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Experimental Analysis of Behavior

Part 1

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CHAPTER 1

Subjects and instrumentation

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1. Introduction

The Experimental Analysis of Behavior traditionally has been concerned with discovering basic principles by which behavior can be explained, predicted, and controlled. Indeed, B.F. Skinner's seminal work 'The Behavior of Organisms' (1938) purported to do just that, with the strong conviction that principles discovered using the laboratory rat would prove to be generally applicable across species. Grandiose as such a proposal seems, virtually all of the findings reported in 'The Behavior of Organisms' have stood the test of repeated replication in other rats, other species, with other types of apparatus, and have led to myriad useful human applications (Catania and Brigham, 1978; Martin and Pear, 1988; cf. Journal of Applied Behavior Analysis). Much of the credit for the success of this early work can be attributed not only to Skinner's scrupulous attention to methodological detail and its documentation, but also to his sensitivity to the implications of behavior that resulted when things went wrong. Skinner's (1956) account of his discovery of the 'unformalized principles of scientific practice' are testimony to the way in which an intimate concern with methodology can be as important to a scientific advance as a carefully formulated hypothesis.

2. Choice of subjects

Because the basic behavioral processes show continuity across species, referring to laboratory animals as 'infrahuman' or tacitly removing humans from the category of animals (as in the phrase 'humans and animals') has struck many behavioral scientists as inappropriate (e.g., Poling, 1984). In this chapter the phrase 'nonhuman animals' is used to avoid terminology that implies that humans are fundamentally different behaviorally from other animals.

Most of the advantages of nonhuman animals as subjects for the study of behavior are obvious: the total control of environment, and sometimes of behavioral and/or genetic history, that is advantageous for basic research can be practically and ethically carried out only with nonhuman animals. In addition, because most behavioral experiments explore a range of parameters of the independent variable in a single subject, nonhuman subjects can be available readily over many weeks or months. Another advantage is not so obvious: use of a nonhuman subject forces the investigator to focus on observable behavior alone, not attitudes, feelings, or conjectures of the subject about his or her behavior.

The rationale for choosing a particular species includes, among other factors, the experimental question, the usual life span of a species relative to the projected length of the experiment, and costs. The range of species that have been used in operant research is broad. A quick review of articles published in the Journal of the Experimental Analysis of Behavior, since its inception in 1958 shows that subjects have included, among others, porpoise, goat, sheep, cow, turtle, fish, octopus and crab as well as the more familiar rat, pigeon and monkey. By far, rats and pigeons have been the most prevalent subjects; monkeys have been selected more often for behavioral pharmacology experiments than for basic operant research per se. The sections below reflect the disproportionate use to date of different species in studies of operant behavior. It is advantageous to use a subject about which a good deal of information is already available. This chapter recognizes, however, that certain species, less frequently used in the Experimental Analysis of Behavior, are appropriate for certain biomedical, psychophysical, or ethological inquiries and that researchers working in those areas may wish to employ operant conditioning procedures as a part of their investigation. Furthermore, there may be interest in extending areas of basic operant research to other species.

The question of relative 'intelligence' of different species as a factor in choosing subjects for behavioral experiments is virtually moot. Such discussions tend to be highly anthropocentric and inconsistent with a functional analysis of the variables that determine behavior in any given circumstance. Hodos and Campbell (1990) have pointed out that evolution was not linear, with humans the most perfectly evolved result, but branching, with *Homo sapiens* only one of a number of recently evolved limbs. Each modern species is perfectly evolved to take advantage of its environmental niche. In fact, meaningful evaluation of the relative intelligence of different species is extremely problematic (Hodos, 1988). Differential susceptibility to control by certain types of stimuli and to learning certain response topographies has been recognized, however. The concept of 'preparedness', for example, summarizes the finding that a species may be more likely to learn some stimulus discriminations in one context rather than in another (see Section 13). A related factor is that when food is used

as a reinforcer with certain species the responses elicited by the food (i.e., as part of the food-related behavior of the species) may interact with the response the researcher has selected to train (Breland and Breland, 1961). The focus of the behavioral scientist properly falls then, not on issues of relative intelligence, but on devising methods that take into account physical and behavioral characteristics of a particular species (e.g., Rubadeau and Conrad, 1963; Bitterman, 1964; cf. Markowitz and Stevens, 1978; Markowitz, 1982).

3. Animal care

Investigators must recognize their ultimate responsibility for the welfare of their subjects. Good communication among those responsible for animal care is essential. Communication breakdown is the most preventable cause of health problems in laboratory animals. Some issues in the care and use of animals in research will be discussed below. Many texts provide information on biology, diseases and characteristics of species commonly used in research (texts covering more than one species include: Fox et al., 1984a; Holmes, 1984; Tuffery, 1987; Harkness and Wagner, 1989; see Section 18.1.2. for references published by governmental and professional organizations).

3.1. Ethics and regulations

Responsibility for animal welfare encompasses not only animal care, but also thoughtful consideration of the parameters of experimental variables and of the relevance of particular manipulations to the purpose of the experiment. The number of subjects per experimental condition depends upon the experimental design (see Part 1, Ch. 4); however, as both an ethical and a practical consideration, experiments should minimize the number of animals used. Proper instruction and supervision of those handling and caring for animals is an ethical and a legally mandated responsibility. Consultation with a veterinarian having laboratory animal experience not only is useful to good long-term care of behavioral research subjects but also is legally required.

Anyone working with animals will be subject to and should be familiar with national, state and/or local animal welfare laws and regulations; these rules apply to many facets of animal procurement, housing, care and use. Many professional organizations have codes of ethics to guide their members engaged in animal research (see the American Psychological Association Guidelines in the Appendix of this volume). The 'NIH Guide for the Care and Use of Laboratory Animals' (see Section 18.1.2) contains the U.S. Public Health Service policy on care and use of animals, and has long been the standard primary reference on research into animal care and use. The U.S. Department of Agriculture (USDA) promulgates regulations pertaining to the procurement, care and use of research animals; they also define the mechanisms by which institutions using animals monitor the use of research animals, such as mandating review of procedures using animals by 'Institutional Animal Care and Use Committees' (see Section 18.1.2). The USDA conducts periodic unannounced inspections of animal facilities; other government agencies may also inspect facilities receiving federal funding. The orientation of this chapter is primarily for investigators doing research in the U.S. Tuffery (1987) discusses practices and legal requirements in the U.K. and some other countries as well.

3.2. Housing

Traditionally it has been recommended and/or required that species be housed in isolation from each other to minimize spread of disease and possible stress to incompatible species. Cage sizes are prescribed by government policy and regulation (see Section 18.1.2). Individual animals in behavioral experiments typically are housed singly for the purposes of environmental control and precise monitoring of food and water consumption. Despite some sentiment that social housing may provide a more enriched environment, species differ in their behavior toward conspecifics when individuals are housed in the same cage arbitrarily. Investigators interested in social housing of any species should consult appropriate references before doing so.

Lighting conditions, including intensity, quality and photoperiod, can affect a wide range of biological and behavioral responses (Baker et al., 1979a; Albers et al., 1982; Pakes et al., 1984). Circadian rhythms themselves affect a number of physiological systems and responses, including drug response (Hekkens et al., 1988). The light/dark cycle chosen for windowless rooms should be controlled by an automatic timer. The actual cycle is chosen arbitrarily (an exception would be for breeding colonies). A cycle of 12 h light/12 h dark is often used, but 14 h light/10 h dark may be more practical, given laboratory personnel work schedules. Although some laboratories maintain constant 24-h light conditions to try to regulate circadian rhythms (particularly with rats, which are nocturnal), this practice is not recommended by some (Tuffery, 1987). Even recommended light intensities have been shown to produce retinal damage in rats and mice at some exposure durations (Baker et al., 1979b; Pakes et al., 1984). Light intensity is greater for animals on the higher shelves of caging systems; and Greenman et al. (1982) found a higher prevalence of retinal atrophy in mice housed on the top shelves than in mice on the lower shelves.

3.3. Feeding and weight regulation

Information on the nutrient and water requirements of many animals is published in The National Academy of Sciences 'Nutrient Requirements of Domestic Animals Series' (see Section 18.1.2). Balanced animal diets, which take these recommendations into account, are available commercially both as chow and as pellets for reinforcement. As long as the expiration dates are heeded, this chow is all that is needed to feed laboratory animals appropriately under free-feeding conditions. Under restricted feeding conditions, however, vitamin supplements often are used. Some experimental procedures may use distilled water (e.g., oral drug delivery). Because tap water is a source of trace elements and calcium, however, prolonged restriction of access to tap water is not advisable without appropriate dietary supplements.

When food (particularly balanced pelleted or liquid diet) is used to maintain responding in an experiment (i.e., as a reinforcer), food access must be controlled and weight must be maintained within some constant, narrowly defined range (referred to as the running weight). As Laties (1987) has argued, such restrictions are not particularly severe because weight reductions are judged against *ad libitum* feeding conditions in a laboratory rather than against the lower weights that result when animals fend for themselves in the wild. Even if food is not being used as a reinforcer, it has been shown that some species are healthier and live longer, without apparent behavioral or sensory deficits, if they do not become obese (Masoro, 1985; Campbell and Gaddy, 1987). Other factors in favor of regulated feeding during behavioral experiments are that obese animals are not particularly active and that fluctuating weights and/or hours of food deprivation add potential extraneous sources of behavioral variability. The running weight often seen as the 'generic' standard is 80% of free-feeding weight. The age of the subject and the period of time over which free-feeding is permitted are critical determinants of whether the 80% rule is a reasonable one for a given species. The goal is to select a weight range that permits the reinforcer to maintain responding during the experimental session and maintains the subject in good health. Although stability in weight and in hours since feeding are generally important to stability in a behavioral baseline, one particular body weight usually is not. A lower weight range may be necessary early in training than after responding has been shaped. If body weight per se seems to be critical to a phenomenon, it can be manipulated systematically, as in studies of adjunctive, or schedule-induced, behavior (Falk, 1972) and drug self-administration (Carroll and Meisch, 1984). Body weight should be reduced to the running weight by removing free access to food and feeding a measured amount each day. It sometimes has been the practice to reach this weight quickly with rats, mice and pigeons by depriving the subject of food for 48–72 h but this practice is not recommended. Constant access to water should be provided. There is an interdependency between food and water intake (e.g., food-restricted animals drink less water), but species differ in their patterns of drinking during the day and in their response to food restriction (see review in Normile and Barraco, 1984).

3.4. General health concerns for humans and laboratory animals

A quarantine period is essential before bringing new animals into an existing colony to protect the colony from introduction of disease or parasites. Likewise, laboratory animals that leave the laboratory environment (e.g., rats or mice used in off-site demonstrations) should be requarantined before being returned to the laboratory. Bringing pets into any area of an animal laboratory is never appropriate. No matter how well-cared for, pets are potential sources of parasites or disease for laboratory animals.

There are many diseases (known as zoonoses) that animals may transmit directly to humans (Fox et al., 1984b). With good quarantine and laboratory maintenance procedures, however, only a few zoonotic diseases require particular vigilance on the part of the researcher; they will be mentioned in the discussion of the various species. Anyone working with laboratory animals should have a current tetanus innoculation. Any bite or scratch must be washed immediately with soap and water. Wearing disposable vinyl examination gloves when handling laboratory animals often is recommended; this can minimize the frequency of hand-washing that is necessary after handing animal subjects. Information on handling each species will be provided in the sections below. Because animals in behavioral research usually are received at a young age and handled almost daily, they become much more tractable than otherwise. Some of the handling methods used in behavioral studies might not be suitable for adult animals that have been handled only infrequently.

3.5. *What to do with research animals at the end of the experiment*

Many behavioral studies consist of a series of experimental conditions, each building on the training and/or results of previous experiments. Euthanasia typically is not part of the experimental protocol of strictly behavioral studies. It is not uncommon, therefore, for the subjects finally to succumb to age-related disorders. In other cases, animals with certain training histories often can be transferred to other investigators. This is particularly encouraged with primates as a strategy for limiting the numbers of primates that must be imported for research. Consideration of appropriate alternatives to euthanasia are encouraged (see Appendix for APA Guidelines). The responsible investigator must be convinced that anyone to whom a subject is entrusted, including another investigator, is well-informed about its proper handling and care and has the proper resources available. While there may be circumstances in which it may be appropriate for a laboratory animal to be returned to the wild (cf. APA Guidelines), purpose-bred laboratory animals have no experience of fending for themselves. If euthanasia is deemed the appropriate course of action, it must be done in accordance with legal and professional guidelines (Clifford, 1984; Tuffery, 1987). A commonly employed method is overdose with a euthanasia solution (typically a mixture of pentobarbital and alcohol), but consult with the attending veterinarian as to current procedures for each species.

4. Rodents

Rodents are the most frequently used subjects in biomedical research; thus, a great deal of information about them is available (Fox et al., 1984a; Holmes, 1984; Harkness and Wagner, 1989; see Section 18.1.2). Rodents are readily available from well-established suppliers of laboratory animals (see Section 18.1.1). These animals breed successfully and frequently in captivity, and some laboratories maintain their own breeding colonies (Baker et al., 1979b; Fox et al., 1984a; Harness and Wagner, 1989). Recommended quarantine periods for rodents range from 7 to 28 days (Fox et al., 1984a). Most behavioral research uses male rodents out of concern for the effects of the female estrous cycle on the stability of behavior of female animals and/or on behavior of males in the same laboratory (e.g., Steiner et al., 1981).

Identification methods for rodents vary. When a relatively small number of animals is being used, many researchers do not specially mark the animals and are very careful about keeping track of returning each one to the appropriate cage. Often physical characteristics serve to distinguish one animal from another (e.g., some researchers draw or photograph the distinctive markings on pigmented rats). An easy marking system is to devise a color code for marking fur or tail with indelible (non-toxic) markers or dyes; these have to be renewed periodically. Standard ear punch codes, tattooing, and ear tags also are available (Fox et al., 1984a).

Rodent incisors grow continuously and are worn down naturally by chewing; in the guinea pig, this is true of the cheek teeth as well. If the animal is not able to gnaw hard objects sufficiently or if the teeth become maloccluded, the incisors become overgrown and can prevent the animal from eating. Beyond this common characteristic, rodent species differ in physical and behavioral characteristics, in their susceptibilities to health problems, and in drug sensitivities.

4.1. *Rats*

All laboratory rats, whether albino or pigmented, are derived originally from the Norway rat (*Rattus norvegicus*). Baker et al. (1979b) contains a fascinating history of the origins and research uses of laboratory rats and lists the wide variety of strains. Rats can be obtained at any age after weaning (weaning occurs at 21 days, puberty at 40–60 days). The strains most commonly used in behavioral research are Sprague-Dawley and Wistar (both albino) and Long-Evans (hooded, pigmented, Fig. 1). Several inbred strains of rats are chosen for behavioral characteristics, such as emotional reactivity (e.g., Maudsley reactive rats, Broadhurst, 1975) and alcohol-sensitive or alcohol-preferring rats (e.g., McClearn, 1981). Differences in shock-avoidance learning among strains of rats have been reported as well (Iso et al., 1988; Shapiro and Riley, 1980). Because of extensive use of the rat in biomedical research, data are available on the effects of a wide range of variables on biological responses in the rat (Lang and Vesell, 1976; Baker et al., 1979a; Pakes et al., 1984). Rat behavior and

Fig. 1. Handling a rat. *Left and middle panels* show finger positioning for picking up and carrying a rat, respectively; the animal shown is an adult male Long-Evans hooded rat. The *right panel* further illustrates positioning the fingers under the rat's forelimbs to maintain good control of the rat and to avoid being bitten. (Photos by L.G. Ator.)

sensory abilities also have been studied extensively (see Munn, 1950, for a review of classic research in these areas and Collier et al., 1977, for a review of feeding studies). Disadvantages of laboratory rats for behavioral research include their short life spans (generally 2.5–3 years) and susceptibility to life-threatening respiratory ailments.

4.1.1. Handling rats
When rats arrive in the laboratory, it is a good practice to handle them daily, even if just to pet them; with frequent handling, rats become docile and later training may be facilitated (West and Michael, 1987). To pick up a rat, place the index finger and thumb of one hand behind the rat's shoulder blades; the palm of that hand may be rested on the rat's back (Fig. 1).

Ideally, the rat is carried with the feet resting on the sleeve of the labcoat covering the opposite forearm. When held with a minimum of pressure and with the feet supported, rats quickly habituate to being handled. With the fingers kept firmly but gently behind the shoulder blades, it is unlikely that the rat can bite. Heavy gloves can interfere with appropriate handling. If any but the thinnest gloves are worn, it is difficult to achieve appropriate control, which makes it likely that the rat will be squeezed too hard, causing it to struggle further and/or be injured. Grasping the rat by the base of the tail is a suitable means for retrieving, but not carrying, a rat. Holding further down the tail may result in the skin being torn off.

4.1.2. Weight regulation of rats
Although research papers in which food was used as a reinforcer often report that rats were maintained at 80 or 85% of free-feeding body weights they often do not state either the time period over which unlimited access to food was provided or the terminal weight. Rats are semicontinuous feeders and can gain weight indefinitely; thus the duration of *ad libitum* feeding determines the free-feeding weight (cf. Peck,

1978, for weight regulation when the diet and response requirements for access to food are varied). Some arbitrary time period for *ad libitum* feeding usually is chosen (e.g., 2 weeks for a young adult rat). If a rat attains a relatively high weight (e.g., 500 g), however, 80% of that weight still may not be one at which training will occur rapidly. If a free-feeding weight for a young rat is much lower (e.g., 350 g), an 80% weight maintained over the rat's lifespan may be unnecessarily restrictive. One of the solutions to this problem is to obtain normative growth information on the weights of free-feeding rats of that strain (e.g., Baker et al., 1979b; Fox et al., 1984a) and to increase the running weights of the experimental animals over time. One could maintain 'control' animals for this purpose to obtain the normative data under one's own laboratory conditions. However, because food restriction extends the life span and retards aging in rats, the control rats might not live as long as the experimental rats nor be entirely comparable (Masoro, 1985; Campbell and Gaddy, 1987). A different solution is to allow the weights of young rats to increase gradually to a specific weight range, one at which rats remain healthy and exhibit stable behavioral baselines. Give young adult rats free access to food and water during the quarantine period. When training begins, give measured amounts of food each day, such that weights increase to some target range. For example, we find 335 ± 10 g to be a suitable range for adult male Long-Evans hooded rats; with female rats, the weight range might be lower, as adult female rats are 50–100 g smaller than males (Baker et al., 1979b). It is common for supplemental food to be weighed, but one can learn to maintain stable weights by choosing particular size pieces of standard rat chow (e.g., 2 medium pieces or 1 medium and 1 small). Even under standard laboratory conditions, the rate at which invidual rats lose weight varies, so choosing an arbitrary amount for all rats does not result in stable weights. Finally, Hurwitz and Davis (1983) describe a 'labor-saving' method for feeding rats in behavioral research, that is, merely providing each rat free access to food for 1 h after the session.

4.1.3. Caring for rats
The best approach to minimizing illness is aggressive preventive maintenance of the colony (Baker et al., 1979a). The probability of activating respiratory diseases (see Section 4.1.4) is increased by sudden environmental changes and stresses (e.g., temperature fluctuations, drafts). A temperature range of 18–27°C (65–79 F) with relative humidity 40–70% is recommended. Low humidity can produce ringtail, which involves tail lesions and may result in sloughing of all or part of the tail (Baker et al., 1979a). Urinary ammonia can potentiate respiratory problems, so change bedding and the pans in experimental chambers frequently. Do not interchange water bottles and sipper tubes between rats. Wipe down experimental chambers periodically with a disinfectant that is a good virucide (e.g., household bleach); a phenolic (e.g., Lysol©) or a chlorhexadine (e.g., Nolvasan©) could also be used. Thorough rinsing is essential. Choose the time of disinfection carefully relative to experimental conditions, because the changed smell of the chamber may influence behavior.

4.1.4. Health concerns with rats

References on rat anatomy, biology, and diseases include Baker et al., 1979b, 1980; Holmes, 1984; Harkness and Wagner, 1989. Rats are unusually resistant to infection; but two common health problems, tumors and respiratory disease, can jeopardize completion of long-term experiments. Tumors can be benign or malignant; veterinary assistance in diagnosing and treating a tumor is important. Any of a variety of respiratory pathogens can be carried into a lab by an asymptomatic carrier and be spread to other animals either directly (rat to rat) or indirectly (airborne). Sudden changes in environmental conditions can increase susceptibility of a host animal to the expression of the disease.

Threat of respiratory disease can be minimized by ordering gnotobiotic rats, that is, rats free of those pathogens causing certain respiratory diseases (but they are not necessarily free of all pathogens). These are often referred to as 'specific pathogen-free, SPF, rats'. Some suppliers have trade names for their gnotobiotic rats and charge extra for them; other suppliers maintain that all their rats are 'virus free'. Although it can be an advantage to order gnotobiotic animals, any benefit is lost if they are brought into an existing colony of rats not obtained from the same source and/or that were not billed as gnotobiotic. If respiratory infection occurs, the only way to truly be rid of it is to start over with a new colony of gnotobiotic rats after thoroughly sanitizing the facilities. This usually is not practical in a behavioral laboratory. Opinion about the likely success of treating respiratory disease in an individual rat varies, probably with the experience of the person consulted. For any chance of success, it is critical to detect the onset of respiratory disease as early as possible. Once a rat is *in extremis*, it is unlikely to survive. The earliest behavioral sign of respiratory illness can be a sudden, otherwise unexplained, decrease in responding during the experimental session; or food may be left uneaten in the home cage, an unusual occurrence for rats under restricted feeding with free access to water. Early physical symptoms can include red-staining around the eyes, nasal and ocular discharges, and/or increased difficulty breathing. Distinguishing the normal breathing sounds of a rat from the rasping or snuffling sound made in respiratory disease can be accomplished in a gentled rat by placing the rat on your shoulder and placing your ear against the rat's side. Quarantine the rat at the first suspicion of illness and provide free access to food, softening it with water if food intake is decreased. Give a broad spectrum antibiotic; consult with a veterinarian for the best currently available (cf. Holmes, 1984). A common, easily administered, treatment has been a regimen of tetracycline · HCl in the drinking water. This approach is controversial because of problems of achieving an appropriate dosage (Porter et al., 1985a, b); the key is to find a tetracycline concentration that does not suppress drinking but which provides an appropriate dose of antibiotic when the usual amount of fluid is consumed. We have had some success with a 5 mg/ml concentration of tetracycline·HCl. It is presented as the only source of fluid for 5 days (it must be mixed fresh daily). With free access to food, rats generally drink sufficient amounts to obtain a 700 mg/kg dose in 24 h

(additional fluid could be given by gavage if necessary). At the end of the dosing period, the rat is monitored for an additional 5 days. If symptoms recur, the regimen is repeated. If there is a high frequency of respiratory illness in a colony, it may be helpful to place the whole colony on the tetracycline regimen for 5 days.

Other troublesome health problems include broken toenails and maloccluded or broken front teeth. Broken nails bleed profusely but heal rapidly of their own accord. Maloccluded incisors must be trimmed. Incisors break if they are caught in some types of wire mesh. Chow must be softened in water until the incisor grows back. For rats under restricted feeding, putting the food ration inside the cage, rather than in a hopper on the side, prevents broken incisors and also minimizes loss of pieces of the food ration. When rats are on free-feeding, placing large quantities of food inside the cage is considered unsanitary, and the large quantity of food in the hopper makes it easier to chew the food through the wire mesh.

Almost all humans working with rats get bitten at least once in their careers due to carelessness or complacency. The laceration will be minimized if one does not jerk away or drop the rat. A major health problem for humans working with rats is the development of allergies, which can be so severe as to preclude further work with rats. Some viruses and bacterial infections (e.g., 'rat bite fever', leptospirosis, salmonella) can be spread from rats to laboratory workers but this is rare in a well-maintained colony (Geller, 1979; Fox et al., 1984a).

4.2. Mice

The species commonly used in research is *Mus musculus*, the house mouse of North America and Europe. Because of the extensive genetic mapping of the laboratory mouse, it is the mammal which has been most thoroughly characterized. There are a large number of inbred and random-bred strains, with a variety of physiological and behavioral characteristics (Foster et al., 1981–1983; Fox et al., 1984a). For example, the development of strains of mice that show differential sensitivities to the effects of alcohol and differential probabilities of alcohol self-administration has resulted in extensive use of mice in behavioral studies of genetic contributions to alcoholism and self-administration of other drugs (Elmer et al., 1988; George and Goldberg, 1989). Schedules of reinforcement have been used with mice in behavioral pharmacology and toxicology (Wenger, 1979); strain differences in control activity levels may be responsible for reported variability in drug response across studies (Wenger, 1989).

The primary disadvantage of mice for some behavioral work is their short life span (2–3 years, puberty at 28–49 days). Like some other rodents, mice live longest if not permitted to become obese (Masoro, 1985). Running weights of 75–80% of *ad libitum* feeding weight have been reported for mice in studies using nutritive reinforces. The weights of male mice asymptote within a narrow range (e.g., 29–35 g), depending on strain; running weights typically are 23–28 g. Permitting weights to rise to a fairly stable maximum (e.g., over a 2-week period if received at 6 weeks of age) before reducing weights by restricted feeding is preferable to permitting weights to rise only to the desired range as mentioned above for rats. Although stable reduced weights can be maintained easily in mice, accidentally missing a day of feeding may prove fatal, in contrast to such regimens with other species. Mice should be picked up by the base of the tail and may be carried this way briefly; they should be placed on a flat hand, while retaining hold of the tail, for longer journeys (see Tuffery, 1987). Holding the mouse by the tip of the tail may strip the skin from it.

Mice are particularly sensitive to temperature fluctuations because of the relatively large surface area per g of body weight (Jacoby and Fox, 1984); a range of 18–26°C (64–79F) is recommended (Harkness and Wagner, 1989). Mice are also more sensitive to water loss than most mammals (Jacoby and Fox, 1984); but water reinforcement has been used with mice (with 20 min post-session access) without ill effect. Reviews of mouse diseases may be found in Foster et al. (1982) and Jacoby and Fox (1984). A number of infectious diseases share clinical signs and can be difficult to diagnose. Mouse hepatitis infection (MHV), actually a group of coronavirus infections, is fairly common; but may not result in expression of clinical signs. Even when clinical signs are not present, MHV can have subtle effects on biomedical research (e.g., by altering liver enzyme levels).

4.3. Gerbils

The Mongolian gerbil (*Meriones unguiculatus*) is used in biomedical research for certain unique anatomical and physiological characteristics, including susceptibility to epileptiform seizures (Holmes, 1984). Limited operant conditioning work has been done with gerbils (e.g., Powell and Peck, 1969). Gerbils are small; adults usually weigh less than 100 g. Puberty occurs at 10–12 weeks; the life span is usually 2–3 years, but can be as long as 4 years. Gerbils tolerate a wide range of ambient temperatures well; if relative humidity is > 50%, however, the fur stands out and appears matted and greasy (Holmes, 1984). Gerbils require unusually small amounts of water (5 ml/100 g body weight/day, Harkness and Wagner, 1989). Gerbils should be housed in containers with a layer of burrowing material; bedding does not require changing as frequently as that of rats or mice due to the small quantity of urine excreted. Gerbils are easily handled and rarely bite; lifting by the base of the tail must be done carefully to avoid stripping the skin.

4.4. Guinea pigs

Guinea pigs (*Cavia porcellus*) are used in studies of immunology, audiology, and infectious disease (Wagner and Manning, 1976; Holmes, 1984). Behavioral research using operant procedures with guinea pigs has been characterized as difficult (e.g., Jonson et al., 1975). Under conventional avoidance contingencies, guinea pigs "become catatonic in response to discomfort and/or fear" (Wagner and Manning, 1976, p. 284); but Heffner et al. (1971) used this sensitivity to advantage to determine auditory threshold under a conditioned suppression procedure. Use of food or water reinforcers can be problematic because some investigators found that deprivation of either had severe deleterious effects. Edible reinforcers used successfully in nondeprived guinea pigs include: carrot juice (Gundy, 1959), sucrose solutions (Wagner and Manning, 1976), a milk and cereal mixture (Berryman, 1976), and commercial guinea pig pellets (Poling and Poling, 1978). However, Petersen et al. (1977) did have success with edible reinforcers in guinea pigs maintained under a deprivation regimen; they describe in detail procedures for training a discriminated operant in guinea pigs. Free-feeding guinea pigs steadily gain weight to 12–15 months before weight asymptotes (700–850 g for females, 950–1200 g for males, Wagner and Manning, 1976; cf. Petersen et al., 1977). Guinea pigs are characterized as 'shy and nervous' and 'neophobic', but they rarely bite or scratch. To pick up a guinea pig, approach it from the front and back with both hands, one hand grasping around the shoulders, the other supporting the rump. Among rodents, guinea pigs are relatively expensive but they have the longest life span (5–6 years; puberty at 5 months). They, and nonhuman primates, are the only common laboratory animals requiring a dietary source of vitamin C (kale is a good supplementary source for guinea pigs, but it must be washed thoroughly). Further information on the biology, care, diseases and idiosyncrasies of guinea pigs is in Wagner and Manning (1976), Fox et al. (1984a), Holmes (1984), Harkness and Wagner (1989).

4.5. Hamsters

The hamster species most popular in biomedical research is the golden or Syrian hamster (*Mesocricetus auratus*, Hoffman et al., 1968). Use of the hamster in the Experimental Analysis of Behavior has been limited (e.g., Shettleworth, 1975; Anderson and Shettleworth, 1977). Hamsters are small, usually weighing 85–130 g. They will bite if handled roughly or startled. A hamster should be lifted by placing both hands under the animal, palms upward around the animal's sides. Alternatively, hamsters will enter a carrying container placed in the cage. Usual life span is 2 years, with some animals living 3–4 years (puberty occurs at 8–10 weeks). Under conditions of low light intensity, short day length, quiet, and cool temperature, hamsters may hibernate (Holmes, 1984; Harkness and Wagner, 1989). Hamsters are relatively healthy animals; the most important hamster disease proliferative enteritis usually affects very young hamsters, and it usually is fatal (Holmes, 1984). Hamsters show idiosyncratic responses to a number of drugs; many antibiotics, including penicillin, are lethal (Holmes, 1984; Hoffman et al., 1968). Texts on the hamster include: Hoffman et al. (1968), Siegel (1985), cf. bibliography in Harkness and Wagner (1989).

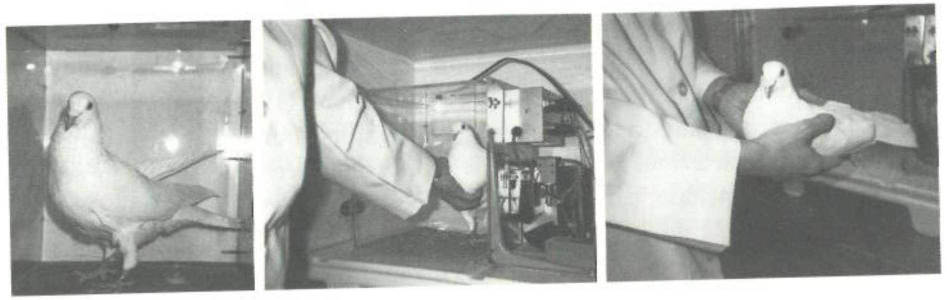

Fig. 2. Handling a pigeon. *Left panel* shows an adult White Carneau pigeon in an experimental chamber. The pigeon may be restrained by positioning one hand over the wing and under the breast if it is difficult to approach with both hands (*middle panel*). Once the pigeon is lifted, the other wing may be restrained (*right panel*). Note in the right panel that the fingers hold the feet along the body. (Photos by J.E. Barrett.)

5. Pigeons

Domestic pigeons (*Columba livia*) have been used extensively as subjects in the Experimental Analysis of Behavior. Ferster and Skinner (1957) systematically investigated virtually all of the currently defined schedules of reinforcement using the pigeon. Their guidelines for using pigeons in behavioral research have been followed by many subsequent investigators. The White Carneau (plural: Carneaux; Fig. 2) or the homing pigeon have been used most often, but there are a wide range of pigeon breeds and varieties kept for show. Pigeons are easily trained and handled, and they have life spans considerably longer than rodents (e.g., up to 15 years). They are hardy and recover well from surgical procedures. Another advantage to the handler is their lack of teeth! Pigeons have not been used frequently in biomedical research and are not well-represented in general references on laboratory animals. Rather, books written for pigeon fanciers are usually more informative (a standard is Levi, 1974; cf. Abs, 1983).

Both male and female pigeons are used in behavioral research. Sexing a pigeon is not easy, even for pigeon breeders, and it is usually not possible to be sure of receiving young birds of one sex or the other. Investigators often discover that a pigeon is female only when they find an egg in the cage. In any event, there is apparently little cause for concern over the effect of reproductive cycles on the stability of experimentally established behavioral baselines in male and female pigeons. Pigeons reach sexual maturity around 6 months. They are usually obtained for behavioral studies at 1 year, but some investigators purchase retired breeders (>6 years). Pigeons typically are banded around 10 days of age by the supplier with a seamless band giving unique identification number.

5.1. Handling pigeons

To pick up a pigeon, place the palms over the front of each wing (wing butt), spreading the fingers over the surface of the wings (wing coverts); the feet are held back along the bird's abdomen (Fig. 2). Hold the wings gently but firmly against the pigeon's body. Too tentative a hold permits wing flapping, which leads to greater difficulty in holding the bird. Wearing thin cotton gloves will prevent the hands from being scratched by the bird's claws; vinyl examination gloves do not hold up as well for this purpose. Clipping the wings and tail feathers is common (Ferster and Skinner, 1957) and facilitates catching an escaped pigeon, but is not necessary. Pigeons are not likely to fly in the dark; therefore, merely turning off the lights in the room, given that there is some extraneous source of light for the human (such as from a hallway), will usually permit easy retrieval of an escaped pigeon.

5.2. Weight regulation of pigeons

The 80% body weight regimen is appropriate for many experiments and easily used in this species. Pigeons tend to self-regulate feeding under free-access conditions and stabilization of the body weight of an adult bird occurs in 2–4 weeks. Weights should be taken daily over the last week to determine stability. The pigeon's weight then is reduced gradually to a target weight by feeding a small amount of food (5–10 g) daily. A typical procedure is to weigh the bird before the daily session (to determine whether the weight is within the appropriate range) and then to weigh the bird again after the session to determine supplemental feeding. The bird is fed the difference (in g) between the current weight and the target weight. If the bird is above the target weight, no supplemental food is given that day. Some investigators feed an additional amount that, in their experience, permits the bird to be at, rather than below, the target weight for the next experimental session. Once trained, pigeons generally continue to perform quite reliably under weights of 85–95% of the free-feeding weight (Ferster and Skinner, 1957).

5.3. Caring for pigeons

Pigeons should have free access to water supplied in an open trough. Pigeons immerse their beaks in water up to the nostrils and drink in one long, continuous draught (cf. Zweers, 1982). Pigeons bathe in water they can step in; thus, provide drinking water in containers accessible only through an opening for the head in a cage wall. Even then the water can be fouled quickly and should be changed daily. Water consumption may be determined by temporal patterns of food availability (Normile and Barraco, 1984). Nutrient requirements are amply discussed by Levi (1974). Grain-fed pigeons should be provided with free access to grit as a mineral supplement and to assist the grinding action of the gizzard for proper digestion. Most commercial brands of pigeon grit contain sea shell, gravel and salt (Levi, 1974). The grit can be provided as a deep layer in the food cup with the daily food ration placed on top of it. Pigeons fed a balanced food-pellet or meal diet may not require grit if the mineral content is adequate. Some investigators prefer to use grain, however, finding that it is a more effective reinforcer than the pellets. The same type of feed as that used as a reinforcer in the experimental session generally is used for supplemental feeding.

Pigeon beaks and nails may need to be trimmed occasionally. Beaks can be either gently filed with an emery board or clipped with sharp scissors. Care must be taken not to trim so deeply as to cause bleeding. Nails can be cut with scissors. Access to grit may minimize the necessity for beak filing.

5.4. *Health concerns with pigeons*

Provided with proper daily care, laboratory pigeons have very few health problems; however, wild birds and those maintained in outdoor coops are subject to a variety of diseases and parasites (Levi, 1974; Fox et al., 1984a). Unlike rats and mice, pigeons are obtained from suppliers who breed them for a variety of purposes, not just laboratory use, and a period of quarantine (3 weeks is best) is especially important.

Ornithosis (also known as psittacosis, chlamydiosis, pigeon breeder's disease, parrot fever) is an infectious-disease hazard for humans working with pigeons. A wide range of symptoms can occur but respiratory involvement (including a form of pneumonia) and conjunctivitis are common (Fox et al., 1984b). Pigeons themselves are susceptible to this disease, although they can carry it without showing symptoms (Levi, 1974). It is spread via feathers and aerosolization of pigeon excretion. Wearing a filter mask when spending time in a pigeon avarium is an important precaution due to the considerable dust from pigeon feathers and dried excreta.

6. Nonhuman primates

Monkeys and apes have not been used as frequently as the laboratory rat and pigeon for behavioral studies. Monkeys have been used extensively in behavioral pharmacology because of their similarity to humans in the pharmacokinetics of psychoactive drugs and of drug-dependence processes; they are also the primary animal models of certain types of biomedical investigations (NIH, 1978; Friedman and Popova, 1983, 1988; King et al., 1988). Monkeys' color vision is like that of man, in contrast to most other mammalian species (Jacobs, 1981). Monkeys have the advantage of relatively long life-spans (15–25 years; Holmes, 1984). Some have been used in behavioral studies for close to 20 years. Chimpanzees (*Pan troglodytes*), of the great ape family, have been preferred for studies of verbal behavior (e.g., Terrace et al., 1979), but due to their status as a threatened and endangered species and because they have

been considered the irreplaceable model for certain human health problems, these animals are extremely expensive (e.g., $5,000–$10,000); in the U.S., their distribution is severely restricted (NIH, 1978).

For many years, virtually all nonhuman primates used in research were wild-caught because of the difficulty of breeding sufficient numbers in captivity. In the 1970s, the importation of certain species became severely restricted due to destruction of primate habitats and the consequent embargos placed on exportation of these primates. In the U.S., a federally coordinated program, the National Primate Plan, was adopted to assure the continued availability of nonhuman primates for research (NIH, 1978; cf. Richter et al., 1984). A cornerstone of this program has been expansion of domestic breeding colonies, coupled with policies of "minimizing the use of primates and for getting the most benefit from those that must be used" (NIH, 1978, p. 12). Criteria for favorable review of research programs using nonhuman primates in the U.S. have been stated formally (NIH, 1978); initiating a research program using monkeys requires stronger scientific justification than even before. See Section 18.1.2 for resources for investigators using nonhuman primates.

Caring for monkeys in long-term experiments is more expensive and labor-intensive than care of most other species of laboratory animals. Per diem charges to the investigator for caging, feed, bedding and animal services typically are the highest for primates. They require significant space for housing. A legal requirement for attention to the 'psychological well-being' of captive primates has created a dialogue over appropriate definitions of this term, which has emphasized the need for additional research on the contribution of cage size, exercise, social housing and environmental enrichment to the well-being of each nonhuman primate species (Novak and Suomi, 1988; Segal, 1989; Woolverton et al., 1989). Because operant experiments involve daily periods of access to manipulable objects, visual and/or auditory stimuli, and response requirements for access to food or other commodities, they generally meet suggested guidelines for environmental enrichment. In fact, operant conditioning methods have been incorporated into many zoos for this purpose (Markowitz and Stevens, 1978; Markowitz, 1982).

Although some techniques for handling monkeys will be described below, anyone initiating a program of behavioral research with monkeys, should learn them first-hand from an experienced investigator.

6.1. *General weight regulation of nonhuman primates*

Rate of metabolism and rate of growth can vary significantly from monkey to monkey, even of the same subspecies. Many investigators find that food restriction (e.g., one postsession feeding per day), rather than reduction to a specific target weight, will result in stable behavioral baselines. Restriction to some percentage of a free-feeding weight may be necessary for initial training or for study of certain experimental questions, but the particular percentage necessary may vary across individual monkeys. Nonhuman primate species differ in their nutrient and energy (gross kilocalorie per kg body weight) requirements (see Section 18.1.2; Ausman et al., 1985, reviews nutrient requirements for squirrel monkeys of various ages and weights). Familiarity with requirements for the species is particularly important if food restriction is to be used and/or if feeding will consist primarily of food pellets formulated for use as reinforcers for 'monkeys' generally. Occasionally such diets will be too low in certain requirements for a given species. Nonhuman primates require a dietary source of vitamin C; providing a supplement of fresh fruit or vegetables daily or a couple of times a week helps prevent vitamin C deficiency, particularly if a large part of the monkey's nutrient requirements is being supplied as food reinforcers.

6.2. *Squirrel monkeys*

Squirrel monkeys (*Saimiri sciureus*) of various subspecies are New World monkeys native to Central and South America (Thorington, 1985). The squirrel monkey exists in significant numbers in the wild; but subspecies from particular geographic areas (e.g., Columbia and Peru), that traditionally have been used for biomedical research, are in limited supply (NIH, 1978). They have been extensively used in biomedical research, including a variety of behavioral studies (Rosenblum and Cooper, 1968; Rosenblum and Coe, 1985). Squirrel monkeys are used frequently in Behavioral Pharmacology (Barrett, 1985).

Adult male squirrel monkeys generally weigh 700–1100 g, and females 500–750 g (Fox et al., 1984a). Sexual maturity in females occurs at approximately 2.5 years, but males are considered 'subadult' for 2-3 years beyond that (Rosenblum and Coe, 1985). Squirrel monkeys are seasonally polyestrous (i.e., the squirrel monkey does not menstruate); the mating season for squirrel monkeys in the northern hemisphere is March to May with 7–13 day female estrous cycles (Richter et al., 1984; Rosenblum and Coe, 1985). Out of mating season, males normally lose weight and undergo testicular atrophy. Both males and females have been used in behavioral research, with no apparent disruptions of behavioral baselines when they are housed singly in the same room and run in the same experimental chambers.

Some investigators routinely seat squirrel monkeys in chairs (see Section 10.2) during experimental sessions, while other investigators merely place the unrestrained squirrel monkey in the experimental chamber. There is some laboratory lore that squirrel monkeys can be difficult to train and that it may be difficult to control stable performances. Some attribute this to their unique reactions to 'stress' or to their characteristically hyperactive movements. Careful attention to choosing the operandum (Section 11.1) is helpful; training a squirrel monkey to press a vertically placed key is more difficult than training to press a projection from the key; increasing the force requirement of a lever may be important to obtaining schedule-characteristic response patterns rather than undifferentiated high rates.

6.2.1. *Weight regulation of squirrel monkeys*

When food restriction is used with the squirrel monkey, free-feeding should be permitted for at least 3–4 weeks past the quarantine period for adults and subadult males so that a stable weight can be determined. Because of natural seasonal weight variation in males, redetermination of the free-feeding weight in and out of mating season may be useful if an arbitrary percentage of body weight is chosen and the monkey is to serve as a subject over a number of years.

6.2.2. *Handling squirrel monkeys*

Squirrel monkeys are easier to handle than many other monkeys because of their small size. They typically are handled with a 'pole and collar' technique (Kelleher et al., 1963; Wood, 1969; see Section 18.2.2). The monkey wears a small leather collar (rolled leather prevents chafing) to which a lightweight leash is attached. The other end of the leash is hooked to a ring outside the cage door. When the monkey is to be removed from the cage, the end of the leash is threaded through a ring on the

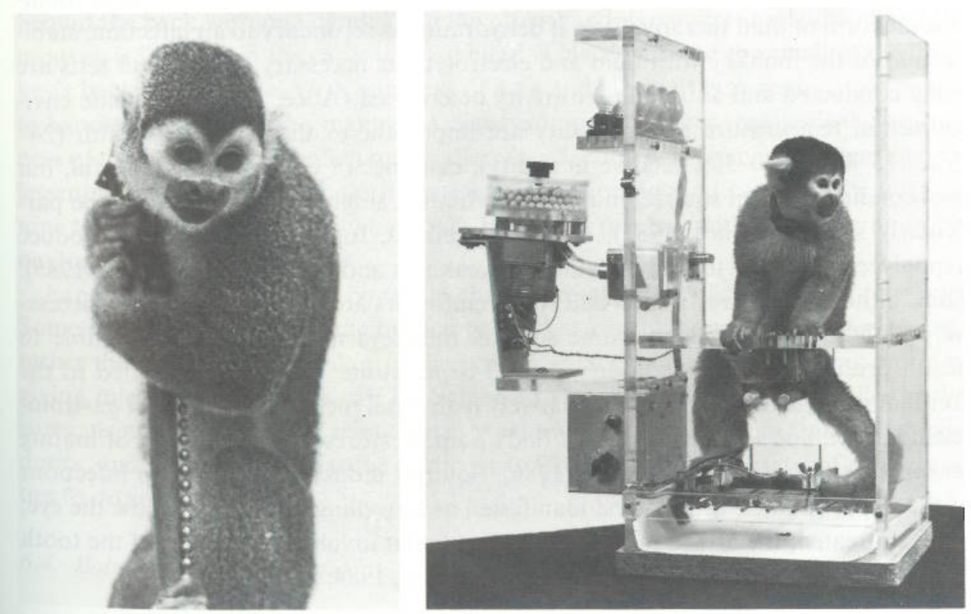

Fig. 3. The squirrel monkey. *Left panel* shows an adult male squirrel monkey being carried using the pole and leash technique. *Right panel* shows a squirrel monkey seated in a chair (constructed in the laboratory). The section of the waistplate beneath the monkey's hands is hinged to permit easing the monkey in and out of the chair. Note the stimulus lights, lever (BRS/LVE, Laurel, MD) and pellet feeder (Gerbrands, Arlington, MA) mounted behind the front wall of the chair itself, which was contructed in the laboratory. A shaved portion of the monkey's tail is positioned across a brass plate to permit shock delivery in studies involving avoidance, punishment or shock-maintained responding. (Left photo courtesy S. Bradbard; right photo reproduced from Barrett, 1985, with permission of the publisher.)

end of a pole; the monkey's head can be drawn against the top of the pole, while the investigator's hand holds the leash at the bottom of the pole, thus protecting himself or herself from being bitten. The monkey will grasp the top of the pole and then can be easily transported (Fig. 3). If the monkey is being placed in a chair (Fig. 3), the handler can hold onto the legs while retaining the head at the top of the pole. The monkey is placed on the seat, and the waistplate is lowered before releasing the chain from the pole. If a squirrel monkey escapes, someone familiar with the monkey can usually entice the monkey back with a food pellet or other treat, and easily rehook the leash to the collar while the monkey is distracted by the treat.

6.2.3. *Health concerns with squirrel monkeys*

Squirrel monkeys are relatively easy to care for, but otherwise hardy squirrel monkeys suddenly may stop eating and drinking and/or become prostrate. Abee (1985) points out that squirrel monkeys are 'stoic' animals and often do not show overt signs of distress until seriously debilitated. Thus, squirrel monkeys must be checked daily and the first sign of illness requires rapid attention. Although a number of conditions (including environmental stress) can produce similar symptoms, the first step is usually some form of fluid therapy. Even if dehydration is secondary to an infection, stabilization of the monkey with fluid and electrolytes is necessary while blood tests are being conducted and antibiotic sensitivity determined (Abee, 1985). Adequate environmental temperature and humidity are important to the monkey's health (24–27°C; 75–80° F; 40–50% relative humidity); extremes of either can be harmful, but cool conditions when squirrel monkeys are housed singly in metal cages can be particularly stressful (Abee, 1985). In some monkeys, food deprivation can produce hypoglycemia, characterized by lethargy, weakness and disorientation (Abee, 1985). Thus, although food restriction and food reinforcers are used routinely and successfully with squirrel monkeys, some squirrel monkeys may be more susceptible to health problems under conditions of food deprivation. This may be related to the fact that squirrel monkeys have a relatively high basal metabolic rate, short gastrointestinal tract, and low percentage of body adipose stores particularly out of mating season (Richter et al., 1984; Abee, 1985). Squirrel monkeys can develop infections of the upper canines, usually first manifested as a swelling of the face below the eye; if left untreated, the abcess may rupture. Treatment involves extraction of the tooth and irrigation with antibacterial solutions (Holmes, 1984; Abee, 1985).

6.3. *Macaques*

Macaques (*M. macaca*) are Old World primates; most species are native to Asia. Rhesus monkeys (*M. mulatta*) are the most popular species of nonhuman primate used for research and drug testing generally (NIH, 1978). For example, much of the important opioid pharmacology, particularly with respect to dependence, has been worked out using the rhesus monkey. Behavioral work also has been reported with

cynomolgus monkeys (*M. fasicularis*), stump-tailed monkeys (*M. arctoides*), pig-tailed monkeys (*M. nemestrina*), and Japanese macaques (*M. fuscata*). Macaques are adaptable and readily trained in standard behavioral procedures. Laboratories report using both males and females as behavioral subjects without any problems from caging the monkeys individually but in the same room. Because of the concerted effort to breed macaques in captivity for research purposes, one can order monkeys of specific ages (puberty occurs at about 3 years; life span is 15–25 years). See Bourne (1975) for specific information on care of rhesus monkeys. When weight is to be regulated in macaques, they are maintained on free-feeding during the quarantine period; after quarantine; they are fed ad lib for another week or 2, until stability in weight is obtained.

Macaques can be handled with a 'pole and collar' technique similar to that described above for the squirrel monkey, except that the monkey walks at the end of the pole rather than being carried (cf. Anderson and Houghton, 1983). Alternatively, the monkey's head is drawn up against the cage door by the leash and the collar is clipped to the cage, immobilizing the head momentarily. The cage door is then opened and the arms are grasped between the elbow and the humerus and restrained behind the back with one hand. With the other hand, the collar is unclipped and the monkey is lifted from the cage; the free hand is placed around the small of the monkey's back for carrying. With monkeys of 8 kg and larger, it may require two people to handle a monkey in this manner. A disadvantage of using macaques is the seriousness of the bites they can inflict on handlers (see Section 6.5). Some references suggest lessening the danger from bites by extracting or clipping (and capping) the long canine teeth (Holmes, 1984; Richter et al., 1984), but this has not been common in behavioral research laboratories.

Experimental sessions can be run in chairs specially designed for rhesus monkeys. Some investigators use an intelligence panel that can be moved from cage to cage rather than moving the monkey to the experimental chamber. For drawing blood or giving injections, macaques can be trained to shuttle from larger to smaller enclosures, using bits of fruit as reinforcers. Most monkeys are adept at unlatching cage doors, and macaques seem to be particularly likely to take advantage of opportunities to do so.

6.4. *Baboons*

Baboons are also Old World monkeys, native to Africa. *Papio anubis, Papio cynocephalus* and mixed *anubis/cynocephalus* types are most often used in research. *Papio papio*, a light-sensitive, seizure-prone species has been used in research on anticonvulsant drugs. Baboons are generally healthy and adapt well to the laboratory. They are especially useful for behavioral pharmacology research but they have not been used as widely as other monkeys because of their large size. Size varies greatly among individuals; adult females typically weigh 11–15 kg while adult males can be 17–50

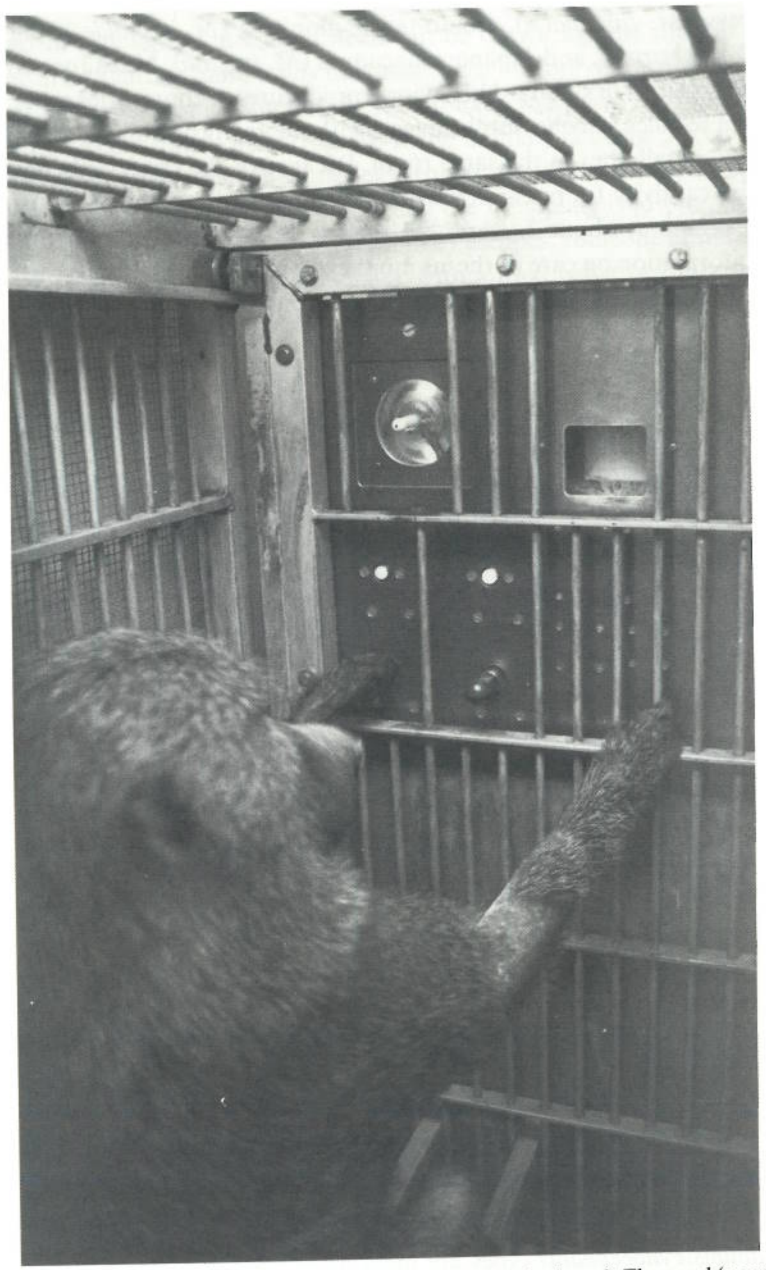

Fig. 4. An intelligence panel for a baboon (an adult male is shown). The panel (constructed in the laboratory) is mounted on a cage (bars were removed to accommodate access to the elements of the panel) with stationary bolts and thumbscrews to permit easy removal of the panel for cage washing. The levers are Lindsley levers (Gerbrands, Arlington, MA), and a jewel light is mounted above each to serve as a discriminative stimulus for the schedule contingencies. In the middle of the intelligence panel is the opening through which food pellets can be retrieved from the food tray. On the upper left quadrant is a fountain-type drinkometer (Kandota, Minneapolis, MN). (Photo by L.G. Ator.)

kg. Puberty occurs between 3–6 years (Holmes, 1984), and usual life span is 15–24 years. Because most baboons in research are wild-caught, precise determination of age is difficult. Tooth eruption patterns can be used to some extent if the baboon is a juvenile (e.g., the long, razor-sharp canines of male baboons erupt between 5–6 years in the wild, but may erupt 1.5 years earlier in captivity (Phillips-Conroy and Jolly, 1988). Experimental sessions often are conducted in the animal's home cage installed with an intelligence panel (Fig. 4). Alternatively, the baboon is trained to move from the cage into the experimental chamber via a shuttle cage. Manual handling of unanesthetized baboons is foolhardy. A loose baboon is best 'caught' by enticing the animal to go into a cage by throwing a treat into it. A cage containing an easily visible piece of fruit can be placed in the doorway of the room, which also restricts the baboon's access to other areas. When the baboon enters the cage, the door can be dropped (easiest if someone is on top of the cage holding the door up). In our experience, escaped baboons do not go towards a human unless that individual is holding or in front of fruit or other treats.

Determining a stable free-feeding weight in baboons can be difficult. Many young adult male baboons will continue to steadily gain weight for years. In our experience, unless the baboon is obese, merely using the once-a-day feeding regimen, even one which permits gradual weight gain, has proven sufficient for most experimental purposes. Shuttle cage arrangements can be designed for weighing baboons, but scales may have to be specially designed to accommodate the cage. Baboons usually are weighed on commercially available scales under ketamine anesthesia (see Section 6.5). Because weights change slowly in these large animals, they generally are not weighed daily. We have found that when the feeding regimen is held constant weighing every 2–3 weeks is sufficient for most behavioral studies.

6.5. General health concerns with nonhuman primates

Many bacterial, parasitic and viral diseases are seen in monkeys, particularly those that are wild-caught (Holmes, 1984; Richter et al., 1984), and monkeys represent one of the most dangerous animal sources of infection for humans. Monkeys must be quarantined for 30–90 days, supervised by a veterinarian familiar with nonhuman primates. During quarantine they are tattooed with a unique identification number. The diseases mentioned below are those that investigators should be particularly aware of after quarantine is successfully completed. Staphylococcal and streptococcal infections can be transmitted from monkeys to humans and vice versa; see Richter et al. (1984) and Holmes (1984) for a fuller discussion of primate diseases.

After quarantine, regular tuberculosis testing is important: tuberculosis is a disease that humans can transmit to nonhuman primates and vice versa (nonhuman primates also are susceptible to bovine and avian strains of tuberculosis; Holmes, 1984). Tuberculin tests should be given every 3 months for most monkey species. Humans working with monkeys should be tested at least annually (Institute of Laboratory

Animal Resources, 1980). If a monkey tests positive, it has been standard veterinary practice to euthanize the animal immediately for the protection of other primates. Although there are reports of successful chemotherapy of tuberculosis, the time course is prolonged (e.g., 12 months, Wolf et al., 1988). Long-term drug therapy (e.g., with isoniazid) as a preventive measure could complicate interpretation of behavioral data (Kraemer et al., 1976) and have other undesirable clinical results (Holmes, 1984).

A number of herpes viruses have been isolated in monkeys. They usually are latent or subclinical infections in host animals, but certain ones can be fatal when transmitted to other species. The most dangerous herpes virus that monkeys transmit to man is Herpes B virus (*Herpesvirus simiae*), found in macaques. In man it causes fatal encephalitis and encephalomyelitis. Transmission can occur through a monkey bite or contamination of a superficial wound with infected saliva; airborne transmission of the disease also can occur. Frequency of infection in humans is low in an actuarial sense, but fatal cases in recent years have reminded researchers of the serious consequences of infection and the need for precaution (Cummins, 1988). It is recommended that protective clothing, particularly filter masks and disposable examination gloves, routinely be worn in areas housing macaques.

Another viral disease of significance in Old World monkeys is measles (rubeola). It is manifested as a rash on the chest and lower portions of the body and can cause pneumonia, rhinitis and conjunctivitis. Anyone working with monkeys should have been vaccinated against measles to guard against bringing it into the laboratory. Chicken pox also has been reported in nonhuman primates (Holmes, 1984).

Because of the danger of bites from all monkeys and the difficulty of managing larger primates, physical examinations, treatment and sometimes weighing (e.g., baboons) is done under chemical restraint. Ketamine·HCl (injected intramuscularly) is preferred for this purpose because it does not depress respiration (Clifford, 1984). The drawback is that muscle relaxation is not good with ketamine and some monkeys develop a tolerance to what little relaxant effects the drug has. Pretreatment with diazepam or midazolam HCl sometimes is necessary for handling a large animal under ketamine restraint (cf. Green et al., 1981).

Bloat is a problem most often mentioned in connection with macaques, but has been observed in squirrel monkeys as well. Bloat is a condition of acute gastric dilatation; often the exact cause is unknown, but 'excessive' food and water intake in a short period of time seem to precede this condition; infectious disease may also play a role. The condition is fatal unless treatment (gastric aspiration, intravenous fluid therapy and possibly antibiotics) begins immediately. Feeding should be restricted for 7–10 days (Holmes, 1984; Richter et al., 1984). Feeding food-restricted monkeys divided meals can help prevent this condition; return to free-feeding after restricted feeding should be gradual.

Monkeys are subject to dental problems and good long-term health maintenance

should include periodic removal of plaque with a dental scaler. The use of sucrose pellets as reinforcers should be carefully considered and candy treats restricted.

Unless special care is taken to provide as natural as possible rearing conditions, captive-bred monkeys tend to show behavioral abnormalities (e.g., stereotypies, eye-poking, Erwin and Deni, 1979) not exhibited by wild-caught adult monkeys (cf. Richter et al., 1984; Rosenblum and Coe, 1985 on the squirrel monkey).

7. Rabbits

Rabbits have been used extensively in pharmacology and physiology and on a more limited basis in studies using operant (e.g., Sewell et al., 1969; Barrett and Stanley, 1982), or respondent, conditioning procedures (e.g., Harvey, 1987). The domestic rabbit (*Oryctolagus cuniculus*) comprises over 100 breeds and varieties (Holmes, 1984); the New Zealand White and the American Dutch are the most popular for

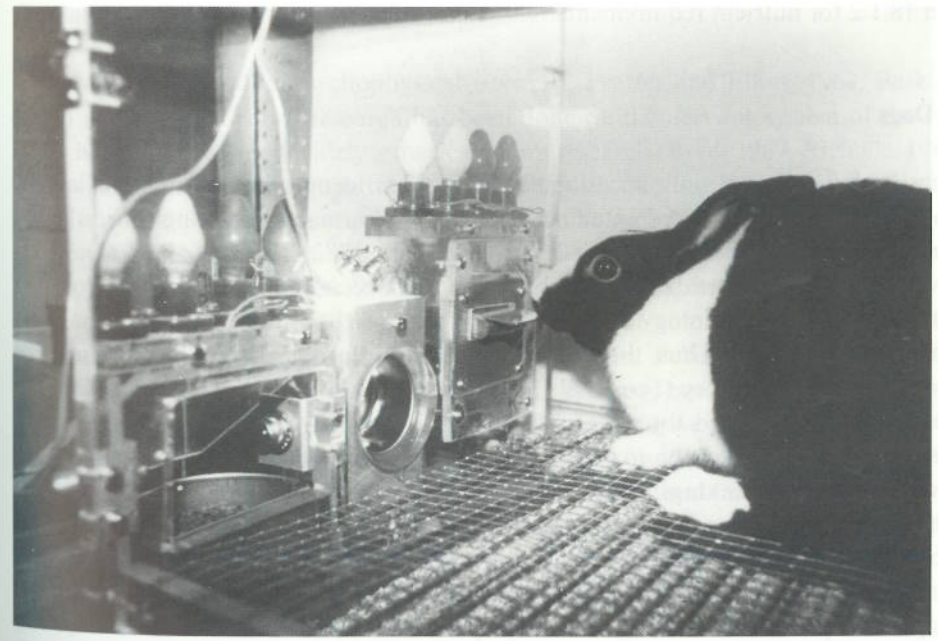

Fig. 5. An adult female Dutch Belted rabbit in an operant chamber (constructed in the laboratory). A rat lever was inverted and extended by adding a stainless steel plate for the rabbit to lift. On the left side of the panel food is freely available and entries into the food tray were detected by interruption of an infrared photocell beam. The opening in the center of the panel is for access to a liquid dipper (see Fig. 10). For further details see Barrett and Stanley (1982). (Photo courtesy J.E. Barrett.)

research. Rabbits have been taught to operate a lever by training the topography of using the nose to lift an inverted lever that had a stainless-steel extension attached to it (Fig. 5; Barrett and Stainley, 1982). Rabbits have a longer life span than rodents (5–13 years with puberty at 3–8 months, Holmes, 1984). Adult rabbits of both sexes weigh 2–6 kg depending on species. Although rabbits can be quite tame with frequent handling, ineffectual control of the rabbit can result in deep scratches to the handler from sharp claws on the strong hind legs. Improper handling can result in serious injury to the rabbit as well. Allowing the hind quarters to thrash in a rotation movement or dropping the rabbit can produce injury to the spine, resulting in posterior paralysis or death. To lift a rabbit, grasp the neck skin (the scruff), with the head directed away from the body, while placing the other hand underneath the belly or the back legs. To carry, keep one hand on the scruff and place the head in the bend of the elbow; place the other hand under the rump. When placing the rabbit into the experimental chamber or the home cage, put the hindquarters in first so that the rabbit does not try to jump in. The rabbit should never be carried by the ears. All rabbit teeth are open-rooted (continually growing), but malocclusion and overgrowth are most likely to occur with the incisors. References on the rabbit include Harkness and Wagner (1989), Holmes (1984), and Weisbroth et al. (1974); see Section 18.1.2 for nutrient requirements.

8. Dogs

Dogs have been used only occasionally as subjects in operant research (review in Gay, 1968) and to a limited extent in Behavioral Pharmacology using schedules of reinforcement (e.g., Waller and Waller, 1962; Risner, 1982; Risner et al., 1988). They have been used in biomedical research for centuries because of the similarity to man in their anatomy, physiology and response to disease; they are also used in pharmaceutical development. Thus, there is a good deal of information on appropriate care of dogs in the laboratory (Fox et al., 1984a; see Section 18.1.2 for nutrient requirements). Most dogs bred for research are beagles or other hound-type dogs. Unless raised with special attention to socialization, however, these dogs are not as tractable as are random-source dogs (those acquired by dealers from pounds or individuals). When a young purpose-bred dog arrives in the laboratory, it is a good idea to house the dog in the same cage with other dogs for a couple of weeks to facilitate adaptation. Daily attention from handlers is also important. Dogs then usually will accompany the experimenter to and from the experimental chamber on a leash; they can be trained to stand on a scale for weighing and readily enter the experimental chamber. In fact, intramuscular injections can be given by a single individual to a dog familiarized with an experimental routine. Weight regulation in a young adult (puberty occurs at 6–12 months) dog is easily accomplished. The stable free-feeding weight is determined through daily weighing over a 2-week period. The target weight

(85 or 90% of the *ad lib* weight is often sufficient) can be achieved (over 1–2 weeks) by restricting the amount fed. There has been some debate over the practice of surgically debarking dogs by clipping the vocal cords to decrease the volume of sound the dog can produce. The only reason to do so is if excessive barking will cause disturbance to those outside the housing area. The cords do regenerate over time, however; so for long-term behavioral research it is better to soundproof housing facilities. On the other hand, others have suggested that well-maintained research facilities and frequent positive contact with caretakers also decreases barking. Laboratory dogs are generally healthy and their life-span (12–20 years) is an advantage for long-term studies. A disadvantage is the greater likelihood of individuals viewing the dog as a pet and not a subject. Another disadvantage has been that most operant equipment for dogs was specially fabricated, although some levers are now commercially available. Dogs can most easily be trained to press a lever that is mounted close to the floor, and Risner (personal communication, July 17, 1989) successfully adapted sewing machine foot pedals for this purpose. Waller (1960) described a nose-operated lever for dogs.

9. Cats

Cats have been used in psychophysical research (Frazier and Elliot, 1963; Berkley, 1970) and a great deal of research has been done on the nervous system of the cat. They have not been used widely in basic operant research (Byrd, 1969; Richelle, 1969; review in Gay, 1968), although the first instrumental conditioning studies were in the cat (Thorndike, 1898). One reason is that cats can be very difficult to train using food reinforcers unless special attention is given to the type of operandum and its proximity to the food magazine (cf. Breland and Breland, 1966). Berkley (1970) reviewed some of the problems, and their solutions, of operant conditioning with cats; see Symmes (1963) for design of an operandum for kittens. Pellet reinforcement for the cat is available, but wet high-protein foods are favored; beef baby food or canned cat food pureed with water are effective without a specific weight reduction regimen. Having the wet food delivered into a food cup via a fixed duration operation of a peristaltic pump works well. A dry balanced cat chow is used for supplemental feeding (see Section 18.1.2 for nutrient requirements); enough chow is given to maintain the cat in its normal weight range. Free access to water should be given; this and adequate exercise are important for preventing urinary blockage, a life-threatening problem in male cats. Friendly cats are easy to manage, but unfriendly cats can be difficult and will scratch or bite. Cats can be almost impossible to hold onto if they are intent on escaping and may need to be transported in carriers. See Fox et al. (1984a) for other information on maintaining cats in a laboratory.

10. Experimental enclosures and intelligence panels

In his autobiography, Skinner (1979) provided an interesting account of the development of the technology of the Experimental Analysis of Behavior. His use of the operant chamber and the cumulative recorder was critical to the systematic, objective and intensive study of the behavior of single subjects.

For many years, behavioral research equipment was designed and built by the investigators themselves. A kind of documentation of the technological evolution of behavioral research can be found in the technical articles published in the Journal of the Experimental Analysis of Behavior, particularly those during the first 16 years of publication (1958–1974). Much of the equipment now available commercially is derived from these individual efforts, but investigators continue to devise methods for meeting new research needs by constructing or modifying equipment. Section 18.2 lists suppliers for the types of equipment described below.

10.1. Chambers

Behavioral experiments typically are conducted in enclosed chambers, what Skinner referred to as operant chambers but what were dubbed 'Skinner boxes' by psychologist Clark Hull (Skinner, 1979). Although commercial chambers are readily available (Fig. 6), investigators often design their own to meet specific requirements or preferences (Figs. 2, 5 and 7). The chambers permit controlled introduction and removal of environmental stimuli. In a standard arrangement, one chamber wall comprises the 'intelligence panel' or 'work panel' on which are mounted operanda (e.g., levers), feeding devices, lights, speakers (Figs. 4, 5, 6 and 7). Depending upon the experiment, different elements may need to be on separate walls which may require special construction (some modular type chambers are available in which different kinds of panels can be easily substituted). The floors of chambers should be appropriate to the species for supporting the feet and collection of feces. Chambers in which shock will be delivered through the floor must have the stainless steel bars spaced sufficiently far apart for feces to fall through, preventing the shock circuit from shorting out. Ferster and Skinner (1957) provide a detailed description of the basic chamber used with pigeons.

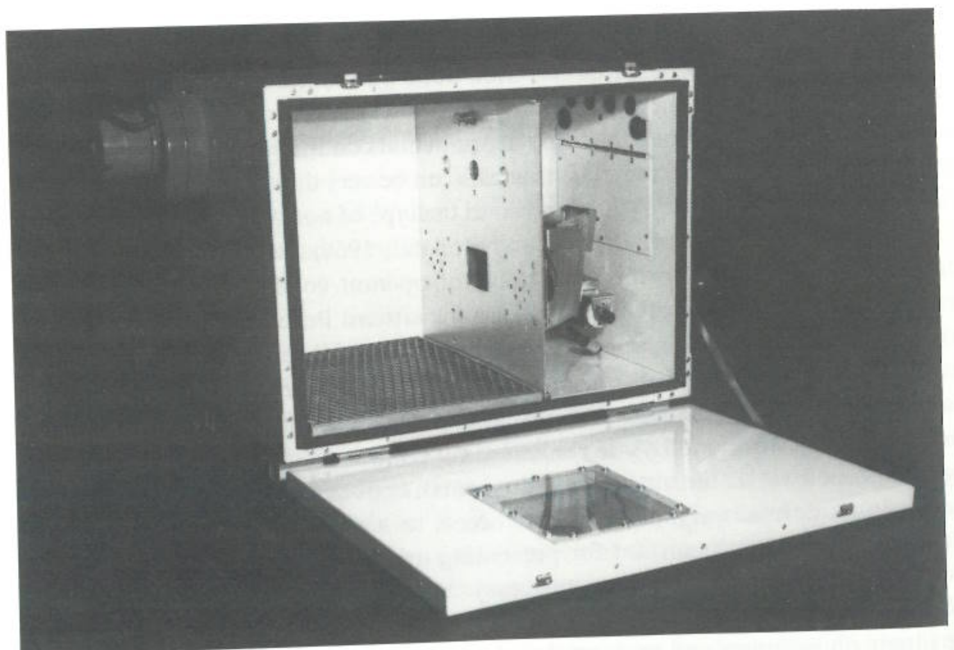

Fig. 6. An operant chamber for a pigeon. The panel contains three keys (Fig. 7) and a centrally placed opening for access to the grain hopper behind the panel (see Fig. 8). The enclosure is sound-attenuating with a ventilation fan installed on the left side. The door contains a one-way mirror to permit viewing the pigeon. (Photo courtesy BRS/LVE, Inc.)

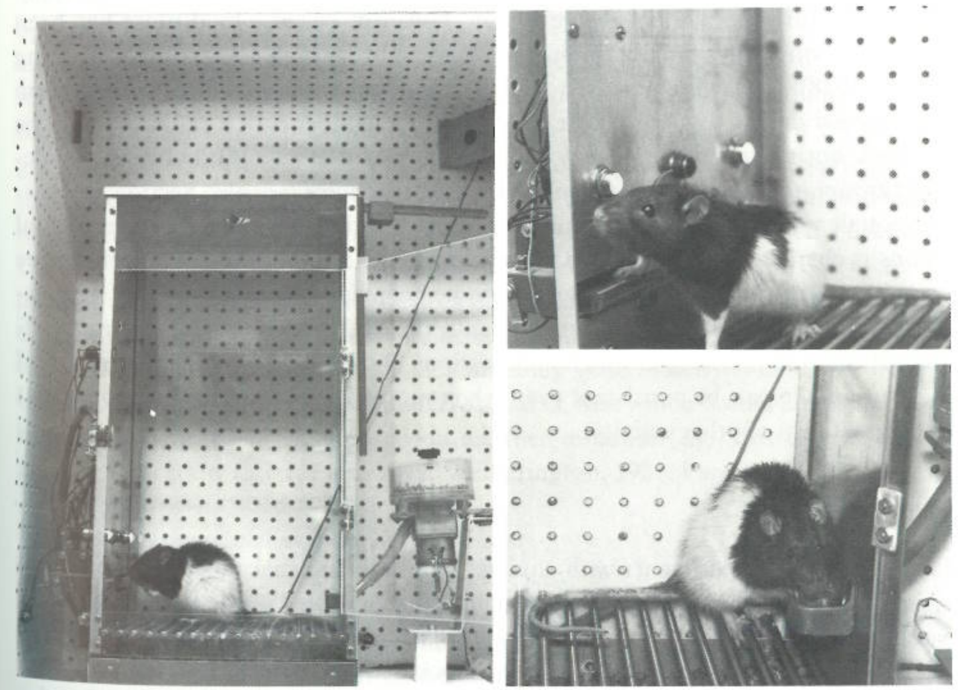

Fig. 7. An operant chamber for a rat. *Left panel* shows the chamber itself placed inside a larger, sound-attenuating enclosure (both constructed in the laboratory); a speaker is mounted in the upper right corner of the enclosure chamber (levers and feeder, Gerbrands, Arlington, MA; food cup, Lafayette, Indianapolis, IN.) The chamber was constructed with extra height to permit tether connections that would be out of reach of the rat for delivering drugs through a chronically indwelling venous catheter or intracranial cannula. (Photos by L.G. Ator.)

Chambers usually have some means of sound attenuation. If the operant chamber is not already part of a sound-attenuating enclosure (Fig. 6), it typically is placed inside such an enclosure (Fig. 7). This minimizes the chance of extraneous noise disrupting responding or of the animal's performance being controlled by sounds from the programming equipment rather than the contingencies themselves (e.g., if a relay closure correlated with reinforcer availability is audible to the subject, lever pressing may be controlled more by that sound than by the variables the experimenter intended). The degree of sound attenuation of the chamber can vary depending upon whether or not the chamber can be placed in an isolated experimental room or whether it must be located in a room where other activity is going on. The ventilation fan on the enclosure (e.g., Fig. 6) provides a form of masking noise, but a low to moderate level of white noise (see Section 13.2) usually is delivered through a speaker also. The intensity (in decibels, dB) generally is adjusted to be that which the experimenter believes will be adequate for the circumstances; that is, the greater the noise level in the laboratory, the louder the white noise would need to be to reduce extraneous sounds. It is best to purchase or construct a chamber with greater sound attenuation than to turn the white noise very high, however, because loud noise has been shown to produce physiological indices of stress and very high dB can impair hearing (cf. Fay, 1988). A viewing port in a wall of the chamber permits direct observation of the subject during sessions. If the experimental chamber is in a room that can be kept dark during sessions, one-way mirrors are useful (Fig. 6); otherwise, a wide-angle through-the-door viewer (peephole) is a better choice (see also Section 15.2).

Although visual and auditory isolation from the laboratory during experimental sessions is characteristic of behavioral experiments and important for a high degree of stability in many behavioral baselines, some behavior is studied without such extreme conditions. For example, experiments on oral and intravenous drug self-administration in primates in which long sessions (3–24 h) are conducted have found that drug intake can be consistent even when monkeys are working in rooms that have a great deal of other activity.

10.2. Chairs

Many behavioral experiments with squirrel monkeys and macaques have involved placing the animal in some form of chair, which then is placed inside the experimental chamber. Chair restraint is useful for particular experimental procedures, such as drug delivery before or during the session, shock delivery to a shaved portion of the tail, or for precise orientation toward visual stimuli; often, however, it is used under all experimental conditions in a given laboratory to make training more comparable across the variety of experimental conditions that may be studied. Chairs for squirrel monkeys usually have been constructed according to the design of Kelleher et al. (1963), with the modification that the intelligence panel is integrated into the front of the chair (Fig. 3). A cable inside the chamber connects to a plug mounted on the

chair (lower front of the chair in Fig. 3) to interface with the programming equipment. Chairs for rhesus monkeys more often are wheeled into a chamber that has the intelligence panel at one end. The monkey is seated by lifting the waistplate and sliding the torso in (see Sections 6.2.2 and 6.3). With experience, both squirrel monkeys and macaques adapt to the procedure and are easily seated for the experimental session. Chairs are commercially available for baboons, but seating a baboon requires the use of ketamine and is not practical for daily sessions. Uninterrupted maintenance of any monkey in a chair across days is not recommended or generally permitted by institutional animal research care and use committees without strong scientific justification.

11. Response recording

The operant response typically selected is one that may be referred to generically as 'lever pressing'. In fact, what is measured is operation of a switch; and the device operated need not be a lever, but rather any mechanism that can be operated easily and repeatedly and recorded objectively and reliably. Collectively, the devices described below have been referred to as operanda (singular: operandum). Although the investigator might presume the operant to be performed with a certain topography (e.g., paw placed on lever), what is recorded is an electrical signal. In fact, the response might be performed in a number of ways, the particular topography having been reinforced adventitiously (i.e., superstitious behavior, cf. Pliskoff and Gollub, 1974, for an amusing example) or representing a less effortful manner of meeting the contingencies. The devices described below can also be used to collect data on collateral behavior, that is, behavior other than that explicitly being conditioned. Collateral behavior includes not only general activity but also behavior termed 'schedule-induced' or 'adjunctive'; that is, that which occurs largely as a function of the contingencies imposed on another response (e.g., drinking and mirror pecking in Section 15.1.1; Falk, 1972; Wetherington, 1982; Part 2, Ch. 6).

11.1. Levers, keys, chains, panels and treadles

Operation of a switch, usually a microswitch, has been the most common response chosen for operant conditioning. The particular device manipulated by the subject, and to which the microswitch is attached, varies across species. Levers, inserted through an opening in the intelligence panel, are used most often with rats and smaller monkeys (Figs. 3 and 7); similar versions are available for mice. Because rats sometimes will gnaw on a lever, solid versions are more durable than hollow ones. For large monkeys, a lever initially developed by Ogden Lindsley for use with human subjects often is employed. This 'Lindsley lever' is operated by pulling on a ball handle attached to a shaft (Figs. 4 and 8). Although the most commonly used levers are fixed

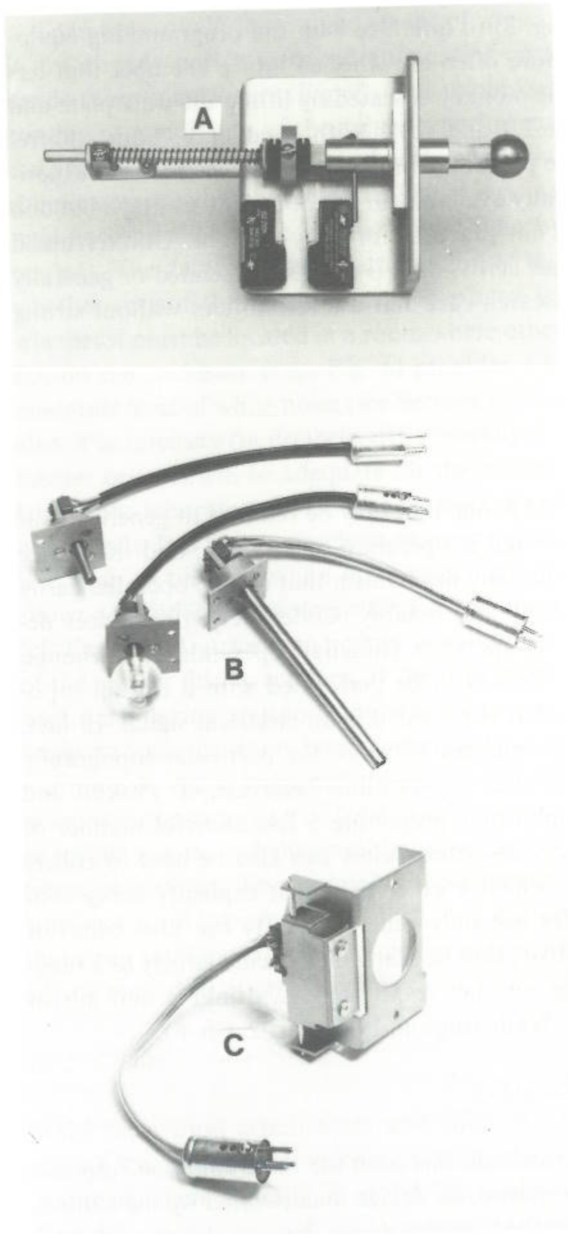

Fig. 8. Various types of operanda. (A) A Lindsley operandum, useful with primates, which operates the microswitches when it is pulled. (Photo courtesy Gerbrands Corp., with permission). (B) Omnidirectional levers, which operate a microswitch when the shaft is moved in any radial direction or pushed in. (Photo courtesy BRS/LVE, Inc.). (C) A key, used with pigeons, which operates a miniature microswitch when the paddle is pecked. (Photo courtesy BRS/LVE, Inc., with permission.)

to the panel, retractable levers permitting the investigator remote control of extension and withdrawal of the lever through the panel are available commercially. A lever modification that has been used with squirrel monkeys is a bead chain suspended from a lever mounted over the chair. This operandum has been used in studies in which a second response, topographically different from a lever press, was important to the experimental design (e.g., Barrett and Stanley, 1980). See Sections 7–9 for rabbit, dog and cat operanda; an omnidirectional lever (e.g., Fig. 8) can be useful when a standard lever press is not the best response for a species (i.e., the lever will operate when brushed or nuzzled).

The operandum used with pigeons typically is referred to as a 'key'. It is a translucent paddle attached to the intelligence panel behind a circular opening (Figs. 6 and 8). A peck on the disk moves the paddle and operates a microswitch. Because pigeons easily can be trained to peck at a lighted disk, it is transilluminated. A variation on the switch-action pigeon key has been described (Altman and Hull, 1973).

Although a 'keypeck' is the response typically chosen for pigeons, this response has been considered problematic for some purposes (cf. Part 1, Ch. 2), and a treadle (i.e., a lever mounted near the floor) has been used to generate a response topography other than pecking (e.g., Foree and LoLordo, 1970; Hemmes, 1973; McSweeney, 1978). Investigators have experimented with different types of treadle. The difficulty with choosing and/or positioning a treadle is that the bird may perch on it, or may peck at it instead of stepping on it, or response rates may be unduly constrained by the difficulty of operating the treadle. Some have constructed lever-type extensions attached to a microswitch (e.g., a T-shaped plexiglass extension) or used a commercially available rat lever that does not extend far enough into the chamber for the bird to perch on. If the treadle surface is inclined, rather than horizontal to the floor, the bird is less likely to perch on it. If pecking the treadle develops, increasing the force requirement may decrease the probability of this behavior.

Larger, sturdier versions of the basic pigeon key are available for use with monkeys, and these are particularly useful for projecting a range of stimuli directly on the key (see Section 13.1); squirrel monkeys are not easily trained to press such keys, though; gluing a projection (e.g., a short hollow plexiglass cylinder) around the circumference may make it easier to obtain the press response. A variation of the key operandum is a rectangular panel that can be mounted in the wall or the floor of the chamber and pushed. The panel may be made of a material that permits transillumination if one wishes to present stimuli directly on the operandum. Mirrors, behind which microswitches are mounted, have been provided as a way of measuring schedule-induced attack in pigeons. Looney and Cohen (1982) describe a variety of methods for automatically recording attack in pigeons (cf. recording of mirror attacks in Section 15.1.1). Hutchinson et al. (1966) gives a method of recording a biting attack against a tube in squirrel monkeys.

The operanda described above all involve switch operation that sends an electrical input to the programming equipment. The switch consists of a set of electric conduc-

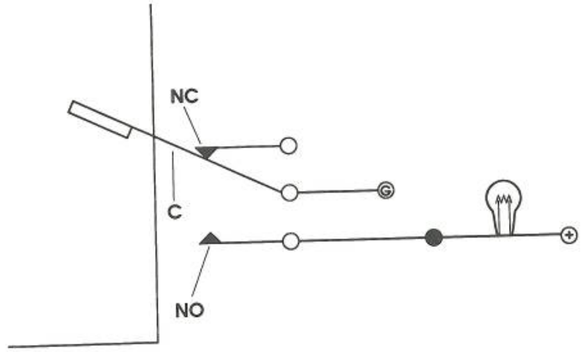

Fig. 9. Schematic of switch operation. Depression of the lever moves the Common (C) contact on the switch from the 'normally closed' (NC) contact on the switch to the 'normally open' (NO) contact on the switch. When the C contact is connected to the negative terminal of a DC power supply, lever operation 'switches' the negative charge, usually termed 'ground' (G), to the NO contact. The NO contact is connected to one terminal of a 24V DC lamp; because the other lamp terminal is connected to the positive (+) terminal of the power supply, the circuit is completed and the lamp will light.

tors, referred to as contacts, which can be either touching or separated. The schematic in Fig. 9 shows a lever attached mechanically to the common (C) element of a set of contacts. Lever operation moves the C contact from its normal or resting position against the top contact (the normally closed, NC, contact) to touch the bottom contact (the normally open, NO, contact). To convert this mechanical event into an electrical event, the contacts must be connected to a power source such that moving the C to the NO contact completes an electrical circuit. In Fig. 9, a 24 VDC lamp will be illuminated when the lever is depressed. Alternatively, the circuit could be wired through the NC contact such that the light is on when the lever is unoperated, with lever operation breaking the circuit to turn the light off for the duration of the lever press. The advantage of wiring an operandum so that the interruption of the NC to C contact defines the recorded response is that the distance or duration of the complete excursion of the switch is not a variable; thus, moving the lever or key only slightly can be recorded, and thus reinforced or punished, immediately. For animals that respond at a high rate, this method of wiring the operandum is preferred; it is the only one capable of accurately recording the high key-pecking rates of pigeons. On the other hand, if one wants to reinforce only a complete excursion of the lever, then the response can be defined by having C to NO contact complete the circuit. The primary rationale for wiring through the NO contact seems to be to promote a more uniform topography across subjects, such as with lever pressing in rats. In some circumstances, the response might be defined as C+NO contact followed by C+NC contact to prevent lever holding (e.g., as in some shock-escape arrangements, see Part 1, Ch. 5).

A problem that can occur with high rates of switch operation in high sensitivity,

low current circuits is 'contact bounce'. This results in multiple switch closures being recorded, artifactually inflating recorded response rates. Contact bounce can be detected by hooking an oscilloscope up to the switch output. It can be eliminated by building a minimum interval (on the order of milliseconds) between recorded switch closures into the circuit: the most elementary way, often used with electromechanical or solid-state programming units (see Section 14), is to place a capacitor across the switch output. The necessary size of the capacitor is determined empirically by looking at switch output on the oscilloscope, so as not to impose an artificially low ceiling on response rate. Alternatively, special circuity may be built into interfaces used with computers (see Part 2, Ch. 5).

Some levers may use a Reed switch. This switch uses a magnet and contacts enclosed in an hermetically sealed vial; it requires very little force, and does not have the problem of contact bounce. The alignment of the magnet with the sensor is critical; if the magnet loses alignment with the switch under high rates of responding, artifactually low rates of responding will be recorded. Thus, the magnet should be large enough to avoid this.

An important parameter of response specification is the minimum force requirement necessary to operate the microswitch and be counted as a response. Some studies have focused on specification of both minimum and maximum force requirements and on response duration as well (Fowler, 1987). Determination of the minimum force required can be determined using a tension gauge. The minimum requirement should be fairly low to permit the response rate to vary over a wide range as independent variables are manipulated. Commercially available levers typically have some means of adjusting the force requirement. Operanda need to be checked regularly for smooth operation and appropriate tension. Exposed contacts on levers or keys will need to be burnished with a contact cleaner occasionally to prevent accumulation of dirt from interfering with the switch operation being recorded.

A running wheel, often used with rats, can be used either as an operandum, with contingencies imposed upon wheel turning, or to measure activity. In addition, the opportunity to run can function as a reinforcer (Section 12.5). A microswitch system is employed to detect movement of the wheel through whatever distance the experimenter wishes (e.g., Zerbolio, 1964). In addition, commercially available running wheels usually come with a built-in counter to record whole revolutions.

11.2. Photocells

In some types of studies, defining the response as interruption of a beam of light striking a photocell is useful. For example, this type of response obviates problems of force requirements being too high for very small or infant animals (cf. Glowa, 1986). The animal can be required to poke its nose through an opening in the panel or to move from one location to another to meet the response requirement. A sophisticated system, making use of infrared emitting and detecting diodes, for identifying the location of a pigeon's pecks at stimuli on a cathode ray screen is described by Clauson et al. (1985). Photocells also can be employed to measure duration of entry into food trays (e.g., Fernie, 1971; Timberlake and Peden, 1987; Fig. 5). Complete systems for measuring licking via optical detection circuitry are commercially available and are suggested to avoid some of the problems of using contact sensors (Section 11.3) for this purpose (cf. Czech, 1982). Photocells can be used to monitor general activity and correct placement of the animal for stimulus presentation in psychophysical studies; with proper adjustment, some types of equipment can provide light beam lengths of more than a meter.

11.3. Contact sensors

A contact sensor detects contact by an animal when the animal bridges 2 open contacts and completes a DC circuit. Such a device is useful if minimum force requirement is a problem, as with the mouse. Contact sensors have been used most often as 'lickometers' or 'drinkometers' (e.g., McLeod and Gollub, 1976; Elmer et al., 1988). The lick response serves either as the instrumental response upon which contingencies are imposed, or as a dependent measure of drinking per se (cf. Section 15.1.1). In a simple arrangement, the cage is grounded, the spout is electrically isolated from the cage, and when the animal licks (or touches) the spout a small DC current flows through the animal to the spout; both frequency and duration of contact can be recorded. If desired, the signal can operate a solenoid valve permitting fluid to flow through the spout for some period of time (Henningfield and Meisch, 1976; cf. Hulse, 1960); one should program delivery to cease if spout contact is broken during reinforcer delivery. The drinkometer in Fig. 4 is of this latter type. The spout is electrically isolated from the panel; a 24 VDC ground wire is attached to the back of the panel, which grounds the cage as well. When the baboon licks the spout, he completes the circuit, which operates a solenoid in the drinkometer and permits fluid flow. Pairs of lights on the faceplate of the drinkometer can serve as discriminative stimuli and/or feedback. As with other responses, any contact will be counted so systematic observation of the subject is important to determine whether the responses actually are licks. For example, in a study of schedule-induced polydipsia, McLeod and Gollub (1976) found that drinking tube contacts by rats exposed first to one type of reinforcement schedule consisted primarily of licks while tube contacts by rats exposed first to another reinforcement schedule consisted primarily of paw contacts. Problems with contact sensors usually involve the circuit being completed by moisture or some other substance or too sensitive a circuit being activated by transients from other equipment. A potentiometer integrated into the circuit to permit regulation of the sensitivity helps with the latter problem; maintaining the cleanliness of the apparatus and daily testing obviate the former. However, counting individual licks still may be a problem if fluid bridges the gap between the spout and the tongue between licks. A total-contact time measure may be more accurate (the

optical systems based on photocells are said to overcome this problem, Section 11.2). Recessing the tube may minimize recording 'accidental' contacts (e.g., tail movements). Weijnen (1989) discusses the role of current levels as well as other issues in sophisticated approaches to using lick sensors. Contact sensors also could be used to measure activity other than licking (e.g., by placing contact sensor strips in certain locations in the chamber).

12. Reinforcer delivery

In the operation of reinforcement, the investigator arranges for a consequence to follow a specified response in the hope that the consequence will increase the probability of the response occurring again. Strictly speaking one cannot refer to a consequence as a reinforcer for an individual organism unless one can demonstrate that it is serving as such with respect to a response (see Part 1, Ch. 3). As a practical matter though, we know from experience many of the events that are likely to serve as reinforcers with different species and the conditions under which they will do so optimally. Some 'unconditioned' reinforcers will be described below. They can be used to shape new behavior and maintain that behavior independently of a specific conditioning history. These are contrasted with 'conditioned' reinforcers that require previous pairing with a reinforcer to be effective (see Part 1, Ch. 3). This is not to say that even unconditioned reinforcers always will maintain behavior in a given subject. To be maximally effective, reinforcers require what has been termed an 'establishing operation' (Michael, 1982). The most obvious of such facilitators is simple deprivation of an item to be used as a reinforcer.

12.1. Food reinforcers and feeders

Food is the most commonly used reinforcer in experiments with laboratory animals. Conditions under which various food items maintain operant behavior consistently are well understood (cf. Collier et al., 1977). The subject must be maintained under restricted feeding conditions so that the reinforcer will maintain a stable behavioral baseline from session to session (see Section 3 and information on individual species in Sections 4–9).

Food pellets are available in semi-purified and grain-based formulas for all the species described in this chapter, as well as others, in weights ranging from 20 mg to 3.5 g and in different flavors for some species (e.g., banana flavor for monkeys). Commercially available pellets for use with dogs sometimes can be made more effective reinforcers by requesting special flavors (e.g., meat, egg). Because the pellets are made to be nutritionally complete, those eaten during the experimental session can supply a major portion or all of the animal's daily nutrient requirement. Nutritive liquid diets often are used with rats and squirrel monkeys. Some substances maintain responding effectively in certain species with minimal weight regulation. Dextrose and sucrose pellets have been used with rodents and primates. Sweetened condensed milk and evaporated milk (diluted or undiluted) are effective with rats and mice (see discussion of reinforcers for mice in Wenger, 1979). Mayes et al. (1979) compared sweetened condensed milk with honey and found that both maintained responding in rats, but noted that honey is advantageous because it does not spoil as easily as milk. Saccharin solutions have been effective with rats and rabbits. A solution of glucose (3% w/v) and saccharin (0.125% w/v) is reported to be an especially effective reinforcer in rats (Carroll et al., 1989). See Sections 4–9 on individual species for other information on effective reinforcers; see Ames (1967) and Mark (1967) for methodological detail on food reinforcers for fish.

Pellet dispensers are mounted outside the chamber or chair and permit a single pellet to drop through a tube into a food cup (Figs. 3 and 7). Feeders with different types of operating mechanisms (e.g., DC solenoid operated, AC motor driven) and power requirements (e.g., 24 VDC or 5 VTTL computer logic minimum voltage) are

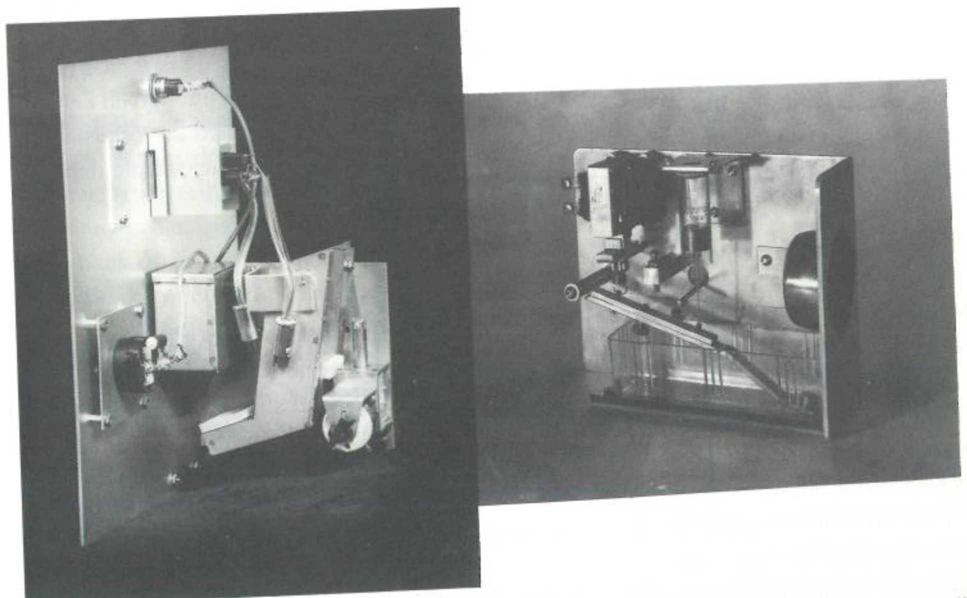

Fig. 10. *Left panel*: A feeder used with pigeons mounted on the back of an intelligence panel (cf. Fig. 6). The hopper is filled with grain or pigeon chow. When operated, a solenoid pulls the bottom of the hopper up to the opening above it. Note also the sonalert mounted on the lower left for delivering tone stimuli. (Photo courtesy BRS/LVE, Inc.) *Right panel*: A dipper feeder used with a rat or squirrel monkey. When operated, a solenoid pulls the dipper arm up from the reservoir filled with liquid into an opening ... it. (Photo courtesy Gerbrands, Corp.)

available to be maximally compatible with the type of interface and/or programming equipment (Section 14). The disk inside the feeder is appropriate to the size of the pellet. If tubing supplied by the manufacturer is not long enough to reach the food cup, Tygon tubing which can be cut to appropriate lengths is a good choice. Although most pellets are billed as 'dustless', some dust does accumulate and the feeder and feeder tube must be cleaned periodically to prevent impairment of pellet delivery. Some people use springs as tubes or pierce small holes in plastic tubing to prevent dust accumulation. Attention to the positioning of the food cup and/or the angle of the tube from the feeder is useful to minimize the possibility of pellets bouncing out of the food cup as they are delivered. The distance the pellet has to drop through the tube should be considered so that an 'unprogrammed' delay of reinforcement does not occur. When the feeder can be mounted just behind the intelligence panel (e.g., Figs. 2 and 7), this is not a problem; but when very large feeders are used, they may have to be mounted farther away from the food cup (e.g., on top of the chamber). If the sound of the feeder motor operation is audible, this will come to function as a discriminative stimulus for approaching the food cup (see Section 13) which can bridge a brief delay between the reinforced response and arrival of the pellet in the food cup. If the feeder is mounted away from the intelligence panel, however, it is useful to program some other salient stimulus change to accompany feeder operation. Inspect pellets as the feeder is filled to remove cracked or broken ones. These can make it more likely the feeder will jam and, of course, will result in less uniformity in reinforcer magnitude. With many feeders, it is best not to fill them to the brim to minimize the probability of the feeder jamming.

Liquid diets or water (see Section 12.2) are delivered via a dipper raised from a trough (Fig. 10). Dippers are available in capacities ranging from 0.01 to 1.0 ml; the dipper itself is removable and different sizes can be interchanged. The angle of the dipper arm must be adjusted so that a fluid residue does not remain on the dipper arm (i.e., within reach of the subject) after it is lowered.

With pigeons, mixed grain or pigeon chow is typically used. Ferster and Skinner (1957) describe a standard composition (cf. Levi, 1974). Food is delivered from a hopper that is drawn up within the pigeon's reach when a solenoid is engaged (Figs. 6 and 10). The amount of the reinforcer is programmed in terms of the number of seconds of access allowed per delivery; usual reinforcer duration has been 3 or 4 s. Pigeons differ in how efficient they are in consuming food from the hopper (Epstein, 1981) and this also can be influenced by feeder design (Epstein, 1985). The primary criterion is a duration of access that maintains responding reliably across the session without evidence of satiation toward the end of the session (see Part 1, Ch. 3). If pigeons are pecking a key at a high rate, they will frequently make 'extra' pecks after the one which meets the schedule requirement for reinforcement. Some investigators therefore time grain access from the last peck, rather than from the 'reinforced' peck (i.e., the reinforcer access time resets with each peck after the reinforced one); obviously, the period of time during which this reset contingency is in effect must be limited. Alternatively, some investigators place a photocell in the hopper so that reinforcement can be timed from when the pigeon's head breaks the photocell beam (Timberlake and Peden, 1987). These strategies for assuring uniformity of access time to the hopper are most important when magnitude of reinforcement is being manipulated, but some investigators use such strategies routinely as a general control for uniformity access subjects. Whether investigators use a commercial grain mixture or buy components separately to make up their own, they try to ensure that the components are similarly sized. Pigeons may eat larger pieces preferentially which results in less preferred components accumulating on the bottom of the hopper and a change in reinforcer quality across the session. This problem is obviated with pigeon chow, but some investigators report that grain maintains responding more reliably across birds under standard conditions. Because pigeons tend to scatter grain or chow as they eat, spilled food can accumulate under the hopper and prevent it from lowering completely out of reach at the end of the programmed reinforcement. Thus rate of the dependent variable may be influenced unintentionally by the bird's spending time reaching for food from the barely available hopper. Cleaning out this area of the chamber regularly avoids this problem. Catania (1965) devised a modification for hoppers to prevent 'grain stealing' in the case just described and if the beak size of a given bird enables it to reach the hopper even when fully lowered.

12.2. Water reinforcers

Water is an inexpensive, effective reinforcer. It can be delivered via either a dipper, such as mentioned above for liquid diet, or a fountain-type drinkometer (see Section 11.3). Water reinforcement with pigeons has been accomplished using a procedure which requires surgical intervention (Lucas et al., 1979). A period of water availability (e.g., an hour) should be provided after the experimental session. Food is usually freely available. Use of water as a reinforcer requires careful attention to the parameters of the deprivation period and to the watering of the subjects on days when sessions are not conducted. Animals can remain healthy longer without food than without water; and the level of water deprivation can influence strongly the amount of food consumed.

12.3. Drugs as reinforcers

Certain intravenously delivered psychoactive drugs will serve as reinforcers (see Part 2, Ch. 2). They have the advantage that establishing operations or deprivation may not be necessary to maintain responding. The main disadvantage involves the behavioral and physical sequelae of drug delivery (e.g., direct effects on behavior, toxicity of high drug doses). Drugs are used as reinforcers in studies in which the drug itself is a focus of investigation or where there is interest in the generality of behavioral phenomena with qualitatively different reinforcers.

12.4. Other reinforcers

Electrical stimulation of certain areas of the brain (particularly the lateral hypothalamus) maintains responding quite reliably in certain species; most work has used rats (Mogenson and Cioe, 1977; Liebman, 1983). Study of conditions under which externally delivered shock serves as a reinforcer, that is, the phenomenon of shock-maintained responding, has been important in the development of reinforcement theory and Behavioral Pharmacology (see Part 1, Ch. 3; Barrett and Stanley, 1980). Other reinforcers have been used occasionally. A few will be mentioned to exemplify the diversity that is possible: turning on a heat lamp when the subject is held in a cooled chamber (mice, Revusky, 1966), access to a running wheel (rats, Premack, 1971), access of a male rat to a receptive female rat (Everitt et al., 1987). Some studies have investigated stimulus change as a reinforcer; under the conditions studied, this has not usually been found to be strongly reinforcing in species other than monkeys (see Kish, 1966).

13. Discriminative stimuli

Visual and auditory stimuli are used in various ways in behavioral studies. A common procedure with a rat, for example, would be to sound a distinctive tone whenever a particular response requirement (e.g., 30 lever presses) was in effect and to juxtapose that condition with some other condition in which the tone was not sounding (e.g., one in which lever presses have no programmed consequences). With experience, the rat would come to press the lever rapidly when the tone was on and not to press when the tone was off. The tone then could be said to be functioning as a discriminative stimulus for lever pressing (see Part 1, Ch. 7). Establishing specific stimuli (or stimulus combinations) as discriminative stimuli paired with differential reinforcement (and/or punishment) contingencies permits one to generate different patterns and rates of responding within the same experimental session (see Part 1, Chs. 3 and 4). The distinction between the physical and functional definitions of a stimulus is important. That is, one can describe a stimulus in physical terms and declare that such a stimulus was presented to the subject (e.g., 'A 1000 Hz tone was sounded during the avoidance schedule', or 'A red 7-watt bulb was illuminated during the availability of the reinforcer'). But only the observation of differential responding in the presence and absence of the stimulus determines whether the stimulus controls behavior (i.e., is discriminative for a response). Elegant psychophysical procedures have been developed for use in various species, and investigators studying sensory capabilities will find Stebbins (1970) a useful reference.

An auditory or, less often, visual stimulus coincident with completion of the required response (i.e., 'feedback') commonly is used to facilitate training the response (see Part 1, Ch. 2). If the feedback stimulus occurs only when the response could be reinforced (i.e., not during a timeout or an intertrial interval) then the probability of the response may be controlled to an even greater degree by the reinforcement contingencies.

A distinctive stimulus change with delivery of the reinforcer, such as the sound of the feeder operation, is used to advantage as a discriminative stimulus for approach to the food tray. Other stimulus changes, such as turning off the houselight and/or keylight and illuminating the food tray for a pigeon, often accompany reinforcer delivery.

Certain types of stimuli are more useful with some species than with others because of physiological capabilities. Many birds and primates have well-developed color vision while that of other species is more limited (Jacobs, 1981). Many animals respond to a much wider range of auditory frequencies than man, but there are differences in the overlap of the ranges. Rats and mice are especially sensitive to sounds, but mice may not be able to hear sounds of very low frequency (pitch). Birds have particularly good visual acuity, whereas they have a more restricted high-frequency range for auditory stimuli than mammals. Catania (1964) discussed visual acuity in the pigeon and its implications for stimulus placement. Fay (1988) compiled the literature on hearing in different species.

'Preparedness', the concept that certain stimuli are easier to establish as discriminative in some species than in others (Seligman, 1970), goes beyond mere physical capacity but may be related to differences in the relative amounts of cortex devoted to a given sensory system in some species (Hodos, 1988). For example, birds and primates have well-developed visual systems and make extensive use of vision, while other animals, such as rats, make less use of vision and more of auditory and olfactory senses; fish have well-developed gustatory systems with which they can discriminate chemical stimulus dimensions of the environment. Many investigators have found that rats learn auditory discriminations more readily than visual, and that birds learn visual discriminations especially readily (e.g., experiments on taste aversion learning, Revusky and Garcia, 1970; Thomas et al., 1988). 'Preparedness' does not mean that training with a less 'prepared' stimulus dimension is impossible, just that it may be more difficult to do so (see also Part 1, Ch. 7). For example, even though rats are thought to have 'poor vision', W.H. Merigan and I trained Sprague-Dawley rats using a simultaneous discrimination procedure to differentiate levels of brightness of visual stimuli to a high degree of resolution.

13.1. Visual stimuli

Most chambers contain a lightbulb used for general illumination during the experimental sessions. This 'houselight' can be programmed to turn on or off correlated with certain contingencies; for example, the houselight is usually turned off during reinforcer delivery with pigeons and in timeout. Because houselight on versus off can [illegible] change (e.g., detection does not require the subject to be

oriented in a certain direction), it can come to control behavior rapidly and may be more effective than discrete lights on a panel with some species (e.g., rats, cats and dogs).

Additional visual stimuli can be arranged with a variety of lamps that can be illuminated or not, independently of the houselight. With the usual intelligence panels, 24 VDC lamps are mounted in the wall and colored glass covers are used to produce different hues; these are often referred to as 'jewel lights' (Figs. 4 and 7). If a larger lighted area is desired, a light panel can be created by covering an opening in the wall with translucent plexiglass and mounting colored light bulbs behind it. When the intelligence panel is made of clear plexiglass, as is usually the case with the panels used with squirrel monkey chairs, sockets for colored light bulbs can be mounted behind the panel (Fig. 3). Christmas tree bulbs (Figs. 3 and 5) have the advantage of being cheap and readily available in a variety of colors, but have the disadvantage of requiring alternating current (AC) in the chamber. Another method for presenting a range of different patterns or colors involves using commercially available rear projection devices that can project up to 12 different stimuli (colors or shapes) onto a pigeon or monkey key in a given session. By illuminating more than one cell at a time an even larger number of distinctive stimuli are available. Different color and pattern groups are available commercially. These often are used in studies of discrimination, generalization, and concept formation with pigeons or monkeys (see Part 1, Chs. 7 and 8). If an even larger number of different stimuli are needed, or one wishes a larger image, a rear-projection screen can be mounted in the wall of the chamber and slides can be projected using a programmable carousel projector (review in Honig and Stewart, 1988). See Clauson et al. (1985) for use of a cathode ray screen to present complex computer-generated stimuli. In using complex photographic and/or patterned stimuli, considerations related to visual acuity are important (e.g., the luminance of the stimuli should either be held constant or randomly varied).

When visual stimuli are presented using DC current, operation of certain pieces of equipment (e.g., solenoid driven feeders) using the same power supply might draw sufficient current to change the level of illumination; if so, using a separate power supply for that piece of equipment solves the problem.

13.2. Auditory stimuli

Auditory stimuli of various frequencies (the psychological dimension of pitch) and intensities (the psychological dimension of loudness) can be generated in a variety of ways. Most commercially available white noise generators, connected to speakers inside the chambers (e.g., Fig. 7), can generate not only white noise, but also tones of varying intensities and frequencies and clicking sounds at various rates and intensities. White noise results from the random or pseudorandom generation of a mixture of audible frequencies, usually 20–20,000 Hz signals, with a filter to screen out square wave spikes from other equipment. More than one sound can be delivered at a time if desired (e.g., white noise for masking during the session with a tone discriminative stimulus turning on and off). When just a tone is required, a sonalert (Fig. 10) can be installed and the intensity varied by means of a potentiometer. A simple way to produce a 'click' is to mount a relay (e.g., 24 VDC or 120 VAC) behind the intelligence panel; operation of the relay produces an audible click, often used as programmed 'feedback' for key or lever operations. As with visual stimuli, the level of specification and control of auditory stimuli will be different depending upon whether dimensions of the stimuli are independent variables, as in psychophysical studies. One might use a separate power supply for auditory stimulus generators to prevent the operation of other pieces of equipment from adding electrical pulses to the auditory stimuli. For precise specification of auditory stimuli, such as in psychophysical work, acoustic signals can be generated by an oscillator and passed through an electronic switch, then through a programmable attenuator to dampen stray signals from the programming equipment, to an amplifier to precisely control intensity, and finally through a high-quality speaker (e.g., Hienz et al., 1981; also references in Fay, 1988).

13.3. Other types of discriminative stimuli

Although visual and auditory stimuli are common discriminative stimuli, other kinds of exteroceptive stimuli are possible (e.g., thermal, vibratory, tactile, olfactory), but have been used rarely. Extance and Goudie (1981) used a compound stimulus consisting of olfactory stimuli from another rat in conjunction with a drug cue and showed greater control by the olfactory stimulus; Mellgren and Brown (1988) employed an olfactory stimulus (air freshener) combined with a certain location to study discrimination learning in foraging. Pigeons are suceptible also to control by olfactory discriminative stimuli. Henton (1969) successfully used amyl acetate vapor and reviews other work on odor discrimination in birds. Problems in employing such stimuli with any species include manipulating the qualitative dimensions of odors and developing methodologies to assure the precise control of their presence and absence (review by Schultz and Tapp, 1973). Flavors have been used extensively with different species in taste aversion experiments (Revusky and Garcia, 1970). Tactile stimuli have been used as stimuli in taste aversion (Domjan et al., 1982) and as elements of compound interoceptive and exteroceptive stimuli in drug discrimination (e.g., Koek and Slangen, 1984; see Part 2, Ch. 2). Thermal stimuli have been used as reinforcers rather than discriminative stimuli (cf. Carlisle, 1970). Although thermal stimuli can be difficult to control, Matthews (1969) describes an apparatus that might be useful in this regard. See Part 2, Ch. 1 for a discussion of time as a discriminative stimulus.

14. Programming the experiment

The elements of the experimental apparatus described above are brought together, usually through a multiwire cable at an interface panel. The interface panel then is connected with the apparatus used to program experimental contingencies and record data. As Dinsmoor (1988) has written: "When antecedent stimuli, responses and consequences are linked by electric circuits, all relationships known to nature or that can be concocted by human imagination should be reproducible and their effects capable of being examined within the laboratory setting" (p. 288). For many years, the programs for scheduling events during the experimental session and for recording the data were arranged using 24 VDC electromechanical switching (relay) circuitry, with components made in the laboratory or purchased commercially. Later, solid state modules were used to arrange the experimental contingencies in some laboratories, but many versions did not have the flexibility of relay circuitry for making programming changes quickly, even during experimental sessions. Recently, many laboratories have converted to computer control of experiments, and it is the most reasonable choice for anyone setting up a new laboratory (see Part 2, Ch. 5). Elements of relay circuitry can be useful adjuncts to computer control, but guidance from someone experienced with such programming is essential for effective use of relay equipment for programming entire experiments (Sidowski, 1966 and Bures and Huston, 1983, contain useful information on basic instrumentation with relay circuitry; an excellent programmed text is Hetzel and Hetzel, 1969).

The number of chambers used for a given experiment usually is a function of practical constraints. If multiple procedures/experiments are being conducted simultaneously in a laboratory, all with the same species, one can either use multiple identical chambers and associated control equipment so that a number of subjects can be studied at the same time in the same experiment, with different experiments being conducted successively across the day. Alternatively, a single chamber could be devoted to a particular experiment with the subjects studied successively across the day.

15. Recording data

Selection of data to collect is a critical part of the programming of the experiment. Other chapters in this volume indicate the data necessary to analyse behavior under different experimental contingencies. Recovering response rate during the time the contingencies were in effect is basic (i.e., exclusive of reinforcer delivery time, time-out, intertrial intervals etc.). The degree of temporal resolution of data analysis during each experimental session depends on the experimental question. For example, one might analyse data within small time blocks of a session to study time course of a drug effect. The sections below describe methods for collecting data other than those cumulated on counters or in computer data files.

15.1. *Cumulative and event recorders*

A hallmark of behavioral experiments is the use of recorders that produce graphic representations of responding in real time. They permit moment-to-moment examination of responding as it occurs during the experimental session. Both cumulative and event recorders (Figs. 11 and 12) have drums that move paper at a constant speed. They are equipped with pens that can be programmed to make a mark on the paper with responses or other events (e.g., reinforcer delivery, onset of discriminative stimuli) during the session. Keller (1974) describes how to modify a cumulative recorder to produce histograms. An advantage of such recorders is that the data are available independently of the computer or of an individual manually recording data from counters (but computer programs and/or hardware are also available to generate cumulative records using a printer). With judicious wiring, the record can aid in identifying or troubleshooting equipment problems. Some recorders incorporate a take-up roller that automatically rolls the paper as it moves across the drum, but cumulative recorders and some event recorders do not. Although systems can be devised for automatically rolling the paper (Millner, 1970), many investigators place

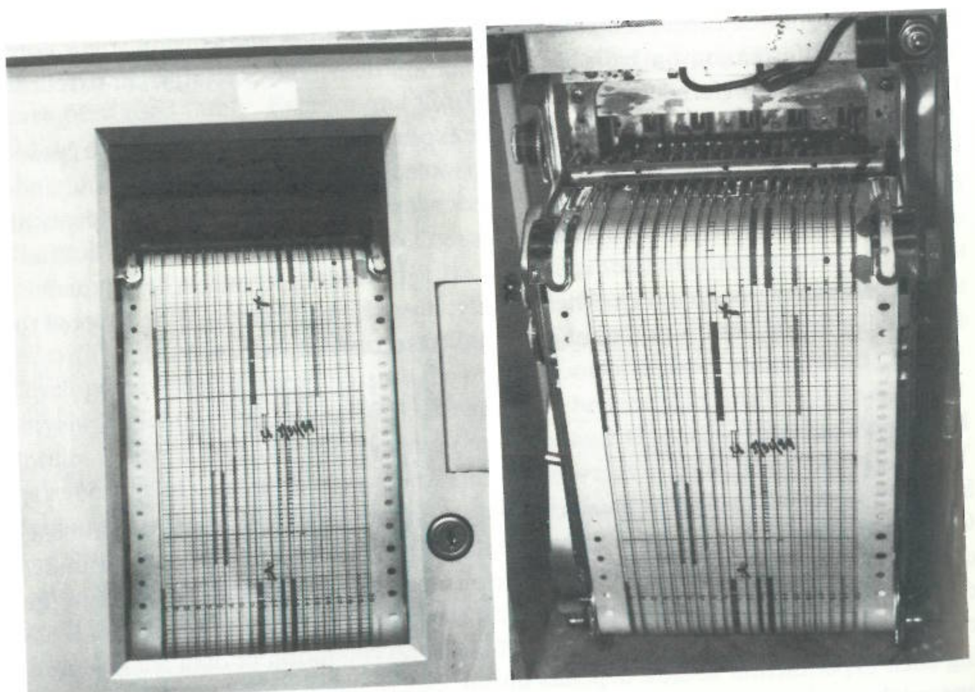

Fig. 11. An event recorder (Esterline-Angus, Indianapolis, IN) equipped with 20 event pens. The pens on this recorder deflect with lever presses for either of 2 levers and pellet delivery for any of 6 operant

a container beneath the paper and cut the record or roll it up manually between sessions. The disadvantage of manual paper rolling is offset by the ease of looking at the completed records while the recorder is running. Records can be cut off the roll periodically and folded accordion fashion to fit letter-size folders; alternatively, records for individual sessions can be cut apart. (The cardboard back of an 8.5×11 in tablet makes a useful template for folding longer records to fit letter-size folders.)

15.1.1. *Using cumulative recorders*

The cumulative recorder developed by Ralph Gerbrands (Dinsmoor, 1987) and manufactured with variations by several companies subsequently has been the standard for many years. Cumulative recorders usually are equipped with a 'stepping pen', and most investigators add one or more event pens (Fig. 12). The advantage of the cumulative recorder over an event recorder is that the stepping pen can be programmed to move vertically up the page a fixed distance with each response (Fig. 12); on some

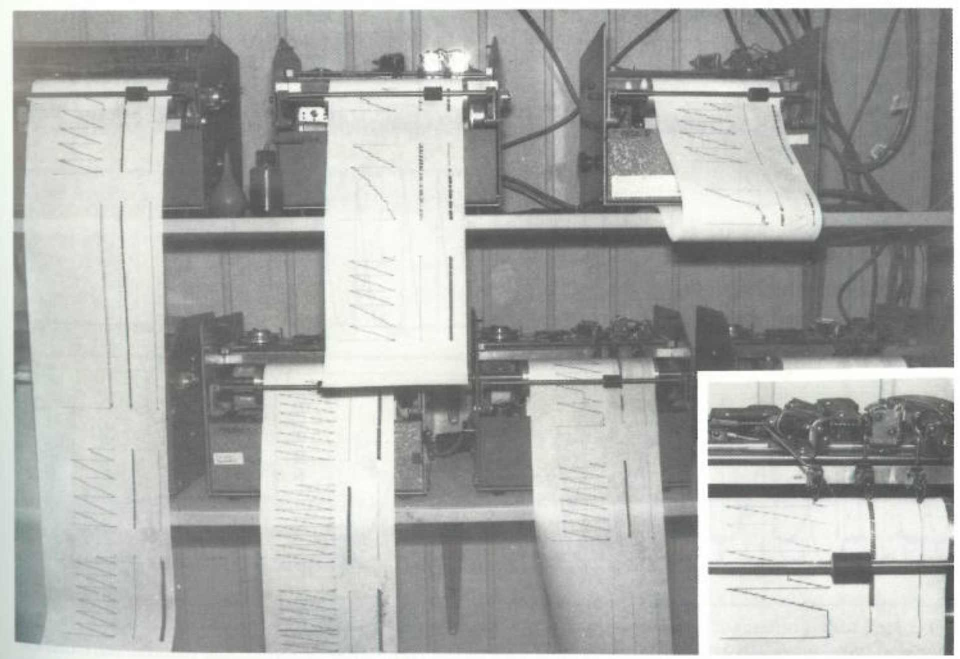

Fig. 12. Cumulative recorders of different vintages (Gerbrands Corp., Arlington, MA) equipped with the standard stepping pen and supplemented with two event pens. The bulb-shaped object on the upper shelf is an ear syringe (sold in drugstores) that is useful for drawing ink into the point of the glass pens (Leeds and Northrup, Columbia, MD). The figure inset shows the recorder for the panel in Fig. 4. The stepping pen (on the left) steps with each lever operation and deflects with pellet delivery. The middle and right pens are event pens which deflect with left and right lever operation, respectively. (Photos by L.G. Ator.)

newer models, this can be set by a switch to be 2, 4 or 8 steps/mm. The slope of the line created as the paper is carried forward by the drum (Figs. 12–14) can be used to calculate the response rate (different paper drive gears can be obtained to change the temporal resolution of the record). The record is used most often to judge response rates at different time points in relative terms and to evaluate the temporal distribution of responding, but calculation of response rate directly from the record is straightforward and avoids 'loss' of data if counters or other recording methods fail (note the scales in Figs. 13 and 14).

The records in Figs. 13 and 14 illustrate how one can program the cumulative recorder functions in various ways to provide the most useful real-time record, akin to a snapshot, of the experimental session. In all the records shown, the drum moved the paper forward at the rate of 5 cm in 10 min and the stepping pen advanced with lever or key operation. Thus, flat places in the record indicate periods of pausing (i.e., not operating the lever). The stepping pen also can be programmed to deflect; this

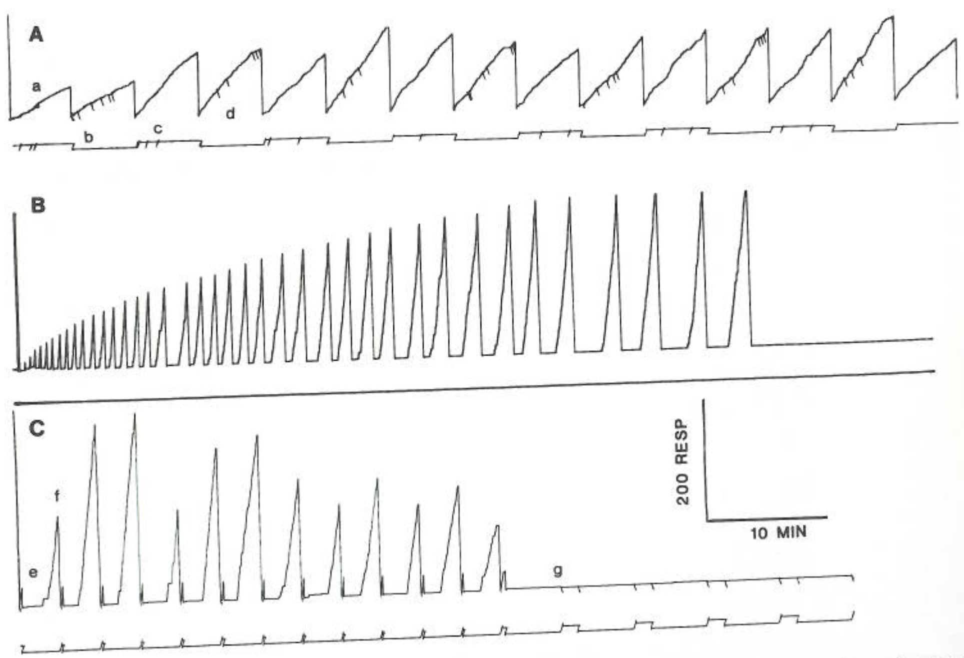

Fig. 13. Cumulative records illustrating various uses of the cumulative recorder; the records are from experimental sessions for rats trained to lever press under three reinforcement schedules (see Part 1, Chs. 3 and 4 for details of the contingencies): (A) multiple variable interval 15 s (avoidance of 0.5 s, 1 mA shock) variable interval 30 s (45 mg food pellet); the two schedules alternated every 5 min (Ator, 1979); (B) progressive ratio 7 (45 mg food pellet), in which the response requirement increased by 7 with each pellet delivery (Merigan and McIntire, 1974); (C) multiple fixed ratio 30 fixed interval 3 min (45 mg food pellet; Ator, 1982); schedule requirements alternated with each pellet delivery. See Section 15.1. for further

mark of the stepping pen is referred to as a 'pip'. The pip often is used to indicate reinforcer delivery (Figs. 12 and 13), but Fig. 14 illustrates different uses: in A, the rat had to press the right lever 20 times before 1 press on the left lever would be reinforced, and the pip indicated all left lever presses, whether reinforced or not. In B, the stepping pen deflected during all contacts with a drinking spout through which ethanol was available. In C, pips indicated operation of microswitches behind a mirror target. Thus, one can see that during some of the lever or key 'pause' times, the baboon was drinking and the pigeon was pecking at the mirror. In Figs. 13C and 14E, the schedule involved a limited-hold 90-s contingency (i.e., failure to make 30 responses within 90 s in a fixed-ratio component or 1 response after the lapsing of the 3-min interval in a fixed-interval component resulted in schedule contingencies changing automatically; the pip indicated the lapsing of the limited hold). Fig. 13C

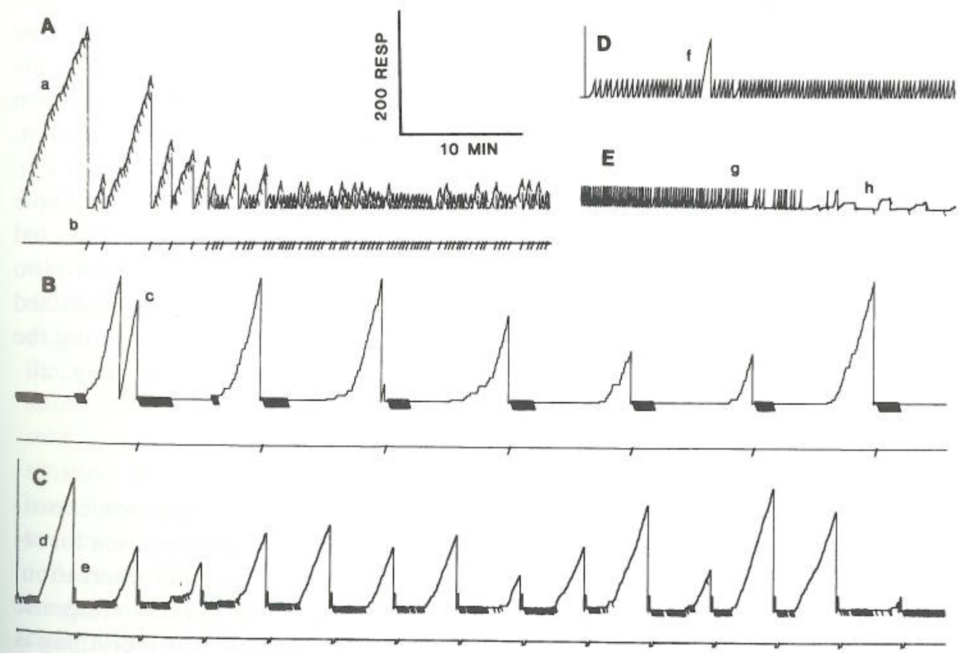

Fig. 14. Cumulative records illustrating various uses of the cumulative recorder functions (see Part 1, Chs. 4 and 5 for details of the contingencies): (A) A record for a rat trained under fixed consecutive number 20 (45 mg food pellet); the rat received the pellet only if he pressed the left lever after 20 or more presses of the right lever (Smith et al., 1976). (B) Data for a baboon trained under fixed interval 600 s (three 1-g banana pellets) with concurrent access to oral ethanol (4% w/v); a contact sensor (drinkometer) detected spout contacts (Ator and Griffiths, unpublished data). (C) A record for a pigeon trained under fixed ratio 25 fixed interval 5 min (4 s grain access) with concurrent access to a large mirror (cf. Ator, 1980). (D and E) Sessions for rats under fixed ratio 30 (45 mg food pellet, Ator, 1982). See Section 15.1. for further details.

shows that under a nonlethal exposure to carbon monoxide, performance was relatively normal until halfway through the session when responding ceased entirely, such that the limited-hold contingency was repeatedly met. Fig. 14E shows the effect of equipment malfunction: the feeder jammed during the session, so that pellets were not delivered. The record suggests that this may have first occurred near g where increased pausing occurred; by h, responding decreased to such a low rate that the limited hold elapsed frequently.

The stepping pen resets when it reaches its full excursion (Figs. 12, 14A and B, the first of the two peaks at c in B), but also can be programmed to reset coincident with some other event. In Fig. 13 (B and C) and 14 (B, C, D and E) the pen reset at food delivery. Fig. 14D shows how this feature permitted identification of an equipment problem; that is, the peak at f shows that the counter being used to detect completion of the fixed-ratio requirement failed and there were about 64 additional presses before reinforcement (note that responding seemed relatively unaffected by this). In Fig. 13A, the stepping pen reset when the schedule contingencies changed. In Fig. 14A, the stepping pen reset whenever the left lever press occurred after the 20 right lever presses required for food delivery; in combination with the use of the pip to show any left lever presses, this feature makes it easy to see the acquisition of the 'counting' response (i.e., not pressing the left lever too soon) across the session.

The event pen only deflects. In addition to the use of the two event pens in Fig. 12, Figs. 13 and 14 show use of event pens to denote which component of the multiple schedule was in effect at any point in the session: in 13C, the event pen was deflected during the fixed-interval schedule contingency and raised during the fixed-ratio schedule requirement; this was reversed in 14C. In 13A, the event pen was deflected continuously during the food reinforcer schedule (e.g., b) but was raised during the avoidance schedule; the event pen then deflected briefly with shock delivery (e.g., c).

15.2. Observational techniques

Because of the simplicity and objectivity of data collection and analysis, most experimenters using schedule-controlled behavior have focussed on instrumentation for recording discrete responses of interest rather than systematized general observation. Subjects should be observed regularly, however, particularly with respect to response topography and other general behavior, if only to assure oneself that everything is working properly. A number of observational techniques for systematic human observation have been described. If observational data are to form a significant part of the experimental report, however, careful consideration to the timing, frequency, and reliability of the observations should be given (e.g., Poling et al., 1980). Some investigators have equipped chambers with closed-circuit TV monitors. The element critical to the success of closed-circuit television monitoring is whether the camera is suitable to the lighting conditions in the chamber. Cameras that are sensitive to low lighting conditions would usually be required. If the chamber is dark for experi-

mental reasons, then using an infrared light source and a camera sensitive to such conditions would be necessary. See Part 2, Ch. 6 for analysis of data derived from observational techniques.

16. Conducting experimental sessions

A regular routine of thoroughly checking the operation of equipment before a series of sessions for burned-out light bulbs, malfunctioning feeders etc. is important. If the experiment is controlled by computer, one can write a version of a program specifically for this purpose. Each subject's experimental session should be started at approximately the same time each day. Maintaining constancy of number of hours of deprivation is one reason, but also diurnal variables can have subtle influences on behavior and on a number of physiological factors, including drug effects (Hekkens et al., 1988). If more than one chamber is set up for the same experimental procedure, a given subject always should be run in the same chamber. Even though chambers may appear identical, there are always some differences, particularly in odors and operandum sensitivity, which would introduce an extraneous influence on behavior (cf. Extance and Goudie, 1981).

It is common to conduct sessions in a behavioral experiment 5, 6 or 7 days a week, the number of days being determined primarily by constraints on personnel to do so. Because most behavioral experiments establish a behavioral baseline against which the effects of some intervention will be judged, a regular running schedule facilitates achieving stability in the target behavior(s) and having ample data for good characterization of the baseline performance. When sessions are not conducted over the weekend, one needs to evaluate Monday performance to see whether it is consistently different. Although a 'Monday effect' after sessions have not been conducted over 2 or more days is part of laboratory lore, some behavioral baselines are more sensitive to this than others. Trying to have weekend feeding done at roughly the same time of day as usual (or mid-day to 'split the difference' across subjects) can minimize the effects of a day or 2 off from the experiment.

Animals typically are weighed each day before the session to determine whether weight is in the target range. A wide variety of animal weighing scales are commercially available, and investigators have devised different methods to facilitate weighing (e.g., Catania, 1962). Handling by different people may introduce variability in response rates in certain species or certain individual animals. This may be particularly true of rats; using a handling device or carrier (cf. Tighe, 1965) may help if it is not possible for the same individual to run the animal each day. A caveat: those handling animals daily can become differentially attached to certain individual animals and begin handling them very differently (e.g., playing with them while weighing before a session). While this can be true of any species, it seems to arise more often with smaller mammals that are easily handled. The daily routine before each session must be consistent across animals to control the variability in responding that could occur as a function of differential handling just before the session.

The length of each experimental session is determined by the amount of behavior desired in each session and/or the number of different contingencies to which the subject will be exposed in a given session. Thus, there is no hard and fast rule. A daily session may be as brief as a few minutes or as long as several hours. Some experiments employ around-the-clock sessions (e.g., drug self-administration studies). The type of reinforcer delivered will also play an important role in determining the length of the session. For experiments using food or water reinforcers, the session should end before satiation occurs. Supplemental feeding or watering in the home cage should occur following the session. It sometimes has been observed that feeding rats immediately after a session seems to result in a slowing of responding toward the end of the session (Baccotti, 1976); therefore, it is prudent not to feed the subject immediately after the session (i.e., wait 15 to 60 min).

17. Conclusion

Methods presented in this chapter represent those most generally used by behavioral scientists working with nonhuman animals, but inevitably the author's own preferences and experience have colored the selection of material to present and advice to give. Probably nowhere in behavioral research are individual prejudices and idiosyncrasies more fervently defended than in the areas of subjects and instrumentation. As with the behavior of our subjects, the scientific practices that are successful for an investigator tend to be repeated, even if those specific methods were not critical (e.g., 80% body weight) or germane (red versus black cumulative recorder ink) to the results. Particular features of apparatus or procedure can influence a behavioral baseline in many ways; a great deal of time and effort can be saved by using those methods that are tried and true. On the other hand, the history of the Experimental Analysis of Behavior is replete with examples of how variations in technique can yield results that illuminate some important aspect of behavior for the observant scientist (cf. Sidman, 1960). A thorough understanding of the methodological variables in an experiment is key to proper interpretation of the behavior that results.

18. Resources

This section lists some sources of animals, equipment and supplies mentioned in this chapter.

18.1. Animals

18.1.1. Suppliers

A listing of licensed U.S. animal dealers is available from: Senior Staff Veterinarian, Animal Care Staff, Regulatory Enforcement and Animal Care, Animal and Plant Health Inspection Service, Room 206, Federal Building, 6505 Belcrest Road, Hyattsville, Maryland 20782. Concerns over inspection reports from licensed animal dealers should be directed to the Freedom of Information office at USDA-APHIS, LPA-FOI, Room 206, Federal Building, 6505 Belcrest Road, Hyattsville, MD 20782, U.S.A.

- NIH Rodent Repository, Veterinary Resources Branch, Division of Research Services Bldg. 14G, Room 102, National Institutes of Health, Bethesda, MD 20014, U.S.A. Serves as a national and international supplier of breeding stocks of rodents and lagomorphs of known genetic characteristics for scientific purposes to universities, NIH contractors, and commercial breeders. (A similar agency that is also a clearinghouse for information on laboratory animal science in the United Kingdom is the United Kingdom Medical Research Council.)
- Palmetto Pigeon Plant, P.O. Drawer 3060, Sumter, SC 29151, U.S.A. is a reliable supplier of pigeons to behavioral laboratories; pigeons also can be obtained from local pigeon breeders.
- Primate Supply Information Clearinghouse, Regional Primate Research Center, SJ-50, Seattle, WA 98195, U.S.A. The Primate Information Service at the University of Washington provides bibliographic services (see below) and also publishes a newsletter to provide information for efficient sharing of laboratory primates among U.S. researchers.

18.1.2. Bibliography

- The Biomedical Investigator's handbook for Researchers Using Animal Models. Foundation for Biomedical Research, 818 Connecticut Ave., N.W., Suite 303, Washington, DC 20006, U.S.A.
- Guide to the Care and Use of Experimental Animals. Canadian Council on Animal Care, 151 Slater, Ottawa, Ontario, Canada K1P 5H3.
- Laboratory Primate Newsletter. Judith E. Schrier (Ed.), Primate Behavior Laboratory, Psychology Department, Brown University, Providence, RI 02912, U.S.A. Published quarterly under a grant from the NIH, it is available free to those doing research with nonhuman primates.
- National Academy of Sciences 'Nutrient Requirements of Domestic Animals Series'. Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, DC 20418, U.S.A. This includes, among others, Nutrient Requirements of Laboratory Animals (1978), which covers rat, mouse, gerbil, guinea pig, hamster, vole and fish; Nutrient Requirements of Nonhuman Primates (1978); Nutrient Requirements of Dogs (1974); Nutrient Requirements of Cats (1978); and Nutrient Requirements of Rabbits (1977).

- NIH Guide for the Care and Use of Laboratory Animals. National Institutes of Health Publication No. 85–23 (revised, 1985). Limited free copies are available from the Office of Science and Health Reports, NIH Division of Research Resources, Room 857, Westwood Building, 533 Westbard Avenue, Bethesda, MD 20892, U.S.A.
- Primate Information Center, Regional Primate Research Center, SJ-50, University of Washington, Seattle, WA 98195, U.S.A. In addition to maintaining the Primate Supply Information Clearinghouse listings (above), the Center provides bibliographies of primate references on a multitude of topics and will do custom-designed literature searches.
- OPRR Public Health Service Policy on Humane Care and Use of Laboratory Animals (revised, Sept. 1986). Office for Protection from Research Risks, Bldg. 31, Rm. 4B09, 9000 Rockville Pike, Bethesda, MD 20892, U.S.A.
- The Recommendations for Governance and Management of Institutional Animal Resources. Association of American Medical Colleges, Association of American Universities, 1 Dupont Circle, N.W., Suite 200, Washington, DC 20036, U.S.A.
- USDA Animal Welfare Act Regulations. The regulations are published in the Federal Register. Information for obtaining the most current rules is available through the Animal and Plant Health Inspection Service, USDA, 6505 Belcrest Road, Hyattsville, MD 20782, U.S.A.

18.2. Equipment and supplies

18.2.1. Complete laboratory instrumentation

The following companies have been reliable suppliers of a wide range of equipment for operant research. Their catalogs list completely equipped operant chambers as well as separate components; they also supply various types of programming equipment. Some companies will accommodate special orders.

BRS/LVE, Inc., 9381-D Davis Avenue, Laurel, MD 20707, U.S.A.
Coulbourn, P.O. Box 2551, Lehigh Valley, PA 18001, U.S.A.
Gerbrands Corporation, 8 Beck Road, Arlington, MA 02174, U.S.A.
Lafayette Instrument, P.O. Box 5729, 3700 Sagamore Parkway, North Lafayette, IN 47903, U.S.A.
Med Associates, Inc., Box 47, East Fairfield, VT 05448, U.S.A.

18.2.2. Supplies and other equipment

The following companies are sources of supplies or more limited selections of equipment than those listed above. General electronics supply houses are good sources for miscellaneous supplies such as jewel light covers and sockets, sonalerts and force tension gauges.

Bio-Serv Inc., P.O. Box 450, Frenchtown, NJ 08825, U.S.A. (food pellets, liquid

Esterline Augus Instrument Corporation, P.O. Box 24000, Indianapolis, IN 46224, U.S.A. (event recorders, paper, ink).
Fenco Cage Products, 1188 Dorchester Avenue, Boston, MA 02125, U.S.A. (pole for transporting squirrel monkeys; also a stainless steel box with a mesh lid into which the monkey can be placed for weighing)
Graphic Controls, P.O. Box 1272, Buffalo, NY 14240, U.S.A. (cumulative recorder paper).
Habers Export Agencies, P.O. Box 436, Glens Falls, NY 12801, U.S.A. (squirrel monkey leash).
Kandota Instruments, Inc., 426 North Herschel Street, St. Paul, MN 55104, U.S.A. (contact sensors – primate and mouse drinkometers).
Leathercraft Co., 1101 East Hector Street, P.O. Box 666, Conshohochen, PA 19428. U.S.A. (squirrel monkey collar).
Leeds and Northrup, 10630 Little Patuxent Parkway, Columbia, MD 21044, U.S.A. (glass cumulative recorder pens).
P.J. Noyes Company, Inc., P.O. Box 381, Lancaster, NH 03584, U.S.A. (food pellets).
Omnitech Electronics, Inc., 5090 Trabue Road, Columbus, OH 43228, U.S.A. (drinking, feeding and activity monitors).

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CHAPTER 2

Response acquisition

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1. Introduction

The study of response acquisition was a prominent feature of early approaches to the study of learning. For example, Thorndike (1898) studied the process by which cats learned to escape from a 'puzzle box', describing the results in terms of how the time to escape the box decreased over successive trials. Within the operant tradition, however, which has as its goal the experimental analysis of the effects of reinforcement and other environmental variables on steady-state behavior (cf. Skinner, 1938; Sidman, 1960), response acquisition is an initial stage, akin to apparatus construction or equipment programming, that precedes the experiment proper. The emphasis on elucidating the functional relation between responses and environmental events also leads to the demand for a response that is readily measured and quantified. The ideal response can be easily executed, can be emitted repeatedly over long periods of time without fatigue, and can vary in ways that are sensitive to manipulations in the independent variable(s) of interest.

Rarely is a response with these characteristics found in the behavioral repertoire that a subject brings to the experimental situation. Rather, a response such as pressing a lever must be acquired before subsequent experimentation can be carried out. A lever press usually is not emitted by a rat without training, but other responses (e.g., forepaw movement) in the behavioral repertoire constitute the elements from which the lever press can be developed. As Morgan described it,

> Just as a sculptor carves a statue out of a block of marble, so does acquisition carve an activity out of a mass of given random movements (1896, p. 23).

New behavior is developed by shaping, a procedure of differential reinforcement that