments. Data analysis should be fun, it should be creative, and it will take a lot of time. Don’t wait until the last minute. Also, don’t forget to employ statistics. At the very least, remember that means without standard deviations and bar graphs without error bars are useless. Show and explain your data to your classmates, their questions and responses will give you a good idea of what you are explaining well and what needs more work.

Notes for the Instructor

Both the joy *and* the horror of a “virtual instrument” based laboratory is its flexibility. The custom software, as distributed, is configured for four channels of EMG, a fifth channel for an external timemark (e.g., triggered pulse generator or an electronic metronome), and automatic video synchronization (although manual synching via the fifth input channel can be easily accomplished). But, these and many other parameters can be readily changed (intentionally or sometimes accidentally by the student). Every effort has been made to provide enough information for someone to get up and running. But, having had to set up the system, I feel compelled to state that it is not necessarily an easy task. But, I would also be remiss if I didn’t say that I think the rewards of running the Human Mastication Lab are truly remarkable. Rather than using this section to bombard the reader with a litany of cautions, I would like to encourage anyone interested in running this lab to feel free to contact me. I will be happy to help you troubleshoot and/or make desired changes in the software configuration.

Acknowledgments

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APPENDIX A
Further Reading

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- Gorniak, G. C., and C. Gans. 1980. Quantitative assay of electromyograms during mastication in domestic cats (*Felis catus*). *Journal of Morphology*, 163:253–281.
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- Hiiemae, K. M. 1978. Mammalian mastication: A review of the activity of the jaw muscles and movements they produce. Pages 359–398, in *Development, function, and evolution of teeth* (P. M. Butler and K. A. Joysey, Editors). Academic Press, London, 523 pages.
- Luschei, E. S., and G. M. Goodwin. 1974. Patterns of mandibular movement and jaw muscle activity during mastication in the monkey. *Journal of Neurophysiology*, 37:954–966.

APPENDIX B
Examples of Projects

1993

Effects of personality as measured by the MBTI on mastication.

Do the primary muscles involved in mastication fatigue?

Analysis of mastication: A food with solid and liquid parts.

The effects of differential lighting on central pattern generators: How does different light affect chewing patterns?

The effects of smell and taste on the frequency of chewing and the measured disparity during mastication.

The effect of exercise on chewing frequency and intensity in young adults.

Does simultaneous chewing and walking reflect coupled oscillation and to what extent is it possible to voluntarily modulate chewing to walking?

The effects of increasing motor-cognitive activity on mastication.

How do cognitive and motor skills affect the frequency and amplitude of mastication cycles?

The effects of caffeine on the human masseter motor neural pathways

1994

Masticatory muscle amplitude as a function of gravitational fields.

Effect of nasal blockade on mastication/respiration phase coupling.

Directed arousal to an external rhythm and its effect on the masticatory central pattern generator.

Is there a relationship between cerebral lateralization and mastication?

The effect of lower extremity hypothermia on mastication.

Will the coupling relationship of mastication and walking be proved or disproved by the Beggs' method?

The influence of the masticatory reflex feedback control system on masseter activity.

What effect does a flash of light have on the entrainment frequency of mastication?

An analysis of the organization and versatility of mandibular CPGs: A study of mastication, speech, and swallowing using surface EMGs.

Effects of high and low intensity aerobic exercise on mastication.

APPENDIX C
Configuration and Selected Equipment Sources

This is a list of the equipment used in the Human Mastication Lab at Emory:

Computer: MacII ci with 160 MB hard drive and 16 MB of RAM. Memory is the limiting factor for displaying raw EMGs using the program "Graph EMG." A 16 MB configuration will allow displaying 12-second slices of raw data. Data files are large (often over 5 MB) and a large hard drive and a networked file server are recommended. At Emory, an ethernet LAN connects the five Mac stations to an Appleshare fileservers and a Laserwriter IIg used for hardcopy output of "virtual" instrument front panels.

Software and peripherals: Available from National Instruments (6504 Bridge Point Parkway, Austin, TX 78730): LabView 2 software, NB-MIO-16XH-18 Multifunction Acquisition Board, NB-DMA2800 Block Mode DMA Board, NB Series RTSI Bus Cable for two boards, and BNC-2080 BNC adaptor board with 1 meter of cable. *Note:* Configure Acquisition and BNC adaptor boards for single-ended, floating ground recording. Outputs of the AC amplifier should be connected to BNC adaptor board inputs ACH0-4. If correlated video is used, the BNC adaptor board output "SCNCLCK" should be connected via any high gain (1000X) DC amplifier to the Trigger Input of the WPI Squib Remote Trigger. The output of the Squib is in turn connected to the "Trigger In" of the Grass PS33Plus Photoc Stimulator. This connectivity will cause the manually armed Squib to trigger a strobe flash visible on videotape automatically at the time the data acquisition board makes its first analog/digital conversion of EMG data.

Custom software: "Main Menu" and "Graph EMG" are available from the author. Other "virtual" instruments available include: Four-channel Storage Oscilloscope, Strip Chart Recorder front-end for an Axoclamp 2A, Video Kiosk using the NEC PC-VCR. *Software may be obtained by mail or via ftp to 128.140.49.32. Login as "LGUEST" with the password "able."*

Four-Channel Differential AC Amplifier (model 1700): A-M Systems, 11627-A Airport Rd., Everett, WA 98204.

Hitachi Oscilloscope (model V-212): This inexpensive two channel CRO is optional and is used only as a quick check of EMG placement and signal quality.

KIT-Mini skin electrodes (#650-950) and **adhesive collars** (#650-455) (1000/pkg): Sensor-Medix, 22705 Savi Ranch Parkway, Yorba Linda, CA 92687.

Redux paste (#651-1008): Hewlett Packard, Medical Products Group, Waltham, MA 02154.

NE PC-VCR (model PV-S98A): NEC Technologies, 1255 Michael Dr., Wood Dale, IL 60191. *Note:* Software for the Human Mastication Lab has been designed to acquire video in the insert editing mode. Therefore, the blank SVHS tapes provided to students must be prestripped with time codes following the directions provided in the PV-S98A manual.

Video camera: The lab uses the now discontinued Panasonic WV-1550 Nuvison B/W cameras with computer MCA 1613 APC 16 mm lens. While any camera will do, you will need at least a 400-line camera to take full advantage of the resolution of the SVHS format. Even though the lab uses black and white cameras, we utilize 13-inch Panasonic CT1382Y color TV monitors. This provides the flexibility to view instructional tapes at each labstation during other portions of the course.

Photo stimulator (model PS33Plus): Grass Instrument Co, 101 Old Colony Ave., PO Box 516, Quincy, MA 02269.

Squib remote trigger: World Precision Instruments, International Trade Center, 175 Sarasota Center Blvd., Sarasota, FL 34240.

If **split-screen video** is desired each student station will need: (1) a second video camera and tripod, (2) a video distribution amplifier (e.g., Pelco DA-104DT), and (3) a video splitter (e.g., Pelco VSS-100DT).