The use of on-line computers in psychobiology

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This paper examines several areas in the use of laboratory computers in psychobiology, specifically how they are being used, the problems in languages and software, in interfacing computers to experimental configurations, and in the hardware involved. The paper defines the experimental tasks and data requirements which tend to distinguish computer usage in physiological research from other areas of psychology and the tasks which absolutely necessitate the use of a computer and in what mode. Finally we present our views of the dangers of computer use and misuse and make our own subjective evaluation of how well computers are living up to their end of the bargain, how well scientists are doing at their end, and where we should go from here.

Laboratory computers have been in use since the late 1950s. The history has been well summarized by, among others, Sidowski (1970, 1972, 1975) and Aaronson and Grupsmith in this issue. We surveyed *The Journal of Comparative and Physiological Psychology*, *Physiology and Behavior*, and *Electroencephalography and Clinical Neurophysiology* for the past 2 years to record the uses of laboratory computers in psychobiology. In such a survey, the information often reflects work begun up to 2 or 3 years earlier, so current trends may not be reflected accurately. In these journals, about 1,452 articles were published between July 1973 and July or September 1975. The results of the survey are shown in Table 1. It is apparent that the use of computers was much greater in studies reported in *EEG and Clinical Neurophysiology*. This undoubtedly reflects the homogeneity of articles in the journal, which reports work very amenable to computer analysis. About 3% of all articles in *Physiology and Behavior* and *Journal of Comparative and Physiological Psychology* used computers, while 24% of the articles in *EEG and Clinical Neurophysiology* used them. Note that any use of a computer was included in the survey, not only laboratory computers, but larger facilities as well. The survey was not limited to laboratory systems. Those applications in which the computer recorded and partially reduced the data were counted in a

data-acquisition category. Only if a statistical analysis was performed was the computer counted in a data analysis category. It is, of course, possible that in some cases larger computer facilities were used for data analysis but not reported in the study.

It is evident from Table 1 that in studies of EEG and related phenomena, computer usage is primarily for data acquisition and analysis; proportionally more use of computers for experimental control occurred in studies published in the other two more traditionally psychological journals. The most striking result of the study, however, is the relatively limited use of computers for any aspect of experimentation, especially that presented in *JCPP* and *Physiology and Behavior*. At least for the studies published during this 2-year period, computers seem to play a much smaller role than might be expected from the excitement generated by availability of these machines.

HARDWARE AND SOFTWARE CONSIDERATIONS IN PSYCHOBIOLOGY

Hardware and software considerations for on-line computers in psychobiology are not unique to the area. The typical computer facility for psychobiological experimentation contains most of the elements familiar to other computer applications. One of the highest priority hardware items is a programmable clock, which enables the experimenter to control the microsecond intervals necessary for data acquisition. In addition to the clock, analog-digital converters and Schmitt triggers are desirable to convert raw analog signals into digital data.

There are at least four characteristics of

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Table 1
Computer Reports in Journals

Publication July 1973-September 1975	Total No. of Articles	Total No. of Papers Using Computers	Off-line	On-line*			
				Total	Con- trol	Data Acqui- sition	Data Analy- sis
Journal of Comparative and Physiological Psychology	614	21 (3.4%)	6 (1 %)	15 (2.4%)	15	14	4
Physiology and Behavior	596	15 (2.5%)	10 (1.6%)	5 (.7%)	3	5	3
EEG and Clinical Neurophysiology	242	58 (24 %)	39 (16 %)	19 (8 %)	3	19	9

*Subareas will not add to total since, in many cases, the same computer was used for two or three tasks.

psychobiological studies which tend to distinguish them from other types of psychological studies.

The first is the requirement for relatively high data-sampling rates. Evoked potential studies generally use rates of 1 KHz per channel. Single and multiple unit studies can require sampling rates in excess of 10 KHz. Intracellular studies of synaptic potentials can require up to 50 KHz sampling rates. These high sample rates lead to the second characteristic: many data points are often taken during each experiment. For example: consider a not-too-sophisticated experimental session involving six data channels, each sampled every millisecond for 512 msec. If there are 128 trials, this represents 393,216 data points. Even if averages over 32 trials are taken, 12,288 data points/subject/session are generated. Because of the large number of data points, there is a need for mass data storage, and some form of computer facility is needed to analyze the volume of data, either in-house or in a large-scale computing facility, as proposed by Donchin and Heflley (1975). This implies the existence of a method of getting the data into the large-scale facility, generally by compatible magnetic tape. Also implied are funds for computing, and often access to computer networks. FORTRAN programs for the entire range of analyses applicable to physiology are presented in such publications as *Statistical Package for Social Scientists (SPSS)* (Nie, Hadlaihuli, Jenkins, Steinbrenner, & Bent, 1975) and Cooley and Lohnes (1971). These programs are readily adaptable to the hardware constraints imposed by minicomputers although the array dimensions generally must be made compatible with the available core storage and necessary modifications may include reducing the number of levels of subscripting. Wood, Sette, and Weiss (1975) review metalanguages (e.g., SCAT, SKED, ACT, and INTERACT) and discuss some of the limitations of compilers and metalanguages.

COMPUTER APPLICATIONS IN PSYCHOBIOLOGICAL EXPERIMENTS

The phases of a typical neurophysiological

experiment are not much different than those of other areas: stimulus presentation, data acquisition, and data analysis. Perhaps in only one case is the use of an on-line computer absolutely necessary. That is the case in which response-contingent stimuli are presented. Such a situation requires that the computer interact rapidly with information provided it by the subject and feedback information to the subject for his next response. Other experimental situations and data analyses can often best be handled off-line and may not make good use of the computer's unique features. This does not imply that on-line computer control of data handling in other situations is necessarily undesirable, but rather that in other situations, the use of an on-line computer should be done with care. Often there exist viable and less expensive, albeit less flashy, alternatives to computer use which may be more efficient. However, in all three phases of an experiment there are valid uses for computers which would be difficult, if not impossible, to instrument by other means.

Stimulus Presentation

Response-contingent situations are exemplified by such paradigms as instrumental conditioning procedures (Fox & Rudell, 1969; Weiss & Laties, 1965), biofeedback training in psychophysiology (Schwartz, 1974), and other types of closely coupled stimulus-response-stimulus sequences (Roemer, 1975). A fine example of the use of a minicomputer for visual stimulation is the experimental series by Spinelli and associates (e.g., Spinelli, 1967; Spinelli, Hirsh, Phelps, & Metzler, 1972). Here a contrasting disk on a screen is moved across the visual field by the computer which simultaneously counts the number of single neuronal discharges per .5-deg visual segments. In this manner, the visual receptive fields of neurons have been systematically mapped in adult cats and compared to the visual pattern experienced as developing kittens.

The computer is used also to control voltage-controlled oscillators (VCO) to determine auditory tuning curves of neurons. The frequencies generated in this way by the VCO can be a systematic

sweep over a frequency range, or a randomized presentation of frequencies to evaluate tuning curves over the frequency range.

An excellent example of the use of computers in contingent stimulus presentation is seen in a study by Fox and Rudell (1970) and in a similar study by Rosenfeld, Rudell, and Fox (1969). In these studies, cats and humans were instrumentally rewarded for alterations in a selected portion of an evoked response to light or tone. In each case, the computer was programmed to calculate the amplitude of a preselected portion of the secondary evoked potential and to present a reward if the amplitude was 1 SD higher (or lower) than the average of previous responses. In this way, progressive shifts in response amplitude were produced over trials. In this case, the computer was absolutely necessary to the study due to the constantly changing criteria being used for reinforcement.

These are some of the modes of stimulus generation made possible by the computer which would be difficult or impossible to produce by other means. However, it appears that laboratory computers have not been used as extensively in stimulus presentation as may have been promised. This may be a stronger comment on the experimental questions being asked than on the capability of the machines.

Data Acquisition and Analysis

In the psychobiological laboratory, it is in data acquisition and analysis that the computer has apparently come into its own. At this point, our discussion extends beyond on-line applications to include digitization of physiological data, which is played back from original AM and FM magnetic tapes. There are several advantages to such off-line analyses, one of which is the more efficient use of computer time, if contingent stimuli are not required. This is particularly true where stimuli are presented with varying times between trials. During these intertrial intervals with the machine on line, it generally must sit idly by waiting for the next trial. By stopping the tape recorders during the intertrial intervals, the idle times are eliminated during the playback, which results in data digitization with much less absolute computer time. In addition, problems of computer downtime during a lengthy experimental session are avoided. The data may then be replayed several times through the computer to analyze several different sets of information, such as (1) slow wave analysis for EEG frequency components, (2) slow wave analysis for evoked potentials, (3) neural spike rates, (4) amplitude windows of neural spikes which separate large unit populations from smaller-sized units, (5) analysis of the interspike intervals (single units), or (6) a change in the time constraints of any of the above categories.

It is evident that data reduction and analysis can

often be best and most efficiently completed off line. In the past, large computers have often been used for this task because of their ability to digest large quantities of information in a short time. The chief drawback to this solution has been cost, especially if a special transmission line is used to convey the data from one machine to the other. For these reasons, investigators have often opted to analyze data in their own laboratory minicomputer off line during inactive periods of the day or night. This is not necessarily an efficient use of the machine since computation can be quite slow. This is offset, however, by the low cost and the fact that the turnaround times are about the same. As large computer costs drop and as computer connect-time costs decrease, more investigators will probably reverse this trend, utilizing the large computer for its number-crunching capabilities.

Problems of Computer Dependency

Several dangers and problems are attendant to the use of any laboratory computer, perhaps especially in psychobiology. Like many other technological creations, the computer is a tool to be utilized in an effective way to obtain answers to important scientific questions, not as an end or as an omnipotent entity that determines the circumstances under which the questions can be asked. The issue here is not whether computers are doing the things promised, but whether investigators are intelligently utilizing the equipment. In many cases, the experiments can be controlled or data acquired and analyzed by means other than a computer and in a more efficient manner. When computers are used in such cases, the danger increases that the computer hardware or software will dictate the terms of the experimental procedure. This particularly insidious aspect of the laboratory minicomputer has a tendency to "steal power from the experimenter." It then becomes too easy to design experiments which are compatible with the existing hardware and software rather than to develop the configurations necessary to adequately deal with the experimental question. In this case, the potential of the computer is abrogated.

One discomfiting trend in psychobiology seems to be an increasing reliance, on the part of investigators, on technical staffs and products which are not fully understood. During the developmental years of electrophysiology, investigators constructed their own equipment since none was commercially available. The advent of integrated circuitry has made the problems associated with the construction of electronic apparatus immeasurably easier, yet the trend to reliance on technical support appears to have increased.

Future Trends

Future trends in the computer field are sure to result in even greater changes in neurophysiological

research than have already occurred, primarily because microcomputers will be available in large quantities at a substantial reduction. Even today, a microprocessor and 8K of core can be purchased for only a few hundred dollars (Robinson, 1974). Much of the present laboratory equipment will be replaceable with off-the-shelf items. We expect to see microcomputers extensively used in data preprocessing or signal conditioning for such tasks as counting neural discharges, performing analog-to-digital and digital-to-analog conversions, doing spectral analyses, handling stimulation presentations and for mass storage of the data. The minicomputer would be used for analysis functions as well as to prepare data for transmission to the larger computer. Alternatively, hand-carried tapes or disk packs prepared by the mini would not be an unacceptable possibility. The role of the large-scale systems would be twofold. First, they would perform cross-compiling functions so that the researcher can generate programs for the minisystem on the maxi, taking advantage of the elegant text editing and formatting aids which reside there. Second, they would increasingly be used for routine large-scale data analysis as other costs decline.

Programs that are produced on the maxis for specific minis could reside in public files, permitting other scientists with similar systems to use them. This would reduce the overall cost of repetitious software development now borne by many grants. A secondary, but not insignificant, by-product would be an automatic standardization of data-storage formats. Currently, the lack of standard data formats within the field essentially precludes the convenient and orderly sharing of programs among scientists, even with identical machinery. Such programs in a public file could then be loaded into the minisystem via a time-sharing connection. The experiment would then be conducted by the micro-mini configuration, with preliminary data reduction accomplished by the microsystem which would then access the minisystem and transfer the reduced data to permanent files for more extensive analysis. Until the cost of high-speed data lines decreases, the interactive transfer of all the data from an experiment is probably not reasonable in terms of either time or costs.

In summary, we foresee increasing application of

integrated circuitry and minicomputers in the experimental situation, coupled with an increasing use of large-scale computer analyses of psychobiological data. This will lead to more general acceptance of computers and a more sophisticated level of questions being asked of such on-line systems than are now being formulated in most laboratories.

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