SESSION I OPENING REMARKS

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SESSION II INVITED ADDRESSES

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Computers in the training of inquiry

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The era of microprocessors provides an opportunity for examination and restructuring of university-level education in psychology. Computers may aid in the development of environments based upon sustained and deepening inquiry on the part of students from their earliest contact with psychology. We have been developing a computerized system for the exercise of skills in psychological inquiry appropriate both as a teaching tool for beginning undergraduates and for the research of permanent and visiting professors. In this paper we discuss our philosophy, some aspects of the organizational and human factors problems involved, and issues of hardware and software design.

Some years ago the American Academy for the Arts and Sciences (Daedalus, 1974, 1975) sponsored a symposium on the malaise of the universities. That two-volume conference published in 1975 contains a haunting indictment of many of the familiar problems of undergraduate education in the United States. These include large and impersonal classes, hours of absorbing

information from printed page and spoken word, and a failure to spark the creativity that some assume to be natural to human intelligence, but which is so infrequent a characteristic of the undergraduate experience. The image of the human implicit in experimental psychology of the 1930s-1950s could certainly be considered a contributor to justifying a relatively passive educational experience in which large amounts of data are to be committed to memory with relatively low amounts of active initiative on the part of the learner.

The research described here was fostered by a series of grants from the National Science Foundation for the development and support of these facilities. Additional support came from the Advanced Research Projects agency of the Department of Defense, Office of Naval Research, and Office of Education. The unique characteristics of our cognitive laboratory computer facility has been shaped by 10 years of faculty, graduate student, and undergraduate student involvement. Much of the initial design of the hardware is due to Steven Boies, now of IBM; much of the software design is due to Nancy Frost, now at the Upjohn Corporation, and to John Sharp. We are grateful to those who have worked on the development of our facilities. The educational views and philosophy outlined in this paper remain our own, however. Information on our facility, reprints, and other information are available from: Cognitive Laboratory, Department of Psychology, University of Oregon, Eugene, Oregon 97403.

Cognitive psychology, with its emphasis on the active nature of information processing, should help produce a change in higher education. Moreover, education is no longer the sure entry into economic well-being and must now compete for the reduced number of late adolescents with other activities that may prove more enjoyable and valuable and for older students whose willingness to support the traditional forms of higher education is in doubt. Prescriptions for these problems range from the organizational (e.g., the flood of new curricula) to the technological (e.g., the use of television, personalized, or computer-assisted instruction). In this paper, we examine the relationship between curriculum design and a particular use of computer technology.

GOALS

We would like to describe one idea about the use of computers that has induced changes in our curriculum designed to address some of these difficult issues. The material that we will present is in part dream, not yet realized, and in part description of a number of developments that have taken place in the psychology department at the University of Oregon in the last 5 years. Both the dream and its realization are called inquiry training. Our desire is for a computer facility that allows the beginning psychology student who never before has touched a computer terminal to conduct meaningful inquiry into important and interesting psychological topics that will eventuate in the kind of experimental results that could be communicated at a meeting of a professional society.

At some schools in which operant ideas are particularly strong (Kulik, 1977), students are given a rat at the start of their career so that they learn the principles of operant psychology by training the rat. Similarly, we see the student's own mind and performance as intrinsically interesting subjects of disciplined inquiry. Through the use of structured experimental exercises, the students learn about their mental processes and aspects of their memory and performance.

We see the computer and its stock of programs as analogous to a library, a library to which the student could return again and again during his psychological career, able to inquire more deeply as he gains the skills necessary to do so. An experimental exercise in the hands of the beginning undergraduate may be used to establish very simple points; a more advanced undergraduate or graduate student can use the same exercise to ask more complex questions. The idea is to use the same experimental facility for the initial student as for the research of established professors. In this plan the activities of the researcher become a kind of model for the work of the student. However, unlike graduate training, in which apprenticeship is a common technique, we use computers to ensure the breadth of coverage of different areas of the field, rather than confining the student too rigidly to the particular research activities of a professor. Nonetheless, like apprenticeship work in graduate school, it seems important to reflect in the available programs those aspects of psychology that are likely to be reinforced by the faculty because of their own interests and enthusiasm.

ENVIRONMENT

Our department has available for research purposes a PDP-15 computer with 24K of core memory and 6 DECTape units. The computer is designed to timeshare five experimental stations. In general, four of these stations are used for individual faculty and graduate student research; the fifth station is used for under-

graduate instruction. This fifth station uses a scan converter to make the computer signals compatible with television displays. An individual and a group station in the undergraduate laboratory uses standard Teletype or display terminals, and each has available 4 bits of keyboard response, as well as television displays.

We do not place very much stress on the hardware because its importance is now slight. Indeed, it would be much easier to develop the same capability around microprocessors, as we intend to do in the future. Our basic ideas are much more realizable now with microprocessor systems than they were with the system we originally developed.

In addition to the PDP-15 computer system, a timesharing PDP-10 computer terminal is available in our undergraduate laboratory. The PDP-10 computer is sufficient for statistical exercises and for low-demand laboratory exercises, but it cannot give us high enough priority to allow us to run experiments in which timing is crucial. The presence of redundant computer systems is important because of the possibility of the failure of any one computer system during a class. This problem could be reduced with the use of microprocessors available at each student station.

Mixing the same general computer facilities for teaching and research purposes has had a number of important beneficial results. The memory-protect ensures that mistakes made by undergraduates do not affect the overall computer system. On the other hand, the presence of a large number of graduate and faculty members doing research in the computer facility provides a source of help for undergraduates that would not otherwise be available. Moreover, the development of experimental exercises by faculty members in the pursuit of their research provides sources of new material and exercises for undergraduate students. Our project was facilitated by the presence of a full-time systems programmer who was able to maintain a level of documentation for our system and provide continuity between research and teaching efforts.

In order to describe the overall project, it seems best to follow the various levels at which students might interact with our system. We begin with the entry level of a beginning student, then describe our research methods level, next, the level of advanced experimental psychology and other advanced undergraduate courses, and, briefly, the conduct of research by graduate students and faculty in this facility.

ENTRY LEVEL

All undergraduate students who come to the University of Oregon have available a manual on our undergraduate curriculum. This manual describes the inquiry training program to the students as follows: "The purpose of the inquiry training program is to provide the opportunity for students to explore aspects of

psychology individually. The modules we have prepared are designed to be useful for a student without any background. As you work with the module you will find they allow you to ask new questions, some of which have never before been explored."

The manual describes the different subcategories of exercises available to the student: "One set of modules, (exploring mental processes), is designed to help you probe your own mind. It is surprising how little knowledge we have about the structures which control our own mental processes. Cognitive psychologists are currently using a variety of techniques to determine just what these structures are. This set of modules draws upon techniques used in cognitive psychology, they should provide you with some insight into your own mental processes."

Another set of modules is described as follows: "Psychologists are increasingly becoming change agents in the real world. Their efforts are based upon systematic and careful observation and upon techniques of modifying the behavior that they observe. One set of modules (modifying behavior) is designed to illustrate some of the methods used in modifying behavior."

In addition to exploring mental processes and modifying behavior, which we describe in more detail later in this paper, we also have some modules on observing behavior, simulating behavior, and performing statistical exercises on data.

The choice of exploring mental processes, behavior modification, and observation as major methods in our inquiry training reflect the heavy concentration in our department of these various fields. We have a large number of cognitive psychologists. We also have a fairly large group of clinical psychologists, whose work is based almost entirely upon behavior modification techniques. Finally, we have a group of developmental and social psychologists, whose methods often involve the systematic observation and coding of behavior. Because these methods dominate the inquiry activities of our department, we have tried to reflect them in the modules available to the undergraduate student. We assumed that a student who had already successfully employed particular techniques would find it easier to communicate with faculty members who employ the same techniques. We do not know the extent to which this supposition has in fact been realized.

Let us examine two of the modules in more detail. One of our modules is called "mental arithmetic." Operationally, it is a reaction time experiment in which subjects can explore the way they perform simple mental addition problems. In each experimental block there are 120 addition problems. For each problem the student reports whether or not the two addends produce the indicated sum. The problems are structured in such a way that the minimum of the two addends is equally often two, three, four, five, or six and above. Among the incorrect problems, the indicated sum may be close

to the correct answer (e.g., $3 + 4 = 8$), a correct multiplication (e.g., $3 \times 4 = 12$), or a control for a correct multiplication (e.g., $3 + 4 = 13$).

At the end of the block, the student receives a summary of the data, as shown in Figure 1. The summary allows the student to plot the reaction time and error as a function of the size of the minimum of the two numbers that he is adding. This is the Groen and Parkman (1972) result, in which one might expect that the size of the minimum is linearly related to reaction time. In addition, by a comparison of correct multiplication, with multiplication controls, students are able to examine the interesting interference effects first reported by Winkelman and Schmidt (1974).

Students can get a complete printout of their reaction times for each successive problem. With these printouts, they can deal with complex questions of sequential dependencies, and so on.

We encourage students to use this module as a way of inquiring into the nature of different strategies for the solution of an arithmetic problem (see "Going Further," Figure 2). If they deliberately count, what does that do to the relationship between reaction time and the size of the minimum? Beginning students usually go no further than this in analyzing the data, but, clearly, a student who has had work in cognitive processes may begin to ask questions of speed-accuracy tradeoff, correlation between the slope and intelligence, and a wide variety of other interesting questions that might be studied with this module.

Before going into more detail on how the modules are used in any instance, we describe one additional module—namely, that used for schedules of reinforcement. The schedules of reinforcement module falls in two parts. In the first part, exercises are designed around a single key. When the student accesses the program, he is given a schedule of reinforcement on the key that corresponds to ratio schedule, interval schedule, or extinction. As he presses the key according to the schedule of reinforcement, numbers increase corresponding to the number of points that he has won.

At the end of a given experimental run, a cumulative curve is plotted showing the reinforcements in relationship to the successive keypresses by the subject (see Figure 3). With such a module, students can examine their performance and mental processes as they adapt to different schedules of reinforcement. They can see the extent to which they can duplicate the kinds of curves shown in introductory textbooks for pigeons and monkeys. A second module involves two keys and allows the subject to study more complicated tandem or conjoint schedules reinforcement that are being used in the study of behavioral economics (Rachlin, Green, Kagel, & Battalio, 1976). In fact, the students can design nearly any schedule of reinforcement for either key by typing in a few numbers. This exercise allows almost limitless types of inquiry. For example,

Sample Interaction

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+C                                (user gets monitor)

MONITOR (V2B)

&RUN ARITH                        (user calls up Mental Arithmetic program)

MENTAL ARITHMETIC (BLOCKS: 1=ADD ONLY, 2=ADD & MULTIPLY)

DATA=

RS#=14573                        (user types in odd starting number for randomizing)
BLKS=1 1                         (user requests 1 block of 'ADD ONLY')
A2                                (computer types results after user runs through
1= 15 598 0 0                   a block of trials)
A3
1= 14 623 1 492
A4
1= 14 626 1 526
A5
1= 11 622 4 757
A678
1= 15 669 0 0
AERR
2= 25 731 5 636
AMUL
2= 26 641 4 656
ACON
2= 15 685 0 0

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Analysis

1. Plot the graph of your reaction time (in milliseconds) against the size of the smaller digit (the hypothetical number of counts, i.e. the A2, A3, A4, A5 and A678 conditions).

Can your graph be approximated by a gently rising straight line (as the counting theory predicts)? _____

If so, what does its slope appear to be? _____ milliseconds per count.

2. Compare your reaction times for associative confusions (items of the type $8 + 2 = 16$, i.e. AMUL), and for nonassociative confusions (e.g., $8 + 2 = 17$, i.e. ACON). Also, compare the errors.

Associative confusions: reaction time _____ errors _____

Nonassociative confusions: reaction time _____ errors _____

Do your times fit with the predictions of the association theory? _____

Figure 1. Sample interaction of mental arithmetic module for entry-level work in inquiry training. The data are summarized in terms of the number of trials, mean RT for correct and incorrect responses in the conditions in which the minimum addend is 2 (A2), 3 (A3), and so on. The first five rows are for "yes" responses (e.g., sum is correct), and the last three are for "no" responses.

Going Further

1. Response speed affects accuracy and vice versa. You can study this effect by attempting to respond as fast as possible on one block of trials, and as accurately as possible on another.
2. Try to do all the problems by consciously counting upward from the larger number (e.g., $6 + 3$ is 7, 8, 9). Observe the slope of your graph under this condition, and compare it with your graph under normal conditions.
3. If you want to observe a powerful interference effect, try doing the task as a multiplication task (pretend the $+$ means multiply). You will notice that some of the answers are correct for multiplication (e.g., $8 + 2 = 16$); respond "yes" to these, and "no" to all others (e.g., $8 + 7 = 15$).
4. To see if memory load affects this task, try memorizing each RT presented to you and jot down your memory of it after you've done the next problem; e.g., suppose you've just responded "yes" to $8 + 7 = 15$ and the RT was 535 msec. Try to hold this figure in your mind as you do the next problem.

Figure 2. Suggestions for going further using the mental arithmetic module.

students can compare a given schedule when it is run alone or combined with a variety of other schedules of reinforcement. In addition to the schedules of reinforcement module, we have used modules on biofeedback, shaping of a simulated mouse, and a behavior modification routine designed to produce a reduction of test anxiety.

There are several features of how the students access these programs and what happens to the data. We have attempted to short-circuit any of the ethical questions with respect to mixing research and teaching. The student is his own subject. None of the data are stored. This also enhances our ability to deal with a large number of student users. Data are held in the PDP-15 core memory during the time that a given student prints out whatever he needs. At that time the information is cleared. This ensures confidentiality of the student's performance and data, since the student is the only one who has access to it. We do not emphasize comparison of his performance with that of any other student.

Our current corpus of inquiry training modules that run on the PDP-15 computer consists of about 15 modules. These exist on a single inquiry training tape mounted on the undergraduate terminal at the start of each experimental day. The student has in the manual a set of instructions that allow him to gain entry to any of these programs. Although the instructions are simple, they frequently lead to problems. It is necessary for the subject first to type control C. We have signs all over the lab trying to get the student to hold down the control character when he types the C. This is followed by the name of the program wanted, followed by a carriage return.

Figure 3. Upper panel is the CRT cumulative curve following a ratio schedule. The data indicate a quite steady response rate. Lower panel shows a schedule in which a ratio and an interval schedule are alternately in effect. The upper portion shows the cumulative curves from two of the interval periods. Note that the subject adjusts to the slow response rate from this schedule. The lower trace shows the two periods of ratio schedule with their characteristically rapid response rate.

Our original plan for these modules was something of a failure. We had thought these experiments would be so intrinsically interesting that, once students had the manual and the opportunity to sit down at the computer terminal, they would want to do so even though no credit was involved. A few students did take advantage of this organization, but many were afraid to touch the terminals. If they did try, they might get into one of the modules, run a few trials, find out that it was rather boring to solve arithmetic problems, and leave. In general, the impact was disappointing. We had to get subjects over the threshold of familiarity with the computer and inquiry before they could successfully interact with these modules. To do this, we created a new introductory course called Psychology 201, in which we have a group laboratory discussion of about 25 students that draws upon the inquiry training modules. Currently, we run nearly 1,000 students/year through this laboratory.

In these groups students are exposed to some inquiry training modules and have a chance to see how they operate. The students are invited back to use them on their own. In fact, the modules have turned out to be much more useful in these group exercises than in individual exercises. In part, it is testimony to the flexibility of the computer as a teaching tool how easily the original idea could be adapted for this new group format.

For example, to introduce reinforcement, we can begin with a mouse-shaping program that adapts beautifully to the group format. The students observe while a dot moves around the television screen on a random path. At the end of any desired period of performance, the instructor can print out the percent of time that the dot moves in each of 12 directions for each successive 10-sec period. Following that, a student can be induced to try to shape the dot by reinforcing the animal for approximations to a given direction. Shaping can be used to show counterconditioning, extinction, and so on.

We then usually use the reinforcement schedule module. A student serves as a subject, for example, in a fixed-ratio schedule in which he produces very, very rapid rates of responding. Another student might then be given a fixed-interval schedule. He begins by banging the key very, very rapidly as he had observed the last subject doing. He adjusts to the fact that this rapid responding does not get him points, and the class can observe the combination of his verbal behavior and performance. These group demonstrations succeed in generating a good deal of interest by the students in the various kinds of computer programs. On occasion, the more interested students return for further work on the inquiry training modules. Much of the individual work on inquiry training has gone on at more advanced levels.

RESEARCH METHODS

Our way of socializing psychology majors occurs in the 300 level, in our research methods (301) and quanti-

tative methods (302) courses. We have attempted to use some of the inquiry training ideas as part of the 301 sequence, but we have really hardly scratched the surface of this potential use of computers in statistics and research methods. Many places in the country have done far more than we have (Main, 1972). The research methods course involves training in a variety of methods, including library research, use of census data, observational methods, constraints of attitude questionnaires, and design of experiments.

Currently, the PDP-10 statistical package is used as a means of giving students in the research methods course who have had statistical background an opportunity to exercise it in their research. The ability to access correlational routines from the statistical package allows students who have had statistics courses prior to research methods to compute appropriate statistical analysis of the type of census data with which they are dealing. The inquiry training modules are also very useful in introducing the logic of experimental design. Both univariate and multivariate experiments can be run rather quickly in large groups, and subjects can see the logic of trying to deal with several variables simultaneously.

ADVANCED EXPERIMENTAL AND UPPER DIVISION INSTRUCTION

We admit students to our advanced experimental course who have done particularly well in research methods or whose general university work has been superior. We encourage students to take the course even though their interests may not be directly connected with the content material because we argue that the training in inquiry will be of general benefit to them in any serious work in psychology, irrespective of area. We have no direct evidence to support this notion, but the fiction that it is true is important for our advising of students. The course is a 1-year junior-level course designed for 20 students, all of whom plan to spend the full year. Both the first and second quarter draw on our general laboratory facilities, but the first quarter is more structured than the second. During the third quarter, students usually work on projects of their own choosing. Many of these projects do use the computer facilities, but not always.

The first quarter involves teaching students a computer language (EXPERIMENT WRITER) that has evolved in such close symbiosis with the course (for a more complete description of the language, see Osgood, Posner, & Lyon, 1973). The computer language has three logical levels of analysis: files, trial definitions, and block definitions. Similarly, the course involves a phase-out method of cognitive psychology experiments. Each experiment provides for the student less of the needed program. Students learn first to deal with parameters that can be changed on-line, then with block definitions, then with trial definitions, and, finally, they create their own stimulus files. Thus the logic of the computer language and the logic of the course are meshed in a way

that allows the student to learn both the essence of experimentation and the computer language. The experiments used in the course are described below. For more extensive treatment of this course and other computerized laboratory courses, the reader can consult Bewley (1974), Levy, Fischler, and Griggs (1979), Main (1972), and Osgood et al. (1973).

We begin our course with a simulation experiment developed by Lindsay and Norman (1977) at the University of California at San Diego. The experiment is a simulation of lateral inhibition in the limulus. We use it primarily as an ice-breaker and to give our students an experimental demonstration in which a precise quantitative solution can be derived by using a number of experimental operations. Most students hit quickly upon the idea of stimulating at one place and moving a second stimulus closer and closer in order to find the interaction between the two stimuli. Most students succeed rather quickly in learning the simple wiring diagram of the program, and this gives many of them their first experience in logical problem solving with experimentation. This is an experience that provides them a certain confidence that there can be a solution, despite the difficulties of experimentation.

From there, students run a second experiment called "threshold." They measure the psychophysical threshold of a simulated subject. Although most students have encountered the concept of noise or variability in their psychological work, a number of students who enter psychological experimentation from the natural sciences are not very familiar with this idea. Thus when they find that the same value of intensity sometimes produces a "yes" response and sometimes a "no" response from the computer, they are surprised. They find after gathering sufficient data that, despite this variability, there is a precise function that can specify the threshold of the subject. This gives them the idea that it may be possible to obtain solutions, even in the presence of the very considerable noise that they will find in the other experiments that they will be doing.

Our next experiment is designed to teach the experimenter to manipulate parameters on-line. The experiment involves signal detection. The stimuli are presented either to the left or to the right of fixation and consist of either a letter followed by a noise mask or a mask alone. The experimenters are able to choose the identity of the letter, its duration and intensity, the time between the letter and the mask, and the duration of the mask. These values are simply typed in for every block of trials. The blocks and trials are fixed by the computer program we have written. The students vary the parameters to obtain a level of error useful for the signal detection analysis. During class time they learn signal detection theory and are taught to calculate d' and β . The use of computer-controlled experimentation gives the subject very easy control over the parameters of this experiment and allows him to generate a very large amount of data very quickly. Although we have rarely found any

difference in d' or β as a function of whether the stimuli go first to the left or to the right hemisphere, it is rather easy to think up reasons why there might be and thus to generate a number of interesting and testable hypotheses. Frequently, teams of excited students go well beyond the exercise to manipulate routine parameters such as intensity in order to check signal detection logic or ideas they might have about hemispheric efficiency.

The next experiment teaches the students to define blocks within our EXPERIMENT WRITER program. A block is an assembly of a number of individual trials. The experiment that we use to teach block definitions is based upon work by Hyman (1953). Students receive one of eight digits that are mapped into four-key responses. By defining relative frequency of these digits in a block of 100 trials, they are able to manipulate the information contributed by the occurrence of every stimulus and response. Thus they can examine the relationship between information and reaction time by comparing different stimulus probabilities. Students are able to examine the effect of stimulus plus response repetition vs. stimulus repetition alone and to see how each varies with time between trials, and so on. Since at this point of the course we are discussing the relation between information and reaction time and the role of automatic vs. controlled processes, this exercise fits in quite well.

In the next experiment we ask students to learn to define individual trials. With this skill they may display on the CRT any kind of trial whose elements have been created as an array and stored. Of course, any of a large number of experiments would be appropriate for this goal. There is an extremely valuable heuristic that works in motivating students. That heuristic is to have an enemy (in this case the instructor) whose work you would like to show to be wrong. To exploit this human tendency, we use a letter-matching experiment (Posner, 1978) in which subjects receive pairs of letters and are required to say if they are physically identical (e.g., AA) or whether they have the same name (e.g., Aa). We present a theory about the relationship between physical and name matches (Posner, 1978) and challenge the students to design an experiment to show that this theory is wrong. The student learns to use the experiment-writer program to construct different types of trials (e.g., AA, Aa, Ac, AB, etc.). He may then assemble these trials into blocks of his own description. For example, he may use all physical identity and difference responses, or he may use physical identity and name-identity trials within the same blocks, and so on. The opportunity to explore the theory in detail by constructing experiments analytic to it provides more excitement than the usual textbook laboratory exercise and allows the subject to gain a certain confidence in his ability to test and sometimes to destroy theoretical ideas.

At this point, students are able to assemble a full experiment. It is helpful to constrain their search in some ways. For this purpose we provide a copy of a

paper by Sternberg (Note 1) that is one of the finest tutorial papers ever written for cognitive psychology. In that paper, Sternberg defines the additive factors method and applies it to 20 areas of psychology. In one sense, the additive factors method teaches students the beauty and logic of factorial design. In another sense, if one accepts the serial processing assumption that Sternberg outlines, the paper also provides the opportunity to make very exciting interpretations of both interactions and additivity. In fact, some of these interpretations are questionable, but we teach the students that it is often necessary to make assumptions in order to discover new things. We also encourage students to design manipulations that allow them to test the internal logic of the method as well as to test new ideas. The use of the EXPERIMENTER WRITER language helps subjects to conceive of their experiment concretely as the development of an array, a trial, and then a block. We ask them to write up the experiment as a proposal and to construct one block of the experiment. The final exam is an oral one in which they run through the experiment and are examined on its logic. In recent years, nearly every student has been capable of developing a rather interesting experimental design, and some of them are quite impressive.

The second quarter of the course develops topics in visual perception. These are also largely done on the computer, and two general topics have dominated: the perception of motion and visual adaptation. Generally, the students are organized into teams and tackle one of these experimental problems by designing an experiment that takes off from a module created by the instructor.

We believe that we have made the computer our servant in this course by allowing it to be the workhorse in teaching cognitive psychology without allowing it to become so obtrusive that the students see themselves primarily as programmers. Thus the computer becomes a tool for fostering inquiry rather than an impediment to it.

Only 20 students in our program per year go through advanced experimental psychology. However, the presence of the modules used in advanced experimental, together with those described for the entry level, allows upper division lecture courses to use them as supplementary demonstrations and exercises. For example, in an upper division course in cognitive processes, computerized experimentation in letter-matching and problem solving simulations were used as an adjunct to the regular course. Several other upper division courses, such as human performance and learning, have also drawn upon the modules in constructing individual laboratory work to be done along with the standard course. In general, instructors have been enthusiastic about the availability of such materials, although, rather surprisingly, relatively few instructors have attempted to design or request the design of modules tailored for their

course materials. Thus we may have overestimated the utility of these modules as parts of the upper division courses.

GRADUATE TRAINING AND RESEARCH

Most graduate students come to our program with considerable knowledge of some form of computer programming. In general, they do not make use of the modules or the EXPERIMENTER WRITER language. However, nearly all of the students who study cognitive psychology use the general cognitive laboratory facility to conduct their research. Thus, our overall computer system is involved in from two to five doctoral theses and about the same number of master's theses per year. In addition, graduate students often run experiments in conjunction with the eight faculty members who use the facility. At the graduate level, we stress the importance of students' being able to follow an interesting psychological problem, irrespective of the methods needed to do so. The computer facility has helped students to reflect this philosophy by making it easy to adopt various methods of perceptual and memory research. This is particularly true of various chronometric (Posner, 1978) methods, such as reaction time, masking, speed-accuracy tradeoffs, and evoked potentials, that have been quite popular in cognitive research.

In addition to graduate training, we have been able to use the facility to accommodate a number of visiting researchers from other universities in this country and Canada, as well as more distant visitors from Italy, Israel, Australia, Finland, Yugoslavia, and Britain. Our emphasis on making inquiry easy by providing a large, flexible, computerized environment has helped attract visitors and make their stays productive. We believe that these visitors have also contributed greatly to the educational atmosphere available in our department.

The best overview of the use of the facility for research can probably be obtained by looking at mailing lists of papers produced from the laboratory in recent years. These are available from the same address as reprints of this paper.

CONCLUSIONS

The design of university education implies an image of the human. We believe that an image of a mainly passive learner, absorbing material in order to eventually be fit into a proper position in the societal hierarchy, will not do for the future of universities and is also inappropriate to ideas emerging from psychological research. A proper goal for education is to produce an environment that will foster the inquiring mind. We believe that computer systems may be one significant aid in the development of such environments. While this

paper has been devoted to a description of one system, we do not believe that any system for developing such an environment is necessarily best. Indeed, we suspect that the teaching environment may need to arise in close relationship to the inquiry activities of the faculty who shape it.

REFERENCE NOTE

1. Sternberg, S. *Decomposing mental processes with reaction-time data*. Invited address presented to the annual meeting of the Midwestern Psychological Association, Detroit, 1971.

REFERENCES

- BEWLEY, W. L. *Cognitive psychology: A computer-oriented laboratory manual*. Hanover, N.H: Project Compute, 1974.
- DAEDALUS. Special issues on American higher education: Toward an uncertain future (Vol. 1). *Proceedings of the American Academy of Arts and Sciences*, 1974, **103**, 1-355.
- DAEDALUS. Special issues on American higher education: Toward an uncertain future (Vol. 2). *Proceedings of the American Academy of Arts and Sciences*, 1975, **104**, 1-366.
- GROEN, G. J., & PARKMAN, J. M. A chronometric analysis of simple addition. *Psychological Review*, 1972, **79**, 329-343.
- HYMAN, R. Stimulus information as a determinant of reaction time. *Journal of Experimental Psychology*, 1953, **75**, 188-196.
- KULIK, J. A. (Ed.). *Undergraduate education in psychology*. Washington, D.C: American Psychological Association, 1977.
- LEVY, C. M., FISCHLER, I. S., & GRIGGS, R. A. *Laboratory in cognition and perception*. Iowa City, Iowa: CONDUIT, 1979.
- LINDSAY, P. H., & NORMAN, D. A. *An introduction to psychology* (3rd ed.). New York: Academic Press, 1977.
- MAIN, D. B. Toward a future-oriented curriculum. *American Psychologist*, 1972, **27**, 245-248.
- OSGOOD, G. W., POSNER, M. I., & LYON, D. Computers in the training of experimental inquiry in psychology. In F. Weingarten (Ed.), *Proceedings of the Fourth Conference on Computers in the Undergraduate Curricula*. Claremont, Calif: Claremont Press, 1973.
- POSNER, M. I. *Chronometric explorations of the mind*. Hillsdale, N.J: Erlbaum, 1978.
- RACHLIN, H., GREEN, L., KAGEL, J. H., & BATTALIO, R. C. Economic demand theory and psychological studies of choice. In G. H. Bower (Ed.), *The psychology of learning and motivation*. New York: Academic Press, 1976.
- WINKELMAN, J. H., & SCHMIDT, J. Associative confusions in mental arithmetic. *Journal of Experimental Psychology*, 1974, **102**, 734-736.