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Addressing nonhuman primate behavioral problems through the application of operant conditioning: Is the human treatment approach a useful model?☆

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Abstract

Training by the systematic application of operant conditioning has been widely applied in the care, management, exhibition, and study of nonhuman primates and many other species, but is less often used to control problematic animal behavior such as stereotyped behavior or self-injurious behavior. We review the topographical features and causal factors of stereotyped and self-injurious behavior in captive nonhuman primates, and the small number of published studies that have used operant conditioning to address these behavioral problems. The techniques developed in treating human stereotyped and self-injurious behavior are then described, and comparisons are made between the two approaches. Virtually all the techniques found to be effective treatments of stereotypy and self-injurious behavior in humans are directly applicable to similar behaviors in captive nonhuman primates. Thus the human work can serve as a model for how we can enhance our attempts to address behavioral problems in captive nonhuman primates. We advocate a philosophy of behavioral management, based partly on the science of behavior analysis, that includes a systematic, scientific approach to the discovery and description of behavioral problems and their treatment.

Keywords: Abnormal behavior; Behavioral pathology; Experimental analysis of behavior; Operant conditioning; Self-injurious behavior; Training

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1. Introduction

Training by the systematic application of operant conditioning has been widely applied in the care, management, exhibition, and study of nonhuman primates and many other species (Breland and Breland, 1961; Aarons, 1973; Skinner, 1988; Priest, 1991; Ogden et al., 1992; Pryor, 1999). Trained animals receive more efficient handling and are more quickly returned to their normal routine, often with less invasive methods of contact and manipulation. It is widely assumed that such training reduces physiological changes associated with stress, and that training animals to cooperate with procedures is therefore beneficial to their welfare by moderating individuals' perceptions of stress during certain procedures. A few recent reports have begun to quantitatively evaluate this assumption (Koban et al., 2005; Lambeth et al., 2004, 2005; Reinhardt et al., 1991; Savastano, 2005; Videan et al., 2005). Despite these numerous applications, the use of operant training to control problematic animal behavior such as stereotyped behavior or self-injurious behavior is less common. Because primate laboratories and zoos are accountable for recording and controlling morbidity and mortality, administrators, clinicians, curators, and scientists alike should be familiar with the most effective methods for the prevention, intervention, and treatment of such potentially dangerous behavior. Although there are some animal studies to guide policy and best practices, the human literature has a track record of more than four decades of investigation into controlling such behavior (e.g., Kahng et al., 2002). We believe that this literature from the behavior analysis research community, and based on human subjects, may be enormously helpful in developing effective training methods for preventing, ameliorating, and treating stereotyped and self-injurious behavior in captive nonhuman primates.

The potential value of the behavior analysis perspective in promoting the welfare of captive nonhuman primates has yet to be realized. Very little attention has been given to examining how the techniques applied to humans might be useful in the context of managing the behavior of nonhuman primates (but see Tarou and Bashaw, 2007). This paper will describe some of the important issues to be considered, and some possible avenues for further investigation. Because so little work has been conducted, this paper will not serve as a handbook for those interested in applying these techniques to captive animals, but instead might serve as a roadmap for future research to be conducted to determine whether the application of these ideas is efficacious. As with any behavioral management technique, it is likely that strengths and weaknesses will be identified as evaluations are completed on the use of behavior analysis methods. One anticipated weakness of this approach may be expense, as it relies on the individual attention of human caregivers with expertise in these methods. Just how expensive it may be, or in what circumstances this approach might be practical, simply cannot yet be determined. Research must first be conducted to evaluate whether behavior analysis techniques are useful in managing captive primate behavioral problems. If they are found to be effective, then the process can begin of refining techniques to become more practical. We will begin working toward this long-term goal by exploring some of the potential that behavior analytic approaches may have to improving the care and well being of captive primates.

2. Stereotyped behavior in nonhuman primates

Captive nonhuman primates exhibit many behavioral patterns that are atypical for their species, including stereotypic behavior. Stereotypic behavior is defined as unvarying, repetitive behavior patterns with no obvious goal or function (Mason, 1993). These behaviors can be classified as qualitatively abnormal (occurring in captivity but not in the wild) or quantitatively abnormal (occurring more or less often in captive settings than in natural settings) (Erwin and Deni, 1979). Locomotor or whole-body stereotypies such as pacing, repetitive somersaulting, repetitive flipping, etc., are the most commonly performed stereotypies in captive primates (Bellanca and Crockett, 2002; Lutz et al., 2003). Repetitive movements of body parts are also common and include nodding motions of the head, movements of the mouth or jaw, and invariant patterns of moving digits, hands or feet (Bourgeois and Brent, 2005). Other atypical behaviors include disturbances of appetitive behaviors such as coprophagy, polydipsia, and repeated regurgitation. Young primates who experience early social deprivation often devote considerable time to self-sucking, body crouching, self-clasping, self-biting, and body-rocking, all of which seem to serve the function of self stimulation (Davenport and Menzel, 1963; Berkson, 1968; Sackett, 1968; Erwin and Deni, 1979; Fritz and Fritz, 1985; Pazol and Bloomsmith, 1993).

Stereotyped behaviors emerge from a number of conditions associated with captivity. This long list of causal factors contributes to the complexity of understanding and appropriately treating these behaviors when they are expressed by individual captive animals. Social deprivation early in life (e.g., social isolation rearing), and social restriction later in life (e.g., individual cage housing) are associated with high levels of stereotypic behavior (Berkson, 1968; Dienske and Griffin, 1978; Meder, 1989; Lutz et al., 2003). Stereotypic behavior also becomes more common as primates mature (Kraemer and Clarke, 1990). The duration of time living alone, and the proportion of a monkey's life spent individually housed are positively related to the incidence of some abnormal behavior patterns (Lutz et al., 2003; Novak, 2003). Husbandry routines such as feeding schedules and restraint practices are implicated as causes of certain types of abnormal behavior (Mason, 1991; Lawrence and Rushen, 1993; Bloomsmith and Lambeth, 1995; Bassett and Buchanan-Smith, 2007), as are space limitations, suboptimal levels of stimulation, and lack of environmental control (Draper and Bernstein, 1963; Capitanio, 1986; Paulk et al., 1977). In some situations, the past history of an individual may be more predictive of abnormal behavior patterns than its present environmental conditions (Mason, 1991; Mason et al., 2007). For example, age of a rhesus macaque when first housed alone is associated with later expression of stereotypic behavior (Lutz et al., 2003). Moving such a monkey into social housing as an adult may not eliminate the stereotypic behavior (Novak, 2003).

3. Self-injurious behavior in nonhuman primates

One of the most troublesome behavioral problems in captive nonhuman primates is self-injurious behavior. Different forms of self-injurious behavior (SIB) have been identified, with topographies including self-directed threats, head-banging, self-biting without wounding, self-wounding, picking of wounds in the skin, and eye gouging (Kraemer and Clarke, 1990; Lawrence and Rushen, 1993; Novak, 2003). These are very similar in form to SIB in humans (see below). These behaviors have the potential to result in injuries, although they are most often exhibited without the actual infliction of injury (Cross and Harlow, 1965; Anderson and Chamove, 1980, 1981; Bayne et al., 1995; Reinhardt and Rossel, 2001; Novak, 2003). In one facility, 14% of the individually housed rhesus monkeys were identified as having wounded themselves over a 5-year period (Novak, 2003).

Multiple factors influence the development and expression of SIB. Males are more likely to express it than females (Lutz et al., 2003; Novak, 2003), and its prevalence varies tremendously among different primate species (Bloomsmith et al., 2004). Among macaques, self-damaging behavior seems to emerge around the time of adolescence or early adulthood, and rearing in a nursery by humans increases the likelihood of its appearance later in life (Novak, 2003). The duration of time monkeys are individually housed is positively associated with SIB (Novak, 2003), and living indoors versus outdoors (Schapiro et al., 1995) increases its prevalence. Monkeys receiving a greater number of procedures such as blood withdrawals or being relocated to a new cage are more likely to show SIB (Novak, 2003).

SIB in nonhuman primates also has clear underpinnings in the neuroendocrine and neurotransmitter systems (Kraemer et al., 1997; New et al., 1997; Tiefenbacher et al., 1999; Weld, 1999). Monkeys with SIB have a dysregulation of the hypothalamic-pituitary-adrenal axis, as indicated by a blunted cortisol response to mild stressors (Novak, 2003). Self-biting may serve to reduce distress as it appears to rapidly lower an escalating heart rate in rhesus monkeys (Novak, 2003), but a complete picture of the neurobiological foundation for the behavior has not yet been revealed. While external stressors seem to be an important environmental "trigger" for some bouts of SIB (Novak, 2003), not all primates exposed to these stressors show the behavior, and there is no obvious and immediate environmental trigger for many instances of SIB. There also appears to be a relationship between SIB and stereotyped behavior as those monkeys with records of self injury exhibit greater numbers of self-directed stereotyped behaviors than those who did not self injure (Lutz et al., 2003). This relationship is not surprising since some SIB may be expressed in a stereotypical fashion (e.g., repeated head-banging), and some SIB may be distinguished from stereotypies only by their potential to cause physical injury.

The development of SIB should be prevented in every case possible. While SIB is not thoroughly understood, it is clear that much of the information just described can be applied to prevention. Recommended procedures would include socially housing monkeys from birth, housing them outdoors, not exposing them to blood withdrawal procedures, etc., since all of these factors have a demonstrated influence on SIB. However, while following even these few recommendations would surely reduce the likelihood of primates developing SIB, currently these recommendations are not practical for all captive primates. Acquiring blood samples is important for primate health care, for example, and may not be avoidable (although the stressful nature of this procedure can, perhaps, be modified). Some, though not all, primates serving as subjects on infectious disease research protocols will probably continue to spend at least part of their lives housed individually. And, even if all new cases of SIB were prevented from this point forward, we would still need to treat primates with existing SIB for the next several decades, as they complete their long lives. For these reasons, treatment for SIB will continue to be necessary. The focus of this paper is on investigating one possible new approach to this treatment.

4. How do stereotyped and self-injurious behavior relate to welfare?

The presence of stereotyped or self-injurious behavior is important in informing determinations about animal well-being. One accepted standard to assess the psychological well-being of animals is to compare the behavior of captive animals to their wild counterparts (Novak and Suomi, 1988; Snowdon and Savage, 1989; Fraser and Broom, 1990; Webster, 2005). While there are limitations to this approach (see Webster, 2005), within this context exhibiting stereotyped or self-injurious behaviors is interpreted as evidence of reduced well-being since these behaviors are not a part of the wild animal's behavioral repertoire. These abnormal behaviors in captivity differ in frequency, form, context, and/or intensity from the behavior of their wild conspecifics, even though they may be statistically the norm for captive animals living in certain circumstances (Erwin and Deni, 1979; Bellanca and Crockett, 2002; Lutz et al., 2003). Stereotyped and self-injurious behaviors are interpreted to reflect poor coping within a given set of environmental demands on the animal (Carlstead, 1998), and are therefore seen as evidence of compromised well-being (Broom, 1991; Lawrence and Rushen, 1993; Carlstead, 1998). Although exceptions are also found, environments that elicit stereotypies are generally sub-optimal (Mason and Latham, 2004; Mason et al., 2007) and, for social species, are associated with reduced opportunities for social interactions with compatible conspecifics. In a practical sense, the presence of abnormal behavior raises concern about the welfare of individual primates by regulators, by those caring for the animals, and by members of the public. And for both welfare and practical reasons, most nonhuman primate enrichment programs have a goal of reducing such behaviors (see Crockett, 1998; Young, 2003).

However, recently Mason and Latham (2004) have concluded that within certain sub-optimal environments, individual animals that perform stereotypies show other evidence of improved welfare (e.g., reduced corticosteroid levels) in comparison to those who do not perform stereotypies. If this is the case for captive primates engaging in stereotypies, it might be undesirable to attempt to eliminate these behavior patterns. Empirical information is certainly needed to ascertain whether reducing or eliminating an existing stereotyped behavior could be harmful to the welfare of an individual primate. The behavior analytic techniques reviewed in this paper have been used to reduce aberrant behaviors, and to simultaneously increase the expression of more ‘‘normal’’ behavior in humans. This combination of behavioral goals may lead to better welfare outcomes than would simply reducing the stereotyped behavior without simultaneously shaping and reinforcing species-appropriate behaviors.

5. Treatments for stereotypy and self-injurious behavior

A wide variety of behavioral management techniques including operant conditioning, environmental enrichment, socialization, and drug therapy have been applied in attempts to reduce stereotyped and self-injurious behavior. With the myriad factors influencing the development and expression of abnormal behaviors and an incomplete understanding of its underlying neurobiology, it is not surprising that there is variation in how interventions affect categories of abnormal behaviors (Laule, 1993). For example, some feeding enrichment techniques reduce appetitive abnormal behaviors such as coprophagy and regurgitation (Bloomsmith et al., 1988; Baker, 1997; Lukas, 1999), but do not affect locomotor stereotypies or those that do not involve an oral component. Vast increases in the amount and quality of space reduce some stereotyped behaviors (Clarke et al., 1982), but more modest increases in cage size do not (Crockett et al., 2000). Inanimate forms of enrichment increased species-typical behavior patterns in young, singly housed rhesus monkeys as compared to controls with no enrichment, but even this fairly intense enrichment program did not affect time devoted to abnormal behavior (Schapiro and Bloomsmith, 1995). Increasing the complexity of the social setting reduced the expression of abnormal behaviors in some settings (Schapiro et al., 1996), but may increase it in others (see Bloomsmith et al., 2005, 2006).

A number of enrichment techniques have proven ineffective in addressing SIB, including puzzle devices (Watson, 1992; Kinsey et al., 1996; Novak et al., 1998), grooming boards (Kinsey et al., 1997), increased cage size (Jorgensen et al., 1997), and computer-assisted enrichment (Preilowsiki et al., 1988). SIB can persist after socialization (Kraemer and Clarke, 1990), but in some situations socialization may reduce it (Reinhardt and Rossel, 2001; Weed et al., 2003). Pharmacological intervention for SIB has shown considerable promise, and there is increased interest in documenting the effects of different types of pharmacological interventions (Eaton et al., 1999; Macy et al., 1999; Weld, 2002; Tiefenbacher et al., 2004).

6. Operant conditioning as a treatment for stereotypy and SIB

There are a small number of published reports that have quantitatively evaluated attempts to use operant conditioning techniques as a treatment for stereotyped behavior or SIB in nonhuman primates. We will review the techniques used and behavioral changes achieved, beginning with case studies and then describing three studies with larger sample sizes.

A male chimpanzee who displayed periods of regurgitation and reingestion following meals was treated with two 30-min training sessions daily (Morgan et al., 1993). Mild punishment (e.g., whistle, verbal reprimand) followed regurgitation and reingestion behaviors, and time outs were also employed. Positive reinforcement followed the cessation of regurgitation, or the expression of more desirable behavior. The target behavior (regurgitation) was reduced from 31 to 12% of time from the baseline to training conditions. However, even after some months of reduced levels of the target behaviors, when training sessions were performed less frequently, the behavior returned to baseline levels.

An adult female orangutan who exhibited self slapping and other stereotyped behaviors, especially when near her male companion, was treated with positive reinforcement training sessions (Raper et al., 2002). She was taught general body examination behaviors (e.g., showing hands, feet), control behaviors (e.g., come, remain at a location), and her calm behavior when near the male was also reinforced. Her stereotypic behavior was reduced from 24 to 11% of her time from baseline to training conditions, and the behaviors were at the lowest levels at the end of the 6-week long pilot study.

A young, male drill monkey showed reduced self-biting and levels of other abnormal behaviors after he and his group members were trained to increase positive social interactions (Cox, 1987; Desmond et al., 1987; Laule, 1993). This was accomplished by positively reinforcing eating and relaxing in close proximity to each other, and by increasing access of keepers to the animals by training the monkeys to move toward targets, and to achieve voluntary separation of animals who could then be worked with individually.

A male bonobo exhibited a great deal of stereotyped behavior (e.g., almost constant hand-clapping, pacing) and self-injurious behaviors including inserting his fingers/hands into his rectum which led to internal damage and bleeding (Prosen and Bell, 2000). His intensive treatment included positive reinforcement training sessions in which normal behaviors were rewarded and undesirable behaviors were ignored, social group manipulations, and drug therapy. The combination of these treatments was largely successful with his SIB only rarely recurring. In a somewhat similar case, a male chimpanzee was treated for severe and frequent SIB using positive reinforcement training for incompatible behaviors, additional enrichment, introduction of a social partner, and drug therapy. This intense combination therapy tremendously reduced the incidence of SIB (Bourgeois et al., 2005).

Seven adolescent male hybrid olive baboons with high rates of stereotypies and self-directed aggression were selected for study (Bourgeois and Brent, 2005). One of several interventions tested in succession was operant conditioning, made up of two daily sessions of 8–10 min each in which the baboons were trained using positive reinforcement to cooperate with husbandry procedures. Self-aggressive behavior resulted in a brief time out by the trainer, and other stereotyped behavior was ignored. Some of the behaviors trained were incompatible with the stereotyped behaviors being expressed, such as reinforcement for remaining in one position which made pacing impossible. These operant conditioning sessions reduced self-directed abnormal behaviors, regurgitation, whole body stereotypies, part-of-body stereotypies, and self-aggression. Alterations in these behaviors generalized to periods outside of when the trainer was present.

Baker and colleagues (Baker et al., 2003; Bloomsmith et al., 2004, 2005) compared the effectiveness of brief training sessions that included positive reinforcement training for body examination behaviors, targeting, and control behaviors on the behavior of 22 rhesus monkeys. The behavioral effect was measured outside of times the trainer was working with the animals to determine whether any behavioral change generalized to periods outside of when the trainer was present. There were no such generalized effects on the incidence of abnormal behaviors, and there was no change in the rate of self-biting associated with the training.

Twenty-two chimpanzees were trained for body examination behaviors, targeting and control behaviors, and these interventions reduced their stereotyped and other abnormal behaviors (such as coprophagy) from 2.5% of time during baseline conditions, to 0.4% of time during the training sessions (Bloomsmith et al., 1997). However, this behavioral alteration did not generalize to periods outside of when the trainer was present, as the behavior returned to baseline levels during those time periods.

Findings from this group of studies, although preliminary in nature, indicate that stereotyped behavior and SIB in nonhuman primates can be modified through the use of operant conditioning. Reductions have been shown in a variety of stereotyped behaviors in several nonhuman primate species living in both zoos and laboratories. In one case behavioral improvement generalized to periods outside of when the trainer was working with the animal (Bourgeois and Brent, 2005), but in two cases it did not (Bloomsmith et al., 1997, 2005). In no studies are the problematic behaviors eliminated, but statistically significant reductions have been achieved. Unfortunately the one study of rhesus monkeys showed no effect on their self-biting (Bloomsmith et al., 2005), which is a very important to reduce in these animals, but a study with baboons did show such a reduction (Bourgeois and Brent, 2005). Since this preliminary work is promising, it is appropriate to look more closely at the studies done with humans as a model for how we might best develop the work that is on-going with nonhuman primates.

7. The human model

In 1979, Harlow and Mears published a helpful book in which they described a lengthy history of nonhuman primate research based on findings and methods derived from prior human studies. This approach turned the concept of ‘‘animal models’’ on its head, illuminating the utility of the ‘‘human model’’. Similarly, by consulting the human-centered literature of environmental psychology, our research group has deployed the human model in our studies and evaluations of primate enclosures and habitats (Maple, 1983; Maple and Finlay, 1986, 1987; Ogden et al., 1990, 1993). The methodology of ‘‘Post-occupancy Evaluation’’ has been especially useful in measuring the behavioral effects of changes in the quantity and quality of animal holding facilities. Both the environmental psychology and applied operant training literatures are substantially broader and deeper for human subjects than they are for animals, and both are promising sources for new ideas and new applications in laboratories and in zoos. As Harlow and Mears (1979, p. 2) concluded, ‘‘There is far more reason to use human data to plan and interpret monkey research than to use monkey data to plan human studies.’’

8. Human studies of SIB and stereotypy

Behavioral treatments for stereotypy and SIB in humans have been conducted for more than 40 years and provide a vast source of potential interventions for both treatment and prevention of similar behaviors in captive animal environments. SIB and stereotypy in humans are largely confined to the developmentally disabled, especially those classified as mentally retarded or autistic. The incidences in these groups range from 7 to 23% (Kahng et al., 2002), and occur mostly in institutional settings. Topographies include head-banging, biting, pica, eye-poking, skin-picking, body-rocking, hand-flapping, rumination, and many others, all of which have been reported in nonhuman primates as well. While there are a number of hypotheses, the origins of these behaviors, certainly in any particular case, are largely unknown, but they may begin in humans as early as one month of age (Kurtz et al., 2003).

However the behaviors might begin, once they are emitted, the environment can exert quite significant effects on their frequency and intensity. Much of the recent research and treatment by the applied behavior analysis community has been devoted to identifying the events in the environment that serve to reinforce or maintain the behavior, and then designing contingency-management procedures to eliminate the reinforcement and thereby reduce the incidence of these behaviors. Even allowing for potential positive result bias (i.e., negative findings are less likely to be published), these efforts have had marked success. The Kahng et al. review (2002) of nearly 400 studies involving more than 700 patients revealed an overall effectiveness of behavior assessment and treatment of greater than 80% reduction in the frequency of the target behaviors, in this case stereotyped behavior or SIB. Such results are strong indicators not only of the power of properly designed and executed behavioral treatment procedures, but also of the major role that the immediate environmental plays in sustaining SIB and stereotypy in humans.

The most carefully executed of these kinds of studies involve a *functional assessment* or *functional analysis* of the conditions that modulate occurrences of the target behaviors (e.g., Iwata et al., 1994, 2000; Fischer et al., 1997; Piazza et al., 1998; Rapp et al., 1999; Kennedy et al., 2000; Hanley et al., 2003). In this case, the target behaviors are SIB and stereotyped behaviors. The procedures are quite sophisticated and detailed, but basically they seek to identify the environmental conditions, including specific reinforcement events, under which the behaviors occur or not. For a simplified example, a social reinforcer such as gaining the attention of caregivers, has been shown in many studies to maintain SIB in some individuals (e.g., Fischer et al., 1997). In other words, when the patient exhibits SIB, s/he gains the attention of those around him/her, and this attention increases the likelihood that the patient will exhibit SIB in the future. With a new patient, one might *assume* that attention plays a role in supporting SIB, but a functional assessment is necessary to determine if this is the case. The assessment would include instances of giving the patient caregiver attention to determine whether the SIB then increased, as well as instances of withdrawing attention following SIB to determine if SIB decreased. In other words, one demonstrates the *functional* significance of attention in controlling the occurrence of the SIB. Of course, even if contingent relations between SIB and attention are demonstrated, other conditions and consequences could also be important and their potential roles should also be assessed. The better one understands the role of events in the environment in influencing the behaviors of interest, the more effective the interventions one can design to moderate the behaviors.

Once maintaining events and conditions have been identified, there are a number of approaches to reducing the incidence of the aberrant behavior. One might assume that the simplest method to reduce the probability of the behavior occurring would be extinction (i.e., withholding reinforcement for a behavior that was previously reinforced, and thereby reducing the future frequency of the behavior), but typically, this is not the case. First, with SIB, simple extinction can be dangerous, because the behaviors may persist indefinitely through the prior effects of intermittent reinforcement, and because instituting extinction can, at least in the short term, *increase* the frequency and intensity of the SIB, leading to even greater injury. Second, simple extinction does not facilitate the expression of alternative, incompatible behaviors; and our goal is not only to reduce aberrant behaviors, but to build a new repertoire of non-injurious behaviors. This two-pronged approach of reducing aberrant behavior and simultaneously increasing more desirable, species-appropriate behavior, is consistent with the goals of many enrichment practitioners to enhance the diversity of natural behavior patterns among captive animals.

The precise techniques chosen for application depend on the outcome of a functional analysis determining the likely maintaining events, but typically combine two or more procedures. A common procedure is to combine extinction with *non-contingent reinforcement*. Under this arrangement, a reinforcer (e.g., attention, food treat) is delivered simply on the basis of time (in fixed or variable intervals) and without regard to what behavior the patient is engaged in—except the target behavior. The target behavior remains unreinforced so that extinction procedures are in effect for that particular behavior (e.g., Lindberg et al., 2003). Non-contingent reinforcement may induce other, incompatible, behaviors that can then be specifically reinforced to increase their frequency of occurrence. The increases in frequency and intensity of the target behavior elicited by simple extinction and which would be dangerous in the case of SIB, do not tend to occur. This is probably because the overall frequency of reinforcement over a certain time period (i.e., reinforcement density) is maintained or increased.

Another quite effective contingency is differential-reinforcement-of-other-behavior (DRO). Under this procedure, any behavior, other than the target behavior, is reinforced under a fixed-time schedule (after a fixed interval of time has passed). However, if the target behavior occurs, the clock will be reset, lengthening the duration to the next delivery of reinforcement. For example, if a monkey is grooming when the predetermined 1-min interval has passed, he will be reinforced with a bit of preferred food. If at the end of the next 1-min time point he is biting himself, he will not be reinforced, and it will be an additional minute more before the reinforcement can again be offered, depending upon the behavior he is showing. Again, this technique is ordinarily combined with other procedures to develop particular alternative behaviors.

A technique that may initially seem inapplicable to animals is *functional communication* (e.g., Hagopian et al., 1998). Once a reinforcer that maintains the target behavior is identified through a functional analysis, some patients can be taught to give an appropriate communicative response to control access to that same reinforcer. For example, if caregiver attention has been found to maintain SIB, the patient might be taught another way to request caregiver attention. This could be a verbal request or a simple gesture, depending on the level of verbal function in the patient. During training, the target response is prevented from occurring by physical constraint or other methods. Basically, this is a variation in training alternative behavior, shifting access to a reinforcer from the target behavior to a new response, and does not necessarily depend on any sort of verbal repertoire. When we train a dog to stand by a door and ‘‘speak’’ to allow it to go out, this might be described as functional communication.

Particular techniques are applied if ‘‘automatic reinforcement’’ (i.e., self-stimulation) is shown to be important in maintaining the SIB in an individual (e.g., Vollmer, 1994). The influence of automatic reinforcement is identified largely by elimination, showing that other sources effect no significant change in the behavior. Because the behavior–consequence relation is internal with automatic reinforcement, treatment can be a challenge (e.g., Ringdahl et al., 1997; Piazza et al., 1998; Ahern et al., 2003; Lindberg et al., 2003). One method shown to be effective is first identifying another preferred reinforcer (e.g., a toy, an activity), and making it available to the patient. That reinforcer is then withdrawn for a set period of time when the target behavior (SIB) occurs. This is a response-cost procedure (e.g., Falcomata et al., 2004) and is a form of punishment. Mild punishment such as this is sometimes viewed as necessary, especially when the potential for major injury, including death is evident. The use of special constraints and protective equipment are other ways of limiting access to automatic reinforcement and allowing other consequences to shape incompatible behaviors that are more desirable.

Training alternative behaviors very often involves initially identifying potential reinforcers other than those maintaining the target behaviors. This requires analysis, because even events like food presentation do not necessarily serve as reinforcers for all animals or in all contexts. Moreover, whether one is speaking of ‘‘primary’’ or ‘‘conditioned’’ reinforcers, history always plays a role. Animals show clear preferences for different consumables (which may vary significantly at different times and conditions) and properly assessing these preferences is essential to effective training. In the human clinical literature much emphasis is placed on preference assessment (e.g., Fisher and Mazur, 1997) and similar techniques could be used with animals (e.g., DeLeon and Iwata, 1996).

What can applied behavior analysis contribute to prevention as opposed to treatment of SIB and stereotypy? As with human institutional settings, for example, captive animal environments tend to be relatively impoverished, even those considered ‘‘natural’’. In addition, such settings tend to operate under strict routines of feeding, cleaning, and other activities, conditions ideal for engendering unwanted interim and schedule-induced behaviors as well as operant behaviors under control of response-independent consequences (see Bassett and Buchanan-Smith, 2007). Conditions for promoting variation in environments and behaviors, including alternative sources of stimulation and consequences (e.g., Catania and Sagvolden, 1980; Fisher and Mazur, 1997; Ringdahl et al., 1997; Lindberg et al., 1999; Miller and Neuringer, 2000; Tarou and Bashaw, 2007) would likely reduce opportunities for aberrant behaviors to develop. As Tarou and Bashaw (2007) carefully describe, a behavior analysis approach can bring new insights to understanding and predicting the effectiveness of various behavioral management procedures. Designing behavioral management programs from this perspective should increase the effectiveness of preventing SIB, stereotypies, and a variety of other problematic behaviors.

9. Comparing studies of operant conditioning between human and nonhuman primates

Virtually all the techniques found to be effective treatments of SIB and stereotypy in humans are directly applicable to similar behaviors in captive nonhuman primates. Indeed, a number of studies with SIB and stereotypy in animals have used some of the methods adopted from human clinical work (as described above), but the techniques are not as thoroughly or deliberately applied, nor are they as thoroughly studied as they have been with human subjects. Those working with nonhuman primates can use the human practitioners as a model for enhancing our efforts. Many facets of our work, both the application to treating individuals and the studies to scientifically document the outcomes, can be improved through such an approach. First, while case studies of individual subjects are sometimes criticized, the applied behavior analysis literature is built on such studies. The precise methods of experimental control and replication that that make a single-subject approach so useful in behavior analysis though, have not been used with nonhuman primates. For example, there have been no published studies with nonhuman primates that included a functional analysis of environmental features that might be eliciting or maintaining stereotyped behavior or SIB. With the multiple causal factors that can influence the development and expression of these behaviors, conducting a functional analysis could be very useful in better understanding and then ameliorating the behavior in individual cases.

Second, many of the nonhuman primate studies are brief, typically just a few weeks long, so sustained effects have not been adequately measured. The appropriate duration for study and analysis depends upon the frequency with which the behavior is expressed. For example, because SIB is often sporadically expressed, this is especially problematic in demonstrating that an intervention has been effective. Adequate durations for interventions could be gleaned from the human literature, which suggests a range of several months of treatment with follow-up data collected for more than a year (Ayllon and Michael, 1959; Kahng et al., 2002). Third, preference assessments to determine the most effective reinforcers are not reported in the nonhuman primate work, although this is routinely conducted for human patients.

Fourth and perhaps most importantly, the operant conditioning itself in the studies of nonhuman primates is very different from that used with the human subjects. The typical approach has been to teach the monkeys or apes a variety of behaviors that are useful for improving their care and husbandry, and to determine whether this type of training led to general behavioral improvement (Morgan et al., 1993 is an exception). In contrast, the approach to treating humans involves gaining a more precise understanding of the environmental context in which the target behavior is expressed, and methodically changing the reinforcement contingencies for that behavior through different techniques. Once these new contingencies are operating in the environment for the subject, and have been shown to reduce the incidence of the target behavior, this environmental condition is maintained so that the behavioral change is maintained. If the contingencies are returned to what they were prior to the intervention, one would expect that the behavior would revert to that as well. Since the effectiveness of the techniques used with humans is much greater, reducing self-injurious behaviors by an average of more than 80% (Kahng et al., 2002), these methods should be applied to the nonhuman primates.

Another major difference between facilities treating humans for stereotyped behavior and SIB, and those treating nonhuman primates is the academic background of people working with the human or nonhuman patients. To apply these sorts of procedures effectively, an experienced staff trained in behavior analysis is required. To most fully apply behavior analysis techniques, primate keepers and others in daily contact with captive animals should be trained in the functional analysis approach described above, the correct use of terminology used in behavior analysis, and to measure the outcomes of the interventions applied. They should be trained to carefully observe the behaviors of the animals in their care, and be aware of the influence of their own behavior when interacting with those animals. They must be aware that as caretakers, through inadvertent reinforcement, they might actually contribute to engendering or sustaining aberrant behaviors by, for example, giving attention to an animal engaging in the behavior. Options for obtaining this type of training include courses in operant conditioning, animal learning or the experimental analysis of behavior in psychology departments at colleges and universities, seeking information from the Association for Behavior Analysis (website address "http://www.abainternational.org/") or from the Cambridge Center for Behavioral Sciences (website address "http://www.behavior.org/"), attending workshops in animal training techniques (e.g. Primate Training and Enrichment Workshops, contact the first author for information), and reading publications in journals such as the *Journal of the Experimental Analysis of Behavior*, the *Journal of Applied Behavior Analysis*, and the *Behavior Analyst*. In the longer term, if behavior analysis techniques prove fruitful, training programs should be designed for the specific needs of those working with captive primates. The cost of this type of training and its implementation will be important to measure and consider.

10. Issues concerning application of the behavior analysis approach

One of the earliest criticisms of contingency-management treatments in dealing with human behavior was that the treatments only dealt with the ‘‘symptoms’’ and not some ‘‘underlying causes’’. Not unexpectedly, much of this criticism came from the psychoanalytic community, as well as other traditional approaches to psychopathology based on so-called medical models. Apparently, behavior-based treatments were considered in the same way one might think of the use of an opiate alkaloid for the ‘‘treatment’’ of cancer—it might alleviate the pain, but do nothing for the underlying *cause* of the disease. Behavior analysis has a quite different perspective on the nature of behavior. For the most part, the behavior of an organism is no more viewed as a symptom than is the motion of a body in physics. Both have their origins in the historical and current environment acting on the object of interest.

One prediction of the ‘‘symptom’’ view is that removal of one symptom by behavioral means will simply bring about another symptom. In exploring the question of ‘‘symptom substitution’’, Ullmann and Krasner asserted at least as early as 1975, that ‘‘. . . under scrupulous examination, at most one out of 20 cases where direct [behavioral] treatment has been used shows some later behavioral difficulty. Symptom substitution may therefore be said to be the exception rather than the rule . . . in the rare instances when new maladaptive behavior is manifested after direct treatment, there are many alternative and more parsimonious explanations . . .’’ (1975, p. 165). Literally hundreds, if not thousands, of studies since 1975 have only strengthened these conclusions.

Perhaps of more direct relevance to the audience of this paper is a study by Ayllon and Michael (1959), ‘‘The psychiatric nurse as a behavioral engineer.’’ This is one of the first and still most compelling demonstrations contradicting the traditional view that treating behavior is only treating a symptom of the problem. This venerable paper is certainly relevant to the issue of training non-behavior analysts, such as primate caregivers, to conduct behavioral assessments and treatment procedures. In this case, psychiatric nurses were taught to apply a variety of behavioral procedures for addressing many different behavioral problems of their patients. Despite their successes in mitigating many of these behavioral problems, the authors commented: ‘‘. . . even after a behavior had been modified, it was not uncommon to hear nurses remark, ‘We’ve changed her behavior. So what? She’s still psychotic.’ It seemed that once a persistent problem was eliminated, its previous importance was forgotten and other undesirable aspects of the patient’s repertoire were assumed to be the most important ones . . . they tended to be somewhat dissatisfied with any change less than a total ‘‘cure.’’ . . . an objection often raised against this approach is that the behavior changes may only be temporary. However, permanent elimination of ward behavior problems requires permanent elimination of the environmental variables that shape up and maintain them. The clinical belief that a favorable behavior change, if properly accomplished, will be permanent probably rests on a faulty evaluation of the role of environmental variables in controlling behavior.’’ (p. 334). In the case of treating nonhuman primates we would similarly expect that if improvements in behavior can be made through applying behavior analysis techniques, these behavioral changes would return to pretreatment levels if the techniques were suspended, just as enrichment practitioners would expect the removal of enrichment to lead to regression to the pre-enrichment state. For this reason, we will need to determine how to maintain the new system of contingencies operating in the subject's environment that have led to the improved behavior.

Another objection to contingency-management systems is that the effectiveness of these techniques is only derived from "damaged" subjects, perhaps imbedded in a "damaged" environment. First, the techniques are effective in modifying all sorts of behaviors from smoking to biting nails to pulling hair to scratching in "normal" individuals (unless one assumes that any undesirable behavior reflects a "damaged" person!). Moreover, the value of the techniques in normal training of a huge variety of behaviors is unassailable (e.g., Pryor, 1999). Captive environments, for humans as well as animals, *are* typically "damaged" in the sense of lacking the richness, complexity, and opportunities for many alternative behaviors present in the "natural" environments. An individual's history and the prevailing conditions in such environments may, in fact, come to control undesirable behaviors. Modifying this environmental influence to engineer more desirable behavioral outcomes is precisely the role that behavior analysts can play in the management of captive animals.

11. A philosophy of behavioral management

Behavioral management incorporates the use of environmental enrichment, animal training, environmental design, operational procedures, and an understanding of the natural behavior of the target species to improve animal care and enhance welfare. An important premise of behavioral management is that the individual tools of enrichment, training, and environmental design can be integrated to better achieve behavioral goals for captive animals than might any one technique applied in isolation (Whittaker et al., 2001). Using a methodical, scientific approach when addressing behavioral problems is an important element of this perspective on managing behavior. We believe that primate behavior can be effectively managed by the application of principles, methods, and procedures of the science of behavior as advocated, for example, by Pierce and Cheney (2004). In their view, agents of behavior change must be fully committed to a "scientific analysis of behavior" with *behavior* as the primary unit of measurement. Since behavior analysis has proved effective in modifying troublesome behavioral problems in human beings, the techniques of behavior modification should be applicable to other species. Indeed, Pryor (1999) has spent her entire career advocating and evaluating behavioral techniques for training and managing behavior in a variety of animals. Positive reinforcement through "clicker training" is the method of choice, avoiding the undesirable consequences that stem from aversive methods of control.

A philosophy of behavioral management, based partly on the science of behavior analysis, requires a scientific approach to the discovery and description of behavioral problems. For example, if SIB is observed, the following steps are required to address the problem (modified from Pierce and Cheney, 2004):

1. Specify the target behavior.
2. Describe the behavior in a way that the observer may count or time it.
3. Collect baseline frequency or duration data.
4. Identify appropriate consequences (positive/negative reinforcers).
5. Identify a responsible person to monitor the situation and serve as an "agent-of-change".
6. Clearly articulate the desired relationship of behavior to consequences.
7. Collect data on the effects of reinforcement.
8. Alter the plan if behavior change is not achieved.

9. Gradually remove arbitrary consequences and replace with natural reinforcers.
10. Generalize to a variety of settings and circumstances.

The empirical nature of behavioral management is of primary importance by this model. The problem is systematically observed and quantified; a method is devised to change the behavior and tested by observation and data collection, leading to conclusions based on measured outcomes. But as the above list also affirms, effective behavioral management is not simply an empirical process based on data acquisition and analysis of target behaviors but is also the proper application of the firmly established principles of the science of behavior analysis. We predict that using a system such as this, which is firmly based on the operant conditioning work applied to humans to address behavioral problems, will be a productive method for improving our understanding and treatment of similar behavioral problems in nonhuman primates.

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