

The EMG Data System

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During the last year and a half the entire EMG data collection and processing system used at Haskins Laboratories has been significantly improved. The use and insertion of wire electrodes is discussed elsewhere (Hirose, 1971). The present paper describes aspects of the data system for readers interested in a technical account of the system consistent with the suggestions of the "Report of the Committee on EMG Instrumentation" (Guld et al., 1970).

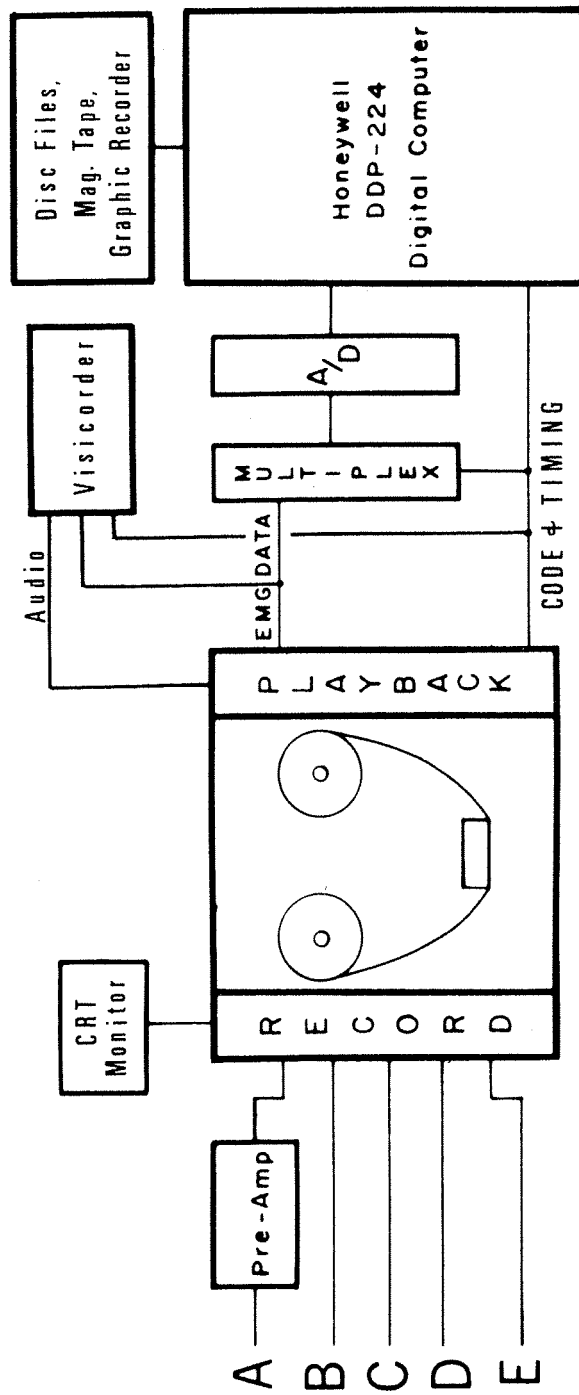
The basic principles of EMG data analysis used in earlier work at Haskins Laboratories have been carried over to the new system. Although the overall procedure for data collection and analysis has been described elsewhere (Cooper, 1965; Music et al., 1965; Sholes, 1965; Harris, 1970; Gay and Harris, 1971), a brief description will be repeated here for orientation.

An EMG experiment typically collects data on many repetitions of a limited set of utterances by one subject. The experiment proceeds in three principal stages: data collection, visual editing, and computer processing (measurement, averaging, and plotting). A major task in making this kind of experimentation feasible, i.e., in coping with the enormous amount of data involved in even a simple experiment, has been the development of procedures and equipment to automate most of the data collection and processing. The present system has largely accomplished this objective and has done so without sacrificing the experimenter's privilege of scrutinizing individual data entries to be sure that they are free of adventitious error. The equipment that has been assembled is shown diagrammatically in Figure 1. Its use will be discussed in the following descriptions of each of the three phases of a typical experiment.

DATA COLLECTION

The initial steps in data collection are, of course, the administration of such anesthesia as is required for patient comfort, insertion of the electrodes, and confirmation of their placement; this part of the procedure is described by Hirose (1971). The subject is then asked to read from randomized lists (or to repeat from a tape recording) the desired series of utterances, with pauses of a few seconds between them. Provision is made (in the programs that will later analyze the data) for up to thirty tokens of as many as thirty types of utterance.

The EMG signals collected by the bipolar wire electrodes go to differential preamplifiers which have gains of 40 db, noise levels (referred to the inputs) of 5 mv RMS, and ca. 100 db common mode rejection. From the preamplifiers, the signals go to distribution amplifiers with adjustable gains that are



- A - EMG (8 Channels)
- B - Air Pressure (2)
- C - Voice
- D - Banter
- E - Digital Code & Timing

Fig. 1

usually set at about 30 db. These amplifiers include 80 Hz high-pass filters with 24 db roll-off to reject movement artifacts and hum. The filtered signals are then recorded on a one-inch, 14-channel instrumentation recorder (Consolidated Electrodynamics VR-3300). The EMG (and other physiological) data are recorded in FM; voice channels and timing and code pulses are recorded as AM signals.

A calibration signal (300 mv \pm 1%) is substituted for each of the physiological signals several times in the course of an experiment. Periodic tests of the reference signal indicate that the long-term drift in the recording and amplifying equipment is less than 1% per month. The primary use of the calibration signals is, of course, to calculate the conversion of the physiological signals to microvolts at the electrodes.

Two recording channels are used for voice signals, one for the subject's utterances and the other for "banter" by the experimenters, in order to take note of events and changes in procedure during the course of the experiment. Two other channels are used to record a clock track and a code and timing track. The former consists of short pulses at a rate of 3200 Hz; the latter, of timing pulses at a rate of 50 Hz, counted down from the clock. Some of the pulses in the timing series are cancelled or inverted in polarity in order to generate a 4-digit octal code number that is incremented and recorded about once per second. (This way of introducing the identification codes has provided a good compromise solution to the problem of making the oscillographic record easily readable by humans and the tape-recorded version readable by computer.)

VISUAL EDITING

For visual inspection of the recorded physiological data, the data channels, voice channel, and code and timing track are played back as input to an 18-channel Honeywell Visicorder. During playbacks, the signals again go through the distribution amplifiers. Each physiological signal is routed through one section of its 80-Hz high-pass filter, resulting in a 36-db total roll-off. With the usual record/playback speed of 7.5 inches per second, the upper frequency limit of the FM channels is 1250 Hz. Thus, the overall frequency response (for EMG signals) is 80-1250 Hz. The signal-to-noise ratio for the FM channels is ca. 40 db.

The oscillographic traces for the voice and the code and timing marks are used by the experimenter to locate the specific portion of the EMG (and other) signals to be processed by the computer. This is done by first identifying each utterance with an octal code that precedes it. Then the temporal offset between this code and a distinctive event in the utterance (the line-up point) is noted. The choice of line-up point depends, of course, on the utterance; typical choices are stop-release or onset of voicing. The offset interval can be taken directly from timing pulses that occur at 20-msec intervals; typically, the offset interval is specified to the nearest 5 msec (a quarter of an interval on the timing trace), which is within the inherent uncertainty--estimated at ca. \pm 10 msec--that is involved in locating the line-up point on the voice trace.

The two descriptors for each utterance (the octal code that identifies it and the offset interval between code and line-up point) are written down in lists by utterance type, and the lists are then entered into the computer.

These lists are merged, with the entries rearranged to be in the order in which the corresponding utterances appear on the instrumentation tape, and this merged list serves as the control information during computer processing.

COMPUTER PROCESSING

The measurement, processing, and plotting of the physiological data are almost completely automatic, although the experimenter can, if he wishes, intervene at various stages to test for, and correct, erroneous entries. The computer programs that make this possible were almost completely rewritten from the earlier programs--a necessary step in order to take advantage of substantial upgrading in the computer facility. Some of the capabilities that are important for EMG processing include four disc units (three for data) to allow for one-pass storage of all the digitized EMG signals for a complete experiment; magnetic tape for long-term storage (in digital form) of all the data generated in an experiment; and a strip chart recorder on which the final data (averaged for each electrode and utterance type) is plotted. All man-computer communication is through a Sanders Communicator, Model 720 (an alphanumeric CRT terminal). Programs for processing data are under control of a Monitor program (on the fourth disc unit) and several are currently being changed over to operate in a time-shared mode, to ease the requirements for computer time. Plans include a CRT display of any portion of the data for inspection and for automatic photography, if desired.

The programs are several in number and divide the processing task in the following way:

- ESEL: Control information comprising the lists of codes and utterances already described is entered and stored in computer memory and on magnetic tape.
- ECHK: The EMG signals are checked for correct control information, and analog input levels are set.
- ERIT: The data are digitized and stored in one pass.
- EDON: The signals are sorted and averaged, and the results are listed on a line printer.
- E\$MG PLOT: Hard-copy output curves are produced.

ESEL

The control information program is straightforward. Data about the utterances in the experiment and their line-up points are entered and stored on magnetic tape for later retrieval. Any item can easily be changed at any time during processing. The experiment size for which the ESEL program was designed is set at a maximum thirty lists of utterance types to be averaged, each of thirty speech utterances of 2-second maximum duration. Up to 8 channels of EMG data can be used.

ECHK

ECHK is the step in data processing that requires most operator attention. Here various checks on the offset between code and line-up point often catch gross measurement errors. There is also a print-out of the maxima and minima sampled in each channel for each code. By inspection of the consistency of these values for utterances of the same type, some obvious errors are detected. Errors are corrected in the control information before proceeding. Also at this time, the input gain levels (for playback from the instrumentation recorder) are set to make maximum use of the available digital data range.

ERIT

The digitizing program begins with playback of the instrumentation tape, the tape recorder being under computer control. The EMG signals in analog form are full-wave rectified and then passed through an RC circuit that performs a running integration. Typically, the time constant is set at 25 msec. The smoothed signals are sampled to 12-bit precision every 5 msec, using a 16-channel multiplexer driven by a clock that is internal to the computer but consistent with the recorded clock track to within 1%. Although twelve bits of data are delivered by the A-to-D converter and are recorded on disc and tape, only seven bits are significant since the system signal-to-noise ratio is approximately 40 db. Only the most significant seven bits are used later for averaging.

Given a 25-msec integration time constant on playback, a 5-msec sampling interval involves almost no loss of information due to sampling, according to the sampling theorem. Theoretical and empirical analyses of the effect of the RC integration circuit on the analog EMG signals is being undertaken and will be reported later.

EDON

In computing the EMG averages for each electrode location and utterance type, our first step is to convert the more-or-less arbitrary signal stored by ERIT to millivolts, using the recordings of the 300 mv reference signal that were made during data collection. Each of the reference signals specified in the control information is sampled and averaged over a 1-second interval. Then conversion factors are calculated for each channel and stored on magnetic tape. Next the sums and sums of squares for each utterance type (for each time sample from a given electrode location) are computed and stored on magnetic tape for further statistical analysis. Currently EDON calculates and converts to millivolts the means and standard deviations divided by the means. These values are printed out for the 5-msec intervals at which the analog data were sampled, referenced to the line-up point as time zero. It is possible, using EDON and ESEL to change any one of the utterance lists, for example, by deleting an erroneous code, and then to compute new sums and sums of squares.

E\$MG PLOT

Hard copy is produced on a Texas Instruments Rectiriter Model RRMA strip chart recorder. The line-up point can be marked on the curves, if that is desired. The recorder is calibrated before each experiment.

SUMMARY

Overall, the new EMG data system appears to give a reliable output relative to actual myographic signals. The stability and signal-to-noise ratios of the system are good. Line-up points can be determined within ± 10 msec. Gross errors are usually found and eliminated as a routine matter. The 25-msec time constant of integration is considered appropriate for the purpose of relating the high-frequency myographic signals to the comparatively slow movements of the articulators. (A time constant of 12.5 msec was tried and found to introduce more high-frequency noise without improving resolution of the averaged output curves.) Thus, the pattern of averaged outputs reflects mainly the pattern of muscle activity. Variability within an utterance type, as reflected in the standard deviation divided by the mean, shows token-to-token variation for EMG measures of the same utterance, though it does not necessarily imply as much variation in the muscle activity per se, since the EMG signal at each moment is determined by the relative phases of the signals from contributing muscle fibers, as well as by the total activity in the vicinity of the electrode.

REFERENCES

- Cooper, F.S. (1965) Research techniques and instrumentation: EMG. Proceedings of the Conference: Communicative Problems in the Cleft Palate, ASHA Reports 1, 153-168.
- Gay, T. and K.S. Harris. (1971) Some recent developments in the use of electromyography in speech research. JSHR 14, 241-246.
- Guld, C., A. Rosenfalck, and R.C. Willison. (1970) Report of the Committee on EMG Instrumentation. Electroenceph. clin. Neurophysiol. 28, 399-413.
- Harris, Katherine S. (1970) Physiological measures of speech movements: EMG and fiberoptic studies. ASHA Reports 5, 271-282.
- Hirose, Hajime. (1971) Electromyography of the articulatory muscles: Current instrumentation and technique. (See this Status Report.)
- Music, R., L. Elbert, N. Reilly, and F.S. Cooper. (1965) Automating the collection and reduction of electromyographic data on speech production. Status Report on Speech Research (Haskins Laboratories) 1, 5.1-5.12.
- Sholes, G.N. (1965) Measuring and averaging the data. Status Report on Speech Research (Haskins Laboratories) 1, 6.1-6.9.