SESSION IV

RESEARCH TOOLS FOR PCs

David Washburn, *Presider*
Georgia State University

The touch screen system in the pigeon laboratory: An initial evaluation of its utility

SPENCER K. MORRISON
University of Colorado, Boulder, Colorado

and

MICHAEL F. BROWN
Villanova University, Villanova, Pennsylvania

The touch screen system has been employed as a device for the measurement of responses and presentation of stimuli in pigeon laboratories for 4 years. Its contributions to the study of the pigeon's behavior include the addition of response location information and an increase in the versatility of stimulus presentation. Along with the advantages of this system come some cautions. Limitations on response registration and time to construct stimuli are both concerns. Using response location as a dependent variable and distance of response registration from the pecking surface as an independent variable, the affordance of the touch screen system is investigated.

During the past 4 years, investigators of the behavior of avian species, in particular the pigeon, have introduced a new technological advancement for the presentation of more complex stimuli and the precise measurement of behavior: the touch screen system. This system consists of a computer that controls stimulus presentation on a color monitor and registers responses by using a matrix of photoelectric emitters and detectors mounted in front of the monitor. When a light beam is broken, information specifying the position of the interruption is sent to the host computer. To date, two published reports have included this method (Pisacreta & Rilling, 1987; Wright, Cook, Rivera, Sands, & Delius, 1988), and there are at least seven such systems in North American animal laboratories. Since the touch screen's incorporation into the pigeon laboratory, some of its advantages and limitations have become apparent. The following evaluation of the system in relation to more conventional apparatuses is based on examples presently in use.

Conventional Stimulus Presentation and Response Measurement

The behavior of the pigeon is typically studied in operant chambers that depend on electromechanical equipment or computers for stimulus presentation and response measurement. Pecking keys are centered on one wall of the chamber, with a food hopper positioned below. The response keys, which are constructed of Plexiglas or a Polacoat lenscreen, are commonly circular, their standard diameter being approximately 2.5 cm (e.g., BRS/LVE model PPK-002). When a key is pecked, a microswitch closes a circuit, thus allowing responses to be detected.

Stimulus presentation is typically controlled by electromechanical equipment or by a microcomputer, with stimuli often produced by "in-line" projectors. The projectors emit a directed light from an incandescent light bulb through one or more film patterns. The pattern is rear-projected onto the translucent response keys, thereby presenting the stimulus. Such film patterns, which come in standard sets provided by the manufacturer, consist of symbols of various forms, or Kodak Wratten filters producing different wavelengths. Stimuli have also been rear-projected with standard slide projectors.

Touch Screen Systems

The touch frame we presently use is manufactured by Carroll Touch (a subsidiary of AMP, Inc.). Carroll Touch

This work was supported by National Institute of Mental Health Grant MH42646. The principal author would like to thank Michael Brown, Robert H. Dufort, and William McKinney for their contributions to the manuscript. Correspondence should be sent to Spencer K. Morrison, Department of Psychology, Box 345, University of Colorado at Boulder, Boulder, CO 80309.

offers "add-on" touch units that include a touch frame that may be attached to the computer monitor of choice, an accompanying interface cable, and interface software. Additionally, fully assembled "total" systems (with the frame mounted on the monitor) are available. Touch frames have been marketed by a number of other companies during the past decade too, but many of these firms no longer supply or support these systems. Carroll Touch appears to be the most reliable vendor at this time.

Touch systems operate by means of two different mechanisms. In one, infrared frames form a matrix of light beams in front of the monitor surface; when a beam is broken, *x*- and *y*-coordinates are sent to the host computer. In the other, the overlay system, two layers of soft plastic with opposing metallic coatings are separated by a layer of insulation; when pressure is applied, the two layers come in contact and *x*- and *y*-coordinates are relayed to the computer. Since physical contact is required to register a response, damage to the overlay touch mechanism may occur with extended use. Distortion of the image by the plastic overlay is also possible. These problems render the overlay touch system inappropriate for studying the behavior of avian species. In contrast, the infrared touch system requires no contact to register responses, and it has no potential for image distortion.

Our system utilizes the add-on infrared touch frame, which surrounds the outer boundaries of a 13-in. NEC multisync color monitor. The touch frame consists of a set of infrared light-emitting diodes (LEDs) with their associated phototransistor detectors, solid-state circuitry with an interface cable, and a power supply. The infrared LEDs create an invisible plane of light composed of a crossing matrix of individual light beams. The dimensions of the matrix vary, depending on the monitor's size. For example, a frame containing a matrix of 48*x* by 32*y* LEDs is required for a 13-in. diagonal monitor. The touch frame resolution is approximately .125 in.

When a beam passing from an LED to a photodetector is broken, the *x*- and *y*-coordinates are calculated within the solid-state circuitry of the touch frame and sent to the host microcomputer (an IBM XT). The specified form of the touch data, as well as the operational commands sent to the touch frame, is controlled by a library of software routines provided by Carroll Touch. These touch screen software routines can be linked to compiled user-generated programs written in one of many possible languages (BASIC, Pascal, etc.). For example, we use the Quick-Basic (Microsoft, Inc.) language and the Carroll Touch library routine "Call Touch(*a*%,*b*%,*c*%,*d*%)" to prompt the system to look for a beam break(s) of various types and report back the coordinates of the beam break(s).

One can also use a commercially available library of graphics routines to construct stimuli and present them using one of many available graphics adapters (EGA, CGA, or VGA). We use the Enhanced Graphics Adapter (EGA), which provides two graphics "pages." This allows one stimulus page to be constructed while a second page is displayed on the video monitor or a blank page to be presented while the stimulus page is constructed.

Software tools, contained in several commercially available graphics libraries (e.g., Smartgraphics, Xgraf, and Probase), may be used to create two- or three-dimensional stimuli of various colors and shapes at any location on the monitor.

A second monitor is used to display, to the investigator, trial information such as the stimulus that is being presented and the performance data.

Touch screen systems suggest a variety of new possibilities for the investigator of the pigeon's behavior. More precise quantification of responses is made available because of the additional location information. Due to the mechanism by which the touch screen operates, the opportunity to observe new behaviors by which the animal may respond to the stimuli is possible. Furthermore, stimulus presentation is enhanced by allowing more flexible stimulus generation. However, with these benefits come some potential problems.

Response measurement. With a conventional pecking key, one can measure only one type of response, namely a peck. The touch frame may be utilized to gather the location of beam breaks and/or to determine the consequences of behavior emitted in response to the stimuli. The touch frame can provide the coordinates of any beam break that occurs within a specified period of time. The location of responses can then serve as a new dependent measure, and the *x*- and *y*-coordinates may also be used by the trial program to determine whether or not a response has occurred within a given area of the screen. If a response lies within the upper and lower limits of a specified response area, a resultant consequence such as the food hopper's being activated then occurs. Dynamic aspects of the response, such as movement across the beam plane, may also be measured.

Peck location as a dependent measure. The peck location data, provided by the touch frame, has proven to be a great asset when used as a dependent measure. Some authors have suggested that pigeons peck around the boundaries of stimuli, but this has not been measurable with conventional pecking keys. With the aid of a touch screen system, Cook and Vivian (1988) have recorded peck location while pigeons performed a texture-discrimination task. On each trial, an array of 288 stimulus elements in an 18×16 matrix was presented. The matrix elements consisted of two different dimensions varying in color and/or shape (i.e., squares, triangles, circles, etc.). A target quadrant of the display consisted of 72 elements on one dimension (e.g., shape: squares), while the remaining area of the display (the distractor area) consisted of a different dimension (e.g., shape: circles), thus presenting a texture gradient. Cook and Vivian, measuring the location of responses precisely, found that the highest frequencies of correct responses were located at the target/distractor boundaries. Cook and Vivian suggest that these boundaries control texture-discrimination performance and may play a vital role in the pigeon's texture perception.

Interaction with the touch screen system. In our initial investigations using the touch screen system, we have

observed responses to stimuli that are quite unlike those observed in standard pigeon chambers. As previously mentioned, unlike conventional equipment, the infrared touch frame does not require contact with the apparatus. When a light beam is broken in the specified area, a response is recorded. Therefore, an unintentional response such as a "tail peck" or an early beam break occurring immediately following the stimulus onset is possible. Fortunately, the probability of a "tail peck" decreases as attention becomes directed to the stimulus display. Early beam breaks may be alleviated by specifying that a period of time must elapse before looking for a beam break, or by cancelling the trial if a beam break occurs before a specified time. In addition to these problems, two distinct types of responses were observed to be directed to positive and negative stimuli during a discrimination task. These intentional responses to the stimuli unexpected by the experimenter were found to be lethal to the design of the experiment.

On each discrimination trial, two stimuli were presented on the monitor, and each had different consequences when responded to. On the left side of the monitor, the discriminative stimulus consisting of an element (i.e., a 2-cm red circle) or compound (i.e., a 2-cm red circle with three vertical lines superimposed) was presented. On the right, an advance stimulus (a .5-cm black circle within a 2-cm white circle) was always displayed. The pigeon was reinforced with mixed grain for responding to the discriminative stimulus area when the stimulus had a positive value. When a negative stimulus was presented, a response directed toward the advance stimulus area was correct. In this case, as a reward, the intertrial interval (ITI) was shortened from its standard duration of 20 sec to 5 sec. Furthermore, if on a negative trial a response was emitted to the discriminative stimulus area, the ITI was lengthened to 40 sec. The time from stimulus onset to the breaking of a beam (i.e., the reaction time) was intended to be the critical dependent measure.

Two distinct behaviors were observed to be emitted toward the discriminative stimuli and advance stimulus. The typical pecking response was observed when the animal responded to the discriminative stimulus. However, the typical response to the advance stimulus was observed to be less directed and may be described as a "swiping" motion. The differences between the movements required to make these responses render the comparison between reaction times to positive and negative stimuli impossible. This "swiping" response, however, may be looked upon as a new behavior by means of which the pigeon interacts with the experimental equipment. Further investigation of the "swiping" response may lead to insights concerning the pigeon's gathering and processing of stimulus information. One possibility is that two different behaviors were elicited by the discriminative stimuli and the advance stimulus, because responses to the former are reinforced by food, whereas responses to the latter are reinforced by a reduction in the ITI. In any event, it seems clear that this "swiping" behavior is dependent on the "affordance" of the touch frame system.

Gibson (1966) introduced the concept of affordance in the context of the perceptual observer's interaction with the environment. Properties of the environment allow or afford particular behaviors to be acted upon them (Gibson, 1979). In the present case, the properties of the touch frame seem to accommodate a set of behaviors different from those supported by mechanical pecking keys.

We believe that our system may be used to illustrate how different behaviors may be elicited by different methods of response registration. The infrared matrix of LEDs is positioned approximately 2 cm in front of the actual pecking surface. Therefore, effective responses need not be as directed to the stimulus as they are when contact with a manipulandum is required. We tested this notion by comparing responses while the LEDs were 2 cm away from the pecking surface to responses emitted while the LEDs were positioned only 1 cm from the surface: *x*- and *y*-coordinates were recorded under each condition for 160 trials. The distance from the center of either stimulus to the location of the first peck was calculated, using the *x*- and *y*-coordinates and the Pythagorean theorem. The mean distances for 8 pigeons are presented in Table 1. As can be seen, the distances of pecks from the stimulus center are substantially greater when the LEDs are positioned 2 cm from the pecking surface than when the LEDs are 1 cm from the pecking surface. A within-subjects analysis was performed on the distances: the effect was found to be significant [$t(7, .05) = 11.7$]. The pecks, when the LEDs were 1 cm away from the pecking surface, were localized around or within the stimulus area. Different behaviors were emitted depending on the manner in which responses were registered.

Stimulus presentation. The touch screen system—in particular, the interface between the microcomputer and the color monitor—provides flexible methods of stimulus construction and display. The stimulus set available to the experimenter is limited only by the imagination. Stimuli may change in size, shape, and location in a matter of milliseconds, thus allowing dynamic stimulus presentation. Taking this point one step further with the aid of the computer, animated graphics become an option. Thus Rilling and LaClaire (1989) have used a touch screen system to present moving targets to pigeons. They presented a rectangle moving across the monitor in a

Table 1
Mean Distances of First Pecks from the Center of the
Stimulus Areas with the Pecking Surface 2 cm
or 1 cm from the Pecking Surface

Pigeon	Distance of LEDs from Pecking Surface	
	2 cm	1 cm
37	295.2	36.1
40	170.3	19.7
42	308.2	43.9
43	241.3	38.0
45	276.6	42.7
46	192.7	39.5
49	299.9	36.1
51	228.1	68.8

Note—Distances are given in pixels.

sinusoidal motion. The location of the pigeon's beak was recorded as it followed the stimulus. When the pigeon's beak corresponded to the position of the stimulus on the monitor, food was presented. The animals were able to accurately track the stimulus, with a slight "lag." This behavior also transferred to stimuli moving in a vertical or even circular direction.

We are currently using the flexibility of computer-generated stimuli in an experiment in which the element and compound stimuli, described above, are visually degraded on half of the discrimination trials. Small black squares are superimposed on the discriminative stimulus to accomplish this. The size of the squares and the proportion of the stimulus that is blackened can easily be manipulated. Furthermore, the precise spatial configuration of the degrading squares is randomly determined on each trial. When constructing these stimuli, we have found that the time to complete stimulus construction may limit the temporal structure of the trial presentation. In other words, the construction of a stimulus page may not be completed by the time of its next presentation. To alleviate this problem, we are now incorporating a library of programming routines called Probase. These routines make it possible to construct and store graphic images in memory quickly.

The use of the color monitor as a stimulus display device not only allows more complex stimuli to be presented but also extends the size of the stimulus set far beyond the capacities of conventional methods. Wright et al. (1988) have provided an illustration of this ability. Using the touch screen system, they presented 156 different sample and comparison stimuli in a matching-to-sample task.

This number of stimulus pairs would have been impossible to present with in-line projectors and impractical to present with slide projectors. They observed that the pigeons matched novel stimuli with a high degree of accuracy. Wright et al. argued that this ability was guided by the formation of matching concepts, which could only be formed by exposure to a large number of exemplars. Before their study appeared, a wealth of literature had suggested that pigeons were not able to form matching concepts, and few papers had provided inconclusive evidence for the limitations of the experimental apparatus as opposed to the psychology of the pigeon. This illustrates the power of new technology—in this case, of the touch screen system.

REFERENCES

- COOK, R. G., & VIVIAN, J. (1988, November). *Texture segregation by pigeons*. Paper presented at the meeting of the Psychonomic Society, Chicago.
- GIBSON, J. J. (1966). *The senses considered as perceptual systems*. Boston: Houghton Mifflin.
- GIBSON, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.
- PISACRETA, R., & RILLING, M. (1987). Infrared touch technology as a response detector in animal research. *Behavior Research Methods, Instruments, & Computers*, **19**, 389-396.
- RILLING, M. E., & LACLAIRE, T. L. (1989). Visually guided catching and tracking skills in pigeons: A preliminary analysis. *Journal of the Experimental Analysis of Behavior*, **52**, 377-385.
- WRIGHT, A. A., COOK, R. G., RIVERA, J. J., SANDS, S. F., & DELIUS, J. D. (1988). Concept learning by pigeons: Matching-to-sample with trial-unique video picture stimuli. *Animal Learning & Behavior*, **16**, 436-444.