Bulletin of the Psychonomic Society
1989, 27 (1), 60-63

Video touch-screen stimulus-response surface for use with primates

TIMOTHY F. ELSMORE and JOHN K. PARKINSON
Walter Reed Army Institute of Research, Washington, D.C.

and

ROGER L. MELLGREN
University of Oklahoma, Norman, Oklahoma

A color video monitor equipped with a touch-sensing system, which is being used as a versatile stimulus presentation and response input device for experiments with nonhuman primate subjects, is described. A PDP-11/23 microcomputer system serves as an intelligent interface between the video monitor and a PDP-11/73 microcomputer system, which controls contingencies and stores data.

Operant conditioning procedures are characterized by a three-term contingency between stimuli, responses, and outcomes (Skinner, 1953). The availability of video touch-screen technology can free experimenters from some of the constraints present in typical electromechanical and projection technologies by providing for one-to-one mapping of responses onto a continuous two-dimensional stimulus display surface. To approximate this sort of mapping, one-dimensional response surfaces have frequently been used. For example, Cumming and Eckerman (1965) trained pigeons to peck near one extreme of a continuous response strip in the presence of bright illumination and near the other extreme in dim illumination. They then determined the position of responses during extinction under conditions of intermediate illumination. Several similar experiments are discussed in a recent review by Bickel and Etzel (1985).

Complex stimulus displays have been produced in a variety of ways. An excellent example is the Wisconsin General Test Apparatus (WGTA), which has been used extensively for the testing of memory and perception in nonhuman primates (R. T. Davis, 1974; Miles, 1965; Mishkin & Delacour, 1975). By employing three-dimensional objects, such as toy cars and cups, as stimuli, the WGTA enables experimenters to use a wide variety of objects as stimuli. Projection techniques have also been used extensively. For example, Wright, Santiago, Sands, Kendrick, and Cook (1985) used a slide projection system to study serial-list processing by pigeons, monkeys, and people.

A system similar to a video touch-screen system was used by Blough (1977), who projected symbols on a cathode-ray tube (CRT) mounted on the wall of a pigeon's test cage. By synchronization with the sweep circuitry of the CRT, a photocell, glued to a pigeon's beak, detected proximity of the beak to one of the symbols being displayed on the screen—the same principal employed with light pens.

Finally, a group of researchers from Warner-Lambert/Parke-Davis Pharmaceutical Research Laboratories (R. E. Davis, Tew, & Marriot, 1985) used a video touch-screen system for evaluating diazepam-induced memory impairments in young and old monkeys. A matrix of nine white squares, with one square alternating between white and green, was projected on a video monitor. Following a retention interval, the white squares were projected again, and the animals were reinforced for touching the spot that had previously flashed green.

Our video touch-screen system was designed for maximum flexibility in generation, modification, and display of images, and the sensing of contacts with the screen. The primary design considerations were: (1) the ability, in off-line mode, to create files of screen images consisting of a wide variety of geometric forms, colors, and hand-drawn shapes; (2) the ability to edit and copy screen images freely; (3) the ability, in on-line mode, to randomly recall, with a maximum latency of 100 msec, any of 1,000 screen images during an experiment; and (4) the ability to report, with a maximum latency of 100 msec and a resolution of 0.8 cm, the location of a touch on the screen.

DESCRIPTION

Overall System

A block diagram of the video touch-screen system is shown in Figure 1. The heart of the system is a PDP-

In conducting the research described in this report, the investigators adhered to the *Guide for the Care and Use of Laboratory Animals*, as promulgated by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council. The views of the authors do not purport to reflect the position of the Department of the Army or the Department of Defense (para 4-3, AR 360-5). Reprints may be obtained from T. F. Elsmore, Department of Medical Neurosciences, Walter Reed Army Institute of Research, Washington, DC 20307-5100.

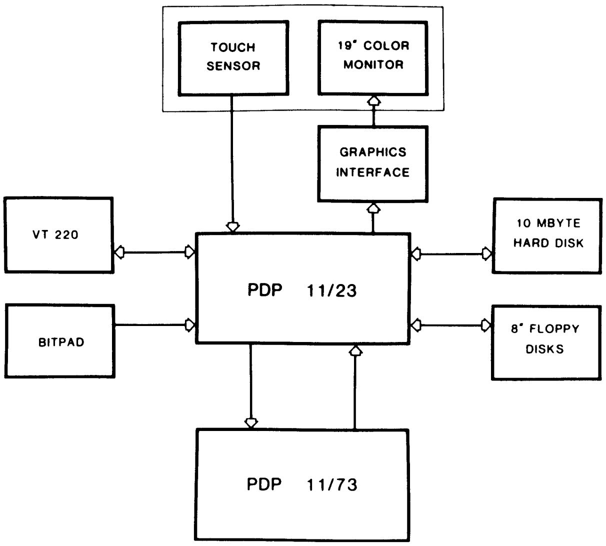

Figure 1. Block diagram of video touch-screen system.

11/23 microcomputer that serves as an intelligent controller for the monitor and touch screen. The 11/23 has 512 kilobytes of memory and is equipped with a terminal (DEC VT220), a 10-megabyte hard disk drive, dual 8-in. floppy-disk drives, and a color graphics interface (Parallax Graphics, 640 × 480 pixel resolution). The video monitor is a 19-in. diagonal Mitsubishi Model 3910 with a low-persistence phosphor and a touch-sensing system (Carroll Touch Technologies) mounted in its bezel. Communication between the touch sensor and the 11/23 is via an RS232 line operating at 9600 baud. The 11/23, in turn, is controlled by a PDP-11/73 microcomputer (the "host"), which uses SKED11 software (Snapper & Inglis, 1985) operating under the RSX11M+ operating system for experimental control and data collection. Communication between the two computers is via two 9,600-baud serial lines.

Software

Off-line image generation. The editor for generation or modification of screen images runs off-line on the PDP-11/23 computer. This menu-driven program, written in FORTRAN IV,[1] permits concatenation of primitive graphics commands, as listed in Table 1, to make screen images. Input for determining location, size, and color of graphics elements is accepted from both the keyboard and the bitpad, which is essentially an electronic drawing board. Each image is assigned a number that is used in editing, copying, deleting, or displaying the image. Images are stored in files that can contain up to 1,000 images.

Run-time software. The run-time program operates in two modes: a start-up mode and an interactive control mode. In the start-up mode, the program prompts the user to specify the image file to be used and the mode in which the touch sensor is to operate (see below). Then the program loads the image file into the memory of the 11/23. This enables the program to provide rapid recall of the images, with no disk accesses required during experiments. When these operations have been completed, the program shifts into an interactive control mode in which the 11/23 receives commands from the host and sends touch-screen reports to the host.

Because speed is critical during experiments, the command sequences for recalling and displaying particular images are quite simple; they consist of the letter "D" followed by the image number expressed as a four-digit integer. For example, the command "D0003" directs the 11/23 to display Image 3. Images can be overlaid to allow complex displays to be constructed from more primitive elements. These commands, which use the "TYPE" command, are generated by SKED11 programs on the 11/73 host computer.

Depending on the start-up specification, contacts with the screen can be sensed in any of three modes. In point mode, the 11/23 reports a single contact with the screen. The report is of the form "Txxxxyyyy," where xxxx and yyyy are the horizontal and vertical coordinates of the touch, expressed in pixels. The resolution of the touch sensor is 0.61 cm. Contact with the screen must be broken before a second touch can be reported. In stream mode, touch reports are transmitted whenever a contacting object moves on the screen; in other words, the reports track movement on the screen, sending a new report whenever the object moves to a new position on the screen. In addition, a report of the form "Exxxxyyyy" is generated when contact with the screen is broken. In continuous mode, transmission of touch reports occurs every 150 msec as long as an object is in the touch-screen area, even if the object is stationary. For communication with SKED11 program, a small FORTRAN program is required to monitor reports of screen contact from the 11/23 and signal that a response has occurred.

Table 1
Graphics Editor Commands

Command	Effect
HELP	Display help text
POLY	Create a filled polygon
OPOLY	Create an outlined polygon
CIRCLE	Create a circle
OCIRCLE	Create an outlined circle
BOX	Create a filled box
OBOX	Create an outlined box
VECTOR	Create a line segment
MVEC	Create multiple chained vectors
COLOR	Define the red, green, and blue components of a color index value
BACKG	Define the red, green, and blue components of the background color
CLEAR	Clear the display

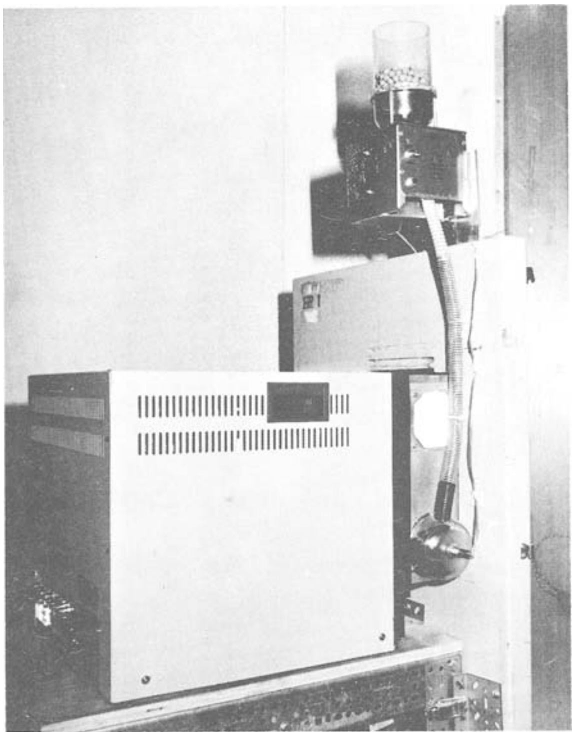

Figure 2. Exterior view of monitor, cart, and door assembly.

Physical Arrangement

The arrangement for conducting experimental sessions is illustrated in Figures 2 and 3. The experimental subjects (female rhesus monkeys) are tested in their home cages. The monitor is mounted on a cart attached to a door that closes the front of the enclosure in which the cage is mounted. Different animals can be tested by attaching this assembly to different cages. The screen is positioned approximately 16 cm from the front of the cage by a wooden bezel. The animals can easily reach the screen through the bars of the cage, which are spaced on 3-cm centers. Food reinforcers (750-mg Noyes banana-flavored whole-diet pellets) are delivered into a food hopper behind an opening in the left side of the wooden bezel. A viewing port is located immediately above the food hopper.

DEMONSTRATION OF USE

Four rhesus monkeys were used as subjects in a demonstration of the use of the system described.

For several days prior to the initiation of training procedures, Noyes food pellets were substituted for the animals' normal food. Following one to three daily sessions of magazine training, in which approximately 100 pellets were delivered, the animals were trained to touch a large (20-cm) red square on the screen. An autoshaping procedure was employed in which the square was displayed for 10 sec, the screen was then cleared, and a pellet was delivered. If the red square was touched, a pellet was delivered immediately. The intertrial interval was 20 sec. For 3 of the 4 animals, this procedure was not effective, and additional manual shaping procedures were required. After touching of the large square was established, the size of the square was reduced, in several steps, to 4 cm, with approximately 20 pellets being used at each size.

After screen-touching was established, more complex discrimination procedures were initiated. First, two squares were displayed, one containing a yellow spot, and the animals were reinforced for touching the square containing a spot. Then a spatial memory procedure was initiated in which two squares, one containing a spot, were displayed. After 5 sec, the spot was removed, and the animals were reinforced for touching the square that had previously contained a spot. When an animal achieved 75% accuracy in a daily session, the number of squares was increased up to a maximum of nine. Figure 4 shows the number of sessions required to reach criterion for each number of alternatives. It is clear that the animals acquired the task rapidly, and that subsequent increases in the number of alternatives did not affect task performance.

DISCUSSION

Initial concerns regarding the durability of the glass screen were unfounded. The subjects did not display ag-

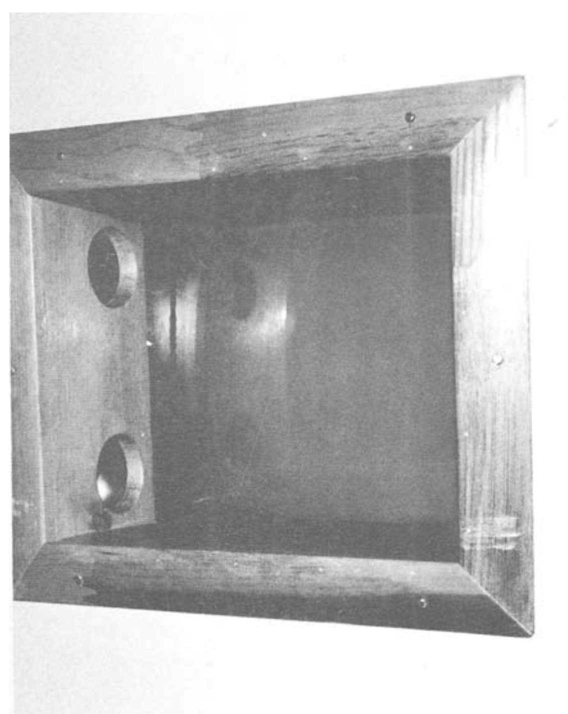

Figure 3. Video screen and bezel with food receptacle on the lower left.

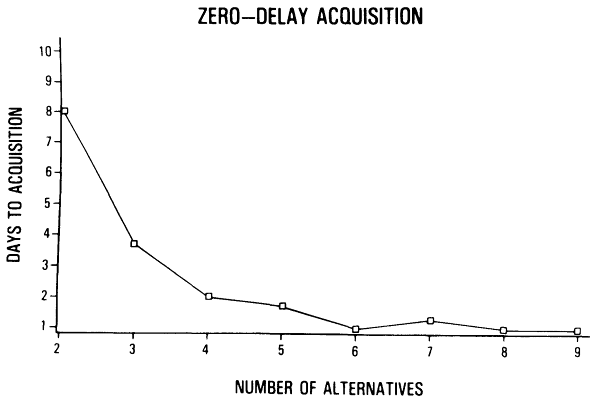

Figure 4. Number of sessions required to meet a criterion of 75% accuracy as the number of spatial alternatives was increased in a spatial memory task.

gressive behavior towards the screen, the typical response topography being a gentle touch or brushing action with the tips of the fingers. In 6 months of daily use, neither the screen nor the touch-sensing system has failed.

The infinite variety of images made possible by using this technology greatly expands the range of experimental questions that may be addressed in the laboratory. A variety of different spatial memory tasks have been programmed, and the ease with which additional images can be generated and new response areas defined greatly simplifies the implementation of complex experimental procedures. Although rhesus monkeys are the subjects in our laboratory, this system could easily be used with human subjects. The versatility of the display system would permit simple implementation of a wide range of neuropsychological and psychophysical procedures. In cases in which species generality of particular research findings was critical, both human and nonhuman primates could be tested on the same apparatus.

Although the system described in this paper is relatively expensive and complex, the ready availability of touch-screen technology would permit development of similar systems with much less expensive hardware. The concept of using video touch-screen technology is clearly feasible for behavioral testing with both human and nonhuman subjects.

REFERENCES

Bickel, W. K., & Etzel, B. C. (1985). The quantal nature of controlling stimulus-response relations as measured in tests of stimulus generalization. *Journal of the Experimental Analysis of Behavior*, **44**, 245-270.

Blough, D. S. (1977). Photoelectric recording of pigeon-peck responses to computer-driven visual displays. *Behavior Research Methods & Instrumentation*, **9**, 259-262.

Cumming, W. W., & Eckerman, D. A. (1965). Stimulus control of a differentiated operant. *Psychonomic Science*, **3**, 313-314.

Davis, R. T. (1974). *Monkeys as perceivers*. New York: Academic Press.

Davis, R. E., Tew, T. F., & Marriott, J. G. (1985). CI-933 reverses diazepam-induced memory impairments in young and aged monkeys. *Neuroscience Abstracts*, **11**, 187.

Miles, R. C. (1965). Discrimination-learning sets. In A. M. Schrier, H. F. Harlow, & F. Stollnitz (Eds.), *Behavior of nonhuman primates* (Vol. 1, pp. 51-95). New York: Academic Press.

Mishkin, M., & Delacour, J. (1975). An analysis of short-term visual memory in the monkey. *Journal of Experimental Psychology: Animal Behavior Processes*, **1**, 326-334.

Skinner, B. F. (1953). *Science and human behavior*. New York: Macmillan.

Snapper, A. G., & Inglis, G. B. (1985). *SKED-11 software system* [Computer Program Manual]. Kalamazoo, MI: State Systems.

Wright, A. A., Santiago, H.C., Sands, S. F., Kendrick, D. F., & Cook, R. G. (1985). Memory processing of serial lists by pigeons, monkeys, and people. *Science*, **229**, 287-289.

NOTE

1. The editor and run-time programs for the generation and modification of screen images was written for the Walter Reed Army Institute of Research by Systex Inc. under Contract DD3RMM 5267-1600 with the Walter Reed Army Medical Center. Appreciation is expressed to Al Bariatti for his help in execution of this contract and to Larry Exposito, president of Systex. Technical details of the system may be obtained by writing to Systex, 5020 Sunnyside Ave., Beltsville, MD 20705.

(Manuscript received March 26, 1988.)