SESSION X LABORATORY APPLICATIONS

Paper Session
Michael Yost, *President*

A computer-controlled laboratory for studying infant event perception

STEVEN J. KRAMER, BENNETT I. BERTENTHAL, and DINA L. BAI
University of Virginia, Charlottesville, Virginia

An integrated software package for testing infants in a habituation procedure is described. The software is written for an Apple II computer with a minimum of 64K of memory. Additional interface cards are required for timing responses and displaying dynamic stimuli. The software is divided into four independent modules: (1) Configure Experiment allows the experimenter to design a specific experiment. (2) Run Experiment controls the running of a previously configured habituation experiment. (3) Calculate Reliability allows a second observer to score the subject for the purpose of computing reliability. (4) Data Summary and Formatting provides a summary of the results and allows the user to flexibly format the data for reading by various statistical packages.

The microcomputer is fast becoming an integral component of all perceptual research (Bertenthal & Kramer, 1984; Cavanagh & Anstis, 1980). In virtually any perception experiment today, it is possible to use a microcomputer for generating stimuli, controlling the timing and sequencing of stimulus presentation, measuring and storing one or more responses, and summarizing the data. Typically, these functions are handled in a piecemeal fashion by dedicated software programs. It should be noted, however, that there are significant advantages to coordinating all of these different applications within an integrated software package.

In this paper, we describe a new software package that was developed for conducting experiments involving the sequential presentation of visual stimuli over a series of trials. Two features are particularly noteworthy. First, the software is designed as an integrated laboratory package. Thus, it is possible to use the same software for designing the experiment, collecting and summarizing the data, and computing reliability. Second, the software circumvents previous limitations in presenting dynamic visual stimuli by using a special-purpose video display processor (TMS 9918A) or by controlling a videocassette

recorder via a computer interface (more details about these devices are presented below). As such, this software is particularly well suited for studying event perception which involves the presentation of dynamic stimuli.

Although this package could be applied to many different paradigms involving the sequential presentation of visual stimuli, it was designed specifically to provide a computer-controlled procedure for testing infants in a habituation paradigm (e.g., Bornstein, 1985). This procedure is frequently the paradigm of choice in infancy research because it obviates the need for a verbal response, and instead takes advantage of one of the better developed motoric responses of the infant, such as visual fixation. For analogous reasons, the habituation procedure is also valuable to animal researchers (Tighe & Leaton, 1976). This procedure is widely used for studying a number of different psychological functions in human infants, including the detection and discrimination of stimuli varying along one or more dimensions (Bertenthal, Proffitt, Spetner, & Thomas, 1985; Bornstein, 1981), categorization (Bornstein, 1984; Eimas, 1975), memory (Lasky & Spiro, 1980; McCall, Hogarty, Hamilton, & Vincent, 1973), and concept formation (Caron, Caron, & Myers, 1982; Ross, 1980).

In its simplest form, the procedure involves repeatedly showing the same stimulus to a subject for a fixed number of trials of equal duration, and then showing a novel stimulus designed to vary systematically from the familiarization stimulus. An increase in responsiveness to the

The development of this software package was supported by NICHD Grant No. HD-16195. Reprint requests should be addressed to: Steven J. Kramer, Department of Psychology, Gilmer Hall, University of Virginia, Charlottesville, VA 22901. Hard copies of this software package are available. Please include \$5 to cover the cost of disk and postage.

novel stimulus is used as evidence that the two stimuli are discriminated. Visual attention or fixation on the stimulus is the response typically used in our research, and is measured as duration of looking.

Although the standard form of the habituation procedure is quite easy to implement, there are a number of variations that significantly increase the complexity of the procedure and thus necessitate using either multiple experimenters or some degree of automation. One variation—the infant-control procedure—allows the baby to define the trial length as well as to determine when the novel stimulus should be presented. In this procedure, the beginning and end of a trial are defined by the initiation and cessation of the baby's response. The criterion used for switching to the novel stimulus is defined as a relative decrease in the response measure, and therefore must be computed on-line for each individual infant. Typically, this procedure can be used effectively only when automated, since it involves such a large number of on-line computations.

The need for automation is even more apparent when the procedure involves multiple exemplars of a class of stimuli. In this paradigm, two or more stimuli sharing some invariant property (e.g., faces of men) are alternately displayed on the habituation trials. The ability of the subject to extract this common property during the habituation trials is then examined by presenting on the test trials a novel exemplar from the same class of stimuli (e.g., a different man's face) as well as a novel exemplar from a different but related class of stimuli (e.g., a woman's face). Response generalization to the novel exemplar from the same class, coupled with response recovery to the stimulus from the new class, is taken as evidence that the invariant property was extracted. In such studies, the experimenter must not only monitor the responses of the subject, but must also keep track of the specific stimulus to be displayed on each trial. If the order of the stimuli is randomized, the complexity of the task makes the running of the experiment by a single operator virtually impossible.

Finally, additional problems are encountered when the stimuli employed are dynamic rather than static. Rather than simply displaying a single static image on each trial, the experimenter must in some way control a changing event. For example, if the events were videotaped, the experimenter would need to control the video recorder in addition to all the other tasks that need to be managed during the experiment.

OVERVIEW OF SOFTWARE AND SYSTEM REQUIREMENTS

The principal objective in writing this software was to automate as much as possible the running of experiments using any of the many different forms of the habituation procedure. The programs included in this software package are written to run on an Apple II computer with at least 64K of memory. A Mountain Hardware Apple Clock

Card is also required to time response duration and stimulus presentations. The program expects to find the clock in Slot 2.¹ If a printer is available for hard copies of the output the interface card is expected in Slot 1.

Two different options are available for displaying the stimuli. Both were developed in response to our interest in the development of motion perception, and, in particular, the perception of biomechanical motions (Bertenthal, Proffitt, & Cutting, 1984; Bertenthal, Proffitt, Spetner, & Thomas, 1985). The first uses the Texas Instruments TMS 9918A video display processor to present computerized animation. This video processor can be purchased already assembled on an interface card (Micromint), and can be placed in any one of the peripheral input/output (I/O) slots. It is particularly useful for displaying smooth motion of colored block shapes, or sprites, on a graphics screen (see Bertenthal & Kramer, 1984). We have used sprites extensively for producing point-light projections of transforming three-dimensional objects (Bertenthal, Proffitt, & Keller, 1985). The second device is a Bell & Howell VCR Interface which can be used to control the operation of a videocassette recorder.² This interface (placed in Slot 3) allows the computer to control presentation of one or more stimuli recorded on videotape by playing the portion of the tape addressed by the computer. Although these two devices are the only ones that the program is designed to use for stimulus presentation, it would be possible to modify the software to enable control of other display devices. Alternatively, the experimenter could manually control stimulus presentation while letting the program handle the data collection.

The software package is divided into four modules, which are selected from a menu. These modules are named to correspond to their main functions: (1) Configure Experiment, (2) Run Experiment, (3) Calculate Reliability, and (4) Data Reduction. In essence, these modules represent four separate Applesoft BASIC programs that are linked by data files. The organization of these programs is depicted in Figure 1. In addition to these four programs, there is a library of assembly language routines that handle the clock and display functions. These routines are accessed from BASIC with ampersand commands.³

THE MODULES

Configure Experiment

This option allows the experimenter to input and save a number of parameters that determine the design of the experiment. Note, this module must be run prior to collecting any data using the Run Experiment module. Two main goals guided the design of this module. First, it was designed to provide flexibility so that changes in procedure could be easily accommodated. Second, it was designed to automatically handle the random assignment of subjects to conditions so that the operator running the experiment could remain unaware of the subject's condition. Parameters defined in this module are divided into

Figure 1. Overview of programs and files included in software package.

three general categories: criterion parameters, design parameters, and stimulus parameters.

Criterion parameters. A criterion must be defined to determine when the habituation phase of the study should be terminated. The parameters used in computing criterion and some typical values are shown in Table 1. Criterion occurs when:

$$(\text{BASELINE}) * (\text{CONSTANT}) > (\text{MOVING AVERAGE})$$

Where BASELINE = Sum of the first N trials

MOVING AVERAGE = Sum of the last N trials

In order to demonstrate how a criterion is defined, consider the values shown in Table 1. These values would be used in calculating a relative criterion, which is reached when the sum of the last three trials is less than half of the sum of the first three trials. An absolute criterion, defined by a fixed number of trials (e.g., 20), could be designed by setting the CONSTANT to 0, and the maximum number of precriterion trials to 20.

Design parameters. These parameters are listed in Table 2. They allow control over the experimental design of the study. The experimenter specifies the number of

subjects, the number of conditions, and the number of test trials. In order to control for spontaneous regression in the response measure after criterion is reached (see Bertenthal, Haith, & Campos, 1983), it is possible to present half the subjects with some number of additional habituation trials. In the program, these trials are referred to as "lag" trials. If the number of lag trials is greater than 0, then half the subjects in each condition will be presented with the specified number of additional habituation trials. After these parameters are entered, the program randomly assigns each of the subjects to one of the

Table 1
Sample Listing of Criterion Parameters

COMPUTE CRITERION	
[BASELINE] * [CONSTANT] > [MOVING AVERAGE]	
# OF TRIALS TO COMPUTE BASELINE	3
# OF TRIALS FOR MOVING AVERAGE	3
VALUE OF CONSTANT (0 TO 1.0)	.5
MINIMUM CRITERION (SEC)	6
MINIMUM # OF PRECRITERION TRIALS	4
MAXIMUM # OF PRECRITERION TRIALS	30

Table 2
Sample Listing of Design Parameters

DESIGN PARAMETERS	
# OF SUBJECTS	60
# OF CONDITIONS	4
# OF LAG TRIALS	2
# OF TEST TRIALS	4

Table 3
Sample Listing of Stimulus Parameters

STIMULUS PARAMETERS	
INTERSTIMULUS INTERVAL (SEC)	24
MAXIMUM TRIAL DURATION (SEC)	60
VCR OR SPRITES (V/S)	5

conditions in such a way that each condition contains an equal number of subjects.

Stimulus parameters. These parameters provide control over the selection and sequencing of the stimuli to be used in the study. A list of these parameters is presented in Table 3, and includes the interstimulus interval, maximum trial duration, and the display mode. As mentioned earlier, the stimulus can be displayed via either a videocassette recorder (VCR) or the TMS 9918A video display processor (SPRITES).

After the above parameters are entered, the sequence of stimuli to be presented during the habituation phase is entered for each condition. This sequence can be assigned by the experimenter or randomized by the computer. If all subjects in a particular condition are to receive the same sequence of stimuli, then that sequence is entered only once. Otherwise, a novel sequence can be specified for each subject. The stimuli to be presented on the test trials, and their order, must also be input for each condition. Again, the order may be randomized if desired, and the order may be the same or different for each subject in a condition.

Entering the parameters and subject information into the program is straightforward. The program displays a number of formatted screens which prompt the user for the necessary information. A number of simple editing functions are available that allow the user to correct mistakes. At any time, the experimenter can skip ahead to the next screen by pressing the escape key. After the study is configured, it is possible to create a hard copy of both the study design and the sequence of stimuli for each subject. In addition, parameters are saved to disk so that they can be accessed when the experiment is actually run. Two files are created. The first contains general information about the study design and is saved as a sequential text file with a user-defined file name appended to the prefix "CONFIG." The second contains information specific to individual subjects and is saved as a random-access file with a user-defined file name appended to the prefix "SUBJ."

The Configure Experiment module also allows previously created files to be loaded for editing. This serves two functions. First, errors in the design can be corrected

easily. Second, a previous file can be used as a "template" for a new study. For instance, if the only difference between two studies involves the choice of stimuli, then only the stimulus parameters and sequences need be reentered. This modified file can then be saved under a new name.

Run Experiment

This program controls the running of a previously configured habituation procedure. The general organization of the program is depicted in Figure 2. In essence, the program selects and displays a stimulus and then allows the experimenter to time some response made by the subject. Before running the study, the experimenter must input the name of the study and the subject number. The program then loads the information from the files created by the Configure Experiment program. Once all the study and subject information is loaded, the experimenter is prompted to begin the experiment by pressing the space bar.

The experiment begins with the computer selecting the first stimulus and displaying it on a monitor viewed by the baby. As soon as the baby orients to the stimulus, the experimenter presses the space bar to start timing the trial. The trial is ended and the clock is stopped when the experimenter presses the space bar a second time. The program then tests whether criterion has been reached and displays either the next habituation stimulus or the first postcriterion stimulus (corresponding to either the first test trial or the first lag trial, depending on the condition). If for some reason it is necessary to rerun one or more trials or to terminate the study, it is possible to press the escape key and then select the appropriate option from a menu. After the last test trial is run, the data collected on that subject is saved to a text file where it can be accessed by the last two modules. In addition, a hard copy of the data is printed.

Calculate Reliability

The purpose of the Calculate Reliability program is to compute interobserver reliability by allowing a second observer to time a subject's responses from a videotaped record of the original session. First the program reads the subject's data that was saved as a text file by the Run Experiment module; then it allows the second observer to time the response of interest on each of the original trials. The operation of the program is identical to that of the Run Experiment module, except that no stimuli are selected and criterion is not calculated. A correlation coefficient and the mean absolute difference between the two sets of observations are calculated and appended to the subject's data file. Finally, new data sheets are printed for that subject which include data from both observers and the reliability scores.

Data Summary and Formatting

After data on all the subjects in a study are collected, this final module is used to produce a summary of the

Figure 2. Flow diagram of operations performed by the Run Experiment program.

results and to prepare the data for further analysis. In order to produce summary data, the program reads in the data from each of the subjects. Summary data from each subject in the experiment are consolidated, organized by condition, and then printed. This summary includes those values that are most informative in differentiating between conditions, such as the total and mean duration of looking during the training phase, the number of trials to reach criterion, and the total duration of looking on the test trials. The means and standard deviations for each condition and for the entire study are also printed. Table 4 presents a sample printout of the summary data.

The data formatting option allows the data to be reformatted so that it can be read by various statistical packages on the Apple II or on a mainframe. The experimenter selects the specific data to be transferred to the file. For instance, it might be necessary to analyze only summary data, rather than the raw data from each trial. The data

for each subject is then written to a sequential text file. Each subject's data will consist of one or more records that do not exceed 80 columns in length. The record number, starting column, and length of each variable are then printed either to paper or to the screen in order to facilitate the creation of data format statements used by the various statistical programs.

CONCLUSION

These four modules provide us with a fully integrated and automated lab for studying infants' sensitivity to dynamic stimuli. Our experience using this computer-controlled procedure is that it offers a number of distinct advantages over less automated or integrated procedures. In the first place, it is much easier to run a habituation procedure, and it is possible for us to train new ex-

Table 4
Sample Printout of the Summary Data

Subject	No. of Trials to Criterion	Sum of Last Two Hab Trials	Sum of Lag Trials	Sum of Test Trials	Sum of First Two Hab Trials	Sum of Hab Trials	Mean of Hab Trials
Condition 1—No Occlusion to Occlusion							
2	7	2.40	11.50	5.85	9.90	20.10	2.87
9	18	5.70	11.60	17.35	10.25	88.65	4.93
10	13	7.80	11.67	8.40	42.45	167.75	12.90
1	10	11.05	8.70	9.50	51.55	133.10	13.31
3	13	7.80	4.20	23.50	20.80	115.60	8.89
6	6	12.75	16.40	12.05	16.60	55.95	9.33
Means	11.17	7.92	10.68	12.78	25.23	96.86	8.71
SD	4.45	3.70	4.03	6.55	17.53	53.52	4.18
Condition 2—Occlusion to No Occlusion							
5	6	9.35	11.73	31.00	10.95	49.80	8.30
4	4	14.20	11.89	25.35	43.80	58.00	14.50
11	16	5.95	11.61	18.00	26.00	137.55	8.60
7	10	7.90	8.75	4.55	19.10	60.95	6.10
8	6	12.00	7.70	51.15	44.95	88.90	14.96
12	9	9.35	9.75	6.70	20.85	86.55	9.62
Means	8.50	9.79	10.24	22.79	27.61	80.46	10.35
SD	4.28	2.93	1.77	17.28	13.86	32.28	3.59

perimenters in a very short period of time. More important, this procedure has allowed us to reduce data loss from experimenter error or equipment problems. Computer control also increases the reliability of the procedure by reducing the number of tasks that the experimenter must perform and by reducing sources of variability in the procedure. Finally, errors in data entry have been eliminated by having the computer handle this function as well. In sum, this software package makes a procedure widely used in infant research easier to implement, more reliable, and sufficiently flexible to accommodate most of the commonly used variations of the habituation paradigm.

REFERENCES

- BERTENTHAL, B. I., HAITH, M. M., & CAMPOS, J. J. (1983). The partial-lag design: A method for controlling spontaneous regression in the infant-control habituation paradigm. *Infant Behavior & Development*, 6, 331-338.
- BERTENTHAL, B. I., & KRAMER, S. J. (1984). The TMS 9918A VDP: A new device for generating moving displays on a microcomputer. *Behavior Research Methods, Instruments, & Computers*, 16, 388-394.
- BERTENTHAL, B. I., PROFFITT, D. R., & CUTTING, J. E. (1984). Infant sensitivity to figural coherence in biomechanical motions. *Journal of Experimental Child Psychology*, 37, 213-230.
- BERTENTHAL, B. I., PROFFITT, D. R., & KELLER, S. E. (1985). 3-D graphics animation program for the Apple II. *Behavior Research Methods, Instruments, & Computers*, 17, 195-202.
- BERTENTHAL, B. I., PROFFITT, D. R., SPETNER, N. B., & THOMAS, M. A. (1985). The development of infant sensitivity to biomechanical motions. *Child Development*, 56, 531-543.
- BORNSTEIN, M. H. (1981). Psychological studies of color vision in human infants: Habituation, dishabituation and categorization, recognition, and conceptualization. In L. P. Lipsitt (Ed.), *Advances in infancy research* (Vol. 1, pp. 1-40). Norwood, NJ: Ablex.
- BORNSTEIN, M. H. (1984). A descriptive taxonomy of psychological categories used by infants. In C. Sophian (Ed.), *The origins of cognitive skills*. Hillsdale, NJ: Erlbaum.
- BORNSTEIN, M. H. (1985). Habituation of attention as a measure of visual information processing in human infants: Summary, systematization, and synthesis. In N. Krasnegor & G. Gottlieb (Eds.), *The measurement of vision and audition during the first year of life*. Norwood, NJ: Ablex.
- CARON, R. F., CARON, A. J., & MYERS, R. S. (1982). Abstraction of invariant face expressions in infancy. *Child Development*, 53, 1008-1015.
- CAVANAGH, P., & ANSTIS, S. M. (1980). Visual psychophysics on the Apple II: Getting started. *Behavior Research Methods & Instrumentation*, 12, 614-626.
- EMAS, P. D. (1975). Speech perception in early infancy. In L. B. Cohen & P. Salapatek (Eds.), *Infant perception: From sensation to cognition* (Vol. 2, pp. 193-231). New York: Academic Press.
- LASKY, R. E., & SPIRO, D. (1980). The processing of tachistoscopically presented visual stimuli by five-month-old infants. *Child Development*, 51, 1292-1294.
- MCCALL, R. B., HOGARTY, P. S., HAMILTON, J. S., & VINCENT, J. H. (1973). Habituation rate and the infant's response to visual discrepancies. *Child Development*, 44, 280-287.
- ROSS, G. S. (1980). Categorization in 1- to 2-year-olds. *Developmental Psychology*, 16, 392-396.
- TIGHE, T. J., & LEATON, R. N. (1976). *Habituation: Perspectives from child development, animal behavior, and neurophysiology*. Hillsdale, NJ: Erlbaum.

NOTES

1. The slot in which the clock resides can be changed by modifying one line of the Applesoft BASIC program. Similar modifications are available for all of the other interface cards that are accessed by the program.
2. The Video Interface Card from Bell & Howell is designed to interface the Apple II to a Sony SLO-320/323 or a Panasonic NV-8200 videocassette recorder. The interface can remotely control the major functions of the recorder and can directly access a specific location on the videotape by keeping track of the synch pulses as the tape is played.
3. Ampersand commands provide a method of extending Applesoft BASIC. In essence, they provide a way of passing control to machine language subroutines by jumping to them whenever the ampersand character followed by a mnemonic for the subroutine and 0-2 arguments (e.g., &SCALE=1) is encountered.