

Behavioral Management of Chimpanzees in Biomedical Research Facilities: The State of the Science

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Abstract

The current status of the behavioral management of chimpanzees housed in US research facilities is examined, and recent advances are described. Behavioral management includes the application of environmental enrichment, animal training, and environmental design for improving animal welfare. Authors surveyed the six major chimpanzee holding facilities and found that the vast majority of chimpanzees are housed socially, with access to the outdoors. The institutions currently invest in behavioral scientists, enrichment specialists, and, most recently, chimpanzee trainers to implement and study chimpanzee behavioral management. This review is based on the substantial scientific literature related to managing social behavior, identifying the behavioral effects of restricted socialization, evaluating various forms of enrichment, and describing positive reinforcement animal training. Authors outline recent accomplishments in behavioral management, summarize behavioral issues that have been evaluated, and identify issues for future consideration. It is proposed that the enhanced application of behavioral management techniques, including training, could significantly reduce chimpanzee stress that is generally associated with experimental manipulations, and could improve animal welfare and the quality of biomedical research. The next challenge is to implement effectively and thoroughly the approaches that have been shown to be beneficial.

Key Words: animal care; animal husbandry; animal training; behavioral management; breeding; chimpanzee; distress; environmental enrichment

Introduction

In this article, we examine practices of behavioral management for chimpanzees, focusing particularly on the scientific work that has been conducted since the mid-1980s to improve the care and well-being of chimpanzees living in research facilities. We also provide information on the current status of behavioral management programs at

the major biomedical institutions that hold chimpanzees in the United States. Several important advances in caring for captive chimpanzees have taken place over this period, including the development of environmental enrichment techniques that encourage species appropriate behavior, an improved understanding of managing the social behavior of chimpanzees living in groups, the assessment of enclosure design features on chimpanzee behavior, and the development of positive reinforcement training techniques to improve care and well-being. We review some of the major studies that have been conducted on chimpanzee behavioral management, and summarize the issues that have been addressed. Finally, we discuss other issues that have not yet been fully evaluated, with an eye toward identifying future priorities.

In 1986, the term “psychological well-being of nonhuman primates” entered the common vocabulary of people who work with captive nonhuman primates. This term was the focus of the 1985 amendment to the Animal Welfare Act, which mandated the provision of physical environments to promote the psychological well-being of nonhuman primates. At that time, the study of environmental enrichment techniques was well under way in zoological parks and animal laboratories (Erwin, et al. 1979; Shepherdson 1998), but the terms “enrichment” and “psychological well-being” had not yet been applied widely. These terms are now an integral part of the work-a-day world of those of us who care for, and about, captive primates. Enrichment is now an important component of the management of captive nonhuman primates (as well as many other species), and it has become progressively more complex and effective—and more expensive. Facilities in which nonhuman primates are maintained now devote significant human and financial resources to environmental enrichment programs, with the aim of improving the well-being of their nonhuman primate charges.

Environmental enrichment has been defined as “an animal husbandry principle that seeks to enhance the quality of captive animal care by identifying and providing the environmental stimuli necessary for optimal psychological and physiological well-being” (Shepherdson 1998, p. 1). Enrichment is judged to be effective when it increases the expression of species-typical behavior and/or reduces the expression of aberrant behavior (Bloomsmith et al. 1988; Maple 1979; Morgan et al. 1998). More recently, a comprehensive term, “behavioral management,” was introduced (Whittaker et al. 2001), which incorporates enrichment,

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positive reinforcement training, and environmental design. This concept builds on a foundation of the natural behavior of the target species, with the aim of improving animal care and enhancing their welfare. An important premise of behavioral management is that the individual tools of enrichment, training, and environmental design can be integrated to achieve behavioral goals for captive animals better and more completely than any one technique applied in isolation (Whittaker et al. 2001). This broad, holistic perspective is effective because it allows one to incorporate all of these components when addressing behavioral issues. We use this perspective in reviewing the state of the science of chimpanzee behavioral management.

Chimpanzees Housed in Research Facilities in the United States

Approximately 1300 chimpanzees are housed in the United States in primate research facilities supported by the National Institutes of Health (NIH¹) (Brent 2004), although some of these chimpanzees will soon move to a sanctuary. These animals reside largely in six facilities: the Yerkes National Primate Research Center, the Southwest Foundation for Biomedical Research, the Primate Foundation of Arizona, the University of Texas M.D. Anderson Cancer Center, the New Iberia Research Center, and the Alamogordo Primate Facility. Some members of this chimpanzee population are used in biomedical research that includes studies of infectious diseases, vaccine development, genetics, neuroscience, toxicity, and behavior. The population also includes numerous animals that have never been used in interventional studies and could form a nucleus to meet future reproduction needs. Currently, reproduction is restricted in federally owned chimpanzees, and in those supported by the NIH National Center for Research Resources (NCRR¹), by a breeding moratorium in place through 2005 (Ray O'Neill, NCRR, Bethesda, MD, personal communication, 2004).

The housing for chimpanzees living in biomedical facilities ranges from large indoor/outdoor enclosures holding groups of up to 20 individuals, to smaller groups or pairs of chimpanzees living in indoor/outdoor run-type housing or various types of play yards, to individually housed animals living in indoor caging. Enclosure size varies from the minimum of 15 ft² of floor space allowable for an individually housed chimpanzee (NRC 1996) to outdoor enclosures of up to 10,000 ft². Because of the diversity in social settings and physical environments in which chimpanzees live, it is necessary to address a diverse array of behavioral management issues.

¹Abbreviations used in this article: NCRR, National Center for Research Resources; NIH, National Institutes of Health.

Survey of Behavioral Management at US Chimpanzee Research Facilities

In July 2004, we conducted a written survey of the behavioral management programs at the six facilities listed above to increase our understanding of the chimpanzee housing situation at these facilities, along with their current behavioral management practices. Survey respondents reported on the 1226 chimpanzees living at their institutions. Of the 1226 chimpanzees maintained at these institutions, 93 (7.6%) were individually housed on a single day chosen to sample for the survey. This number included all chimpanzees singly housed for any reason on that particular day, whether due to research protocol, health problems, behavioral problems, and so forth. Singly housed chimpanzees can generally see, hear, and in some cases touch other chimpanzees through a barrier, so single housing does not involve complete isolation from other chimpanzees. It is clear that at the point sampled, the vast majority of chimpanzees in biomedical laboratories were living socially. The same number of animals (93/7.6%) were housed indoors without outdoor access, and the majority (but not all) were the singly housed animals described above.

All six facilities had behavioral management programs in place, but there was variation in the staffing and organization of the programs. In most of the institutions, staff members were assigned to a specific aspect of behavioral management such as enrichment, training, or applied behavioral research. One facility shared behavioral management duties among all care staff members. All institutions involved the entire animal care staff in at least some aspects of behavioral management, but we did not quantify the degree of this effort in the survey. Each institution employed a Ph.D.-level behavioral scientist who was responsible for and/or conducted studies of chimpanzee behavioral management. These scientists typically directed the efforts of technical specialists in enrichment or animal training, and worked with animal care and veterinary staff members to implement the behavioral management programs. Five of the six facilities had formal chimpanzee training programs, all of which relied primarily on positive reinforcement techniques to gain cooperation with procedures.

The facilities employed, on average, one dedicated enrichment technician for every 146 chimpanzees, and one chimpanzee trainer for every 156 animals. Enrichment positions were established much earlier than dedicated trainers, and most of the latter have been appointed since 1999. It is therefore particularly notable that the number of trainers is nearly equivalent to the number of enrichment technicians, indicating the value that this new specialty is bringing to chimpanzee management. The six facilities also employed an average of one other behavioral management specialist for each 223 chimpanzees in their care. However, often the duties of these individuals (e.g., managing chimpanzee introductions and observing for aggression problems) were shared by animal care and veterinary care staff; and because that shared effort was not reflected in our sur-

vey, this effort appears deceptively low. Finally, the chimpanzee facilities employed an average of one applied behavioral researcher (generally the Ph.D.-level individuals mentioned above, and in some cases other research support personnel) for every 300 chimpanzees.

The survey findings are an indication of the importance that biomedical institutions now place on enhancing the care of chimpanzees. Whereas before 1986, no positions in these institutions were dedicated solely to environmental enrichment or animal training, they now are commonplace. An increasing focus on science is also evident, as reflected by the number of Ph.D.-level individuals recruited into behavioral management positions.

We also found that facility improvement was a priority at each of the institutions, with four having built new chimpanzee housing or completed major renovations since 1999. These efforts require a large capital investment, and the improvement of chimpanzee well-being was cited in each case as a major reason for the construction or renovation.

Survey respondents ranked six behavioral issues as the most important for chimpanzees in research settings: (1) self-injurious behavior, (2) abnormal and stereotyped behavior, (3) housing inadequacies, (3) social behavior deficits, (4) aggression, (5) stressful research protocols, and (6) boredom. Responses regarding other behavioral problems or issues needing to be addressed over the next 5 yr focused overwhelmingly on breeding and maternal competency, should the current breeding moratorium be lifted. There is widespread concern that many chimpanzees will not breed or care for their infants, following the extended period of reduced reproduction that has been in place due to the breeding moratorium. Other issues the respondents raised include disruptions when animals are taken from their home compound for research purposes, and the possibility of better preparing chimpanzees for involvement in research protocols by managing group compositions differently.

Science and Chimpanzee Behavioral Management

Individuals who administer and fund US biomedical facilities that house chimpanzees believe it is important to develop a scientific framework for decision making in chimpanzee behavioral management. Using the findings of objective, quantitative, well-designed studies is far superior to relying simply on subjective experience or the advice of others for numerous reasons, which include the following:

- Using hypothesis-driven experimental design ensures appropriate sample size, statistical analyses, and data collection with reliable and reproducible techniques. This approach helps ensure that the resultant recommendations are worthwhile and should lead to real improvements in the behavior and well-being of the chimpanzees.
- Using a scientific approach with standardized elements in the studies allows a comparative assessment of vari-

ous behavioral management techniques used to address particular behavioral problems.

- Complex problems, which characterize many of the multifaceted issues related to chimpanzees, are best understood when data can be analyzed systematically and controlled for possible confounding factors. For example, identifying the many factors that might influence chimpanzee maternal behavior (e.g., early social history, age, current housing, prior exposure to infants) requires complex statistical analyses to disentangle the possible causative effects of each variable.
- Quantitative data allow a more precise cost:benefit analysis of particular forms of behavioral management. For example, knowing how long it might take to train a chimpanzee to cooperate with a blood withdrawal procedure while the animal is conscious would help to determine whether this training should be accommodated within a given biomedical research protocol. Such data also allow ineffective forms of behavioral management to be identified readily.
- Sound scientific data describing behavioral change are convincing to administrators, research investigators, members of the public, and regulators that true benefits are being derived from the resources spent on behavioral management.

Recent Publications on Chimpanzee Behavioral Management

The significant advances in applied behavioral science of chimpanzees maintained in a laboratory environment are evident in the prolific literature on the topic. In addition, the behavior of chimpanzees is well studied outside laboratories, with decades of research both in the wild and at zoological parks. We need to take full advantage of this tremendous body of knowledge and ensure that this information is applied to improve the way we house, care for, and conduct research on chimpanzees (see Pruett and McGrew 2001; Wrangham 1992 for reviews on the application of wild chimpanzee behavior to captive management).

We completed an analysis of the publications that address various elements of chimpanzee behavioral management from 1986 through 2003. We began with publications from 1986 because two seminal events occurred that year: the Animal Welfare Act was amended to include the psychological well-being of nonhuman primates, and the National Chimpanzee Breeding and Research Program (now called the NIH Chimpanzee Management Program) was established by the NIH NCRR. One goal of the National Chimpanzee Breeding and Research Program was to develop a body of scientific literature that would answer questions related to chimpanzee well-being. We ended our compilation with 2003 publications so that we could conclude with an entire publication year. We identified publications that focused on or specifically included chimpanzees, and those publications with objectives of applying behav-

Table 1. Books published from 1986 to 2003 with significant contributions to chimpanzee behavioral management

Publication (see text)	Comments
<i>Housing, Care and Psychological Wellbeing of Captive and Laboratory Primates</i> (Bloomsmith 1989a)	Includes three chapters on chimpanzees
<i>Chimpanzee Conservation and Public Health: Environments for the Future</i> (Erwin and Landon 1992)	Entire publication focused on issues relating to chimpanzees in biomedical facilities
<i>The Chimpanzee Species Survival Plan: Chimpanzee Husbandry Manual</i> (Fulk and Garland 1992)	Prepared under the auspices of the American Association of Zoos and Aquariums
<i>Chimpanzee Cultures</i> (Wrangham et al. 1994)	Several chapters describing the social lives of captive chimpanzees
<i>The Role of the Chimpanzee in Research</i> (Eder et al. 1994)	Several chapters on captive breeding, management programs, and behavior
<i>Chimpanzees in Research: Strategies for Their Ethical Care, Management, and Use</i> (NRC 1997)	Recommendations regarding social housing and long-term care of chimpanzees
<i>Care and Management of Captive Chimpanzees</i> (Brent 2001)	The most complete set of information on chimpanzee care, used by the Chimpanzee SSP for husbandry guidelines.

ioral management findings to improvements in the care, reproduction, or management of captive chimpanzees (the publication list and methods used are available from M.A.B.).

During the 1986-2003 period, publications relating at least in part to chimpanzee behavioral management included seven books, 91 peer-reviewed articles, 199 abstracts and conference proceedings, and 28 other publications in newsletters and trade journals (Table 1).

Most of the peer-reviewed articles offer objective analyses of behavioral data with some scholarly discussion of chimpanzee well-being. The publication rate of such articles peaked in 1993 (Figure 1). The decline in more recent years may be due to reduced funding for such research and/or a perception that more of this type of research is not needed. The output of abstracts and conference proceedings has continued to increase (see Figure 1), likely due to a combination of factors, including the large number of conferences with a

behavioral management component and an increased number of zoo-based projects.

Summary of Scientific Progress in Various Categories of Behavioral Management

The issues that have been addressed in the behavioral management literature are summarized below. In this discussion, we begin to differentiate issues that are being addressed from issues that require further study.

Management of Social Behavior

Social enrichment refers broadly to the social lives of chimpanzees—social interactions with other chimpanzees as well as with other species (e.g., dogs or humans). Optimizing the management of social behavior is essential to maintaining a breeding population of chimpanzees that retain their behavioral competence over generations. The wide array of studied social issues includes the following: introducing unfamiliar chimpanzees into groups (Alford et al. 1995; Baker and Aureli 2000; Brent et al. 1997; Fritz 1989; Seres et al. 2001); maintaining species-typical, multimale, multifemale social groups (Baker et al. 2000; Bloomsmith 1989b; Fitch et al. 1989; Pruett and Bloomsmith 1995); and comparing differences in the behavioral development of young chimpanzees as they mature in different social settings (Bloomsmith et al. 1994b; Maki et al. 1993; Spijkerman et al. 1995, 1996, 1997). Understanding factors that affect maternal competence (Bard 1994; Bloomsmith et al. 2003; Hannah and Brotman 1990) is central to ensuring the future behavioral capability of chimpanzees because infants

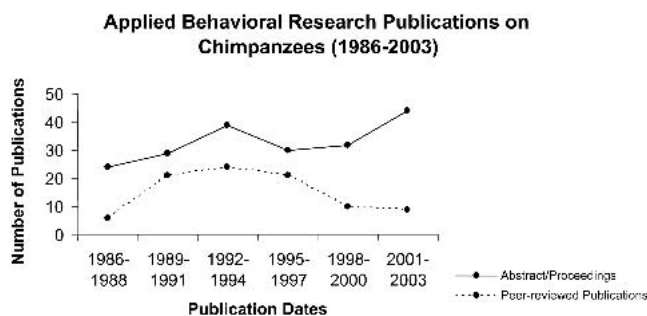


Figure 1 Number of peer-reviewed publications and published abstracts or conference proceedings focusing on chimpanzee behavioral management in 3-yr increments, from 1986 through 2003.

of incompetent mothers are more likely to be deficient behaviorally (Davenport and Rogers 1970; Nash et al. 1999; Rogers and Davenport 1970). Social interactions with humans can lead to behavioral improvement in chimpanzees and may be an important type of enrichment (Baker 2004).

Because captive chimpanzees may aggress or even kill one another (de Waal 1986; Spijkerman and van Hooff 1990), it is critical to understand and control aggression, particularly given the trend of housing chimpanzees in larger groups. Managing aggression exemplifies the need for studies of social behavior. Aggression can be influenced by feeding techniques (Bloomsmith and Lambeth 1995; Howell et al. 1993), the reproductive status of females (Bloomsmith et al. 1991, 1992; Shefferly and Fritz 1992), available space (Aureli and de Waal 1997; Caws and Aureli 2003; de Waal 1989), and aggression in nearby groups (Baker and Aureli 1996). Human activity around chimpanzees can increase wounding rates (Lambeth et al. 1997), yet positive reinforcement training can reduce aggression (Bloomsmith et al. 1994a). Likewise, drug treatment can be applied to moderate aggression (Orkin 1993).

Effects of Limited Socialization

Early social deficiencies can disrupt the behavior of chimpanzees throughout their long lives. Deficiencies may manifest in sexual behavior, maternal behavior, and abnormal or stereotyped behavior (Brent et al. 1996; Fritz et al. 1992b; King and Mellen 1994; Nash et al. 1999; Pazol and Bloomsmith 1993, 1997). We need to identify the range of early rearing experiences that lead to normal behavioral outcomes. Even though human rearing in a nursery setting has been associated with a variety of behavioral deficits (Nash et al. 1999), modern nursery rearing practices can reduce some of these negative outcomes (Bloomsmith et al. 2005).

Two studies have examined behavioral change associated with single housing for adult chimpanzees. Both short-term (Brent et al. 1989b) and long-term effects have been documented (Baker 1996), with more serious behavioral problems evident in the longer term. In a recently published book chapter, Brent (2001a) thoroughly reviews the single housing of chimpanzees and behavioral management techniques that should be applied.

Feeding Enrichment

Feeding enrichment is an important interventive technique, and simulating the feeding and foraging experiences of wild chimpanzees is a useful addition to the captive environment (Bloomsmith 1989a). Feeding enrichment can alter chimpanzee behavior in species-appropriate directions, which include increases in time searching for, acquiring, and processing food, provision of opportunities for using tools (e.g., sticks for simulated termite fishing), and moderation of certain abnormal behaviors (Baker 1997; Bloomsmith

et al. 1988; Fritz et al. 1992a). Many investigators have evaluated a variety of feeding devices, feeding techniques, and alterations in feeding schedules (Baker and Easley 1996; Bloomsmith and Lambeth 1995; Bloomstrand et al. 1986; Brent and Eichberg 1991; Howell et al. 1993; Lambeth and Bloomsmith 1994; Maki et al. 1989; Visalberghi et al. 2002), as well as the significant problem of weight gain that can be associated with feeding enrichment (Brent 1995).

Physical Enrichment

Physical enrichment encompasses everything from supplying chimpanzees with objects, to structures and furnishings in their enclosures, to entire new enclosures. Numerous investigators have evaluated and compared the effectiveness of various types of manipulable objects (Bloomsmith et al. 1990a; Brent and Stone 1998; Brent et al. 1989a; Pruetz and Bloomsmith 1992; Sanz et al. 1999). Reports have documented that novel objects (Paquette and Prescott 1988) and destructible objects (e.g., paper, cardboard, and tree branches) are used by chimpanzees more frequently and consistently over time than indestructible items (Brent and Stone 1998; Maki and Bloomsmith 1989; Pruetz and Bloomsmith 1992). Chimpanzees' use of some forms of physical enrichment declines rapidly after initial exposure (Bloomsmith et al. 1990a; Paquette and Prescott 1988; Pruetz and Bloomsmith 1992). Although the level of long-term use of this enrichment is low, it is stable (Bloomsmith et al. 1990a; Brent and Stone 1996; Maki and Bloomsmith 1989). Information on chimpanzees' use of different types of enclosures and preferences for certain environmental features (Bettinger et al. 1994; Brent et al. 1991; Caws and Aureli 2003; Goff et al. 1994) is particularly helpful in the design and renovation of enclosures.

Sensory Enrichment

Sensory enrichment includes additions to the visual, auditory, olfactory, or tactile environment of the animal. The effects of the following approaches are well documented: showing videotapes with varied content to chimpanzees (Bloomsmith and Lambeth 2000; Bloomsmith et al. 1990b); giving them mirrors (Lambeth and Bloomsmith 1992); and providing the opportunity for them to watch television (Brent et al. 1989a), listen to music (Howell et al. 2003), and even watch tanks of goldfish (Kessel and Brent 1996). In general, chimpanzees attend to these types of enrichment, but few other behavioral benefits are found, although music has been reported to cause a reduction in agitated and aggressive behaviors (Howell et al. 2003). Habituation appears to be a drawback of some sensory enrichment such as television and mirrors (Brent and Stone 1996), although as with some forms of physical enrichment, stable but low levels of use are maintained over time. In one case (Lambeth and Bloomsmith 1992), young chimpanzees actually

increased their use of mirrors over time. Sensory enrichment may be more important for chimpanzees living indoors and in smaller enclosures because these situations are inherently less stimulating.

Occupational Enrichment

Occupational enrichment refers to enrichment that might elicit activities such as problem solving, learning, choosing, or controlling some feature of the environment. This type of approach should be encouraged because most forms of enrichment do not offer an on-going challenge, which is important to animals such as chimpanzees, due to their advanced cognitive abilities, and because it may reduce habituation to a specific device. To date, very little relevant research has been conducted in this area, despite the fact that occupational enrichment is sometimes used with chimpanzees as well as other nonhuman primate species. Examples of enrichment include using simple computer games with joysticks (Bloomsmithe et al. 2001), giving the chimpanzees opportunities to choose among videotapes with different content (Bloomsmithe et al. 2000), and to use tools (Brent et al. 1995). There is great potential in further investigation of occupational enrichment, including a possible interface with cognitive neuroscience investigations. The use of complex learning or memory tasks, challenging stimulus detection or assessment paradigms, and other neuroscience testing procedures can be interpreted as stimulating forms of enrichment, especially when they are performed without coercive techniques (e.g., restricting access to food or water).

Animal Training

The recognition that positive reinforcement training can be used as a tool to enhance chimpanzee care and welfare is a major development that dates back to the mid-1980s. The voluntary cooperation of chimpanzees with routine husbandry activities, veterinary procedures, and research procedures has been greatly expanded (Bloomsmithe 1992; Whittaker et al. 2001). Benefits of training include greater ease and efficiency in working with chimpanzees, reduced distress (Lambeth et al. 2004), and increased cognitive stimulation for the chimpanzees involved. To date, few quantitative studies evaluating the chimpanzee training process have been published (Bloomsmithe et al. 1998; Lambeth et al. 2004; Laule et al. 1996), but this area of research should be emphasized because of its potential for widespread benefit and the increased interest in training as a management tool at each of the major biomedical holders of chimpanzees.

Direct and Contingent Distress Associated with Research Using Chimpanzees

It is important to make a distinction between what we have termed “direct distress” and “contingent distress” when ex-

amining the welfare of chimpanzees involved in biomedical research. Russell and Burch (1959) first described the general concept behind this approach. Direct distress is an unavoidable consequence of a research intervention or other procedure conducted on an animal. For example, a chimpanzee exhibiting fever after being experimentally infected with malaria is experiencing direct distress. In contrast, contingent distress is an incidental or inadvertent by-product of the procedure. So, for example, when that same chimpanzee on the malaria study is physically restrained for the withdrawal of a blood sample needed for the study, he is experiencing contingent distress due to the physical restraint. Poor laboratory animal husbandry practices can lead to contingent distress and can alter animal-based experimental results because this distress is an uncontrolled variable. Thus, when contingent distress can be eliminated or reduced, the result improves both animal welfare and the quality of the research.

Most biomedical research involving chimpanzees is associated with minimal disease and direct distress. However, contingent distress can be significant. For example, individual housing of chimpanzees in indoor cages when they are involved in an infectious disease research protocol may reduce their opportunities for species-specific behaviors such as locomotion, foraging, resting, problem solving, and physical contact with a conspecific. In addition, the animals may be exposed to repetitive research procedures, which can be stressful. These events, which surround the research rather than resulting directly from the disease or condition under study, are the most significant challenges to the well-being of these chimpanzees.

Improving behavioral management of chimpanzees can reduce the contingent distress associated with the experimental interventions by reducing disturbance and increasing opportunities for species-appropriate activities. For example, some chimpanzees are singly housed indoors because of the need for frequent collection of biological samples for the research. Investigators often use a cage with a “squeeze back” mechanism to restrain the chimpanzee for an injection or sample collection, despite the distress to the animals, because the technique is relatively fast and reliable. Conversely, appropriate training of the animal may allow safe and reliable collection of biological samples (e.g., voluntary cooperation with injections or blood withdrawals) while the chimpanzee remains in its home enclosure. Such approaches may not be practical or cost effective in all instances, and we urge investigators to perform additional studies to gain more insight into these and other approaches. Chimpanzee well-being would be significantly enhanced if we could minimize single housing and train chimpanzees to cooperate with repetitive research procedures.

Topics for Future Studies of Chimpanzee Behavioral Management

Important questions about chimpanzee behavioral management remain unanswered, and some of the more controver-

sial aspects of the use of chimpanzees in biomedical research have yet to be addressed. Nevertheless, it is important to pursue these questions because objective, quantitative data collected on such issues can help to illuminate their rational discussion. The following topics that warrant continued study are described very briefly below: managing social groups, single housing, self-injurious behavior, enrichment, adding physiological measures to assessments, and the impact of behavioral management on biomedical research.

Managing Social Groups

A considerable amount of research has been performed to improve the management of social groups of chimpanzees. Because this work applies to the majority of biomedical chimpanzees, it is needed and made even more necessary by the trend to house chimpanzees in complex enclosures and in large social groups. Likewise, it is important to continue to investigate aggression, particularly in multimale groups and in groups that contain maturing males. Further evaluation of pharmacological interventions for aggression would be informative.

There has been considerable discussion on whether the current breeding moratorium should be lifted to maintain the current captive chimpanzee population. If this prohibition ends, nursery rearing methods could be studied further in an effort to gain useful information related to the long-term effects of these methods on reproductive behavior. Due to the moratorium, the current dearth of infant chimpanzees born into social groups has altered group structure, and maturing chimpanzees may have little or no exposure to infants. This alteration has the potential to affect their future maternal skills, or the ability in the future to house infants safely with them. Indeed, additional data should be compiled on these topics.

Single Housing

A relatively small proportion of biomedical chimpanzees are housed individually. However, given the reduced well-being of these animals (Brent 2001) and the intense interest in this issue expressed by the public and by critics of biomedical research, we believe that more research related to single housing is warranted. Many difficult and some quite controversial questions should be answered. The following are examples of unresolved issues: Could more chimpanzees be socially housed while assigned to research protocols (Prince et al. 1989)? Can interactions with humans substitute for interaction with a chimpanzee? What level of distress is experienced by singly housed chimpanzees, and do they recover once they are returned to more complex settings? Do short bouts of such restriction have less of an impact than longer bouts? Could the caging be improved for

chimpanzees that must be individually housed? What metrics can be developed to design such a cost:benefit analysis?

Self-injurious Behavior

A recent survey has revealed that self-injurious behavior is manifested in approximately 3% of captive chimpanzees (K. Neu and M.A.B., manuscript in preparation). Even though this portion of the population is small, its severity warrants special focus. Respondents to our survey mentioned self-injurious behavior most commonly as an important behavioral problem, even though it is not widespread. We are not aware of any type of remedial measures that have been studied formally for chimpanzee self-injurious behavior, and it would be useful to investigate pharmacological approaches as well as other forms of intervention.

Enrichment

Chimpanzee enrichment should incorporate more complexity, challenge, and diversity so that habituation is less of a problem and the use of enrichment is more cognitively stimulating. If achievable, the result should reduce the expression of abnormal behavior and boredom, both of which were identified as major problems by individuals who completed our survey. Additional work is needed to evaluate the roles that choice and control over the environment might have on chimpanzee well-being because these factors are often cited as critical, albeit not well-tested, characteristics of animal well-being. More attention should be given to improving resting sites and providing for nesting behavior because wild chimpanzees devote a considerable amount of time to both behaviors, and these opportunities are generally not well integrated into behavioral management programs (Pruetz and McGrew 2001). Improvements should be made to captive environments that do not yet begin to simulate the locomotor requirements of the natural environment.

Adding Physiological Measures to Assessments

More research should incorporate physiological measures to complement behavioral measures of well-being (Novak and Suomi 1988). It is relatively common for investigators to apply measures of cortisol, heart rate, and other indicators to evaluate well-being in various animal species, but minimal work has been undertaken in this area with chimpanzees. These dependent measures are important, particularly when moderating distress is an objective of the intervention being tested. Physiological analyses should be applied to evaluate training techniques, compare various types of social groupings, and evaluate the effects of single housing on chimpanzees.

Impact of Behavioral Management on Biomedical Research

Clearly, enlightened behavioral management has the potential to improve the chimpanzee as a research model by reducing contingent distress that can confound studies and by improving access to chimpanzees for the collection of biological samples. It is important to include these benefits when conducting a cost:benefit analysis.

Taking the Next Step

Integrated approaches to the behavioral management of chimpanzees can incorporate the many tested techniques and strategies in the continuing effort to improve the understanding and management of captive chimpanzee behavior. Individuals who care for chimpanzees can make informed decisions in cases such as the following: when choosing the most appropriate environmental enrichment techniques to promote desired behavioral changes in particular chimpanzees, when renovating existing facilities or designing new ones, in deciding the best social grouping for young chimpanzees, in determining how to moderate excessively high aggression in a large social group, and in deciding whether chimpanzees should be trained to cooperate with animal care or research procedures. However, no recipe book is, or should be, available. The way in which these tools are applied depends on the goals of the program, the facilities, the available human resources, the supplies and equipment, and the individual chimpanzees. Findings from some studies may not apply well to other circumstances. However, it is abundantly clear that behavioral science has helped to determine viable means for modifying the behavior of captive chimpanzees in desirable ways.

Much has been learned about the behavioral management of chimpanzees and promoting their psychological well-being. The question arises as to what should now be done to advance chimpanzee welfare further. When the amended Animal Welfare Act was first enacted, there was debate about the appropriateness of implementing enrichment that had not yet been tested. How did we know it was worth doing, and was it worth the potential disruption to research programs if we did not know it would improve the well-being of the animals? Given all that we have learned since that time, we can now answer this question for the chimpanzee. Indeed, we *can* improve and modify captive chimpanzee behavior through behavioral management techniques so that it is more similar to that of wild chimpanzees. The challenge now is not to determine what should be done for the chimpanzees but instead, to implement effectively and thoroughly what has already been shown to be useful. A "bias for action" (Keeling et al. 1991) in implementing these programs is justified now, more than ever.

Concluding Thoughts

The many obstacles to implementing behavioral management programs more fully are a continuing challenge. To answer this challenge at this time, we believe it is necessary to pursue the following goals:

- To strengthen the role of behavioral management specialists in decision-making processes at facilities that house chimpanzees. This modification will require veterinary and animal care staff to work more closely with behavioral scientists than has traditionally been the case. However, the fact that behavioral scientists, enrichment specialists, and trainers are now present in all of the major biomedical facilities holding chimpanzees indicates substantial progress and a willingness of these institutions to invest financial resources into these programs.
- To support increased opportunities for advanced training of chimpanzee care staff with regard to behavioral management. The skills and knowledge needed to train a chimpanzee to receive an injection, to introduce unfamiliar chimpanzees to one another, or to combat self-injurious behavior should become part of the arsenal of tools that front-line chimpanzee caregivers learn and practice daily.
- To ensure that investigators who use chimpanzee subjects are informed of behavioral management techniques so they may be confident that the accommodations they are making with their research are worthwhile.
- To provide sufficient resources to bolster the further development of behavioral management programs, and to continue conducting high-quality scientific investigations in this field.

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