GATE TIME=0002.00 SEC.

CHANNEL	RATE
0	0065.38 PPS
1	0084.45 PPS
2	0112.25 PPS
3	0091.63 PPS
4	0043.81 PPS

Fig. 6. Typical display of firing rates recorded simultaneously from five model neurons.

to provide simultaneous numerical displays of firing rates determined from five individual neurons or neuron models. Both the time at which averaging begins and the time over which the averaging takes place can be controlled by an external gate signal. A typical display is shown in Fig. 6.

SUMMARY

A versatile interface for the PDP-8 has been described which allows the computer to accept times of occurrence of nerve impulses from physiological or real-time analog simulation experiments. The interface provides a means for efficiently handling the large amount of data

produced in electrophysiological studies in vision and hearing.

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five channels of the interface are used

A PDP-12 system for on-line acquisition of heart rate data*

JOYCE KERR, MICHAEL TOBIN†, NORMAN MILKMAN††
ZAVEN KHACHATURIAN, THOMAS WILLIAMS, and JOSEPH SCHACHTER
University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania 15213

A research program for investigating the responsiveness of infants at high risk for developing schizophrenia is described briefly. Two measures of reactivity to brief auditory stimuli, the evoked heart-rate response and the evoked potential of the brain, are recorded for analysis by the PDP-12 computer. An interface to the PDP-12, called the R peak detector and R-R interval counter, is used for reducing the EKG to R-R intervals, with an accuracy of ± 1 msec. The current usage of the PDP-12 and its IBM-compatible tape transports is discussed, and proposed developments for on-line statistical analyses of the physiological data and real-time control of the experiment are presented.

RESEARCH PROGRAM

The Research Center in Child Psychiatry of the Pittsburgh Child Guidance Center and the University of Pittsburgh is undertaking a program to investigate the psychophysiology of infants who may be predisposed to schizophrenia. It is known that genetic factors play a role in the etiology of schizophrenia, and it is possible that those genetic factors may be influencing the functioning of the central nervous system at birth. By comparing the responsiveness of neonates at high risk for schizophrenia to that of neonates at low risk for the mental disorder, we hope to show the presence of differences in nervous system functioning before extrauterine environmental influences become important factors in the development of the illness.

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†Now at the New York State Psychiatric Institute, New York, New York.

††Now at Rockefeller University, New York, New York.

In the Laboratory of Human Developmental Psychobiology, neonates are tested on the second and third days of life for a 4-h session each day. A brief auditory stimulus, consisting of a single cycle of a 1,200-Hz tone, is delivered to the infant through loudspeakers at intervals of 30 to 45 sec. Fifty trials at each of three intensities and 50 control, or no-stimulus, trials are presented over a background of random noise.

Two measures of reactivity to the auditory stimuli, the evoked heart-rate response and the evoked potential of the brain, are recorded by the PDP-12 for statistical analysis. The EKG, EEG, and timing signals are also recorded on analog tape, permitting subsequent computer analysis. In addition, the EKG, EEG, EMG, EOG, respiration, and cardiachometer output are monitored on a polygraph throughout the test session. These polygraph recordings can be used for relating the evoked potential and heart-rate responses to the overall state of the infant, or to sleep stage.

HEART-RATE DATA

Earlier work on the evoked heart-rate response in infants (Schachter et al, in press), which used computer conversion of EKG records, showed that a more efficient method for reducing the EKG to R-R intervals was necessary. Standard cardiachometers can be used to provide the interval between R peaks, but the accuracy of these instruments is $\pm 5\%$ in terms of beats/minute. At a neonatal heart rate of 120 bpm, this corresponds to a ± 25 -msec variation in the R-R interval, a level of accuracy which is inadequate for measuring the small but statistically significant neonatal evoked heart-rate response. An alternative method of obtaining R-R intervals would be to sample the EKG continuously with an A/D converter and to identify the R peaks by computer programming, but we wished to save the power of our small laboratory computer for recording and analyzing other physiological responses simultaneously.

Therefore, an interface to the PDP-12, called the R peak detector and R-R interval counter, was designed to reduce EKG data to R-R intervals with an accuracy of ± 1 msec (Tobin et al, 1970). Unlike standard cardiachometers, the accuracy of this instrument is relatively independent of the frequency and amplitude of the incoming data. The reliability of the R peak detector has been checked by comparing repeated readings of EKG signals recorded on analog magnetic tape. In addition, pulses from a function generator were fed into the instrument at known time intervals, and the readings of the R peak detector were printed out on the PDP-12 Teletype. In both cases the measurement error did not exceed ± 1 msec. The validity of the instrument was evaluated by

Fig. 1. A diagram of the laboratory components. See text for description.

comparing its reading of the EKG on analog tape to the R-R intervals obtained by A/D conversion and computer analysis of the QRS complexes. The differences between the two sets of measurements had a normal distribution of about zero, with a standard deviation of 1 msec.

DESCRIPTION OF LABORATORY

A diagram of the components of the laboratory is shown in Fig. 1. The programmable digital logic unit, or PDL, which was designed by Mr. Tobin, utilizes DEC logic modules and a paper-tape reader for program input. This unit provides signals indicating the start and end of a trial, and a pulse for triggering the auditory stimulus. The amplitude of the trigger pulse is used to select one of the four stimulus conditions, one of the three intensities, or the control condition. The sequence of the signals from the PDL and the intervals between them can be prepared on punched paper tape before the experimental session. The output of the PDL is available to

the computer, the polygraph, the analog tape recorder, and the stimulus generating equipment.

The acoustical equipment consists of a function generator that gates one cycle of the 1,200-Hz tone, a random noise generator, a stereo audio amplifier, and four loudspeakers. The infant and loudspeakers are located within an acoustic chamber. The recording equipment includes a 12-channel polygraph, a 7-channel analog tape recorder, and two IBM-compatible digital tape units (PEC) interfaced to the PDP-12.

PDP-12 PROGRAMMING SYSTEM

The initial programming system written for the PDP-12 receives input from the R peak detector upon an interrupt, EEG data from the A/D converter upon overflow of the KW12 clock, and pulses from the PDL via the A/D converter. The R-R intervals read from the I/O bus are retained in memory during the 25-sec trial and are written on PEC tape at the end of the trial. EEG data are sampled every 5 msec for 1.3 sec and are stored on Lintape throughout the experimental session. At the end of the experiment, the contents of the Lintape are copied as a separate file on the PEC tape. The resulting digital tape consists of three data sets: an EBCDIC header record, consisting of information identifying the S and experiment, as received from the Teletype at the beginning of the experiment; a second file composed of R-R intervals written in FORTRAN-compatible unformatted binary; and a third file, also in FORTRAN binary, containing the evoked potential data.

The data are processed on the IBM System/360, using a multivariate measure of the evoked response (Williams et al, 1970). Discriminant function analyses are performed on both measures of reactivity, generating probability values for every trial of the experiment. These probabilities form the basis for assessing the reactivity of the high-risk and low-risk infants.

Although we are now using the IBM System/360 for these multivariate statistical analyses, we hope to become independent of the 360 by increasing

the memory of storage capabilities of our PDP-12. In future modifications of the programming system, statistical analyses will be performed on the PDP-12 following each trial of the experiment. Trial-by-trial measures of the evoked responses will provide flexibility in the real-time control of the experiment by the PDP-12.

In our previous research we have been concerned with developing a more accurate measure of cardiac reactivity. New methods for quantifying the activity of the EEG are also being developed. These and other measures of the infant's physiological state will be used for real-time control of the experiment. For example, the state of cardiac activity at the time of stimulus presentation may influence the shape or amplitude of the evoked heart-rate response. Heart-rate acceleration, deceleration, overall level, and lability are some of the parameters to be investigated. In addition, the effect of delivering the stimulus at various delays after the occurrence of the last R peak could be ascertained. Similarly, measures of EEG activity could be used to control stimulus presentation. By sampling eye-movement activity on the PDP-12, periods of REM sleep could be identified and selected for experimental investigation. Computer-controlled adjustments in the intensity of the auditory stimuli during these REM periods would provide a measure of the depth of sleep.

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