Behavioural Processes 81 (2009) 105–113

Contents lists available at ScienceDirect

Behavioural Processes

journal homepage: www.elsevier.com/locate/behavproc

Behavioral research in pigeons with ARENA: An Automated Remote Environmental Navigation Apparatus

Kenneth J. Leising, Dennis Garlick, Michael Parenteau, Aaron P. Blaisdell*

University of California, Los Angeles, United States

ARTICLE INFO

Article history:
Received 5 November 2008
Received in revised form 30 January 2009
Accepted 20 February 2009

Keywords:
Pigeon
Autoshaping
Conditional discrimination
Open field
Touchscreen
Simultaneous discrimination

ABSTRACT

Three experiments established the effectiveness of an Automated Remote Environmental Navigation Apparatus (ARENA) developed in our lab to study behavioral processes in pigeons. The technology utilizes one or more wireless modules, each capable of presenting colored lights as visual stimuli to signal reward and of detecting subject peck responses. In Experiment 1, subjects were instrumentally shaped to peck at a single ARENA module following an unsuccessful autoshaping procedure. In Experiment 2, pigeons were trained with a simultaneous discrimination procedure during which two modules were illuminated different colors; pecks to one color (S+) were reinforced while pecks to the other color (S−) were not. Pigeons learned to preferentially peck the module displaying the S+. In Experiment 3, two modules were lit the same color concurrently from a set of six colors in a conditional discrimination task. For three of the colors pecks to the module in one location (e.g., upper quadrant) were reinforced while for the remaining colors pecks at the other module (e.g., lower quadrant) were reinforced. After learning this discrimination, the color-reinforced location assignments were reversed. Pigeons successfully acquired the reversal. ARENA is an automated system for open-field studies and a more ecologically valid alternative to the touchscreen.

It is integral to science that any measure of observed behavior be both accurate and reliable. Notable advances in the reliability of behavioral measurement in the psychological and neuroscience literature include the development of the operant box connected to a cumulative recorder (e.g., Skinner, 1938, 1956), of tracking systems for spatial behavior (e.g., Clarke et al., 1985; Noldus et al., 2001), and the use of touchscreen-equipped operant boxes for pigeons (e.g., Allan, 1992; Blough, 1986; Pisacreta and Rilling, 1987; Wright et al., 1988), rats (e.g., Bussey et al., 1994; Cook et al., 2004; Markham et al., 1996; Sahgal and Steckler, 1994), and primates (e.g., Elsmore et al., 1989). Each apparatus improved reliability by using the latest technology to automate data collection. Additionally, the use of an operant box minimized the contribution of handling effects to variance in the data by presenting continuous trials. Some of these technologies, however, resulted in more contrived, less naturalistic settings. For instance, two-dimensional depictions of objects or scenes with color properties designed to suit trichromatic primates rather than pentachromatic avians likely appear less natural to a pigeon than do the real, three-dimensional objects or scenes they represent (e.g., Cabe, 1976; Cole and Honig, 1994; Friedman et al., 2005; Zeigler and Bischof, 1993; but see also Spetch and Friedman, 2006a,b). The degraded ecological validity is often a concern for the generalization of findings collected using these technologies to a larger population or different contexts.

Open-field studies continue to be used as a more naturalistic alternative to the operant box. Open-field studies have been used to investigate behavior in a variety of species, including humans, cats, dogs, rats, and pigeons, and using dependent measures involving whole body movements, partial body movements, and adrenal and electrophysiological activity (see Walsh and Cummins, 1976 for a review). Although widely used, Walsh and Cummins concluded that the construct validity and reliability of many of these dependent measures for open-field study remain unproven and that this failure undermines the interpretations and conclusions of the studies based upon them. Even the literature reporting on a single species (e.g., pigeons) in an open field indicates that few researchers adopt identical criteria for their dependent measure; this inconsistency complicates comparisons across different laboratories. Another disadvantage to using the traditional open field is that the number of trials given and subjects tested per day is severely limited by labor demands and the time consuming nature of a discrete-trial procedure. These limitations have resulted in few open-field studies which have parametrically varied the independent variable to more completely evaluate its relationship to behavior.

We have found data collection in open-field studies in our own lab to be constrained by two factors. The first constraint is the

* Corresponding author at: UCLA Department of Psychology, 1285 Franz Hall, Box 951563, Los Angeles, CA 90095-1563, United States. Tel.: +1 310 267 4589; fax: +1 310 206 5895.
E-mail address: blaisdell@psych.ucla.edu (A.P. Blaisdell).

0376-6357/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.beproc.2009.02.008

placement of food rewards directly in the open-field setting. Food goals must be replaced or at least moved to new locations after each trial. Second, landmarks or other types of discriminative stimuli placed directly in the open-field setting must be relocated to new positions prior to each trial. Both of these procedures necessitate the removal of the subject from the open field, thereby introducing handling effects and disrupting the smooth progression of the subject's behavior. A number of studies have tried to address these issues through the use of a start box (e.g., Biegler and Morris, 1999; Lechelt and Spetch, 1997) or specialized reward location (e.g., Biegler and Morris, 1999; Cheng, 1988), but to our knowledge no open-field apparatus has combined automation of reward delivery and stimulus presentation to create a fully automated system.

Recently, Badelt and Blaisdell (2008) reported the development of a circuit using a capacitive sensor for detecting proximity and response of a subject. This sensor can be incorporated into a variety of configurations and adapted to numerous apparatus to automate response detection. For example, Badelt and Blaisdell tested the validity and reliability of the circuit in detecting perching behavior of pigeons, the passage of rats and mice through an alley maze or open field, and the detection of a pigeon pecking or a rat nose poking into a small cup. In the apparatus for pigeons, the circumference of the cup (9.4 cm) was a little greater than that of a standard United States of America quarter (8.0 cm) and the depth of the cup was equal to its diameter (3.0 cm). The cup was embedded in the center of a small plastic box (see Fig. 1). The plastic box housed a circuit board, sensor electrodes, a set of light-emitting diodes (LEDs), batteries, and a wireless transmitter and receiver. The LEDs protruded into the bottom of the cup and served to illuminate the area when activated by the computer. We have built a number of these boxes which can be controlled remotely by a computer to both detect subject responses and to display colored lights from the LEDs. When placed on the floor of an open field, these devices can be used to automate a variety of behavioral procedures, ranging from simple Pavlovian and operant conditioning to spatial and temporal cognition to patterning and rule learning. The entire behavioral system, called ARENA (Automated Remote Environmental Navigation Apparatus), consists of a holding cage with a food hopper, an automatic door, and the ARENA modules placed on the floor of the open field. This system has the potential to resolve many of the remaining issues discussed above that involve the collection and scoring of behavior in an open field.

Here we report a series of experiments designed to test the efficacy of this new technology. The use of this new technology within an open-field setting (1) improves the objectivity of the behavioral measure since the animal's responses are detected via the apparatus and data recording does not depend on interpretation by an observer, (2) eliminating handling of the subject in between trials minimizes handling-induced stress and agitation; for example, in pilot studies using a landmark-based task in a traditional open field subjects would frequently remain stationary for several minutes at the start of a trial before reengaging in foraging behavior, (3) stimuli can be changed instantaneously which reduces labor demands on the experimenter, and (4) automated reward delivery at a single location eliminates the influence of visual or odor cues at the site of reward (e.g., food buried by the experimenter). These benefits combine to enable many more trials to be conducted in a single session; in the past a session with 80 trials of a landmark-based search task in the open field was not feasible but can be completed in ARENA in 1 h.

We tested pigeons in three basic conditioning procedures—autoshaping/instrumental shaping, a simultaneous discrimination, and a conditional discrimination. We selected these procedures because they are among those most commonly used to study basic behavioral and cognitive processes in laboratory animals. All three of these procedures involve presentation of visual stimuli

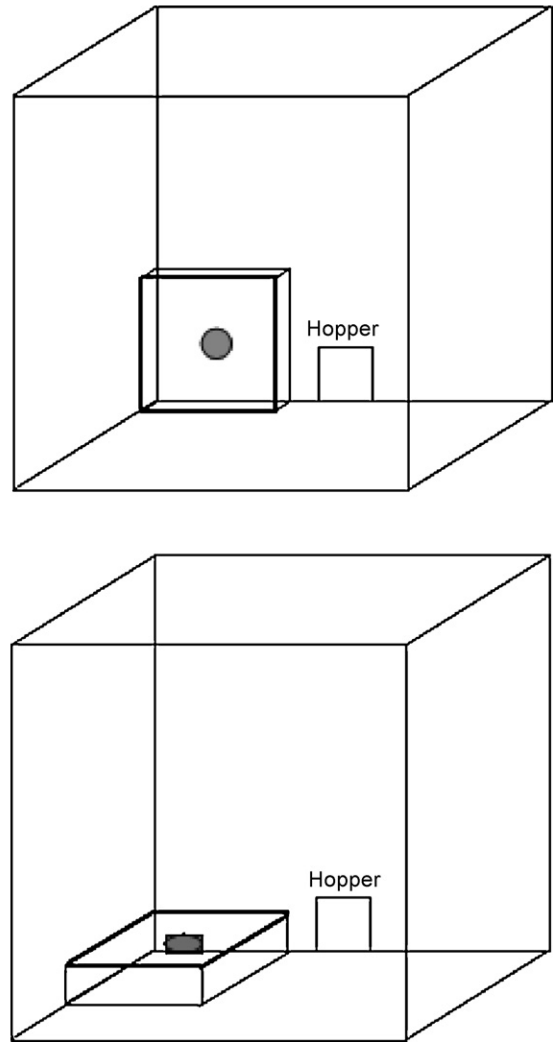

Fig. 1. A schematic representation of the operant box used in Experiment 1 and the placement of the ARENA module. The top panel shows the module vertically positioned, while the bottom panel shows the module in the horizontal position. The grey filled circle indicates the stimulus-response area. 'Hopper' indicates the location of food reinforcement. Figure not drawn to scale.

and detection of subject response, and probe the development of behavior in response to stimulus-outcome or response-outcome contingencies. Furthermore, these procedures involve the continuous presentations of trials as in more conventional studies conducted in the operant box.

1. Experiment 1

This experiment used autoshaping (a.k.a., sign tracking) and instrumental shaping procedures to determine whether subjects would interact with a single ARENA module in a manner that would make it useful for behavioral studies. An autoshaping procedure involves the development of a Pavlovian conditioned response to a signal (conditioned stimulus or CS) of a motivating stimulus (unconditioned stimulus or US) such as the delivery of food (Brown and Jenkins, 1968). Notably, the delivery of the US does not depend on the subject's response, and thus any response to the CS that develops is a true Pavlovian conditioned response. An instrumental shaping procedure is similar except that a subject's response is necessary for the delivery of the reward.

One critical component of the ARENA module to be tested was the reliability of the capacitive sensor to detect responses to the