Quantitatively Tested Environmental Enrichment Options for Singly-Caged Nonhuman Primates: A Review

Viktor Reinhardt and Annie Reinhardt
4605 Crescent Road,
Madison, WI 53711

ABSTRACT

Quantitative information regarding environmental enrichment for singly-caged nonhuman primates was summarized. Of 52 data-supported publications reviewed, 37 made clear reference to the period of time subjects were exposed to the enrichment at data collection. The majority (78 %) of studies examined inanimate, the minority (22 %) animate enrichment strategies.

Compatible companionship has a therapeutic effect on behavioral disorders, providing long- term stimulation of a great variety of species-typical social behavior patterns. Inanimate objects have little impact on behavioral disorders, but some of them provide appropriate means for the expression of species-typical activities. Foraging devices considerably extend foraging times while temporarily ameliorating behavioral disorders. More space is less likely to enrich the environment than are social stimulation and increase in cage complexity.

Future research will have to take dependent variables such as age, gender, and the period of time the subject is exposed to the enrichment at the moment of data collection more systematically into account to allow an integrative, comparative evaluation of different enrichment options.

INTRODUCTION

The amendment to the Animal Welfare Act, passed by Congress in 1985 and promulgated by the Department of Agriculture in 1991, prompted numerous efforts in the development of environmental enrichment strategies in compliance with the new rules. A bibliography compiled by the National Agricultural Library in 1990 lists 186 publications on this issue (USDA, 1991 a). Forty-rive of them deal with singly-caged animals, with only 19 providing quantitative data while the other 26 are descriptive, technical and/or methodological reports. The relatively small number of articles -dealing with singly-caged animals is surprising (Fajzi et al., 1989), since the majority of laboratory primates have conventionally been singly-caged (Bayne, 1989b; Burt & Plant, 1990; Line et al., 1990a). Not less surprising is the paucity of quantitative information, as "much time and money may be wasted and animals may even be harmed, if enrichments are not appropriately evaluated" (Bloomsmith et al., 1991). "Most reports simply describe the [enrichment] objects that were provided or comment briefly about how they were used by the animals" (Line & Morgan, 1991).

The present paper is an updated review of environmental enrichment for singly-caged primates. It focuses strictly on studies with quantitative data regarding the stimulatory effect of environmental enrichment options on singly-caged animals. In accordance with the Final Rule concerning the care of nonhuman primates, "environmental enrichment" was

defined as anything that provides "means of expressing non-injurious species-typical activities" (USDA, 1991 b).

The amelioration or disappearance of behavioral disorders (e.g., self-abusive behavior, stereotypic non-goal-oriented patterns of locomotions and postures) is often taken as a criterion of improved 11 psychological well-being" (USDA, 1991 a) in accordance with the Final Rule (Bloomsmith et al., 1988; Chamove & Anderson, 1989; Meunier et al., 1989; Rupiniak & Iverson, 1989; Line et al., 1990a; CCAC, 1993). The present review, therefore, also takes into account publications that provide data concerning the impact of environmental enrichment strategies on the occurrence of behavioral disorders.

INANIMATE ENVIRONMENTAL ENRICHMENT

a) Manipulable Objects

Gnawing sticks were the first enrichment objects ever tested. Champoux et al. (1987) provided 48 singly-caged adult female and male rhesus macaques (*Macaca mulatta*) each with a deciduous branch segment for a period of 12 weeks. To assess the use of the sticks, their reduction in volume was measured every two weeks. Twenty-six animals used their sticks for gnawing and manipulating throughout the 12 weeks; five animals exhibited initial interest but stopped using their sticks after two to six weeks. Reinhardt (1989) conducted a follow-up study with 25 singly-caged adult male rhesus macaques that had been exposed to branch segments for one year. Thirteen subjects used their sticks during a two-hour observation session. The pieces of wood distracted the animals on average 3% of the time. A study of rhesus macaques living in pairs revealed a significant age-dependence of stick usage. After 1.5 years of exposure to stick gnawing, 18 subadults (3.5 - 4 years old) spent on average 9.5% of one-hour recordings gnawing and manipulating their pieces of wood, while 48 adults (9 - 30 years old) did so during only 2.8% of time (Reinhardt, 1990a). Gnawing sticks did not diminish the occurrence of behavioral disorders in 12 adult singly-caged rhesus macaques during four weeks of exposure (Line & Morgan, 1991).

Line et al. (1989a) tested the novelty effect of interlocking plastic blocks and nylon balls in ten singly-caged adult rhesus macaques. These items elicited non-injurious activities such as manipulating, rubbing and smelling. Nine animals were distracted by the blocks during the first 25 minutes of exposure; all animals were distracted by the nylon ball. Mean duration of object interaction was 19%, and 20% respectively of time. Bayne (1989a) extended the nylon ball study and tested singly-caged rhesus macaques (M. mulatta), stump-tailed macaques (*M. arctoides*) and long-tailed macaques (*M. fascicularis*) of different age classes that were exposed to the balls for three months or longer. "Approximately 10% of the monkeys (average of 34 animals) in a room utilized the ball at any given time" (Bayne, 1989a). Line (1987) reported that 10% of 148 rhesus macaques and none of 33 long-tailed macaques paid attention to nylon balls (during an unspecified test period) after 11 months of exposure. Introducing nylon balls to 12 adult singly- caged rhesus macaques for four weeks did not affect the occurrence of behavioral disorders (Line & Morgan, 1991).

Crockett et al. (1989) presented five singly-caged pigtail macaques (*Macaca nemistrina*) and ten singly-caged long-tailed macaques of different age classes with rubber toys once or twice a day for up to seven weeks. The toys elicited manipulating, gnawing and licking in 11 animals. The authors reported greater active toy interest in pigtail macaques than in long-tailed macaques, with males not differing from females, and captive-born not differing from wild-born subjects. The monkeys were distracted by the toys approximately 7% of one-hour sessions, 14 days after repeated temporary exposure. The authors found no evidence that the toys affected the level of behavioral disorders (cf. Line et al., 1991a).

Rubber toys have also been tested in chimpanzees (*Pan troglodytes*). Brent et al. (1989a) offered one toy each to 14 individually-housed subjects of unspecified sex (mean age 9.8 years) for two weeks. The animals engaged in manipulative and play behavior approximately 60% of the first ten minutes after toy exposure. The amount of time spent using the toy dropped to approximately 25% during the next test on day two, and it remained at this level throughout the rest of the study period. The incidence of stereotypical behaviors decreased significantly when the toys were used. Without providing supportive data, the authors report that "the novelty of the toys was more interesting to younger and more active animals" (Brent et al., 1989).

Bayne et al. (1990) introduced nylon rings or burlap strips to nine single-housed chimpanzees of both sexes, ranging in age from two to six years. Each subject was exposed to one object for five weeks. The mean rate of manipulation was 33% of 45 checks of unspecified duration for the ring, 28% for the burlap strips.

b) Foraging Devices

Evans et al. (1989) observed 28 singly-caged female long-tailed macaques of unspecified age, presented once every day with a pickup board loaded with 90 marshmallows. "All animals performed consistently" throughout a two-week period. "Retrieval time reached asymptote at approximately two sec/marshmallow within three to rive sessions" (Evans et al., 1989). This indicates that the board stimulated the animals on average three minutes per day to perform foraging behavior.

Bloom & Cook (1989) were able to extend feeding times of two single-caged adult rhesus macaques from approximately ten minutes to 25 minutes by offering them their standard single portion of Purina Monkey Chow in a commercial puzzle feeder attached to the outside of the animals' cages. The device was used as a primary feeder device.

Line et al. (1989b) presented five adult singly-caged rhesus macaque females, each with a puzzle feeder loaded once a day with ten monkey biscuits. All subjects used the device, and the average number of biscuits retrieved per day increased from 0.4 during week one to 3.8 during week four, despite the fact that other monkey biscuits were also available free-choice. Murchison (1991) tested an inexpensive, self made PVC-pipe food puzzle in eight long-tailed macaques of both sexes and various age classes. Each animal's puzzle was loaded with six whole peanuts in the shell once every day. The animals retrieved on average 4.5 peanuts per day, three weeks after initial exposure to the feeder. Females were more proficient than males. Murchison (1992) presented another food puzzle, consisting of a perforated hollow hard plastic ball attached to the outside of the cage, to two adult male and two adult female singly-caged long-tailed macaques and to four adult female singly-caged pigtail macaques. The puzzles were loaded each morning with 12 whole peanuts. Subjects removed on average nine peanuts on the last day, i.e., day 32 of exposure. "Male *M. fascicularis* spent more time [21.5%] manipulating the foraging device than females [7.5%]" (Murchison, 1992).

Markowitz & Line (1989) attached a box containing a radio and a food dispenser to the homecages of five adult female rhesus macaques. The animals could control the apparatus via contact detectors. Three subjects "continued to obtain banana pellets throughout the five-month study. Of the remaining two, one made very few responses for the first 13 weeks, then became the highest responder for the last seven weeks; the other made a few responses in the first week, and only occasional responses thereafter" (Markowitz & Line, 1989). The animals earned on average approximately 500 banana pellets per day, 20 weeks after continuous exposure to the dispenser. Referring to another set if data (Line et al., 1991) Line & Morgan (1991) reported that ten adult female rhesus macaques used the foraging device "for an average of 24% of the observation time during a period of 12 weeks." Preilowslki et al. (1988) noted a 27% reduction in behavioral disorders in

one adult male rhesus macaque presented with a food dispensing manipulandum for ten days. Gullekson et al. (1991) examined the stimulative effect of a seed-dispenser in three male and three female long-tailed macaques of unspecified age on day one and two of exposure. The authors list pooled numbers of events of various behavior categories, but do not indicate how much time individuals actually interacted with the dispenser. Harris (1988) noted an increase in feeding time from approximately 8% to 12% per 30-minute observation sessions and a 50% reduction in auto-aggressive behavior in five male and five female singly-caged long-tailed macaques of various age classes when food was spread on woodchips rather than placed in feeder boxes.

Bayne et al. (1991) tested fleece boards that were attached to the outside of the cages of eight adult singly-housed rhesus macaques of both sexes for a minimum of six months. The fleece was covered with flavored food particles on a daily basis. The animals spent an average of 40% of 30-minute observation sessions using the board for grooming and foraging. The interaction time with the board increased progressively from approximately 17% at the beginning to 72% at the end of the study. This was accompanied by a decrease in the amount of time engaged in behavioral disorders, from approximately 25% to 5%. Lam et al. (1991) introduced fleece cushions, one at a time, into the cages of singly-housed adult male long-tailed macaques. Three animals received plain cushions on six consecutive days. On day six, an average 14% of the first hour immediately after daily exposure was spent plucking at, stroking, or parting small pieces of the fleece with the fingers. The three other animals were given cushions sprinkled with flavored tidbits once a day also for six days. These subjects were engaged on average 27% of the first hour of exposure picking crumbs from the fleece and consuming them, or directly licking the fleece. The introduction of the fleece pad whether with or without crumbs caused a marked temporary reduction (up to 73%) in time spent engaged in behavioral disorders. Bayne et al. (1992a) mounted Plexiglas boards covered with artificial turf in the homecages of eight adult singly-housed male rhesus macaques. Specially flavored crumbled biscuits were placed in the turf daily as a supplement to the regular feeding regimen. The percentage of 30-minute test periods spent foraging from the turf increased from approximately 2% to 77% in the course of six months. This was accompanied by a decline in the amount of time engaged in abnormal behaviors from approximately 39% to 9%.

c) Perches

Reinhardt et al. (1987) installed deciduous tree branches, one each into the cages of 86 adult rhesus macaques of both sexes. After two months of exposure, 54 animals were observed using their branch for perching, balancing, holding, shaking and gnawing in the course of a five- minute session. The incidence of branch use showed no significant differences between females (87% of 77) and males (88% of nine) as well as between wild-born (94% of 32) and captive-born subjects (83% of 54).

Reinhardt & Smith (1988) provided nine singly-caged adult female rhesus macaques polyvinyl chloride (PVC) pipes instead of tree branches. An average of 5.8 animals were using their perch during five-minute observation sessions four weeks after exposure. Reinhardt (1 990c) compared the usefulness of PVC perches versus branches in 20 singly-caged four-year old rhesus males. The monkeys were housed in lower-row double cages, provided with a PVC perch in one half and an oak branch in the other half. Both perches had the same radius and were installed in the same way. Of the 20 subjects tested, 18 used the PVC perches, 19 the oak perches during a one-hour observation one year after exposure. The animals spent on average 43% of the time with the two structures: 19% with the PVC perch and 24% with the oak branch. The difference was not significant, suggesting that the monkeys showed no preference for either of the two materials. Schmidt et al. (1989) monitored three subadult male rhesus macaques that- had been singly- housed in squeeze cages equipped with an aluminum perch for two to 13 months. The monkeys made use of their perch for feeding, grooming and sleeping on

average 61% of 30-minute observation sessions. Watson (1991) evaluated the use of a stain less steel perch-consisting of three parallel rods-by 31 female and 31 "Male adult long-tailed macaques. Individuals were tested during systematic 20-minute observation sessions distributed over a 14-week exposure period. Independent of gender or duration of exposure, all monkeys used their perches in a species-typical way more than 84% of the time.

Reinhardt (1989) investigated perch usage in relation to cage location in 25 adult male rhesus macaques. The subjects had lived in equal-sized cages that were each equipped with a diagonally installed PVC perch for one year. All monkeys were seen sitting on the perches during two one- hour observation sessions. The proportion of time spent on the perch was on average 48% for 11 animals living in lower-row cages, it was only 16% for 14 animals living in upper-row cages. The difference was significant. This finding has been confirmed in pair-housed adult female rhesus macaques, with lower-row caged animals spending on average 32% of time, upper row caged animals only 7% of time on PVC perches (Woodbeck & Reinhardt, 1991).

Reinhardt (1990a) assessed possible age differences in perch usage in 60 pair-housed rhesus macaques housed in lower-row cages. Each pair had access to one diagonally installed PVC perch for over 1.5 years. Young animals (n=18; 3.5 - 4 years old) spent on average 17% of the time on the perch, old animals (n=42; 9 - 30 years old) only 8%; the difference was significant.

Bayne ef al. (1992b) presented eight male rhesus macaques, each with four different enrichment objects: A perch, a rubber toy, a plastic toy, and a fleece board. "The subjects spent the greatest proportion of the interactive time on the perch" (Bayne et al., 1992).

d) Swings

Swings have not been tested in singly-caged nonhuman primates. Kopecky & Reinhardt (1991), however, observed a clear preference for PVC perches over PVC swings (average usage 10.8% vs. 1.4% of time) in 14 paired adult rhesus macaques exposed simultaneously to both enrichment options.

e) Playpens

Bryant et al. (1988) transferred six adult singly-caged male long-tailed macaques from their home cages daily for short periods into playpens. The pens had viewing panels and were equipped each with a swing, a nylon rope, a nylon ball, a telephone directory, a surgical glove, and a deep woodchip litter tray scattered with sunflower seeds and peanuts. The scattered food, the viewing panel and the telephone directory captured the attention of the animals approximately 67% of the first 30 minutes after daily transfer into the pen, during week three. The monkeys showed a conspicuous lack of interest in the other enrichment objects. The occurrence of behavioral disorders was temporarily reduced, but increased again on return to the home cage.

f) Television

Brent et al. (1989a) tested 14 chimpanzees of unspecified sex (mean age 9.8 years) that were singly-housed in television-equipped rooms. The television was turned on for six hours daily during two weeks. The animals spent an estimated 52% of the first two hours of initial television exposure watching the program. Watching time decreased thereafter and remained at a level of about 20% throughout the remainder of the study period. Bloomsmith et al. (1990) examined three

individually-housed adult female and one subadult male chimpanzees during presentation of different videotapes, each one shown four times to each subject within a two week period. The animals watched the tapes on average 74% of 20-minute presentations without showing evidence of habituation to repeated exposure (four times) to the same tape. There was no difference between the amount of time watching a television show and a tape of various chimpanzee behavior. Meunier et a]. (1989) noted a 58% reduction of behavioral disorders in six male rhesus macaques of unspecified age during "three to five 15-minute video showings. The animals watched tapes 73% of the time". Harris (1988) introduced "a device designed to deliver a food reward and/or access to television-based visual stimulus material" to five male and rive female singly-caged long-tailed macaques of various age classes. The animals watched television on average 2% of 30-minute test sessions. Without providing specific data, Kaplan & Lobao (1991) reported "no apparent benefit" of cage toys, television, ropes and mirrors for individually-housed rhesus macaques.

g) Space

Line et al. (1990c) evaluated the effectiveness of increasing cage size in enriching the environment of ten singly-caged adult rhesus macaque females. Transfer from standard cages (61 x 66 x 81 cm) to larger cages (86 x 66 x 8l cm) and "double" cages (70 x 90 x 110 cm) for two weeks affected neither the animals' activity levels nor their expression of behavioral disorders. Line et al. (1991 b) reconfirmed their observations in six other adult female rhesus macaques that were moved from 0.46 m2 to 0.56 m2 cages. Line's findings are congruent with those of Bayne & McCully (1989) who were unable to detect an attenuative effect on behavioral disorders in six adult male rhesus macaques after being transferred from 4.3 ft2 cages into 6.0 ft2 cages for two months.

ANIMATE ENVIRONMENTAL ENRICHMENT

Socializing previously single-caged nonhuman primates for the purpose of environmental enrichment has been attempted by only a few investigators.

Ranheim & Reinhardt (1989) tested 12 previously single-caged adult unrelated female rhesus macaques 2.5 years after formation of six compatible pairs. Partners of all six pairs interacted with each other in non-injurious, species-typical ways during a one-hour observation session. The proportion of time spent interacting with each other averaged 35%. Reinhardt (1990a) reported in a follow-up study of 22 isosexual adult rhesus pairs that females were more engaged socially than males. During one-hour observations conducted more than 1.5 years after pair formation, females spent on average 29% of the time interacting with one another in an affiliative manner, males did so on average 14% of the time; the difference was statistically significant. Reinhardt (1990b) observed 20 stump-tailed macaques of different age classes and sexes two months after the formation of ten pairs. The 18 partners of nine pairs interacted with each other in species- typical ways during a one-hour recording session. Companions were actively distracted by each other on average 22% of the time. Brent (1992) paired four chimpanzees of unspecified age and sex. After living together for an unspecified duration, "the subjects spent approximately 11 % of the observation time in socially directed behaviors" (Brent, 1992).

Transferring singly-caged animals into a compatible pair arrangement reduces the expression of behavioral disorders. In a study of social enrichment for singly-caged adult rhesus macaques with infants, three of 29 adult subjects exhibited behavioral disorders (Reinhardt et al., 1987b). All three females "gradually abandoned their peculiar habits, and none of them showed behavioral disorders after living with an infant for four months" (Reinhardt et al., 1987b). In a further investigation of the behavioral responses of unrelated rhesus macaque females to pair formation, seven of 36 subjects showed behavioral disorders. Six of these animals abandoned their habits within the first four weeks of living together with

a companion (Reinhardt et al., 1988). Line et al. (1990a) examined the impact of compatible pair housing on the behavior of ten previously single-caged adult female long-tailed macaques. Companions engaged in non-injurious species-typical interactions on average 32% of ten-minute observation sessions during the first two weeks after pair formation. The amount of time devoted to behavioral disorders decreased significantly from 7% in the single condition to less than 1 % in the pair condition. Schapiro et al. (1992) tested 34 juvenile rhesus macaques one year after being transferred from a single-housing to a heterosexual pair-housing condition. When pair-housed, ,.animals spent [significantly] more time playing and [significantly] less time in abnormal behaviors".

Line et al. (1990d) attempted to establish a permanent heterosexual group of 13 aged rhesus macaques. The animals engaged in non-injurious as well as in injurious species-typical interactions approximately 5% of the time. Serious aggressive harassment of several animals necessitated splitting the group after eight days. Wolff & Ruppert (1991) established six heterosexual groups of six subadult rhesus macaques, six subadult and adult rhesus macaques, two mix-sexed groups composed of six long-tailed and rhesus macaques, and two groups of six adult capuchin monkeys. Groups were formed temporarily in an exercise cage for four hours per week. Behavioral data were collected during nine weekly sessions. Regrouping was necessary during the first five weeks to reduce aggressive disputes. Thereafter group compositions remained stable. The approximate percentage of time spent interacting with group members was 50% of in the subadult rhesus macaque group, 20% in the subadult/adult rhesus macaque group, 25% in the mixed-species groups, and 5% in the capuchin groups. Temporary grouping in an exercise cage had no ameliorating effect on behavioral disorders. Harris (1988) observed an unspecified number of subadult (average age 3.3 years) female long-tailed macaques in single- and social-housing (presumably group-housing) conditions, each animal during ten 15-minute sessions. The animals engaged in behavioral disorders for significantly less time when being social-housed than when being single-housed. Bayne et al. (1991) formed a compatible group of six adult capuchin monkeys (*Cebus apella*) of both sexes and one juvenile that had previously been single-caged. The authors observed the animals for a total of 34 days in each housing condition and noted a significant reduction in behavioral disorders in the group housing condition.

Providing singly-caged animals compatible companionship is a simply way to facilitate the expression of their inherent social disposition. Partners of adult rhesus macaque pairs - here 36-year old SENILE is being groomed by her 27-year old partner SISSA - pend approximately 25% of their time interacting with each other in species-typical ways.

DISCUSSION

The present paper has summarized quantitative information regarding environmental enrichment for singly-caged nonhuman primates in accordance with current federal rules. Of the 52 publications reviewed, 63% (33) deal with rhesus macaques, only 37% (19) with other primate species. The disproportionate focus on rhesus macaques is understandable (rhesus are the most commonly used laboratory primates) but should not diminish efforts in exploring environmental enrichment options for other species. Enrichment that is safe and effective for one species may be useless for another species. The development and testing of appropriate environmental enrichment is still in its early stage, and special efforts are needed to expand current experiences primarily gathered with rhesus macaques.

Thirty-seven (Table [not scanned])of the 52 publications reviewed are evaluable, making clear reference to the period of time subjects were exposed to the enrichment at the time of data collection. Such information is essential to rule out short-term novelty effects of the enrichment option tested (Line et al., 1990b; Line et al., 1991; Weick et al., 1991). The 37 reports provide information on one or several of the following parameters:

a) Proportion of animals studied that actually use the enrichment option in non-injurious species- typical ways per specified time period,

b) average percentage of time subjects are distracted by the enrichment in non-injurious species- typical ways,

c) average number of performance units observed per subject per specified time period,

d) impact of the enrichment option on the expression of behavioral disorders.

The emphasis of these studies lies on inanimate (78%) rather than animate enrichment (22%; Table [not scanned]). This is unfortunate, as most laboratory primates are social animals. Sociability is most distinctive characteristic (Pereira et al., 1989; de Waal, 1991), central to their very survival in the wild (Bernstein, 1991). Contrary to warnings that social housing might undermine "the integrity of the scientific enterprise" (Novak & Suomi, 1991) it has been demonstrated that pair housing of compatible, previously singly-caged rhesus macaques does not jeopardize the subjects' physical and psychological well-being nor does it interfere with many common research protocols and routine management procedures (Reinhardt, 1990d; cf. Schapiro et al., 1991a). When given the choice, rhesus macaques as well as stump-tailed macaques prefer animate (a compatible companion) to inanimate (gnawing stick, perch) enrichment (Reinhardt, 1990b,c; cf. Schapiro et al., 1991b), and they prefer not to be alone even though this may imply a reduction of their available cage space (Reinhardt & Reinhardt, 199 1). The proportion of time previously single-caged rhesus macaques spent interacting with compatible partners (Ranheim & Reinhardt, 1989; Wolf & Ruppert, 1991) is comparable with the situation in wild populations (Teas et al., 1980). This indicates that adequate animate enrichment creates favorable conditions for the expression of the

animals' basic social disposition within the given constraints of confinement. The transfer of macaques from single to compatible pair housing has a consistent ameliorating effect on behavioral disorders, suggesting that appropriate companionship may have a therapeutic effect.

Adult males - here 12-year old GEORGE - treat their infant companions as protectively as females do.

Future research will have to focus more on the development of animate environmental enrichment options for other primate species to optimize their living conditions in the laboratory. It is generally agreed that for social species of nonhuman primates, social interaction with other nonhuman primates is "probably the optimum enrichment possibility" (Keeling, 1990; cf. Bramblett, 1989). Keeping social animals under chronic social deprivation for whatever reason devaluates them for scientific research because they no longer truly represent their own kind (cf. Brinkman, 1987; Brent et al., 1989b; Gilbert & Wrenshall, 1989; Clark, 1990; de Waal, 1991).

Despite the heterogeneity of the studies reviewed, the following conclusions can be drawn regarding inanimate enrichment:

1. Perches and gnawing sticks are effective in offering macaques adequate means to express non-injurious species-typical behavior. Unlike plastic blocks, nylon balls and rubber toys, perches and gnawing sticks have a well documented distractive value over extended periods of continual exposure.

2. Manipulable enrichment objects have little impact on behavioral disorders.

3. Foraging devices may considerably extend the time subjects spend collecting their food while reducing the time engaged in behavioral disorders.

4. Repeated temporary exposure to fleece may stimulate macaques to perform species-typical grooming behavior.

5. Temporary transfer of macaques into a play pen with deep woodchip litter has a high species- appropriate distractive value and a temporary ameliorating effect on behavioral disorders.

6. Television or videotapes may effectively distract chimpanzees and possibly also macaques; the long-term attractiveness needs to be evaluated.

7. Modest increases in cage size are less likely to enrich the environment of singly-caged laboratory primates than are changes in social opportunities or an increase in environmental complexity (Line et al., 1990c).

ACKNOWLEDGMENTS

We are thankful to Jackie Kinney for proofreading the text. This project was partly supported by NIH grant RR-00167 to the Wisconsin Regional Primate Research Center. Publication number 31-046 of the WRPRC.

REFERENCES

Bayne, K.A.L. (1989a). Nylon ball re-visited. **Laboratory Primate Newsletter, 28** (1), 5-6.

Bayne, K.A.L. (1989b). Resolving issues of psychological well-being and management of laboratory primates. In E.F. Segal (Ed.) **Housing, care and psychological well-being of captive and Laboratory primates**. (pp. 27-39). Park Ridge, NJ: Noyes Publications.

Bayne, K.A.L. & McCully, C. (1989). The effect of cage size on the behavior of individually housed rhesus monkeys. **Lab Animal, 18** (7), 25-28.

Bayne, K.A.L., Dexter, S.L. & Etzler, D. (1990). Monitoring an enrichment program: A pilot evaluation. **Lab Animal, 19** (7), 33-42.

Bayne, K., Dexter, S. & Suomi, S. (1991). Social housing ameliorates behavioral pathology in Cebus apella. **Laboratory Primate Newsletter, 30** (2), 9-12.

Bayne, K., Mainzer, H., Dexter, S., Campbell, G., Yamada, F. & Suomi, S. (1991). The reduction of abnormal behaviors in individually housed rhesus monkeys (*Macaca mulatta*) with a foraging/grooming board. **American Journal of Primatology, 23**, 23-35.

Bayne, K., Dexter, S., Mainzer, H., McCully, C., Campbell, G. & Yamada, F. (1992a). The use of artificial turf as a foraging substrate for individually housed rhesus monkeys (*Macaca mulatta*). **Animal Welfare, 1**, 39-53.

Bayne, K., Hurst, J.K. & Dexter, S.L. (1992b). Evaluation of the preference to and behavioral effects of an enriched environment on male rhesus monkeys. **Laboratory Animal Science, 42**, 3845.

Bernstein, I.S. (1991). Social housing of monkeys and apes: Group formations. **Laboratory Animal Science, 41**, 329-333.

Bloom, K.R. & Cook, M. (1989). Environmental enrichment: Behavioral responses of rhesus to puzzle feeders. Lab Animal, 18 (5), 25-31.

Bloomsmith, M.A., Alford, P.L. & Maple, T.L. (1989). Successful feeding enrichment for captive chimpanzees. **American Journal of Primatology Supplement, 1**, 9-15.

Bloomsmith, M.A., Keeling, M.E. & Lambeth, S.P. (1990). Videotapes: Environmental enrichment for singly housed chimpanzees. **Lab Animal, 19** (1), 42-46.

Bloomsmith, M.A., Brent, L.Y. & Schapiro, S.J. (1991). Guidelines for developing and managing an environmental enrichment program for nonhuman primates. **Laboratory Animal Science, 41**, 372-377.

Bramblett, C.A. (1989). Enrichment options for guenons in the laboratory. **American Journal of Primatology Supplement, 1,** 59-63.

Brent, L., Lee, D.R. & Eichberg, J.W. (1989a). Evaluation of two environmental enrichment devices for singly caged chimpanzees (*Pan troglodytes*). **American Journal of Primatology Supplement, 1**, 65-70.

Brent, L., Lee, D.R. & Eichberg, J.W. (1989b). The effects of single caging on chimpanzee behavior. **Laboratory Animal Science, 39**, 345-346.

Brent, L. (1992). The effects of cage size and pair housing on the behavior of captive chimpanzees. **American Journal of Primatology, 27**, 20.

Brinkman, C. (1987). Single caging of social primates: Problems and some solutions. **Australian Primatology, 20** (1), 17.

Bryant, C.E., Rupniak, N.M.J. & Iversen, S.D. (1988). Effects of different environmental enrichment devices on cage stereotypies and autoaggression in captive cynomolgus monkeys. **Journal of Medical Primatology, 17,** 257-267.

Burt, D.A. & Plant, M. (1990). Observation on a caging system for housing stump-tailed macaques. **Animal Technology, 33**, 175-179.

Canadian Council on Animal Care. (1993). **Guide to the Care and Use of Experimental Animals. Volume 1.** CCAC: Ottawa.

Chamove, A.S. & Anderson, J.R. (1989). Examining environmental enrichment. In E.F. Segal (Ed.), **Housing, care and psychological well-being of captive and laboratory primates** (pp. 183- 199). Park Ridge, NJ: Noyes Publications.

Champoux, M., Hempel, M. & Reinhardt, V. (1987). Environmental enrichment with sticks for singly-caged adult rhesus monkeys. **Laboratory Primate Newsletter, 26** (4), 5-7.

Clark, B. (1990). Environmental enrichment: An overview of theory and application for captive non-human primates. **Animal Keeper's Forum, 17** (8), 272-282.

Crockett, C., Bielitzki, J., Carey, A. & Velez, A. (1989). Kong toys as enrichment devices for singly-caged macaques. **Laboratory Primate Newsletter, 28** (2), 21-22.

Evans, H.L., Taylor, J.D., Ernst, J. & Graefe, J.F. (1989). Methods to evaluate the well-being of laboratory primates: Comparisons of macaques and tamarins. **Laboratory Animal Science, 39**,318-323.

Fajzi, K., Reinhardt, V. & Smith, M.D. (1989). A review of environmental enrichment strategies for singly caged nonhuman primates. **Lab Animal, 18** (2), 23-35.

Gilbert, S.G. & Wrenshall, E. (1989). Environmental enrichment for monkeys used in behavioral toxicology studies. In E.F. Segal (Ed.), **Housing, care and psychological well-being of captive and laboratory primates** (pp. 244-254). Park Ridge, NJ: Noyes Publications.

Gullekson, R., Bench, L., Harrigan, K. & Pyle, K. (1991). Seedfeeder as a foraging device for singly-housed cynomolgus monkeys (*Macaca fascicularis*). **Lab Animal, 20** (6), 44-46.

Harris, D. (1988). **Welfare and housing of old world nonhuman primates** (*Macaca fascicularis* and *Papio* sp.). Potters Bar, Hertfordshire, England: University Federation for Animal Welfare.

Kaplan, M.L. & Lobao, B.J. (1991). A unique housing system for rhesus macaques. **Lab Animal, 20** (6), 48-50.

Keeling, M.E (1990). A historical view. In J.A. Mench & L. Krulisch (Eds.), **Well-being of nonhuman primates in research** (pp. 12-14). Bethesda, MD: Scientist Center for Animal Welfare.

Kopecky, J. & Reinhardt, V. (1991). Comparing the effectiveness of PVC swings versus PVC perches as environmental enrichment objects for caged female rhesus macaques (*Macaca mulatta*). **Laboratory Primate Newsletter, 30** (2),5-6.

Lam, K., Rupniak, N.M.J. & Iversen, S.D. (1991). Use of a grooming and foraging substrate to reduce cage stereotypies in macaques. **Journal of Medical Primatology, 20**, 104-109.

Line, S.W. (1987). Environmental enrichment for laboratory primates. **Journal of the American Veterinary Medical Association, 19**, 854-859.

Line, S.W., Clarke, A.S. & Markowitz, H. (1989a) Adult female rhesus macaque responses to novel objects. **Lab Animal, 18** (4), 33-49.

Line, S.W., Markowitz, H., Morgan, K.N. & Strong, S. (1989b). Evaluation of attempts to enrich the environment of singlecaged nonhuman primates. In J.W. Driscoll (Ed.) **Animal care and use in behavioral research: Regulations, issues and applications** (pp. 103-117) Beltsville, MD: National Agricultural Library.

Line, S.W., Morgan, K.N., Markowitz, H., Roberts, J.A. & Riddell, M. (1990a). Behavioral responses of female long-tailed macaques (*Macaca fascicularis*) to pair formation. **Laboratory Primate Newsletter, 29** (4), 1-5.

Line, S.W., Clarke, A.S., Markowitz, H. & Ellman, G. (1990b). Responses of female rhesus macaques to an environmental enrichment apparatus. **Laboratory Animals, 24**, 213-220.

Line, S.W., Morgan, K.N., Markowitz, H. & Strong, S. (1990c). Increased cage size does not alter heart rate or behavior in female rhesus monkeys. **American Journal of Primatology, 20**, 107- 113.

Line, S.W., Morgan, K.N., Roberts, J.A. & Markowitz, H. (1990d). Preliminary comments on resocialization of aged rhesus macaques. **Laboratory Primate Newsletter, 29** (1), 8-12.

Line, S.W. & Morgan, K.N. (1991). The effects of two novel objects on the behavior of singly caged adult rhesus macaques. **Laboratory Animal Science, 41**, 365-369.

Line, S.W., Morgan, K.N. & Markowitz, H. (1991a). Simple toys do not alter the behavior of aged rhesus monkeys. **Zoo Biology, 10**, 473-484.

Line, S.W., Markowitz, H., Morgan, K.N. & Strong, S. (1991b). Effects of cage size and environmental enrichment on behavioral and physiological responses of rhesus macaques to the stress of daily events. In M.A. Novak & A.J. Petto (Eds.), **Through the looking glass: Issues of psychological well-being of captive nonhuman primates** (pp. 160-179). Washington, DC: American Psychological Association.

Markowitz, H. & Line, S. (1989). Primate research models and environmental enrichment. In E.F. Segal (Ed.), **Housing, care and psychological well-being in captive and laboratory primates** (pp.202-212) Park Ridge, NJ: Noyes Publications.

Meunier, L.D., Duktig, J.T. & Landi, M.S. (1989). Modification of stereotypic behavior in rhesus monkeys using videotapes, puzzle feeders, and foraging boxes. **Laboratory Animal Science, 39**, 479.

Murchison, M.A. (1991). PVC-pipe food puzzle for singly caged primates. **Laboratory Primate Newsletter, 30** (3), 12-14.

Novak, M.A. & Suomi, S.J. (1991). Social interaction in nonhuman primates: An underlying theme for primate research. **Laboratory Animal Science, 41**, 308-314.

Pereira, M.E., Macedonia, J.M., Haring, D.M. & Simons, E.L. (1989). Maintenance of primates in captivity for research: The need for naturalistic environments. In E.F. Segal (Ed.), **Housing, care and psychological well-being of captive and laboratory primates** (pp. 40-60). Park Ridge, NJ: Noyes Publications.

Preilowski, B., Reger, M. & Engele, H. (1988). Combining scientific experimentation with conventional housing; A pilot study with rhesus monkeys. **American Journal of Primatology, 14**, 223-234.

Ranheim, S. & Reinhardt, V. (1989). Compatible rhesus monkeys provide long-term stimulation for each other. **Laboratory Primate Newsletter, 28** (3), 1-2.

Reinhardt, V. (1989). Evaluation of the long-term effectiveness of two environmental enrichment objects for singly-caged rhesus macaques. **Lab Animal, 18** (6), 31-33.

Reinhardt, V. (1990a). Time budget of caged rhesus monkeys exposed to a companion, a PVC perch, and a piece of wood for an extended time. **American Journal of Primatology, 20**, 51- 56.

Reinhardt, V. (1990b). Environmental enrichment program for caged stump-tailed macaques (*Macaca arctoides*). **Laboratory Primate Newsletter, 29** (2), 10-11.

Reinhardt, V. (1990c). Comparing the effectiveness of PVC perches versus wooden perches as environmental enrichment objects for singly caged rhesus monkeys. **Laboratory Primate Newsletter, 29** (1), 13-14.

Reinhardt, V. (1990d). Social enrichment for laboratory primates: A critical review. **Laboratory Primate Newsletter, 29** (3), 7-11.

Reinhardt, V., Houser, W.D., Cowley, D. & Champoux, M. (1987a). Preliminary comments on environmental enrichment with branches for individually caged rhesus monkeys. **Laboratory Primate Newsletter, 26** (1), 1-3.

Reinhardt, V., Houser, W.D., Eisele, S.G. & Champoux, M. (1987b). Social.enrichment of the environment with infants for singly-caged adult rhesus monkeys. **Zoo Biology, 6,** 365-371.

Reinhardt, V., Houser, D., Eisele, S., Cowley, D. & Vertein, R. (1988). Behavioral responses of unrelated rhesus monkey females paired for the purpose of environmental enrichment. **American Journal of Primatology, 14**, 135-140.

Reinhardt, V. & Smith, M. (1988). PVC pipes effectively enrich the environment of caged rhesus monkeys. **Laboratory Primate Newsletter, 27** (3), 4-5.

Reinhardt, V. & Reinhardt, A. (1991). Impact of a privacy panel on the behavior of caged female rhesus monkeys living in pairs. **Journal of Experimental Animal Science, 34**, 55-58.

Rupiniak, N.M.J. & Iverson, S.D. (1989). Psychological welfare, behavior, and housing conditions for laboratory primates: a discussion. **Laboratory Animal Welfare Research Primates** (pp.31-38). Hertfordshire, England: UFAW.

Ruppenthal, G.C., Walker, C.G. & Sackett, G.P. (1991). Rearing infant monkeys (*Macaca nemestrina*) in pairs produces deficient social development compared with rearing in single cages. **American Journal of Primatology, 25**, 103113.

Schapiro, S.J., Bloomsmith, M.A., Kessel, A.L. & Keeling, M.E. (1991 a). Effects of environmental enrichment on plasma cortisol levels of juvenile specific pathogen free (SPF) rhesus monkeys. **American Journal of Primatology, 24**.

Schapiro, S.J., Bloomsmith, M.A., Kessel, A.L., Bushong, D. & Keeling, M.A. (1991b). Effects of environmental enrichment on the social behavior of pair-housed juvenile specific pathogen free (SPF) rhesus monkeys. **American Journal of Primatology, 24**, 133-134.

Schmidt, E., Dold, G.M. & McIntosh, J.S. (1989). A perch for primate squeeze cages. **Laboratory Animal Science, 39**, 166-167.

Teas, J., Ritchie, T., Taylor, H. & Southwick, C. (1980). Population patterns of behavioral ecology of rhesus monkeys (*Macaca mulatta)* in Nepal. In D.G. Undburg (Ed.), **The Macaques** (pp.247-262). New York: Van Nostrand Reinhold.

U.S. Department of Agriculture (1991a). Information Resources for Environmental Enrichment of Primates: 1987-1990. **Agricultural Library,** March 1991.

U.S. Department of Agriculture (1991b). Animal welfare, standards, final rule. **Federal Register, 56**, 6426-6505.

de Waal, F.B.M. (1991). The social nature of primates. In M.A. Novak & A.J. Petto (Eds.), **Through the Looking Glass: Psychological well-being in captive nonhuman primates** (pp.69- 77). Washington, DC: American Psychological Association.

Watson, D.S.B. (1991). A built-in perch for primate squeeze cages. **Laboratory Animal Science, 41**.

Weick, B.G., Perkins, S.E., Burnett, D.E., Rice, T.R. & Staley, E.C. (1991). Environmental enrichment objects and singlyhoused rhesus monkeys: Individual preferences and the restoration of novelty. **American Association for Laboratory Animal Science Bulletin, 30** (4), 18.

Wolff, A. F, Ruppert, G. (1991). A practical assessment of a ;nonhuman primate exercise program. **Lab Animal, 20** (2), 36-39.

Woodbeck, T. & Reinhardt, V. (1991). Perch use by *Macaca mulatta* in relation to cage location. **Laboratory Primate**

This article originally appeared in *Humane Innovations and Alternatives in Animal Experimentation 6*, 374-384 (1992). Reprinted with permission of the Editor.