

### III. Measuring and Averaging the Data

Some of the work that goes into reducing our electromyographic data has now been automated under the supervision of our DDP-24 computer. A summary account of this automatization follows.

The data reduction consists mainly of constructing average voltage curves. Certain other statistics are also calculated. The routine that now finds the averages represents a half-way house between an earlier batch-type of processing of the data and an on-line, real-time processing that may lie in the future. In particular, one crucial decision has still been reserved for the investigator rather than the machine: determining where the line-up point shall be in each of the segments that goes into an average.

This decision is reached on the basis of pen-written charts of an experimental run. The run itself is stored on multi-channel magnetic tape. When the line-up points have been decided on, and made available to the computer, the magnetic tape is played through into the computer and the desired average curves are calculated.

For the computer, then, there are two inputs. First, control information about the data and, then, the data. The control information is typed into the computer or read from paper tape. The data is multiplexed from the magnetic tape into the computer with suitable smoothing and digitalization intervening.

Because of limited computer storage, only one group of EMG segments is averaged on one pass of the data tape. An EMG time

segment may, nonetheless, hold from one to eight simultaneous electrode potential curves. Storage consists not of the individual 6-bit data points, but rather of a growing sum of the readings at each point along the average curve-to-be and a parallel sum of the squares. If all EMG electrode channels are being read, a segment of about one second in length can be accommodated at the fastest sampling rate of 200 cps.

Following input of the data, two outputs are possible. Either the accumulated data, in the form of sums and sums of squares, together with its control information, may be punched onto paper tape for later use, or it may be reduced at once and displayed by the console typewriter as a series of graphs or tables.

#### Determining the line-up point.

During an experimental run, the continuous signals from electrodes attached to the subject are laid down on magnetic tape. At the same time two housekeeping tracks are generated and stored on the tape. One, a clock-track at 3200 cps, will run the multiplexer on playback. The other, counted down from the clock to 50 cps, holds a series of spaced numbers or codes. From time to time during the run, a trigger pulse causes a code to be laid down in the code-track and then steps the code-count by one. These spaced codes serve a double function. They segment the tape and hence the run, and they assign a distinct sequential name to each segment. The code generator is described elsewhere in this Report.

The trigger pulses that precipitate the codes have two origins. They may come from one channel of the two-channel cue tape, the other channel of which normally holds the cue utterances the subject is to repeat. Or they may come from a manual button under the investigator's control at run time, if a cue tape does not figure in the run. Or there may be alternation

between the two origins.

For the subject, a run is usually a sequence of short utterances. Typically, there are several different utterance types in a run and for each utterance type the investigator has included several copies. The copies are usually present in a semi-random order. The copies of utterance type A might be the first, sixth, twentieth, etc. utterances of the run; while the copies of utterance type B might be the second, tenth, nineteenth, etc. utterances of the run; and so on. The computer, which works on only one utterance type at a time, sorts out the proper utterances during any particular pass of the data tape.

Utterances the subject makes are locatable by referring to a code that occurred earlier. If a cue tape is being used, the code may well be triggered at the same time the model utterance is presented. Because the code is laid down at the same time as the stimulus, it precedes the response it identifies. If the codes are triggered manually, they may well be laid down at the same time the subject makes an utterance or slightly thereafter. In this case, a code precedes and identifies some later utterance the subject will make.

When the run is played to the pen-writers, the sequence of codes is displayed along with the EMG traces. The investigator may in this way identify the location of each stretch of potentials he wants to have reduced. This location, called the line-up point, is specified by its distance after its code-name, more precisely, by the distance after the beginning of its code.

Control information.

In sum, for each utterance going into an average the investigator will tell the computer two things: the name (code) of the utterance and its line-up point.

For each utterance type, he will supply information that applies in common to all the utterances in it. Included in this

information are such items as: the duration of the type with respect to the line-up point; the codes for reference signals of known value and for their relative zero signals; optionally, the codes for potentials of the subject at rest. Each of these, unlike the utterance codes, cues inputs that averaged to a single number rather than a curve. The investigator will also choose the effective sampling interval: any multiple of 5 msec.

Data input.

While the data tape is running, the computer has access to five sources of external information. These provide the digitalized data and some system status information. The data itself is multiplexed to an analog-to-digital converter, thence to a six-bit internal channel. The current code is constantly available from an external register of twelve bits. A one-bit external sense line is turned on each time a multiplex cycle begins. Two other one-bit external sense lines are turned on at the beginning and the end, respectively, of codes encountered on the tape.

Between the tape and the multiplexer, the electrode signals are full wave rectified and smoothed by a resistance-capacitance circuit. We have recently used a time constant of some 10 msec with a 5 msec sampling interval.

The multiplexer is set up for sixteen channels. Of these no more than eight in sequence are transmitting significant information from electrodes. Thus at a given time, the least time discrepancy between channels is on the order of 0.3 msec and the greatest may be on the order of 2.5 msec. The computer also senses when non-significant channels pass through the multiplexer. It uses this information as a timing device to keep sub-routines that have branched apart in step with each other.

The multiplexer is driven by the 3200 cps clock on the

magnetic tape. At the beginning of each pass of the data tape, the computer, on cue from an external sense line, aligns the multiplex cycle with the code track. This ensures that on every pass codes will always be detected at the same time relative to the beginning of a multiplex cycle. From then on, the computer, referring to another external sense line, aligns itself with the multiplexer and hence the clock at the beginning of each multiplex cycle. Certain durations on the tape -- the codes -- are of known and constant length, about a third of a second. These durations are counted up by the computer, using two external sense lines, and bring about an error halt if found to be off. This trap has proved to be a check not so much on poor tape quality as of transients in the system.

The beginning of a code, also perceived by external sense line, causes the program to inspect its lists of required codes. If the sensed code is listed, the corresponding delay-before-data-input is fetched and a countdown begins. Once the countdown is over and data input has begun, the program is again in a state to begin a new countdown. So at any particular time, the program is either counting down prior to data input, or inputting data, or both, or neither: two or more countdowns or inputs at the same time are not provided for. Nor is there provision to cue more than one input from a code during any one pass of the tape.

As many as four lists of required codes are present: utterance data, reference signals, zero signals, and subject at rest. Since these are not all treated in quite the same way, slightly different input routines are called upon according to the kind of code found.

They have in common that upon input a datum is checked for overflow and then added into the appropriate sum. The square is formed and added into the appropriate sum of the squares. The limits imposed by single precision storage put the maximum N for

an utterance type in the thousands; for reference signals, in the tens; both way over our present needs.

It may be noted that a first reduction is imposed on the data even before storage. Limited storage space, among other considerations, militates against storing the data unreduced, even in a packed format. The preliminary reduction routine outlined above begins to approach the time available between multiplexed channels when the program housekeeping operations are also taken into account. In a word, we are pressing the size and speed of our present computer.

#### Data reduction and output.

Of the four thousand words of computer storage, some three-quarters has been allotted to data and control information during EMG processing. This leaves about a thousand words for program. Needless to say, the program section is changed several times during a complete processing operation. There are, presently, four separate program fills. The first supervises the setting of system levels prior to input. The second supervises the preparation of control information. The third supervises the actual input of data. The fourth supervises the reduction of the data and its print-out.

The data reduction and print-out program operates on the accumulated sums and sums of squares but does not alter them. The investigator may choose among several typewriter print-outs in succession by setting various console toggle switches. The print-out may be in tabular or graphic form. It may be the mean curve, the mean with standard deviation ( $\sigma$ ) or standard deviation estimate ( $\underline{s}$ ), the mean with confidence limits at the .95 or the .99 level. These statistics are calculated in 38-bit floating-point arithmetic to protect significance.

A piece of a print-out of the mean with confidence limits is attached as Figure 1. The utterance is "pock" and the segment

corresponds in the main to the initial /p/ as shown by an electrode located to the side of the subject's chin. The small peak at about -100 msec represents activity as the lips are closed to start the /p/; the large peak at about -25 msec represents activity as the lips are opened to release and terminate the /p/. Time zero, the line-up point, is here the onset of voicing during the vowel following the /p/, as determined from visual inspection of a voice-trace channel. The 25 msec delay between /p/-release and voicing-onset is presumably filled with aspiration.

A piece of a tabular print-out of the mean with g is attached as Figure 2. The utterance is the same. The EMG channels are all located around the mouth.

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# pak

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MEAN ■ AND CONFIDENCE LIMITS \* (P=.01) IN MICROVOLTS  
FOR EMG CHANNEL 1 AT RELATIVE TIMES SHOWN

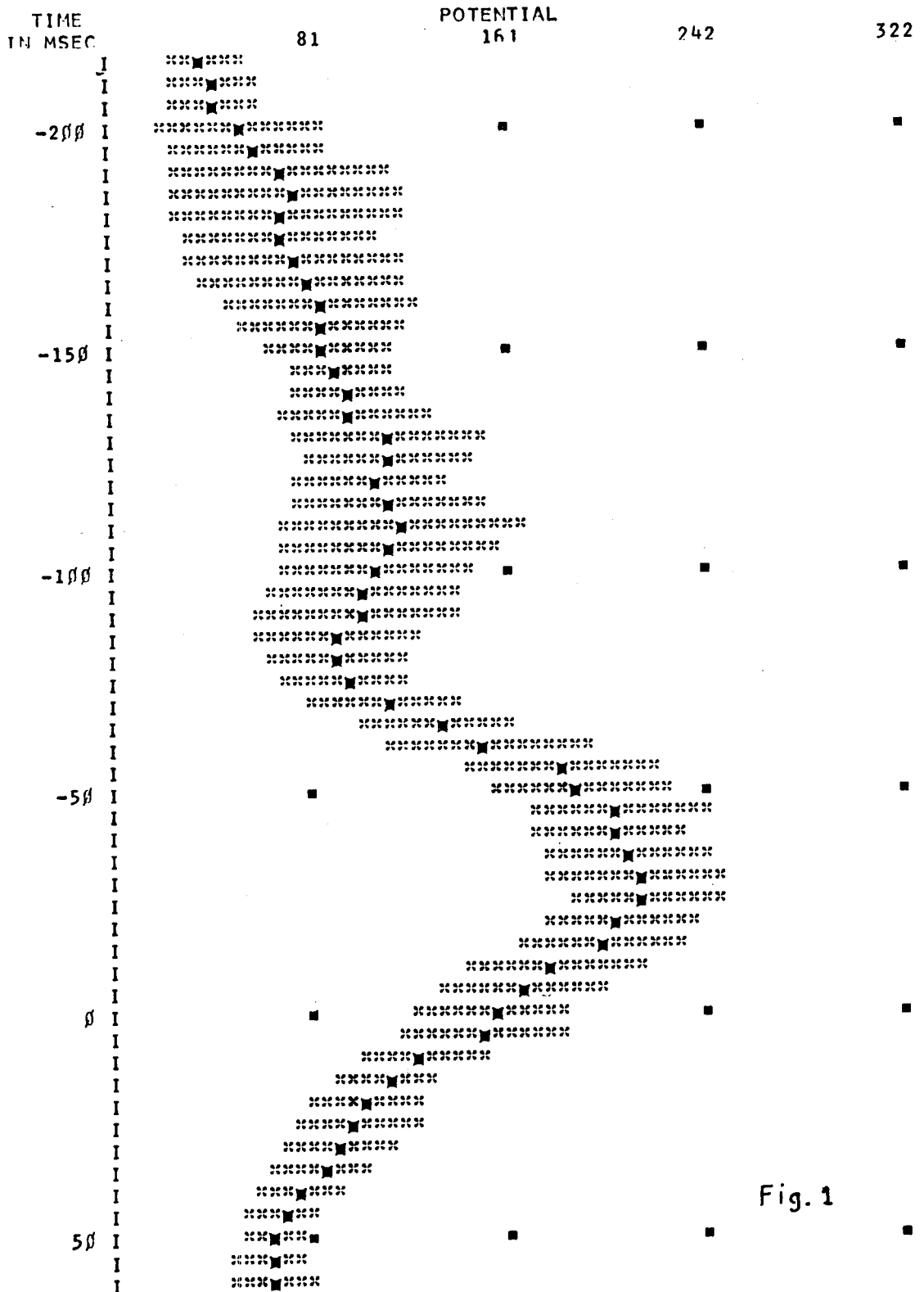


Fig. 1

MEAN AND STANDARD DEVIATION ESTIMATE IN MICROVOLTS  
FOR EMG CHANNELS AT RELATIVE TIMES SHOWN

N = 18 TOKENS (NAME & DELAY:)

35- 305	61- 325	72- 307	113- 298
120- 258	140- 308	211- 287	236- 239
253- 260	262- 266	264- 263	305- 345
310- 331	323- 259	332- 276	360- 272
362- 320	401- 343		

TIME IN MSEC	CHANNEL				
	1	2	3	4	5
-70	111 42	108 65	73 20	146 39	77 26
-65	134 43	127 83	72 17	132 31	77 20
-60	152 61	155 117	68 25	128 28	80 30
-55	183 57	187 165	70 27	126 30	90 36
-50	190 50	222 147	67 21	124 29	88 24
-45	206 52	249 170	76 35	133 43	103 29
-40	202 46	343 197	79 40	144 42	108 30
-35	210 45	408 152	83 41	157 52	99 48
-30	213 49	444 135	99 41	174 43	108 45
-25	218 46	485 161	93 35	176 42	110 30
-20	206 45	469 142	104 42	179 54	102 33
-15	199 49	461 113	118 61	168 49	98 57
-10	180 52	378 141	97 47	154 55	91 32
-5	168 47	321 176	109 39	157 49	100 24
0	154 41	312 140	94 32	155 45	88 29
5	151 47	253 153	81 40	139 35	89 39
10	125 37	255 154	89 30	136 37	82 19
15	111 30	259 139	78 25	129 37	74 19