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Modifying the behaviour of singly caged baboons: evaluating the effectiveness of four enrichment techniques

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Abstract

*Techniques to reduce or prevent behavioural disturbances in singly caged primates vary in form and effectiveness, with some behaviours being exceptionally resistant to treatment. Seven singly caged adolescent male olive hybrid baboons (*Papio hamadryas anubis*) were selected for behavioural intervention because of their severe abnormal behaviour. A continuous, all-occurrence sampling method yielded mean durations of abnormal and normal behaviour throughout the 10-week study. Analysis of baseline behaviour verified substantial durations of abnormal behaviour (mean = 9.80 min per 30-min observation period). We tested the effectiveness of four enrichment techniques: positive reinforcement training (PRT), food enrichment, non-food enrichment, and social enrichment (pair/trio housing). Each of the four enrichment conditions was implemented for a two-week period, with 10 30-min observations conducted per subject. We used repeated-measures analysis of variance to examine differences in behaviour durations between baseline and each enrichment condition. The social enrichment condition resulted in the most positive behavioural changes, including increased social behaviour and near elimination of abnormal behaviours (mean = 0.69 min per 30-min observation). Significant reductions in total abnormal behaviour levels were also found for other types of enrichment, but only social enrichment and PRT were effective in reducing whole-body stereotypies. Cage-directed and self-directed behaviours significantly decreased, whereas activity levels significantly increased during all enrichment conditions. The results of this project indicate that animate enrichment (human or conspecific stimulation), as opposed to inanimate enrichment, provides optimal means of behaviour modification for singly caged baboons. These findings have substantial implications for the welfare of captive primates in promoting successful therapeutic approaches for the behavioural management of laboratory primate species and for allocating limited enrichment resources.*

Keywords: *abnormal behaviour, animal welfare, baboon, behaviour modification, enrichment, positive reinforcement training*

Introduction

Chimpanzees (*Pan troglodytes*), macaques (*Macaca* sp.), baboons (*Papio* sp.) and other common laboratory primates are known to exhibit a number of diverse abnormal behaviours in response to socially restrictive or stimulus-poor environments such as single caging (Capitanio 1986; Brent *et al* 1989). The absence of social and environmental stimulation in conjunction with uncontrollable stressors can lead to degradation of the mental health and psychological well-being of these individuals, and the subsequent emergence of abnormal behaviour patterns (Erwin & Deni 1979; Brent *et al* 1998; Lutz *et al* 2003a; Novak 2003). To allow for a more species-appropriate environment, many laboratories have been moving in the direction of social housing of their primates, either in groups or in pairs, where possible and as resources allow. Nevertheless, protocol constraints, pair or group incompatibility, medical treatment and other circumstances often require single caging for varying durations. It is therefore important to understand the various abnormal behaviour patterns frequently exhibited by these primates, the contexts under which they arise and are maintained, and the effectiveness of interventional measures aimed at ameliorating these behaviours.

Many factors may contribute to the development, emergence and maintenance of abnormal behaviours, such as individual characteristics (eg sex, age, temperament), inadequate rearing experiences, environmental stressors, lack of adequate space or structures, absence of social interaction, lack of control over surroundings, or minimal sensory stimulation (Lutz *et al* 2000; Bellanca & Crockett 2002). It is likely that a number of these factors interact to produce the problem behaviours exhibited by singly caged primates. To further complicate the issue of etiology, disturbances may be elicited by conditions and stimuli very different from those that first triggered the behaviour. Over time, these behaviours can become coping mechanisms elicited in response to diverse stressors and less amenable to treatment because of their self-reinforcing nature (Laule 1993; Novak 2003).

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Single caging of primates is incompatible with most species' propensity to interact socially (de Waal 1991). Wild baboons, like other common laboratory primates, live in large, complex social groups where they spend much of their time interacting with conspecifics, as well as foraging for and processing food (Altmann 1980; Strum 1987). For singly caged primates, environmental enrichment can provide an outlet for these innate drives by offering occupational devices or materials that invite behaviours similar to those exhibited in the wild (Mellen & MacPhee 2001). Enrichment strategies for captive primates have typically consisted of three types of enrichment: food enrichment (the most common approach) (Bloomsmith *et al* 1988; Boccia 1989; Bayne *et al* 1991; Watson 1992), non-food enrichment (Line & Morgan 1991; Brent & Stone 1996), and social enrichment (Reinhardt *et al* 1988; Kessel & Brent 1997; Asvestas 1998; Lynch 1998). Of these methods, social, or animate, enrichment has been shown to be the most effective in reducing abnormal behaviour in singly caged macaques (Reinhardt *et al* 1988; Line *et al* 1990; Schapiro *et al* 1996a).

Positive reinforcement training (PRT), previously utilised solely to achieve the voluntary participation of captive animals in husbandry procedures (Reinhardt 1991; Knowles *et al* 1995; Laule *et al* 1996; Bloomsmith *et al* 1998), has more recently been considered as a form of enrichment (Bloomsmith 1992; Bloomsmith *et al* 1993; Schapiro *et al* 1995; Laule & Desmond 1998). During training sessions, Bloomsmith (1992) noted an observable reduction in abnormal self-directed behaviours in chimpanzees. Bayne *et al* (1993) also found a significant reduction in stereotypic, self-directed and cage-directed behaviours in singly caged rhesus macaques (*Macaca mulatta*) with 6 min per week per primate of unstructured human interaction and treat dispensing. Despite these positive findings, the use of PRT or human interaction with the specific intention of behaviour modification (reducing abnormal behaviour or otherwise improving the quality of behaviour) in animals has been attempted in only a few cases (Bielitzki 1979). Morgan *et al* (1993) found that training in conjunction with dietary change substantially reduced the frequency of regurgitation and reingestion in a captive chimpanzee. Using training, Laule (1984, 1993) successfully eliminated problem behaviours (eg aggression, regurgitation, biting) in a wide range of captive mammalian species, including primates. Bloomsmith *et al* (1994) demonstrated that dominant male chimpanzees could be trained to 'allow' subordinate group members to gain access to desirable food, thus diminishing feeding aggression in large group enclosures.

The principles of operant conditioning, such as positive reinforcement, form the core of behaviour modification techniques for human adults and children with behavioural and developmental disorders, mental retardation and mental illness (Volmer *et al* 1992; Marcus & Volmer 1996; Lovaas & Buch 1997; Britton *et al* 2000). These techniques facilitate the development and maintenance of alternative, more adaptive behavioural responses and eliminate, or dramatically reduce, self-stimulatory behaviours, stereotyped motor patterns (Rojahn *et al* 1997), self-injury (Schroeder *et al* 1990) and other abnormal behaviours. Given the success of operant conditioning techniques in ameliorating behavioural disturbances in human individuals, these techniques may prove efficacious for behaviour modification in nonhuman primates.

For nonhuman primates, most quantitative information on the effectiveness of behavioural management techniques (eg enrichment and PRT) in reducing or preventing abnormal behaviour is available for macaque species (Bayne *et al* 1991; Byrne & Suomi 1991; Watson 1992; Eaton *et al* 1994; Schapiro & Bloomsmith 1994; Kinsey *et al* 1996; Schapiro *et al* 1996a,b,c, 1997; Novak *et al* 1998) and chimpanzees (Bloomsmith *et al* 1988, 1997). Baboons, although common laboratory primates, are comparatively less well studied (Brent & Long 1995; Kessel & Brent 1995a,b; Pyle *et al* 1996). While commonalities exist across species, primates are also highly individualistic in response to environmental stimuli and stressors, and this variability has strong implications for the behavioural management of all species. More individualistic and behaviourally tailored intervention techniques may be required to reduce abnormal behaviour in singly caged primates.

The goal of this project was to evaluate the therapeutic value of different enrichment techniques in behaviourally disturbed baboons. From June to August 2002, we conducted a 10-week study evaluating the effectiveness of four behaviour modification techniques in reducing abnormal behaviour in seven singly caged adolescent male baboons: PRT, food enrichment, non-food enrichment, and social enrichment (housing in two pairs and one trio). The effect of each enrichment condition on mean duration of abnormal and normal behaviour was examined. It was hypothesised that all four behaviour modification techniques would result in the successful reduction of abnormal behaviour initially observed, and that specific abnormal behaviours would respond differentially to the four treatment conditions (eg food enrichment would be more effective in reducing abnormal self-directed behaviour and less effective in diminishing whole-body stereotypies).

Materials and methods

Subjects

The primates involved in this study were seven male olive hybrid baboons (*Papio hamadryas anubis*) housed at the Southwest Foundation for Biomedical Research, Texas, USA (mean weight = 11.4 kg, mean age = 4.2 years). All exhibited chronic abnormal behaviour and were targeted for intensive enrichment efforts by the Behavioral Intervention Program staff (see Table 1).

The baboons were individually housed in aluminium cages (0.88 × 0.9 × 1.3 m, length × width × height) opposite each other in the same room. The baboons shared the room with three adult females and one adult male olive baboon. All

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Table 1 Background history and baboon information at onset of study.

ID	Age (years)	Weight (kg)	Rearing history	Age at onset of single caging*	Characteristic abnormal behaviours	Social housing condition
A	3	9.1	Mother-reared**	1 yr, 8 mo	Regurgitation and reingestion, head toss	Trio with D and E
B	4	13.4	Nursery-reared***	1 yr, 10 mo	Regurgitation and reingestion, self-aggression, pacing, head toss, hair-pulling	Paired with C
C	4	12.4	Nursery-reared	1 yr, 10 mo	Regurgitation and reingestion, bouncing, tic-like head shake, rocking, self-aggression	Paired with B
D	3	10.5	Mother-reared	1 yr, 4 mo	Regurgitation and reingestion; mouth movement, wiggling digits, back flip, pacing, head toss	Trio with A and E
E	3	7.8	Mother-reared	1 yr, 5 mo	Regurgitation and reingestion, lining up biscuits on cage bars, head toss, food smearing	Trio with D and E
F	4	13.7	Mother-reared	1 yr, 11 mo	Regurgitation and reingestion, head toss, pacing, masturbation	Paired with G
G	4	13.2	Nursery-reared	1 yr, 10 mo	Self-aggression (biting wrists and ankles [no lacerations]), body bangs, face slapping, hyperaggression, pacing, head toss	Paired with F

* All subjects singly caged on 5 January 2000
** All mother-reared animals reared in outdoor uni-male, multi-female groups
*** All nursery-reared animals raised in the nursery until 7 months of age and then transferred to an outdoor peer group

individuals were moved to an adjacent room with identical lighting, temperature, dimensions and cages approximately every three weeks for cage and room cleaning. Room change was not considered a confounding variable in this study as the procedure had been in effect for two years and the schedules, caretakers, diet and roommates were not changed. Room lights were automatically controlled on a 12h:12h light:dark cycle with lights turned off at 1800h. Commercially manufactured monkey biscuits were given twice daily (at 0800h and 1600h) and fresh water was available *ad libitum*. In addition, the baboons received fresh fruit once per day (at 1500h–1700h), as well as a PVC feeding device, requiring manipulation in order to access treats inside, on Tuesday and Thursday mornings (retrieved after 24 h). A local FM radio station played throughout the day.

Observations

As the baboons were not habituated to observer presence, an 8 mm Sony™ camcorder (CCD-TRV108) was used for video recording in order to obtain a more accurate representation of behaviour. A continuous, all-occurrence sampling method yielded individual and mean durations of abnormal and normal behaviours (for descriptions, see Table 2). The Noldus Observer™ software package was used for all observations and database entry. Observations were distributed throughout the day, but did not take place during the periods 0900h–1000h and 1400h–1500h when the room was being cleaned.

The baboons were initially observed individually for two weeks in order to obtain a baseline analysis of behaviour. A total of 105 30-min baseline observations (52.5 h) were conducted, with 15 observations per individual. The four enrichment conditions (PRT, food enrichment, non-food enrichment and social enrichment) each lasted for two weeks during which each baboon was observed for a total of 10 30-min observations (70 observations per condition; 35 h). Thus, the baboons were observed for a total of 385 30-min observations (192.5 h) throughout the 10-week study period. The baboons received the respective enrichment every day (morning and afternoon at varied [unpredictable] times) during each condition, and a predetermined schedule was utilised to ensure that each individual was observed for proportionate times with and without the specified enrichment. During observations without enrichment, the enrichment item was either temporarily removed for 30 min, had been previously consumed and was no longer present, or had not yet been provided. For the training condition, the without-enrichment observations took place before or after training sessions. Because of the baboons' close proximity to, and the likelihood of distraction or frustration by, roommates with very different (and potentially more desirable) items/conditions, the order of the enrichment conditions was the same for all seven subjects. Routine daily and weekly enrichment continued throughout the conditions.

For the social enrichment phase of the study, it was not possible to conduct observations with and without the enrichment, as it would require removing the companion and singly caging the baboons. Thus, all 10 observations conducted during the social enrichment condition took place with companions present.

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Table 2 Categories of behaviours analysed, and details of component behaviours.

Behaviour	Description
Self-directed (abnormal)	Abnormal behaviours directed toward individual's body parts. Includes: lick-self, masturbate, poke-eye/salute, self-suck, cover eyes, hair-pull
Self-aggression	Violence directed toward own body (hit, bite, or bang against cage) with sufficient force to cause pain/injury
Regurgitation (reingestion)	Deliberately vomit (and often reingest) already swallowed food
Whole-body stereotypies	Rigid repetitive behaviours involving movement of entire body. Includes: stereotypic locomotion (repetitive whole-body movements excluding pacing or flipping), bounce, spin, rock, pace, flip
Part-of-body stereotypies	Inflexible repetitive behaviours involving only part of the body. Includes: nod (back and forth or side to side movement of head), head toss, wiggle digits, mouth movements
Other abnormal	Behaviours occurring at low frequency. Includes: depression posture, bizarre posture, hyperaggression, hypersubmission, food smear, faeces paint, coprophagy, drink urine, polydipsia (excessive drinking), hair eat, other abnormal behaviours
Active	Normal species-typical activity; also included state of active alert
Cage-directed	Oral or manual manipulation of cage or water dispenser
Self-directed (normal)	Groom or manipulate hair or body with fingers or teeth
Enrichment-directed	Any activity involving provided stimuli. Includes: bite/attack, display with, manually manipulate, orally manipulate, play or rest with enrichment
Social	Behaviours involving interaction with conspecifics. Includes: affiliative, aggressive, sexual, and submissive behaviours

Research design

Condition I: Positive reinforcement training (PRT)

PRT sessions took place twice per day and each lasted approximately 60 min. Individual training was divided between the baboons so that each received approximately 8–10 min of training per session. Using a metal clicker as a conditioned reinforcer and a small food reward (eg dried fruit), all seven individuals were trained to cooperate for various husbandry procedures. Behaviours chosen for shaping were within the behavioural repertoire of the species and were often incompatible with abnormal behaviours — for example, stationing the animal in the front of the cage with hands and feet on the caging made pacing and self-directed behaviour impossible. A 10-s time-out coupled with a hand signal was utilised only in response to self-aggression. More benign abnormal behaviours (eg flipping, pacing) were ignored, thus not reinforced. Under no circumstances was food or water withheld or physical punishment utilised in behaviour shaping, and participation was entirely voluntary.

Condition II: Food enrichment

Food enrichment entailed the provision of novel foods, frozen fruit/juice, pureed or other textured foods, seasonal fruits, whole foods or foods that were challenging to process (eg corn in the husk) and foraging/feeding devices requiring extra manipulation to extract a desired food (eg Challenger Ball™ [Bio-Serv, Frenchtown, New Jersey, USA]). Items were offered twice per day and a foraging/feeder device was given to two individuals every day. To avoid overfeeding, on Tuesdays and Thursdays when weekly PVC feeders were given, the foraging/feeder devices for this condition were not given and extra food enrichment was given only once (in the afternoon). Baboon G exhibited self-aggressive behaviour in response to novel stimuli (eg toys or feeders) and feeders were removed promptly from his cage when empty in order to minimise the distress of having the device on the cage all night, while not withholding food enrichment from him all together.

Condition III: Non-food enrichment

Non-food sensory items were offered twice per day. These included toys with different textures (eg Rhino Toys™, Fleece Boards™), destructible and indestructible items (eg blank newsprint, Nylabones™), visual stimuli (eg bubbles, bright pictures) and auditory enrichment (eg nature sounds, Bio-Serv™ primate rattles) (all trade mark items: Bio-Serv, Frenchtown, New Jersey, USA; also used Sassy Inc, Kentwood, MI, USA). So as not to provoke abnormal behaviours with potentially frightening items such as mirrors, items were shown to the primates before placing them in or on their cage. The baboons were able to 'choose' presented items by extending their hands to accept the toy or to choose between two items. Items were not given or were promptly removed if the individuals reacted negatively to their presence. For self-aggressive individuals, every effort was made to utilise items or methods that did not elicit this response (eg showing items instead of placing them on or in caging).

Condition IV: Social enrichment

The baboons were sedated and moved to larger cages (1.5 × 1.1 × 1.5 m, length × width × height) where they were

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housed in two pairs and one trio according to variables such as age, weight, rearing history, dominance rank, temperament and observed interactions while singly caged. The amount of space per individual was similar (pairs) or slightly less (trio) than in single cages. The sedated companions were given identification collars (for colony management purposes), then placed within the same cage and allowed to wake up together. The baboons were monitored for potential incompatibility and injury. All attempts were made to ensure animal safety during the pairing process and preparations were made to remove companions if necessary. Biscuits were spread out during feedings to ensure equal access and to minimise aggression.

Data summarisation and analysis

Individual and mean durations and descriptive statistics for all behaviours were obtained using Noldus Observer™ software. The durations of time (seconds per 30-min observation per condition) engaged in abnormal and normal behaviour for each individual, as well as for the composite group, were combined using Microsoft Excel™. In addition to the eleven behaviour categories listed in Table 2, total abnormal behaviour was also analysed, yielding 12 behaviour categories for analysis. Using a standard block design, we used repeated-measures analysis of variance to determine the change in behaviour across the five conditions and to compare the treatments. Responses of actual duration were log-transformed to stabilise variability. For each behaviour category, the log of the duration for each enrichment condition was compared to the log of the duration of the baseline and the other enrichment conditions, generating a total of 10 pairwise comparisons. A Bonferroni multiple-comparisons test corrected for multiple pairwise testing (0.05/10 = 0.005) and controlled for experiment-wise error rate by maintaining an overall alpha level of 0.05.

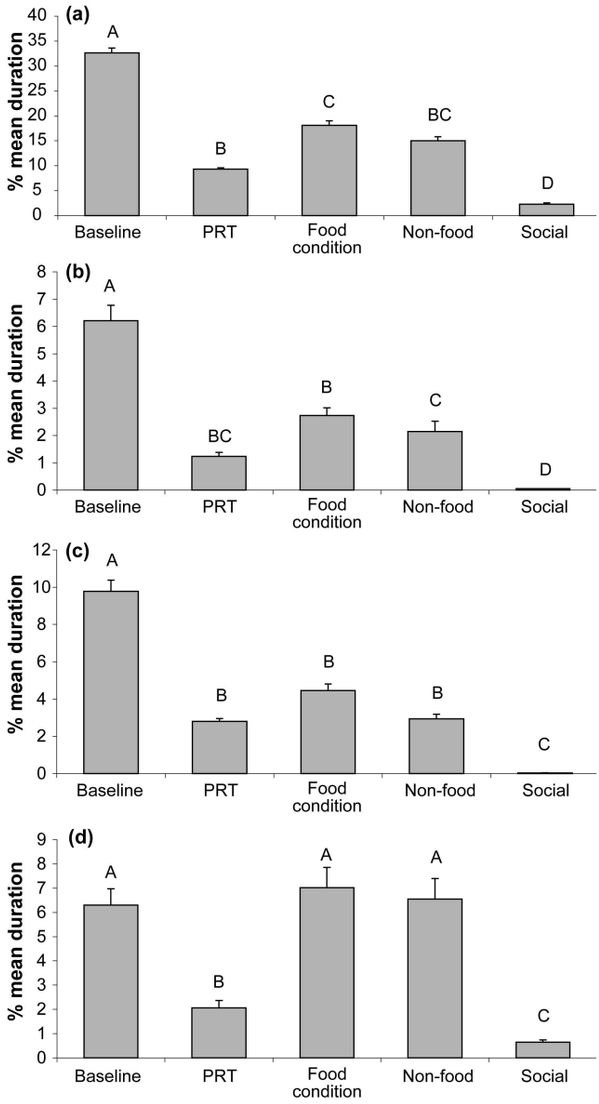
In addition to evaluating the impact of different types of enrichment on abnormal behaviour, we were interested in the generalisability of behavioural effects of the enrichment to periods when the enrichment was unavailable. Observations for the PRT, food, and non-food conditions were summarised as those with and without the enrichment available and compared using paired-samples *t*-tests.

Results

Abnormal behaviours

Significant differences were found across conditions for all abnormal behaviour categories (total, $F_{4,374} = 11.09$, $P < 0.001$; abnormal self-directed, $F_{4,374} = 50.52$, $P < 0.001$; whole-body stereotypies, $F_{4,374} = 30.50$, $P < 0.001$; part-of-body stereotypies, $F_{4,374} = 39.82$, $P < 0.001$; regurgitation, $F_{4,374} = 93.03$, $P < 0.001$; self-aggression, $F_{4,374} = 9.36$, $P < 0.001$; other abnormal, $F_{4,374} = 49.24$, $P < 0.001$). Total abnormal, abnormal self-directed, regurgitation and other abnormal behaviours decreased significantly from baseline levels in all enrichment conditions (see Figure 1). Only PRT and social enrichment effectively decreased whole-body stereotypies. Part-of-body stereotypies decreased significantly from baseline levels (mean = 1.0, standard error [SE] = 0.32 min per observation) in all enrichment conditions, with the lowest levels occurring in the non-food enrichment condition (mean = 0.19, SE = 0.11 min per observation). Self-aggression occurred at highest levels during the baseline condition (mean = 0.55, SE = 0.34; range = 0.00–2.55 min per observation) and decreased significantly in all enrichment conditions (mean = 0.18, SE = 0.12 min per observation); however, the enrichment

Figure 1



Percent mean durations (min per 30-min observation) of behaviour category for group (n = 7) across five conditions: baseline, PRT, food enrichment, non-food enrichment and social enrichment. Conditions with the same letter are not significantly different at the 0.05 level. **(a)** Percent mean durations of total abnormal behaviour; **(b)** Percent mean durations of abnormal self-directed behaviour; **(c)** Percent mean durations of regurgitation (reingestion); **(d)** Percent mean durations of whole-body stereotypies.

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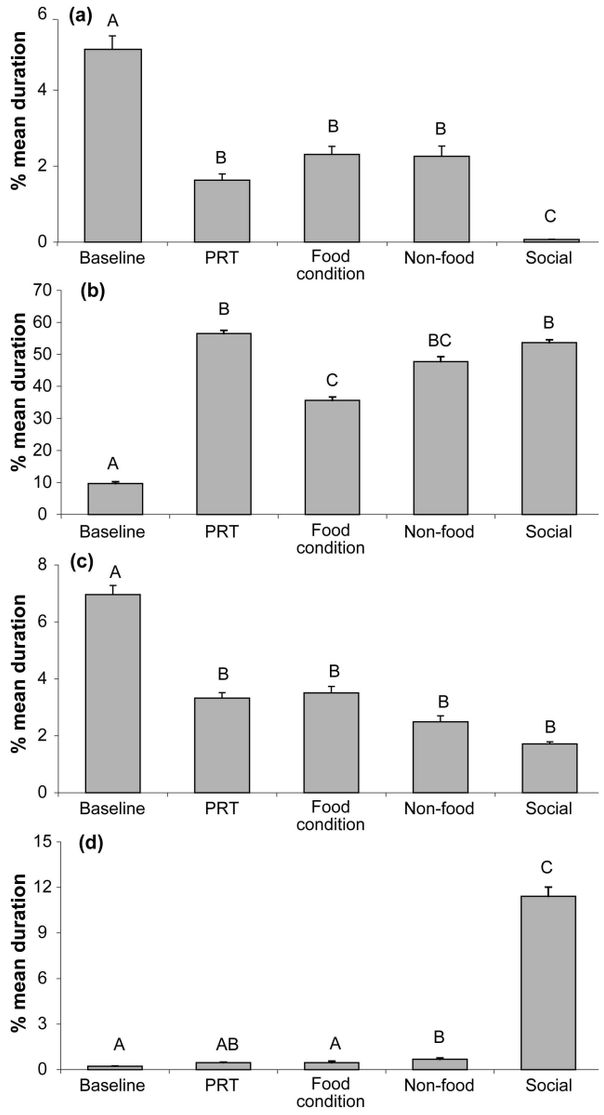
Figure 2



Percent mean durations (min per 30-min observation) of behaviour category for group (n = 7) across five conditions: baseline, PRT, food enrichment, non-food enrichment, and social enrichment. Conditions with the same letter are not significantly different at the 0.05 level. **(a)** Percent mean durations of other abnormal behaviour; **(b)** Percent mean durations of species-typical activity; **(c)** Percent mean durations of normal self-directed behaviour; **(d)** Percent mean durations of social interactions.

conditions did not differ significantly from each other for this behaviour ($P > 0.05$).

Additionally, we found that total abnormal behaviour for each enrichment condition was lower than baseline levels (mean = 9.80 min per observation), both when the specific enrichment was available and when it was not (PRT, with enrichment = 1.61 min per observation, without enrichment = 4.05 min; food enrichment, with enrichment = 4.05 min per observation, without enrichment = 7.29 min; non-food enrichment, with enrichment = 2.63 min per observation, without enrichment = 6.56 min). Despite these positive changes, total abnormal behaviour was significantly higher when enrichment was not available (PRT, $t = 5.89$, $df = 6$, $P < 0.001$; food enrichment, $t = –6.25$, $df = 6$, $P < 0.001$; non-food enrichment, $t = –4.41$, $df = 6$, $P < 0.005$).

Normal behaviours

All normal behaviours were found to differ significantly across conditions (normal self-directed, $F_{4,374} = 21.79$, $P < 0.001$; enrichment-directed, $F_{4,374} = 17.26$, $P < 0.001$; activity, $F_{4,374} = 163.34$, $P < 0.001$; cage-directed, $F_{4,374} = 95.29$, $P < 0.001$; social interaction, $F_{4,374} = 142.38$, $P < 0.001$). Duration of cage-directed behaviour decreased significantly from baseline levels (mean = 5.85, SE = 0.4 min per observation) in all enrichment conditions ($P < 0.05$), and occurred the least with social enrichment (mean = 0.2, SE = 0.03 min per observation). Enrichment-directed behaviour, while increasing slightly in the non-food condition (mean = 6.88, SE = 2.38 min per observation), did not differ significantly from baseline (mean = 3.54, SE = 0.51 min per observation) in any condition, except social enrichment where it decreased significantly (mean = 0.76, SE = 0.27 min per observation). Species-typical activity, normal self-directed behaviour, and social interaction differed significantly across conditions (see Figure 2).

Group formation results

Pairing was successful for all seven individuals, with no serious injuries or overt aggression observed. Rough-and-tumble 'wrestling' was observed and dominance positions were quickly established, with all dominance disputes followed by bouts of grooming. All individuals were observed gaining easy access to food, receiving and initiating grooming, and engaging in species-typical social interaction.

Self-aggression and Baboon G

All novel items elicited a self-aggressive response in Baboon G and were promptly removed or not offered. Non-tactile enrichment only was utilised during the non-food condition (eg music, bubbles, showing toys), with magazine pictures most successful in decreasing self-aggressive behaviour. During these sessions, durations of self-aggression decreased to 0% of the observations. During social enrichment, Baboon G began redirecting aggression to a large plastic ball, holding the ball to his chest and repeatedly biting it in place of his own body. These balls had been present in his cage previously; however, he had never been observed utilising them for this potentially therapeutic purpose. In the final days of the social enrichment condition, self-aggression was not observed at all.

Discussion

This project evaluated the efficacy of four enrichment techniques to ameliorate chronic abnormal behaviour patterns in singly caged baboons. The subjects of this intensive behaviour modification approach exhibited many forms of

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stereotypical and abnormal self-directed behaviours during baseline and enrichment conditions; however, enrichment significantly reduced the durations of abnormal behaviour. All seven baboons were male, individually housed at a young age and for a lengthy period of time — all risk factors for the development of abnormal behaviour, as identified in singly caged rhesus macaques by Lutz *et al* (2003b).

Overall, we found that all enrichment conditions significantly decreased abnormal behaviour and positively affected species-typical behaviour. Social enrichment (pair/trio caging) and PRT were the most effective means of behaviour modification for the baboons. Training also had the greatest generalised positive effect, with the lowest levels of abnormal behaviour persisting during the observations conducted without enrichment. These findings highlight the importance of the 'social' aspect of enrichment techniques, and their superior ability to reduce chronic abnormal behaviour.

Single caging entails a reduction in the size and complexity of the physical environment, as well as a lack of social contact and stimulation when compared to the environment experienced by most group-housed animals. We argue on the basis of our results that it is probably the reduction in or loss of social contact that is most salient to the development of behavioural pathologies, and that enrichment techniques that focus on increasing social stimulation are the most effective in reducing their incidence (Line *et al* 1990; Schapiro *et al* 1996b).

All enrichment conditions utilised novel items and methods, and the dramatic decreases in abnormal behaviour may be due, in part, to novelty effects. Rapid habituation to enrichment is a common problem with captive primates and it is possible that these enrichment techniques may not have had such a profound impact on behaviour if used over a longer period of time or if novel items failed to be added on a continual basis (Line 1987; Line *et al* 1991; Brent & Stone 1996). As animate stimuli are consistently novel, rapid habituation may be less likely to occur with social enrichment (Reinhardt 1990). In support of this finding, the subjects of this study were later moved to outdoor social groups and observations over the following twelve months indicated that abnormal behaviours remained at a low level (unpublished data).

Most environmental enrichment programmes focus on the provision of feeding enrichment and toys to singly caged nonhuman primates. These enrichment items are often expensive, destructible and time consuming to fill, clean and maintain. While a comprehensive enrichment programme should include varied techniques to appeal to different individuals, an increased emphasis on conspecific and other social stimulation may have a greater impact on abnormal behaviour in nonhuman primates.

Social enrichment

Every abnormal behaviour category analysed in this study occurred at the lowest level during the social enrichment condition (or occurred at a level that was not significantly different from the lowest level), results supported by similar studies conducted with baboons and other primate species (Line *et al* 1990; Kessel & Brent 1997, 2001; Lynch 1998; Reinhardt 1999). The dramatic reduction in regurgitation during this condition suggests that the previously high level of this behaviour might be related to stress or boredom associated with single caging. Like other common laboratory primates, baboons are inherently social and are denied critical social interaction when singly caged (de Waal 1991). Altmann and Altmann (1970, p 47) noted that savannah baboons (*Papio hamadryas cynocephalus*), unless severely injured or incapacitated, "are never completely isolated from a social group". Allowing tactile contact in captive primates may be of principal importance in promoting psychological well-being, by inviting species-typical behaviours such as grooming and play, and facilitating appropriate means of moderating the impact of environmental stressors (Reinhardt *et al* 1988). A companion represents a dynamic, engaging, consistently novel and responsive stimulus that is more potent and enduring than any inanimate object (Reinhardt 1990). Where possible, a move toward social housing may ultimately save time and money, as the primates require less additional enrichment and monitoring of psychological well-being by staff. The results of our study indicate that, where resources allow and companions are compatible, pair or small group housing of laboratory baboons is an effective means of reducing and eliminating abnormal behaviour.

Positive reinforcement training

Total abnormal behaviour and whole-body stereotypies were lower in this condition than in the other inanimate enrichment conditions, demonstrating that training is another effective means of targeting and reducing abnormal behaviour in captive primates (Bielitzki 1979; Laule 1993; Morgan *et al* 1993). In a recent evaluation of training efforts for captive primates, Schapiro *et al* (2003, p 184) conclude that both "desirable and undesirable behaviours can be manipulated using these (positive reinforcement) techniques". While this study did not examine the behavioural effects of unstructured human interaction, such as play, structured PRT sessions have been reported to be more beneficial and effective in moderating abnormal and undesirable behaviour (Bloomsmith *et al* 1997; Baker *et al* 2003). Training allows for precise targeting and modification of specific problem behaviours, thus providing more control and direct application in behavioural intervention.

PRT may be an effective enrichment strategy (Bloomsmith *et al* 1993) as well as a means of behaviour modification for severely disturbed primates. Training sessions offer an opportunity to voluntarily engage in and succeed at problem-solving tasks, to 'work' for a desired reward, and to make choices with observable environmental outcomes (Laule & Desmond 1998). Similar to the dynamic environment created by a conspecific companion, training provides a consistently novel, stimulating and responsive environment that is both engaging and constructive for captive

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primates. Furthermore, training increases predictability and control for the participant, two aspects considered influential in the psychological well-being of captive primates (USDA 1991; NRC 1998). As training may be challenging to implement on a large scale, it might first be applied to the most severely disturbed individuals, such as those that are self-aggressive or self-injurious.

Food enrichment

Feeding and foraging devices have been shown to be effective in temporarily reducing abnormal behaviours and inactivity in singly caged rhesus macaques (Meunier *et al* 1989; Bayne *et al* 1991; Novak *et al* 1998), long-tailed macaques (*Macaca fascicularis*) (Watson 1992) and baboons (Brent & Long 1995; Pyle *et al* 1996). For this study, food enrichment was successful in decreasing abnormal behaviour from baseline levels; however, it was not the most successful of the four techniques implemented. Whole-body stereotypies actually increased significantly from low levels during PRT to levels not significantly different from baseline during food enrichment, a response similar to that found with singly caged rhesus macaques and long-tailed macaques in response to a foraging/feeder device (Watson 1992; Lutz & Farrow 1996). Brent *et al* (1998) note that repetitive stereotypies might be negatively affected by enrichment that increases arousal, a likely outcome when offering desirable yet hard-to-access food. The increase may have been due to a general anticipation of desirable food throughout the condition, despite maintaining unpredictable schedules (Bloomsmith & Lambeth 1995). Interestingly, regurgitation and reingestion of food remained significantly decreased from baseline levels during food enrichment, suggesting that sweet/desirable food does not increase this behaviour in baboons.

Non-food enrichment

Non-food enrichment effectively reduced abnormal behaviour in all categories, except whole-body stereotypies, from their previous baseline levels. These positive results may be attributed to sustained novelty because different items were provided daily. The baboons were also allowed to 'choose' one of two items presented to them by reaching for a desired toy, and it is possible that choosing an item makes it more interesting and instils a sense of control in the individual.

Novel items alone have not been shown to be as effective as other methods in reducing stereotypic behaviour patterns in rhesus macaques (Line & Morgan 1991), and they may be more effective if combined with other forms of enrichment. Occasionally transferring singly caged primates to an enriched activity cage with toys, perches and feeders may be one means of decreasing abnormal behaviour and inactivity (Kessel & Brent 1995a,b); however, abnormal behaviours may return to elevated levels once back in the home cage (Bryant *et al* 1988). Providing novel opportunities for increased exploration and object manipulation inside home cages may be a more successful means of counteracting abnormal behaviour in singly caged primates. Overall, non-food enrichment resulted in positive changes in behaviour for the baboons and should continue to be an important part of behaviour modification and environmental enrichment strategies.

Individual sensitivity

The results of this study illustrate that any single form of enrichment may not be sufficient to reduce all abnormal behaviours for an individual, and may even exacerbate particular disturbances. Enrichment devices can be overwhelming, frustrating (eg challenging feeding devices), or frightening to individuals with profound behavioural disturbances. In accordance with recent findings by Lutz *et al* (2003a) and Novak (2003), the observation that certain conditions tended to elicit self-aggressive responses from the baboons in this study suggests that this behaviour is very closely associated with stress.

While it has been shown that feeding enrichment can be successful in temporarily reducing various abnormal behaviours, severe self-directed behaviours (eg self-aggression) can remain unaffected or even intensified by feeding devices (Kinsey *et al* 1996). Novak *et al* (1998) found that, similar to the behaviour of Baboon G, some singly caged rhesus macaques would bite themselves while trying to access food within a feeding device. Although there has been no evidence of a direct physiological link between self-aggression and a highly reactive temperament in monkeys, such highly reactive individuals seem to consistently respond negatively (eg to be easily agitated, hyperaggressive, self-aggressive) to unpredictable stimuli, novelty and stress (Chase *et al* 1999). This distinctive quality of many severely disturbed primates complicates methods of behavioural intervention, as standard enrichment techniques are often developed and implemented based on their novelty and unpredictability. Ironically, these features that are so appealing to healthy primates can be overwhelming and detrimental for psychologically disturbed individuals. For this reason, it is important not to assume that enrichment techniques will have a favourable effect on all or most primate species, but to approach behavioural intervention with attention to specific individual and behavioural needs where possible and as resources allow.

Conclusions

Each enrichment condition resulted in measurable positive changes in behaviour, with social enrichment and PRT most effective in reducing abnormal behaviour in seven adolescent baboons. These techniques are probably the least commonly used behavioural intervention techniques for laboratory primates and may prove efficacious in future implementation. Where single caging is required, PRT may be more effective than standard enrichment approaches in reducing abnormal behaviour. By assessing different responses to enrichment, more individualistic and behaviourally tailored intervention strategies may be formulated and implemented in order to reduce abnormal behaviour and ensure the psychological and behavioural health of singly caged primates.

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Animal welfare implications

Where social and environmental conditions differ markedly from a species' natural surroundings, the emergence and maintenance of abnormal behaviours are indicative of poor psychological well-being. Increased scrutiny of enrichment techniques and stringent evaluation of their effectiveness in ameliorating behaviour disturbances helps to ensure the promotion of psychological well-being for all captive primates. By assessing the effectiveness or ineffectiveness of behavioural modification techniques, a better understanding of the factors that influence the development and maintenance of abnormal behaviour, as well as knowledge of how to successfully treat and prevent these disturbances, may be attained.

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