# Engineering Environments for Behavioral Opportunities in the Zoo

Hal Markowitz
Washington Park Zoo
Portland, Oregon

Although intensive efforts in behavioral engineering in the zoo have a history of only a half-dozen years, the realization that captive animals should have more stimulating environments is hardly new. In 1925, Robert Yerkes wrote, "The greatest possibility for captive primates lies in the invention and installation of apparatus which can be used for play or work" (Yerkes, 1925). While the effectiveness and potentially humane characteristics of operant models are gaining wide understanding in applied areas of human work, acceptance of well-identified prescriptions for animal environmental improvement has been much slower in coming (Markowitz, 1975b Markowitz & Stevens, 1977).

The use of variants of instrumental conditioning techniques in animal training for "shows" is certainly well established, and most people in the zoo and aquarium world have a general understanding of terms like "bridging stimuli" or "reward methods" for developing and controlling complex behavior. But, these are identified as techniques to show the public what complex, and sometimes bizarre, behaviors one can get from animals with contingency training. The sight of a chimpanzee riding astride a set of dolphins may generate considerable attendance and television exposure for a commercial aquarium and consequently gain support as a revenue-producing device. Improving the captive animals' everyday living conditions and devoting part of the operating budget to these improvements is seen as a totally separate question.

"Zoos need to change if they are to remain defensible institutions in today's world . . ." These words spoken by a zoo staff member at a closed meeting are almost always applauded by colleagues. Identical words uttered by an "outsider" are sufficient to raise the hackles on the same audience. Slowly, with pressure from humane groups and the increased participation of zoologically-trained staff in animal parks, there is real movement away from menagerie traditions. In some rare situations where large endowments or wonderful climates allow, extensive naturalistic open range may be provided, as in the beautiful Wild Animal Park associated with the San Diego Zoo. For most other zoos, initial major efforts involve fiberglass trees and other facades to give the appearance of the animal's natural milieu. While these improvements in display may be defensible as an educational device to illustrate what the captive animal's wild home might have looked like, they are usually functionally sterile and provide little to show what wild *behavior* visitors might expect. The tradition in zoos has been to use graphics to tell people what the animal in nature might be like.

Throughout much of the recent history of zoos, researchers who exhibit an appreciation of the management difficulties of captive wild animals have been welcome to make observational studies in the zoo (Rumbaugh, 1972). Observational studies have long yielded data indicating excessive stereotypy and self-mutilation for many captive species with unresponsive environments. It is also clear that for many captive animals, it is rarely possible to see some of the most spectacular species specific behaviors because there is no reinforcement for their maintenance in the zoo. In the worst cases, so little interesting behavior is exhibited that visitors may conclude that the animal's repertoire is limited to "mugging" and experimentation with excrement.

Our efforts in behavioral engineering are initial attempts to provide animals opportunity to illustrate their special behavioral capabilities. There has been consistent effort to provide the animal opportunities to have a responsive environment, rather than providing a show for the public at the animal's expense. In many cases, as will be illustrated below, the resident animal has an opportunity to "turn the public on" at its whim, rather than performing on command.

Zoos are by definition artificial environments. The relatively universal lack of adequate funding prevents approaches to the ideal "naturalistic" exhibits which each of us can envision. Despite these handicaps, much more use should be made of modern technology in enhancing our zoo environments. Most prominently, it is apparent that inroads can be made in two major areas: feeding methods and encouragement of activity. In both cases, significant changes can be accomplished

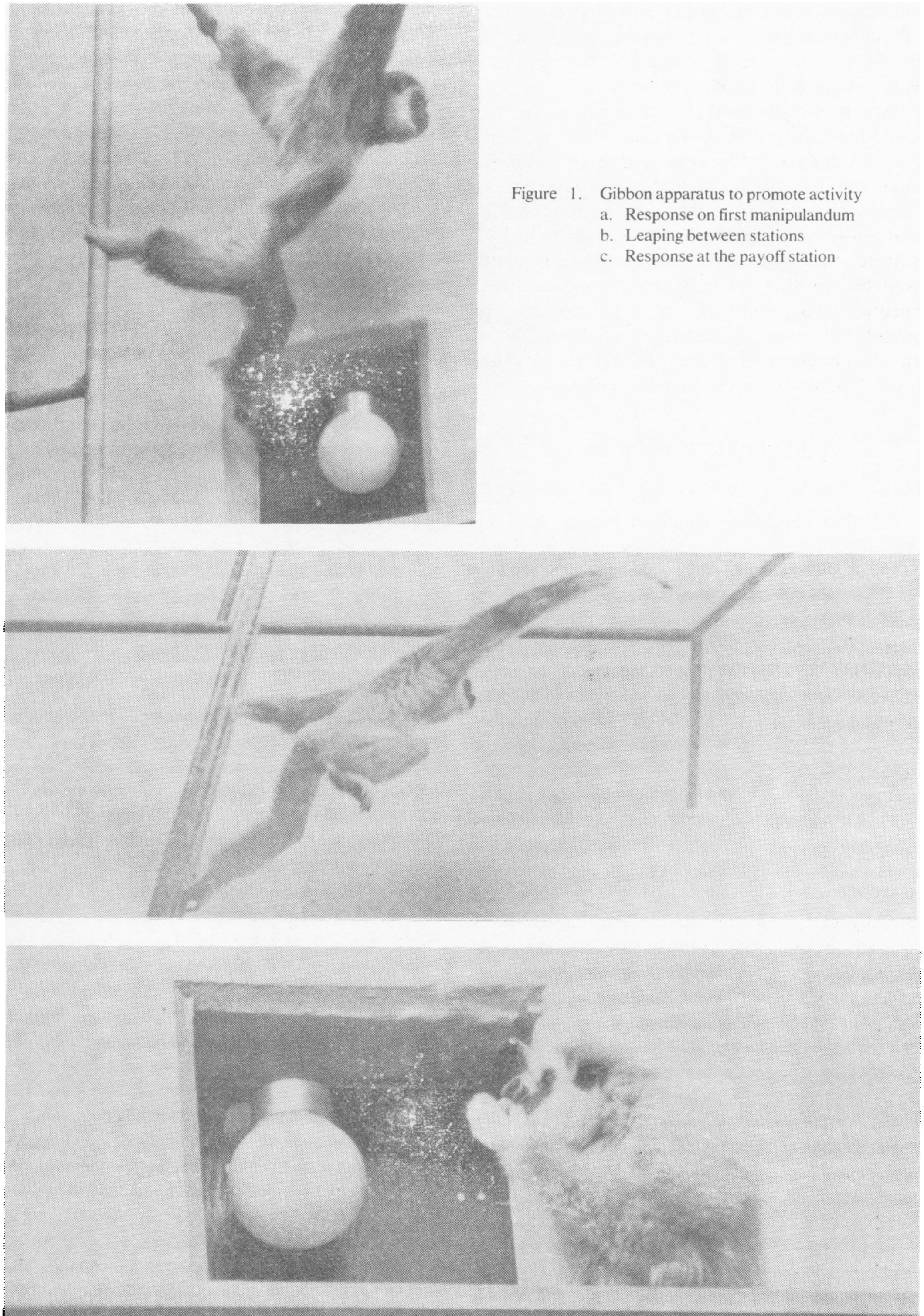


Figure 1. Gibbon apparatus to promote activity
- a. Response on first manipulandum
- b. Leaping between stations
- c. Response at the payoff station

with much less expense than is involved; e.g., in rebuilding and redesigning of elaborate facades which provide the public more "natural" feeling, but may do little to provide stimulation for the residents.

Examples of behavioral engineering in the zoo described here will be divided into three sections. The first deals with temporary improvements in regimen for animals who, by budgetary necessity, are maintained in outdated facilities. Section two includes a few comparative learning studies which illustrate the wealth of information potentially available in the active study of zoo animals. Finally, initial results of our first opportunity to provide behavioral engineering apparatus as part of the development of a new exhibit (Markowitz, Juvik, Fial, & Andrews) will be described.

## Additions to Old Exhibits

### *Harvey Wallbanger and Family: A Case History*

The first behavioral engineering project at the Washington Park Zoo was with white-handed gibbons *(Hylobates lar)*. This problem was selected because seeing these handsome apes grovel for food on the cement floor seemed especially grotesque (Markowitz, 1973, 1975c). Since the budget precluded building a forest for them to move between tree branches, our primary aim was to encourage increased activity in the form of brachiation and leaping and to allow feeding without descending to the ground.

Fortunately, there was a relatively large cage to work with which had two openings about 9 meters apart midway up the back wall (approximately 4.6 meters above the ground). Two special panels were designed, each of which had a large lever and stimulus globe. The right hand apparatus also had a food dispenser. Prior to installation and design of the equipment, considerable time was spent consulting with primate house staff about convenient locations which would reduce any impediments to routine care (Markowitz & Woodworth, 1977).

Initial shaping was accomplished by requiring successive approximations to pressing the right lever. A remote control was used which allowed the experimenter to be in front of the cage and in a matter of a few days, all three full-grown cage residents were successfully operating the manipulandum to obtain pieces of apple, orange, banana, carrot, and monkey chow. The second portion of the chained behavioral requirements was much more demanding because of the considerable separation of the stations. Reinforcements were delivered for movement away from the payoff station by gradual increments until each ape finally reached and operated the first lever. There were some predictions that it might take years to establish the behavior, but the gibbons were such adept students that, in approximately a month, they were all able to complete the entire sequence (see Figure 1). By the tenth week of our work, they were averaging more than 114 round trips per day; thus, significantly increasing cage activity and simultaneously providing zoo visitors with a demonstration of their learning ability.

Attentive readers must, by now, be anxious for an explanation about social interactions. With all of the animals in a single large cage, once shaping was accomplished, would they steal food from one another? Might they develop some cooperative methods of reducing the work requirement, etc? The answers were bound to be surprising since the literature was devoid of similar "social" behavioral engineering with captive animals. Despite our readiness for surprises, the first three years of this work provided some behaviors which we had to see repeated many times before we were willing to accept them. The two adolescent males with whom we began, were different from one another, not only in their social behavior, but in their response to this new challenge.

Harvey (who was named because of his characteristic wall-banging in mid-flight) soon took over much of the hard work. He would make the big swing to the remote platform, thus turning on the second set of apparatus which is right next to the food chute. Kahlil, Momma, and Super Squirt (who was still nursing at the beginning of our work) would perch at the second station and pull the lever which led to reinforcement. Eventually, Harvey would retire in the face of this exploitation and would not respond to the remote stimulus until the others left the payoff station. Out of necessity, Harvey became so adept that he could accomplish the entire sequence in less than two seconds. The other slower gibbons would move part way across the cage and the race to the food often resulted in a "dead heat". It became a matter of chance which gibbon ate on each trial. Perhaps most interesting is the fact that conventions like these changed over time. Harvey relented with respect to his mother and would feed her without hesitation, but when Kahlil went to the payoff station, Harvey would quit until he backed off sufficiently to ensure that Harvey would have a reasonable chance to compete for the food.

Super Squirt apparently learned the entire sequence by observation and imitation. Three years from the inception of the experiment, he was the most spectacular of the animals in some ways and accomplished at least as much work as Harvey. The gibbons earned all of their food for six years, provided a very popular exhibit for the public, and consumed slightly more than they did prior to behavioral engineering. There was almost never any fighting over food and cage appearance was improved and the keeper's job made somewhat easier, because food was not left in a pile on the floor.

Several months into the experiment, we decided to find a way to allow the public to initiate some of the stimuli for the gibbons. After much consideration, it was decided that we would use a coin box which charged 10 cents to start a sequence of trials. This coin box allows the zoo visitor to represent a random interval generator, but if no one comes along to deposit a coin, an override timer starts the sequence every two minutes anyway. Considerable time was taken to develop a brief but important graphic for the coin box:

> Research Contribution: Ten cents will start a trial when the light on this box is lit. The counter shows the total number of pieces of food earned by the animals today. Animals are not machines and they may choose not to respond when the light is turned on. All money collected here will be used to develop more activities for our animals.

In retrospect, the notion of a coin box was a lucky idea. No one complained about contributing in this way and we had many positive responses from people who thought that this was a neat way to support increased activities for the animals. We had hoped to raise a few hundred dollars for an oscilloscope. Instead, the public responded by contributing thousands of dollars in dimes each year which helped us to begin additional projects like those described below.

### *A Token Economy and Its Effects on Rocky's Old Lady and the Kids*

The gibbon work produced more interesting questions than answers, as one might expect in an experiment involving intelligent and complex subjects and a complex milieu. One particularly intriguing set of questions concerned cooperation, stealing, and altruistic behavior. Even a champion anthropomorphist would have difficulty deciding whether, when two gibbons arrived at the reinforcement station simultaneously and broke a piece of food betwen them, this represented sharing or stealing. To provide some partial answers to these kinds of questions, a token economy was selected for the next primate project. The diana monkey *(Cercopithecus diana)* collection was selected because they were an interesting family group. A 16-year-old female, her 8-year-old mate (Rocky), their adolescent and infant offspring were there at the inception of the work. As work progressed, an additional offspring was born each year.

First, the dianas were taught to exchange large plastic poker chips for food by depositing the chips in a coin slot. After a period of several months in which there was only an occasional unshaped response, we discovered that a minor alteration in the slot greatly facilitated training. Where apes might have little problem depositing tokens in a narrow vertical slot, these monkeys who showed every appearance of trying hard, had great difficulty depositing tokens in an aperture more than twice as wide as the token. A V-shaped funnel which channeled into the slot was added and within two days, some of the dianas were successfully depositing tokens for food.

A surprising early result was the inability of the adult female (Beulah) to learn to deposit tokens. Beulah's best attempt was to sit at the feeding station, looking at the slot and drop the token along side it. Also surprising at this first stage of experimentation was her mate's differential behavior with respect to his family. Rocky would regularly share food with Beulah, even letting her sit on the platform with him as he exchanged tokens for oranges, apples, bananas, carrots, or monkey chow. When the youngsters tried a similar ploy, he would unceremoniously knock them off the platform. Fortunately, the juvenile quickly learned to spend tokens himself and was not so greedy with the products of his efforts.

We finally progressed to the next stage of shaping in spite of Beulah's apparent lack of success, since she was getting sufficient food. (This turned out to be a fortunate decision since four years later, when her later offspring had acquired the response by copying Rocky and the juvenile, Beulah was still unsuccessful in exchanging tokens for food.) In order to obtain the tokens, the dianas must accomplish a sequence of behavior similar to that described for the gibbons (see Figure 2). The monkeys were shaped by successive approximation to pull a chain at the token delivery station, located about 3.6 meters above and 5.2 meters to the side of the feeding platform. Finally, the dianas were

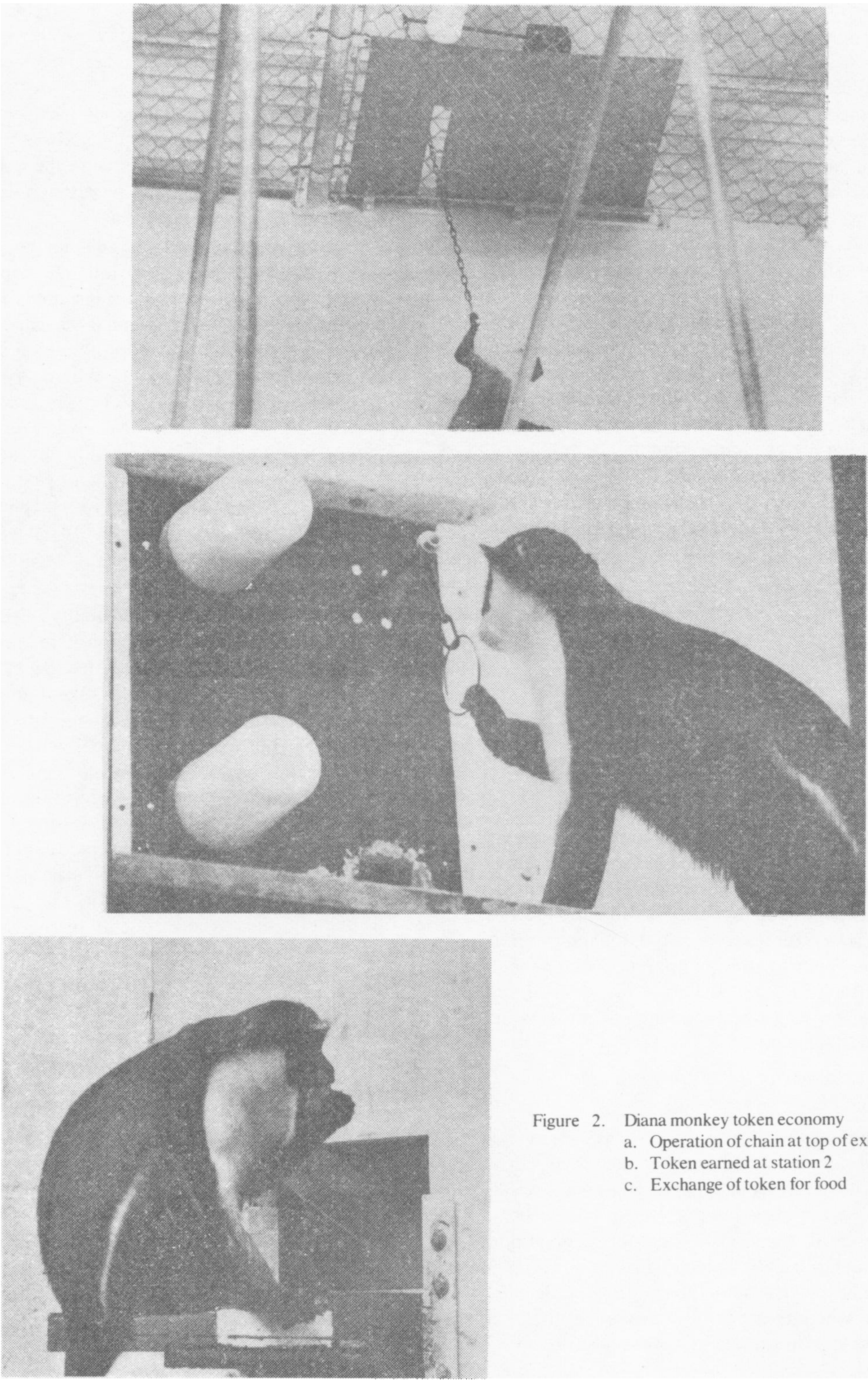


Figure 2. Diana monkey token economy
a. Operation of chain at top of exhibit
b. Token earned at station 2
c. Exchange of token for food

shaped to move all the way to the top of the cage where pulling on a long chain enabled the payoff station (see Figure 2). This set of training was accomplished with ease for all of the subjects except Beulah, since the adolescent and the infant began to swing on the chain almost immediately upon its installation. Beulah finally adopted a specific way to "earn" food. She would encourage the others to work and would occasionally pull one of the chains where the token was delivered, but would always give up the token to some other animal to spend; then she would successfully steal the food in many cases.

Another remarkable result was the great stereotypy which Rocky showed in learning the sequence. When he moved around the top flight of the cage, which included bars going in almost every direction, he would invariably walk past the bar leading to the chain, turn around and always make a right turn on the way to the first response. In contrast, the youngsters would take all sorts of varied shortcuts depending on their starting position. Rocky was allowed to "take over" at his whim and completed the entire sequence without intrusion. Once the task was clearly mastered, however, the dianas would often pull chains for one another, even sitting patiently watching other monkeys exchange those tokens for food.

Eventually, a coin box identical to that described for the gibbons was installed, and this has provided a way for the public to interact with the monkeys and contribute to a healthy feeding regimen (Schmidt & Markowitz, 1977). In addition to the basic data collected on this token economy, the activity generated by the apparatus has provided opportunities for a number of observational studies by other researchers (e.g., Soper, 1973; Bandura, 1974). Zoo visitors also become ardent observers and "cheerleaders" as they gain respect for the agility with which these monkeys earn their food (Chasan, 1974).

### *Getting It On In the Cat House*

Another effort to provide increased entertainment and activity for zoo residents involves servals *(Felis serval)*. In the wild, these spectacularly quick cats flush fowl from the brush and catch them in flight. In captivity, they are noted for their pacing and apparent lack of ways to display their talents.

Georgianne Schmuckal studied the behavior of three servals in a "normal" cage for a year to establish baseline behavior. Then as a last part of her thesis work, she studied the effects of spaced feeding to determine its influences upon factors like aggression. Since there is sexual dimorphism in the species and the male was larger and somewhat stronger than the two females, we wanted to take every precaution to be certain that spaced feeding would not endanger the cats. This study, conducted manually, yielded interesting and surprising results: the animals fed in a rigid hierarchy with very little fighting. The male always ate first. One of the females was always the second one to eat (in spite of the fact that there was little difference in size or age). Each successive animal was allowed access to food only after the others were partially satiated.

All of this work was in preparation for our final goal of developing some animated prey for the servals. Zoo personnel and visitors would neither see it as humane, nor would it be economically feasible, to release birds or other live prey on a regular basis. So, we invented the "flying meatball". The first stage of development of this equipment was to calibrate the level that the prey should be flown. Since most of the field literature and photographs showed horizontal leaping, we were all quite surprised when we found that the serval would literally leap two body lengths off the floor to capture meatballs. (see Figure 3).

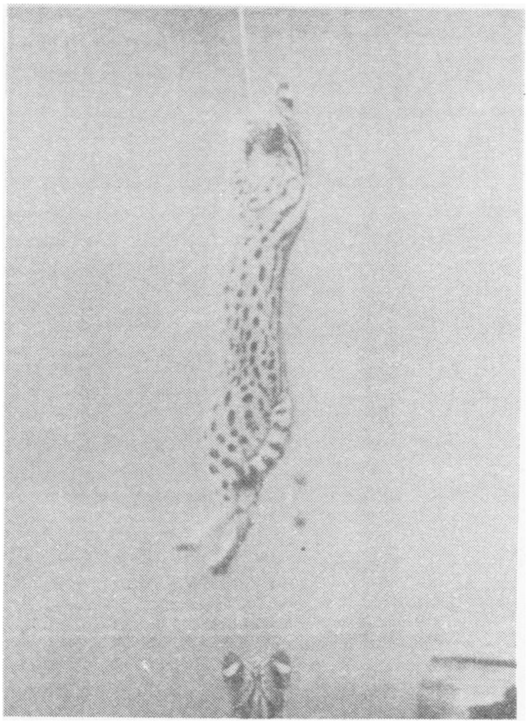


Figure 3. Serval leaping for meatball

Servals eat very little compared with some of the other species with which we have worked. Consequently, daily sessions were relatively brief, but did provide considerable activity. One last interesting note about this work is that the use of this apparatus in daily exercise by the servals allowed the zoo veterinarian to diagnose a chronic diaphragmatic hernia in the male which certainly would have gone undetected in the usual zoo environment (Schmidt & Markowitz, 1977).

### *About River Otters and Sliding*

In the wild, river otters *(Lutra canadensis)* often develop "slides" where they regularly enter streams. These slides form as a function of erosion and the compacted fecal matter of the otter which is rich in fish scales (Grzimek, 1972). Many zoos and aquariums provide slides for otter, but when careful attention is paid to the use of these slides, the frequency of use is astonishingly low (Myers, 1977).

When two otter were donated to the Washington Park Zoo along with their slide, we decided to try shaping some sliding and eventually to allow the otters to earn fish in a contingent fashion. The work was partially facilitated by the fact that their previous owner had often played with them with the slide and the otters were rather gregarious. It took only a few sessions to have them regularly sliding for fish and we soon ran upon the problem that all of the fish that it was healthy for them to eat in a single day were consumed in a half-hour at the most.

Finally, a photocell system was installed on the slide and the otters were rewarded with two fish catapulted over the wall each time that either or both of them used the slide. This system has worked well and the next plan is to look at ways in which the feeding behavior can be made more naturalistic. With substantial reconstruction of the exhibit area, it should be possible to make slides which look much more like those in the wild than the painted swimming pool model currently being used. At the same time, plans are being made for automatic delivery of live fish from random underwater locks. This new design should more closely approximate behavior in nature where otters slide into the water and then search for fish. We also know from a number of preliminary studies how much animation live fish will bring to the display and for some odd reason, while other predator-prey relationships are unpalatable to the zoo-visiting public, the consumption of fish seems to be acceptable.

### *Games Animals Play*

The mandrill *(Papio sphinx)* is a largely terrestrial primate which has a lifestyle which has made observation by field workers rather limited (Rowell, 1972). There is significant sexual dimorphism with the male being much larger. In the exhibit at Portland, the male significantly restricted space usage by the females (Markowitz & Yanofsky, 1977). Because the cage did not provide much in the way of space to provide a lot of ground movement, it was decided to install a game for the mandrills' entertainment. This speed game includes two relatively identical consoles for the resident and visitors, programming and data collection electronics, and a scoreboard (see Figure 4). Since it is the mandrills' game, the discriminative stimulus (an "I want to play" button in the form of a transluminated disk in the upper left-hand corner on their console) lights and remains available until the mandrill elects to play. The male mandrill immediately took over the game and the rest of this discussion will therefore describe his interactions with the public.

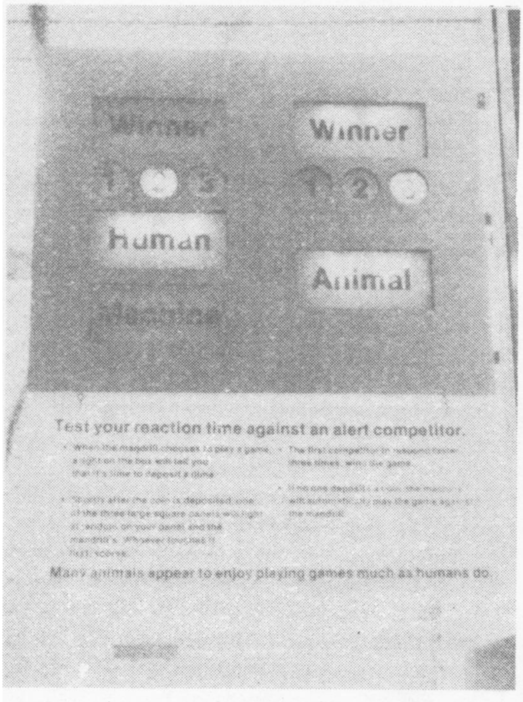
After the I Want to Play button has been pressed, the public has 15 seconds in which to ask to compete by depositing a dime. If no visitor chooses to compete, the computer automatically generates a game for the mandrill. The rules are very simple: One of the three squares lights on a random basis at identical time and location for the two consoles. Whichever contestant touches the lighted square first, wins (premature responses automatically lose). The victor of the contest is the first to accumulate three wins and, as the game progresses, results are displayed on the large public scoreboard. There is also a set of indicator lights to provide feedback for the mandrill about how many wins have been accumulated. When the mandrill wins a contest, he gets a piece of food. When the public wins, they get the knowlege that they were faster than a monkey. At the same time, we are provided the opportunity for a lot of interesting studies of reaction time, and the results have been quite dramatic.

The mandrill beats the public more than 70 percent of the time. This is not surprising since he currently competes with the computer at reaction times as fast as .310 seconds. All of the data is automatically accumulated in a solid state memory and is dumped on a cassette for computer analysis each day. This exhibit has been exceedingly popular with zoo visitors and with the national media and has consequently benefited the zoo. Perhaps more important, our data clearly show that the mandrill's occupation with the game has deferred his energies from constantly threatening or chasing his female companions. Their space usage has multiplicatively increased and stereotypic behaviors in the cage in general have been reduced (Markowitz & Yanofsky, 1977).

The latest game installed for primates is a tic-tac-toe contest for orangutans *(Pongo pygmaeus)*. This microprocessor-based system provides automatic generation of contests and data accumulation. In the first stage of training, the orangutan is learning to play by competing with the computer, but eventually the public will be given an opportunity to play if they wish in a fashion similar to that of the mandrill speed game.

After initial shaping to respond to the "I want to play" light and to the lighted "0"s, the orangutan began to compete with the first computer program. This program followed the rules of tic-tac-toe, but did not win until no other alternative was available. It may surprise the reader to know that because of the restrictive number of moves in tic-tac-toe, this "try to lose" game often defeats young children. In the current stage, the orangutan is competing with random games; i.e., the program follows the rules and neither "intentionally" tries to win nor to lose. Since the orangutan is an able and complex animal, there is little doubt that eventually he will almost always win or tie against human competitors.

Figure 4. Mandrill speed game apparatus
a. Mandrill plays the game



b. Scoreboard results

## Comparative Learning

We have studied species discrimination capabilities in a wide variety of animals. This testing has sometimes been accomplished with individual animals and sometimes in social situations. A brief description of harbor seal *(Phoca vitulina)* studies and some conducted with elephants *(Elephas maximus)* will illustrate some unexpected outcomes.

### *On Elephants and Forgetting*

Eight years prior to our work, Leslie Squier had conducted the first studies of operant conditioning of the Indian elephant in the Portland Zoo (Squier, 1964). Among the tasks completed was a light-dark simultaneous discrimination. Squier's apparatus was refurbished, and three adult female elephants were retested with an eight-year intertrial interval (Markowitz, Schmidt, Nadal, & Squier, 1975). The first elephant tested made only two errors and required six minutes to reach a criterion of 20 consecutive correct responses on this problem. This result was interesting, but not totally unexpected since elephants are known to be quite capable students, and they had little to potentially interfere with this one formal set of early training.

Testing of the other elephants yielded very different results. Not only did they not show Tuy Hoa's excellence in performing the task, but they took much longer than original training to begin to successfully respond. As a function of this research, a visual anomoly was discovered which would have gone undetected were it not for this testing. Retinal photographs corroborating the vascular deficiency in these elephants promoted keeper support for the advantages of active research programs. Currently, the first detailed tests of visual acuity in the Indian elephant are the focus of this work.

### *Seals Solve Problems Their Way*

Our first harbor seal visual discrimination tests were run in a specially prepared chamber (see Figure 5). Brian Johnson and I chose this situation largely because we thought it would yield useful results for his thesis. As time progressed, I felt increasingly uncomfortable with the fact that the most interesting behaviors were occurring outside the chamber and decided to re-engineer the situation to allow the seals to be free-swimming while they made discriminations. The new apparatus included two globes separated by approximately 8 meters (see Figure 6). Each of the globes could be lighted independently and each could produce a distinct sound.

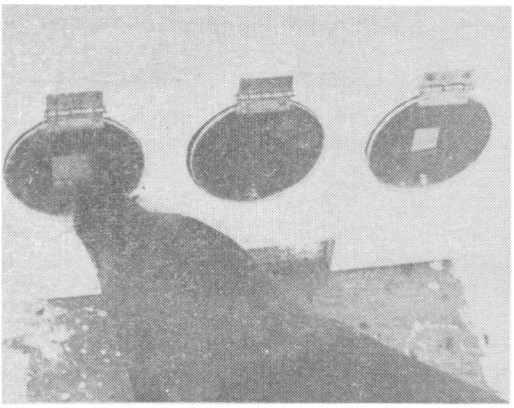


Figure 5. Harbor seals working in operant chamber

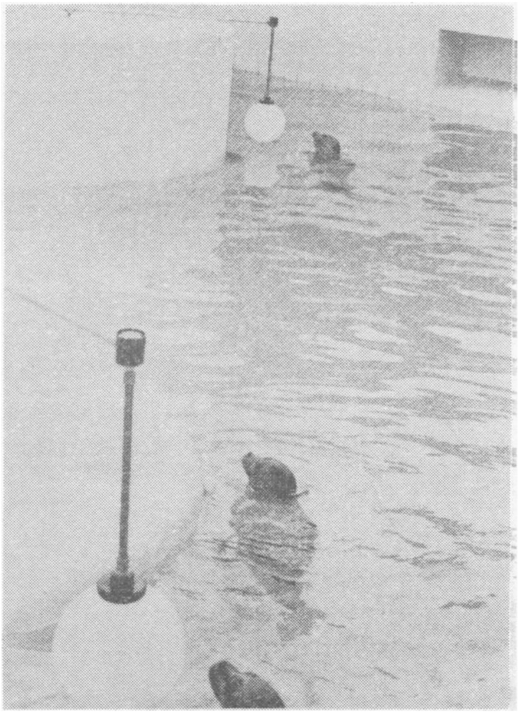


Figure 6. Harbor seal apparatus for studying discrimination learning in free swimming condition.

For five years, we have collected reversal discrimination data using very simple paradigms. First, the lighted, noisy globe is "correct" (with side randomized) to a criterion of 20 consecutive correct choices. When criterion is reached, reinforcement comes for going to the silent, dark globe. The richness of the data can only be touched on in a review paper.

Each of the seals learned how to make the discrimination, but they soon set up some individual strategies. Milhouse was delegated the work, and the other seals illustrated their memory of the contingencies by going to the appropriate side where reinforcement was delivered. The strategies which they used were so intriguing (Markowitz, 1975a, 1975c; Markowitz & Woodworth, 1977) that we continued delivering reinforcement on the side of the correct response until it became difficult for Milhouse to get his fair share of the fish. Milhouse had developed techniques like swimming nonchalantly away from the globes until the other seals would eventually join him. Then he would porpoise out of the water, take off with a great spurt, hit the globe "on the fly", and race to catch the food before the others. Finally the other seals would not be decoyed and we had to change the rules.

Fish were now delivered in one of three places on a random basis contingent upon a correct response but with locus of reinforcement unrelated with side correct. The seals continued to allow Milhouse to do the work and proceeded to set up favorite poaching locations. This set up a rather nice equilibrium in which each of the seals got an equal share of the fish. A visiting herring gull precipitated the next major work reorganization by the seals. For several days, this bird (which had a distinctive hooked beak making identification easy) flew in for each session and observed Milhouse's fish-earning technique. Suddenly one day without warning, the gull swept down from the roof where it had been watching and snatched the fish from before Milhouse's nose.

For more than three months prior to this theft, no seal other than Milhouse had made a single response on the manipulanda during testing sessions. When "his fish" disappeared, Milhouse hauled out on the island and would not go back to work. Neptune went back to the task and made 11 correct responses before his first error. This illustrates clearly that the other seals had not forgotten the task, but had arbitrarily allowed one subject to do all the work as long as he would. The measurement of group behavior in solving learning tasks in open noisy exhibits yields data which may defy traditional parametric analyses, but it also provides a richness unparalleled in more restrictive testing situations.

## Behavioral Equipment for a New Exhibit

A couple of years ago we were shown the first design plans for the new Panaewa Rainforest Zoo in Hilo, Hawaii. The invitation to do some behavioral engineering at Panaewa was exciting for a number of reasons: Instead of planning a traditional zoo, crowding in as many different species as possible, the plan was to design major exhibits, providing decent space and foliage which might flourish in this tropical rain forest. The curator and his staff acknowledged that captive animals should have as much opportunity for naturalistic behavior as possible and participated actively in the selection of behavioral tasks.

A Sumatran swamp, apporximately an acre in size, was selected as the first major project. Primary residents of this swamp were to be tigers *(Panthera tigris)* and gibbons *(Hylobates lar)*. Equipment was designed with two major objectives: to produce opportunities for species typical behaviors and to facilitate routine husbandry.

### *Gibbons*

A massive pole structure was erected on the gibbon island, from which were suspended a half-dozen rope vines. Vine hangers were designed to appear as natural as possible, and they included special sealed mechanisms to detect when each was

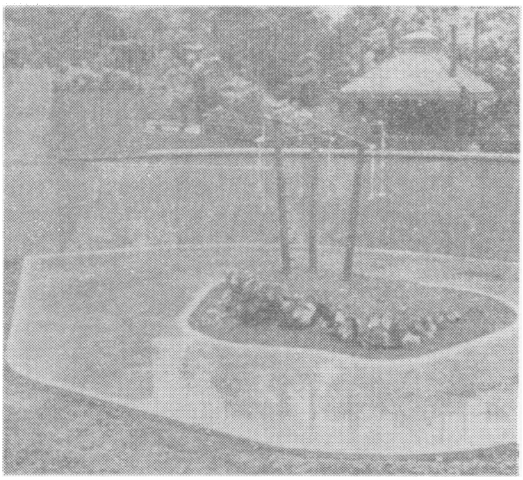


Figure 7. Panaewa Zoo gibbon island and cable for movement to hut

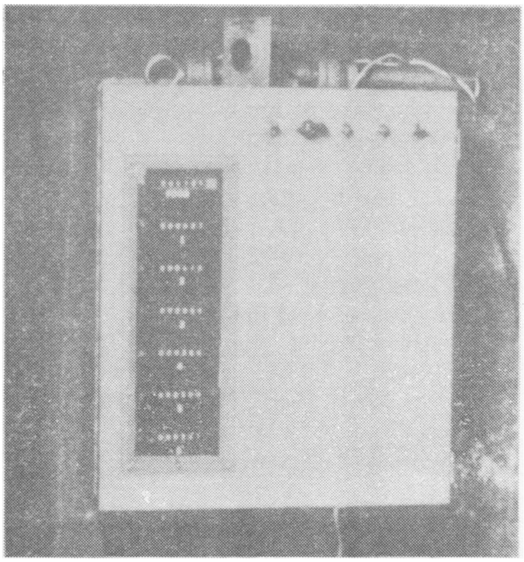


Figure 8. Panaewa gibbon behavioral control equipment

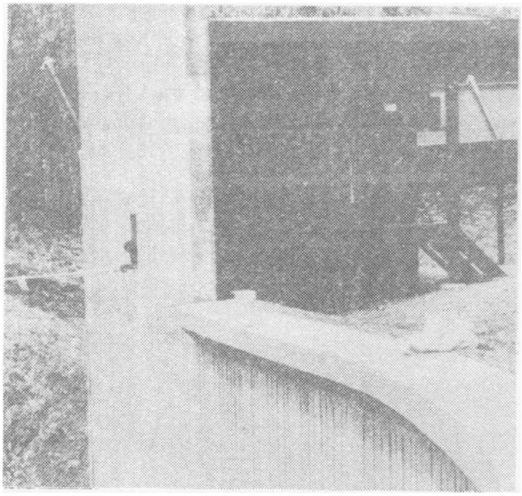


Figure 9. Panaewa gibbon feeding apparatus on side of gibbon hut

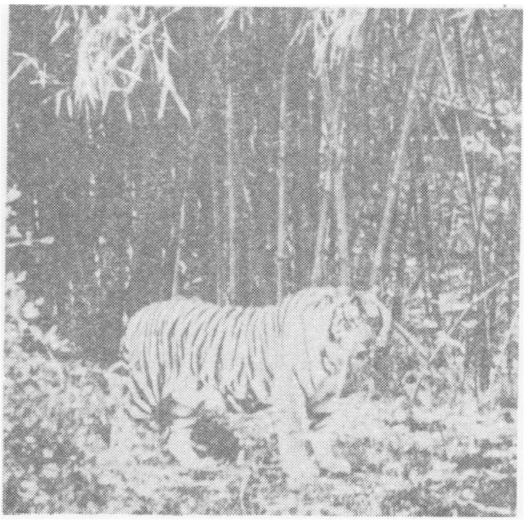


Figure 10. Forest area of the Sumatran swamp in Panaewa

swung upon. The home hut for the gibbons was 28 meters from the island structure and a steel cable wrapped with hemp was provided for travel between the pole structure and the feeding quarters (see Figure 7). Data reduction control and feeding equipment were located in the hut area (see Figures 8 & 9).

With the control apparatus, the zoo staff can select some required number of vines between which the gibbons must move to earn food. Although it would have been aesthetically pleasing to deliver fresh food on the island, simulating wild gibbon feeding (Chivers, 1972), husbandry considerations led us to deliver food in the shelter. Thus we were able to require some healthful activity of the gibbons on public view and still guarantee that they could be easily confined in the hut for examination. For readers unfamiliar with maintenance of gibbons in large, open areas, it should be mentioned that capture can be quite traumatic for keeper and resident alike.

Static counters give indication of the number of pieces of food which have been earned, the number of times that each of the vines has been swung upon, and which vines are currently being counted toward criterion. Initial animal use of the apparatus (Markowitz, et al, 1977) gives promise that this will be a very successful husbandry, display and research paradigm.

### *Tigers*

Major forest areas of the swamp incorporate bamboo and evergreen trees and a lushness seldom paralleled in the zoo world (see Figure 10). Because it would neither be economically feasible nor well accepted by the public to bring in large, live game for the tigers to bring down, we designed four field activities. Public education was also a major concern, and the entire set of activities is described on a dynamic graphic display controlled by the master computer which controls the equipment and records data. A complex, constantly changing set of activities was included so that earning food would not represent a stereotypic or eventually boring activity for the tigers. For ease of description, the final sequence of events will be described below, but it should be emphasized that it may be a year or two before the tigers elect to learn all of the contingencies. The computer programs are intentionally written to allow progress at the animal's own elective pace.

When all training is completed, a visitor to the pavillion overlooking the swamp will be provided the following scene: A TV screen scrolls out information about the ecology and behavior of the tiger. It includes information about the diminishing wild habitat and the differences between captive and wild opportunities. When the tiger wishes, he scratches on a favorite tree, indicating the desire to begin the chase. The tree has a special sensing device which detects scratches, but ignores virtually all other prevalent stimuli. The height of the detector requires the animal to rear up and extend its body. As soon as the tiger scratches, the public's graphic abruptly changes to tell them that the tigers are interested in eating. The public is invited to participate by selecting, via pushbutton, the order in which three more activities will become available. If no selection is made by a visitor within 30 seconds, the computer randomly selects the activities (see Figure 11).

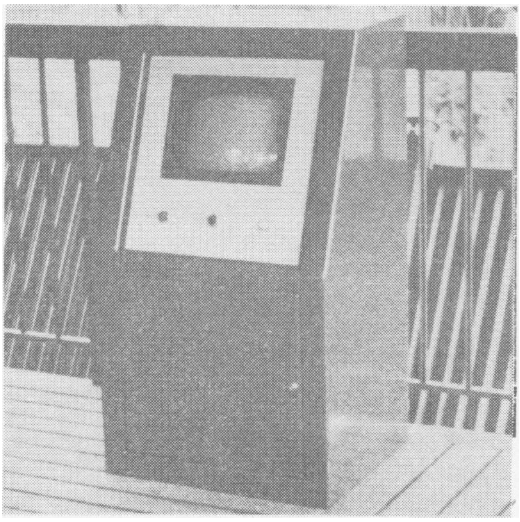


Figure 11. Visitor console and TV display for Panaewa tiger exhibit

The three activities involve the pursuit of natural-appearing ground prey and movement across a berm contoured to encourage climbing and leaping. The prey animals run across 4' mounds and are constructed with more than a half-ton of steel each. Covering the apparatus is a multi-layered, natural-appearing surface with the final coat incorporating lava earth from the surrounding environment (see Figure 12). When the tiger pounces on or swats the rabbit or the squirrel, they disappear from sight, representing capture. Throughout the sequence, the public TV screen gives a running commentary; e.g., "The squirrel is running", "The squirrel is captured". The 6' high berm includes a treadle for detection of the tiger's exercise (see Figure 13).

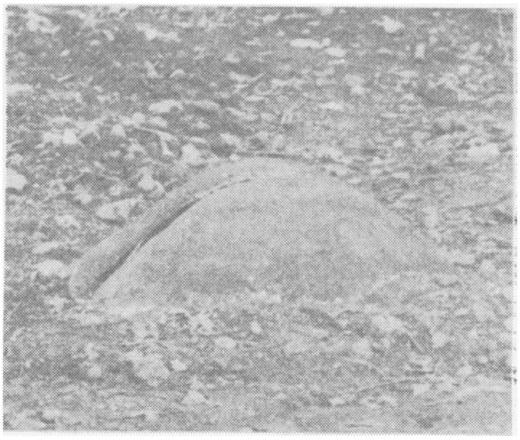


Figure 12. Mound for artificial prey

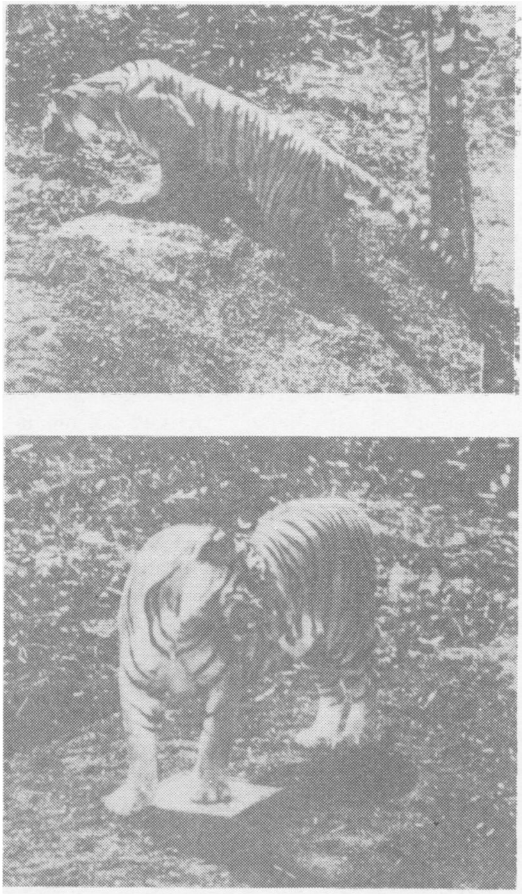


Figure 13. Tiger activities in berm area
a. Tiger climbs
b. Tiger operates treadle

The activities have been designed to be as attractive as possible to the tiger and to provide appropriate discriminative stimulus. Both the berm treadle and the tree scratch detector emit bird-like sounds to attract the tiger to the area (they also coincidentally attract all the local birds). Finally, when the three randomly occuring activities have all been completed, fresh meat is delivered automatically from a chiller beneath the public's viewing pavillion. The appearance to the visitor is of the tiger rushing towards them as the screen annunciates that the tiger has completed his exercise and is being delivered fresh food.

The flexibility of special computer circuitry with programmable memories was selected because we anticipate that it will take a long time for all of the learning to occur. The computer permits the public to participate through the training period. For example, on some days, when the tiger is learning to capture the rabbit, the TV screen informs the public of this and invites them to initiate the rabbit's movement. In similar fashion, each of the other activities is being individually taught, and the next step will proceed to provide random pairs and finally, the entire random sequence of exercise-encouraging equipment will be introduced.

We believe that this will provide a much more educational and entertaining experience than is available in most tiger exhibits. It should simultaneously help to guarantee the opportunity for ready detection of physical disabilities which comes with predictable activity (Schmidt & Markowitz, 1977). From a display and husbandry standpoint, this system provides minimum fuss for the zoo staff, ease of feeding measured amounts of veterinary-selected diets, and concentrates some of the tiger's activities in areas away from the gibbons. It also provides some guarantee that the public will occasionally have opportunity to observe the tigers away from an almost totally concealing bamboo forest into which they most beautifully blend (see Figure 14).

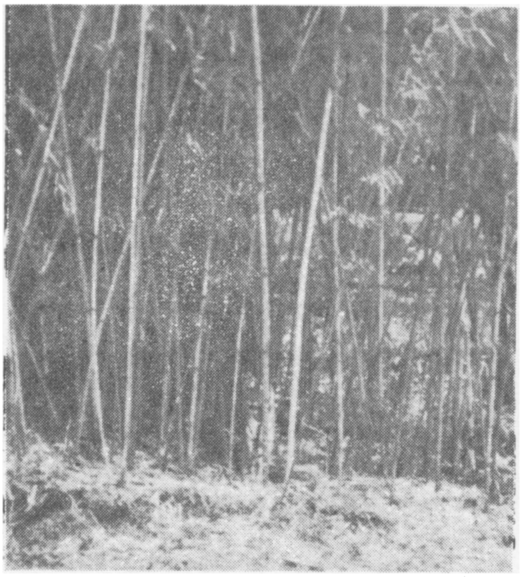


Figure 14. Bamboo forest blends with tiger's "camouflage"

## Conclusion

Much of the effort of the first half-dozen years of behavioral engineering in the zoo has been devoted to persuading zoo personnel of the need for increased behavioral opportunities for animals. For example, in a paper titled, "In Defense of Unnatural Acts Between Consenting Animals," the distinction between compulsive models of animal "conditioning" and those that provide the animal more control of its environment was stressed. For most readers of this journal, it will be unnecessary to extensively cover this issue except to point out the initial antithesis to operant positions on the part of most traditional zoo personnel. There are all the false worries about Orwellian control and domination that have been championed by general opponents of the analysis and control of behavior. This is compounded by a fear of anything new and apprehension about sophisticated electrical or mechanical devices. There persist a number of critics of behavioral engineering in the zoo (e.g., Hancocks, 1977) whose major point seems to be that this work is unnatural.

In a very simple sense, the answer to most of these criticisms is that terms like "natural" only have meaning when they have referents (Markowitz, 1977). If one is discussing the choice between leaving animals in their natural habitats and putting them in artificial environments with behavioral opportunities, almost everyone would prefer to leave and protect the animal in nature. But, many zoo workers lose sight of the fact that the choice confronting them is exhibits without explicit behavioral opportunities for the animals versus engineered environments which do address behavior.

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