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A minicomputer program for the resolution of response frequency and latency in classical conditioning preparations*

HOWARD S. BISSELL and MICHAEL J. SCAVIO, JR.
California State University, Fullerton, California 92634

This classical conditioning program is capable of controlling stimulus events and recording response data in experiments using the rabbit's nictitating membrane and/or iaw-movement responses. The main features of the program, implemented on the PDP-12 computer, are the ability to resolve response latency within a 1-msec error range and to display the response topography on the computer's cathode ray tube. The extreme accuracy in latency measurement cannot be duplicated either by conventional hand-scoring methods involving oscillographic records or by other minicomputer conditioning programs.

The following program, adapted to Digital Equipment Corporation's (DEC's) PDP-12 computer, controls classical conditioning experiments involving the rabbit's nictitating membrane and jaw-movement responses. This package attempts to duplicate some features existing in conditioning programs developed for DEC's PDP-8/E (Millenson, Kehoe, Tait, & Gormezano, 1973; Tait & Gormezano, 1974). It also includes additions which improve the measurement of response latency and allow for the display of the response topography on the PDP-12's cathode ray tube (CRT).

In past research utilizing the nictitating membrane response in aversive conditioning (e.g., Gormezano, Schneiderman, Deaux, & Fuentes, 1962) and the jaw-movement response in appetitive conditioning (e.g., Smith, DiLollo, & Gormezano, 1966), the various measures of learning (e.g., frequency, latency, peak latency, amplitude, etc.) have usually been calculated by hand-scoring conditioned response (CR) topographies provided by ink-writing oscillographs. Now, with the availability of minicomputers, the tedious hand-scoring method can be eliminated (Millenson et al, 1973). Accordingly, the conditioning programs for the PDP-8/E have been written with the capability of determining several dependent measures. These measures are based upon stored digital voltage values constituting response topographies recorded from several S stations. In order to hold complete response topographies without exhausting the supply of core memory, the PDP-8/E programs must sample the response channels intermittently (e.g., once every 20 msec). Therefore, an error factor can be introduced in the calculation of time-dependent response measures. One of the major concerns of the present program is to gain extremely accurate resolution of CR latency (CR latency is defined as the time from the onset of the conditioned stimulus to the onset of the CR). Since latency as well as frequency information can be extracted without having to store response topographies, this program is allowed to sample the response channels each millisecond. In addition, one large memory buffer is used to receive the sampled voltage values from a selected channel. These values are used to construct the response topography which is displayed on the CRT during the intertrial interval (ITI).

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HARDWARE CONFIGURATION

The computer facility consists of a PDP-12 with 8K core memory, a KW12 real-time clock, an ASR-33 Teletype, an AD12 analog-to-digital (A/D) converter and multiplexor with eight input channels, two TU55 tape drives with a TC12 Linc-tape controller, and a DR12 relay controller with six programmable relays. In conditioning, the relays present the stimulus events simultaneously in six experimental stations. Light intensity changes or tone serve as conditioned stimuli (CSs). Electric shock applied to the paraorbital region of the eye and water injected directly into the oral cavity are respective unconditioned stimuli (USs) for the nictitating membrane and jaw-movement responses. The transducers for recording responses are 10,000-ohm Giannini microtorque potentiomters. Gormezano (1966) and Smith, DiLollo, and Gormezano (1966) describe the methods for coupling the transducers to the membrane and jaw-movement responses. Each potentiometer represents a variable resistive value in a conventional Wheatstone bridge circuit. The output voltage from a bridge, generated by a membrane or jaw-movement response, passes through a linear operational amplifier (National Semiconductor Corporation, Model LM 741) and current-limiting resistors before entering the appropriate A/D channel on the PDP-12 chassis. The direct analog input to the A/D is made through standard phone-jack plugs. Restriction of the input is required to match the sensitivity range (±1 V dc) of the A/D. By

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OBS CS: 1200
CS ON: 200
CS OFF: 600
US ON: 600
US OFF: 900
NO. TRIALS: 100
SET SWITCHES AND PRESS <RETURN>.

READY!


1     -1     -3     -3     -3     -3     -3
2    846    730    675    560    450    431
3     -1     -1     -1     -1     -1     -1
4     -3     -1     -1     -1     -1     -1
5    141    285    167    251    201    256
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Fig. 1. Example of the Teletype dialogue for entering conditioning parameters along with a data printout for five trials.

connecting microampere meters (Western-Electric, Model D-169118) in parallel with the input, visual monitoring of the voltage levels on the six channels is possible. Individual corrections for baseline drift can be made by adjusting the appropriate Helipot potentiometer functioning as another resistive value in the bridge circuits.

SOFTWARE DESIGN

The conditioning package is composed of two interacting subprograms (MAIN and INTERRUPT). MAIN consists of routines for entering conditioning parameters, interpreting responses, and displaying the response topography on the CRT. INTERRUPT services the clock, the first Schmitt-trigger located on the clock control panel, the A/D converter, the Teletype, and the relays.

Immediately after the program is loaded, MAIN initiates the parameter-entering routine on the Teletype. As Fig. 1 shows, the routine receives the parameters for the current session by having the operator answer printed queries. Each query is followed by a colon, and the operator replies by typing in the desired decimal value followed by a carriage return. The entered values are then stored in INTERRUPT. The parameters specified in Fig. 1 indicate the length of the observation interval ("OBS CS:") for each conditioning trial to be 1,200 msec. It is during this period that the CS and US are presented and the A/D is engaged in response monitoring. The respective onsets of the CS and US are shown to be 200 and 600 msec after the start of the observation interval, with the durations of the CS and US being 400 and 300 msec. These queries establishing the observation interval, the CS, and the US also appear in the Millenson et al program (1973). The query, "NO. TRIALS:", asks for the number of conditioning trials, and the next statement is a reminder to the operator to set console switches if the CRT display is desired. The display is enabled when Sense Switch 2 is set, and the selection of the response channel to be displayed is determined by setting the last three right switches, existing in an octal configuration, to the appropriate channel number. Since the selection of the channel can be changed at any time, the operator has the option of viewing the topography from one channel or all channels over successive trials. With the completion of the switch settings, the operator presses the return key on the Teletype and the word "READY!" is printed.

Presentation of conditioning trials requires Sense Switch 0 to be kept in the set position. A trial occurs whenever a positive-going voltage, passed by a Gerbrands filmstrip reader, is sensed by the Schmitt trigger. In this manner, the ITIs are determined. Following the completion of each trial, a line is printed on the Teletype, indicating response frequency and latency (in milliseconds) retrieved from the six experimental stations. Hypothetical data for five conditioning trials are shown in Fig. 1 below "READY!". Each row of values begins with the trial number, followed by the successive reports from the stations. Interpretation of this output is provided below.

The flowcharts depicted in Figs. 2 and 3 indicate the manner in which MAIN and INTERRUPT interact to control the conditioning experiment. When the observation interval for a trial begins, INTERRUPT (Fig. 2) counts the clock pulses, occurring at 1 kHz, into a location "msecs." Every millisecond, this location is compared to values in other locations holding the CS and US parameters. Upon concordance, the appropriate action is taken. For example, when the contents of "msecs" and "cson" are identical, the relay presenting the CS is closed. Also, on every clock pulse, INTERRUPT samples the six A/D channels. Whenever the voltage level on a channel is greater than the response criterion value, the current contents of "msecs" (the elapsed time) are transferred to MAIN. In the present transducer configuration, an absolute A/D value of octal 26, corresponding to ½ mm of membrane or jaw-movement responding, defines the onset of a response. MAIN (Fig. 3) stores the elapsed times in locations set aside for the experimental stations. Once an elapsed time has been received, MAIN initiates the following actions. First, no other elapsed time offered by INTERRUPT for the station will be accepted. Next, a determination is made as to whether the response came before or after CS onset. This is done by subtracting the pre-CS period of the observation interval from the elapsed time. If a minus number results, a "−3" is placed in the output buffer, indicating pre-CS responding by the S. A positive number obtained after the subtraction represents the response latency measured from CS onset, and this value is placed in the output buffer. Given that no response is recorded for a channel, no transfer takes place between INTERRUPT and MAIN, with the consequence that a "−1" will appear in the printout for the station. At the end of the observation interval, INTERRUPT enables the Teletype and completes the printout for the trial. Returning to the data for the five trials contained in Fig. 1, it can be seen that on the second trial unconditioned responses were recorded from all stations, since the interval between the onsets of the CS and US (the interstimulus interval) is 400 msec. However, the fifth trial revealed CR latencies being obtained from all stations. On the other trials, either pre-CS responding ("–3") or no responding ("–1") were evidenced.

Interaction between MAIN and INTERRUPT is also required to produce the CRT display. After the observation interval has been specified, MAIN constructs a buffer which contains the same number of locations as there are milliseconds in the observation interval. During the observation interval, the successive millisecond voltage values from the selected A/D channel are stored by INTERRUPT (Fig. 2) in this buffer. Upon completion of the observation interval, MAIN (Fig. 3) enters its display routine. The voltage values in the

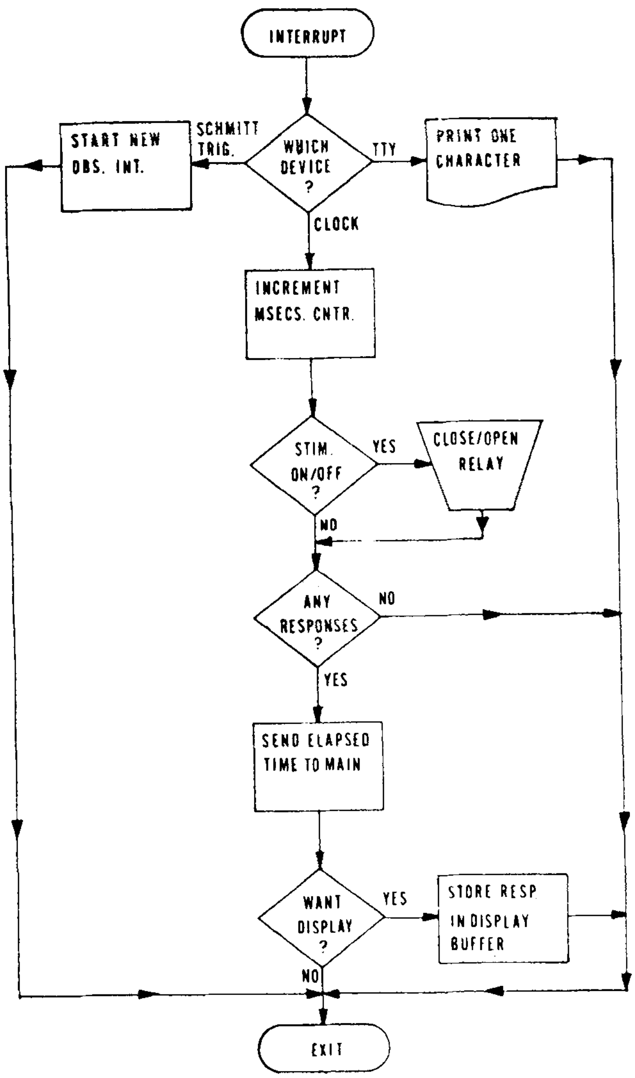

Fig. 2. Flowchart for the operations of INTERRUPT.

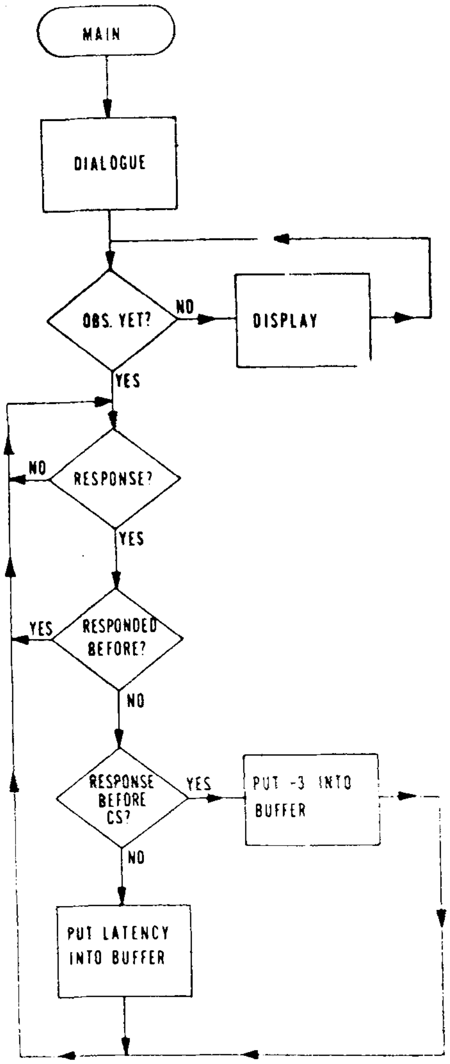

Fig. 3. Flowchart for the operations of MAIN.

buffer are first scaled by dividing them by a constant before they are shown as points on the CRT. The routine can present a maximum of 500 points along a single horizontal time line. Hence, one complete time line across the center of the CRT corresponds to a 500-msec observation interval. Vertical markers are placed on the time line to indicate the onsets of the CS and US. The points constituting the response topography have vertical deviations from the time line. If the observation interval is 500 msec or less, the scaling factor is one which allows the topography to be presented full sized. For observation intervals greater than 500 msec, additional time line segments are added to the display and the scaling factor becomes equal to the number of individual time lines on the CRT. For example, the 1,200-msec observation interval specified in Fig. 1 would be represented by two 500-msec time lines and a relatively short third line corresponding to the last 200 msec of the observation interval. The lines, sweeping from left to right, would be located at equal vertical distances apart on the CRT. The scaling factor would be three, so that the topography can fit into the area bounded by the time lines. With this procedure, topographies in observation intervals as long as 4,000 msec can be displayed. Since the routine continuously reads out the voltage values to the CRT during the ITI, the image is refreshed before it can fade away. MAIN terminates the display upon the initiation of the next trial's observation interval. The display feature has been very valuable in verifying the reliability of the transducer system in that a continuous check of the signal quality to the computer is provided. Moreover, the display allows an independent way to assess response latency against the program's Teletype printout of this information, and measures requiring the complete topography can be taken from the CRT. Following the final trial of conditioning, control of the computer is returned to the factory-supplied DIAL-MS operating system, which is used to load programs placed on the high-speed tape drives.

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