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Tool use task as environmental enrichment for captive chimpanzees

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Abstract

Wild chimpanzees spend 50–80% of their time foraging, using tools and other forms of manipulation, while captive chimpanzees cannot. In this study, a device—honey in a bottle to be "fished" with artificial materials—that elicits tool use was presented to six captive chimpanzees housed in pairs. The task successfully reduced inactivity by about 52%, increased foraging opportunity from 0 to around 31% and elicited tool use and manipulation. Dominants, who had more access to the device, showed significantly more behavioural changes than subordinates. There was no statistical evidence of habituation to the device, though there was evidence of habituation to the materials. The task effectively extended the subjects' behavioural repertoire in the direction of that of wild chimpanzees.

Keywords: Animal welfare; Chimpanzees; Environmental enrichment; Honey-fishing; Tool use

1. Introduction

There is growing interest in environmental enrichment for the enhancement of husbandry conditions in captivity, reflecting world-wide concern about animal welfare. Enrichment should ideally bring the behavioural repertoire and activity budget of captive animals closer to that of wild conspecifics. Generally, increases in species-typical behaviour and decreases in atypical behaviour have been considered

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indicative of psychological well-being (Line, 1987; Bloomsmith, 1989; Chamove, 1989a,b).

Long-term studies in Africa have shown that chimpanzees (*Pan troglodytes*) spend considerable amounts of time engaged in feeding and foraging (Doran, 1997). This activity includes tool use (Goodall, 1986; Yamakoshi, 1998), defined here as the use of a detached object to achieve an immediate goal. An analysis of the behavioural repertoire of chimpanzee communities across Africa described several forms of tool use as ''habitual'' or even ''customary'' (Whiten et al., 1999), such as the use of probes to extract fluids and insects.

Foraging and feeding involve high levels of locomotion, cognitive skill and dexterity, but in captivity are considerably less complex and time-consuming (Bloomstrand et al., 1986; Chamove, 1989a,b), with tool use being mostly non-existent. The lack of social and cognitive stimulation, and appropriate food/foraging opportunities, all contribute to the reduction of feeding time, and characterise restrictive captive environments, associated with stereotypic behaviours in primates (see Erwin et al., 1979; Fritz and Fritz, 1979; Paquette and Prescott, 1988), as well as other animals (Spoolder et al., 1995; Cooper and Jackson, 1996).

Regardless of the reasons for inactivity, stereotypic abnormal behaviours and the reduction in feeding time, the current size of the captive population merits further the improvement of husbandry conditions (Brent et al., 1991).

Several devices have been designed to provide animals with interesting activities that reduce boredom, elicit exploration and promote a broader range of species-typical activities. Feeding devices, in addition to inanimate objects, have been shown to be effective enrichment alternatives, especially for socially restricted individuals (Schapiro et al., 1991). These efforts allowed animals to exhibit more natural behaviours and promoted desirable behavioural changes (Paquette and Prescott, 1988; Bayne et al., 1991).

In recent years, studies involving tool use have increased, in particular simulations of behaviour observed in wild chimpanzees (Nash, 1982; Sumita et al., 1985; Maki et al., 1989; Paquette, 1992). Even when their focus is on clarifying cognitive skills, these can provide environmental enrichment. The simulation of a tool use activity observed in the wild provides opportunities for the acquisition of species-typical behaviour. Moreover, it stimulates the subjects' cognitive abilities while engaged in tasks, exercising their problem-solving ability.

However, environmental enrichment attempts require detailed assessment of both the activity budget of subjects prior to the application of the technique and of the consequent behavioural responses to assess the feasibility of long-term implementation (Chamove, 1989a,b). This study, measuring response over a series of experimental phases, monitors behavioural change invoked by the introduction of tool use, when alternative forms of environmental enrichment (physical or social) were not available. Besides eliciting behaviours similar to termite fishing observed in the wild (Goodall, 1986; Boesch and Boesch, 1990), the tool use task involves cognitive stimulation. The aims of the present study were to assess the impact of the introduction of a tool use task, evaluating it as an environmental enrichment effort and comparing it with similar studies. The effects of the task on the psychological well-being of the subjects and its feasibility as a long-term enrichment were tested and discussed.

2. Methods

2.1. Subjects and housing conditions

The subjects were six adult female chimpanzees (*Pan troglodytes*), three born in Africa (Sachi, Kanae and Kumiko) and the others with birth place unknown (Betie, Oumu and Nikko), kept at Kumamoto Primates Park, Sanwa Kagaku Kenkyusho, Co. Ltd. They were not kin and were housed in pairs as follows: Betie (30 years) and Oumu (28 years); Sachi (24 years) and Kanae (22 years); Nikko (27 years) and Kumiko (24 years). They may have had prior experience with tools, albeit under different conditions, as they were formerly housed in social groups, in bigger compounds where artificial concrete termite mounds and branches were available.

The facility consisted of a series of linked cages of 4.5 m in length, 2.0 m in width and 2.2 m in height, where pair subjects and others chimpanzees were kept during the day (and the experiments conducted). During the night, pairs were confined in 3.5 m long by 2.0 m wide cages. As the cages were lined up side by side, individuals could interact with the chimpanzees in neighbouring cages (through the bars) in addition to the individual with whom it was paired. The cages, with concrete floors and steel bar walls, were provided with tyres, tree trunks cut horizontally, and plastic water containers. Chimpanzees were never deprived of food during the study, being fed twice daily with fruits, vegetables and chow, inside the night cage. Water was provided ad libitum. To avoid the possibility of observational learning, subject pairs were housed in cages adjacent to non-subject pairs, alternately.

2.2. Materials and task

The task was a simulation of ant-fishing behaviour, using honey as a reward. Thirty grams of honey were poured into 45 ml transparent polyethylene bottles, 60 mm deep. These bottles were set up in small acrylic boxes, attached externally, and out of the chimpanzees' reach, to acrylic panels. The panels were, in turn, attached to bars on the front of the subjects' cage. In the centre of each panel was a 5.0 mm diameter hole, providing access to a 3.0 cm^2 opening at the top of the bottles. The distances from the panel hole to the top and bottom of the honey were approximately 10 and 40 mm, respectively.

Two sets of 20 different material types were presented in each cage during the experiment (Fig. 1). The materials were simple objects, such as plastic brushes, wires, metal chains, strings, bolts, vinyl pouches, plastic spoons, metal pins, rubber tubes, wooden chopsticks, etc. ranging from 6.5 to 21 cm in length, and 1 to 20 mm in diameter. Materials had to be inserted into the hole of the panel in order to obtain honey (part of the behavioural sequence described as performance). Not all materials were appropriate for the task, as they were thicker than the diameter of the hole, or not flexible/stiff enough to bend towards the honey inside the bottle. Availability of inappropriate materials was important, not only because of the assessment of learning processes involved in selecting efficient tools (see Celli et al., 2001), but also because selection per se was considered a desirable cognitive stimulation, and the time spent searching for appropriate materials represented

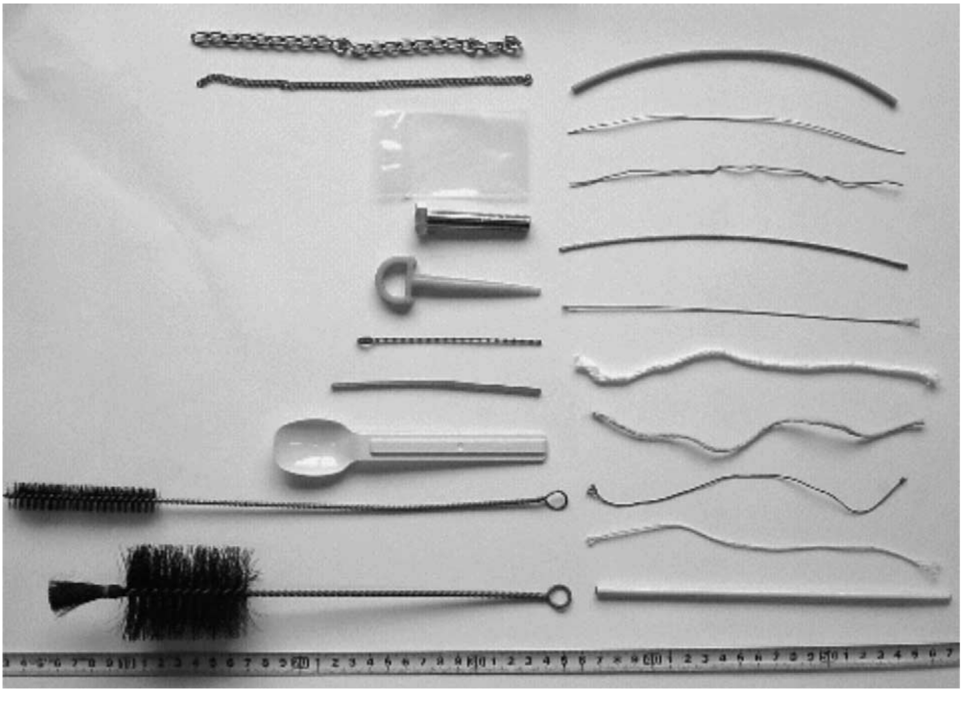

Fig. 1. Set of 20 artificial materials presented to the subjects, to be used as tools for the honey-fishing task.

manipulation rather than inactivity. Subjects had no prior experience of manipulating these materials.

2.3. Procedure

Baseline data was initially gathered over 2 days, during which time, observations of all behavioural patterns were recorded. For this condition, called A, materials were neither available nor panels attached.

During subsequent conditions, one panel was attached to the bars of each cage and two sets of materials presented, scattered below the panels, before the beginning of the session. During the habituation condition, called B and conducted for 3 days, no honey was provided. Again, all behaviours were recorded, focusing on the subjects' investigation of the panel and manipulation of the two sets of materials.

In test condition C, conducted for 10 days, materials were scattered below the panel, and a bottle containing honey was placed inside the acrylic box in each panel. All manipulation of the materials, performance of the task, subjects' activity and interactions between the paired subjects were recorded during experimental hours.

In the last test condition, termed D, only three of the six subjects, one from each experimental pair, were present. Since the panel tended to be monopolised by one chimpanzee, the individuals who spent more time performing in earlier sessions were prevented from participating in condition D sessions (the hierarchy within each pair was previously identified by author KN, a caretaker, after long-term observation). These subjects remained isolated in night cages during the 1-h experiments. Though separating pairs and isolating animals might cause stress and not be ideal from a welfare standpoint, the procedure was necessary to give less skilled individuals access to the tool use site, as learning processes were also assessed in this study (see Celli et al., 2001). During this condition, each subordinate subject was tested for 10 days.

All observations were conducted between 09:00 and 12:00 h, outside of normal feeding times. A single 1-h session was run on each pair on each observation day, in a randomised order. During all sessions of baseline, habituation and test condition C, the behaviour of both chimpanzees in each cage, was recorded with two video cameras, one fixed in front of the honey-bottle and the other in front of another part of the cage. Test condition D was recorded with only one video camera per cage, fixed in front of the honey-bottle. For this condition, the sessions were conducted simultaneously in all cages, in order to minimise the time that dominant individuals were confined in the night cages.

2.4. Data analysis

We classified the subjects' behaviours into several categories (see Table 1). To determine the activity budget of the subjects, the videotapes were analysed using 1-h focal animal sampling (Altmann, 1974) at 1-s intervals.

The total duration in seconds of each behavioural category, in each session, was calculated in all conditions as a percentage of total time, including the category "performance", representing the honey-fishing behaviour. Performance was measured for each subject of each pair for the sessions in test conditions C and D, and further divided into subordinate and dominant performance, as described above. For the categories tool use (other than honey-fishing) and aggression, the frequency of occurrence was also calculated.

Table 1
Categories of behaviours observed in the captive subjects

Categories	Description
Inactivity	Sleeping, lying, standing or sitting with no directed actions
Manipulation	Investigation (sniffing, handling) of objects in the cage and materials provided
Chewing[a]	Materials being chewed with no apparent intention of transformation/tool use
Transformation[a]	Biting or breaking materials with the purpose of modifying it to use as tools
Performance[a]	Use of materials provided as tools to fish for honey
Self	Careful inspection of one's fur and body parts with hands or lips (grooming)
Locomotion	Non-repetitive walking on the ground or climbing (more than one meter)
Abnormal	Coprophagy; repetitive regurgitation; hair pulling; stereotyped locomotion
Tool use[b]	Use of materials given or previously available in the cage with a specific goal
Social	Play, greetings, embracing, social grooming, sexual contact, reconciliation
Observation	Looking intently at a peer at less then 0.5 m
Aggression	Display, threat or physical contact (fight) towards other chimpanzee
Other	Other activities different from those described above (i.e. drinking water)

[a] Categories observed only after presentation of materials and task.
[b] Excludes the use of tools to perform the honey-fishing task.

Although the number of subjects was relatively small, we used parametric statistical tests. To equalise variance in the data between conditions, all percentage data were transformed by arcsine root transformations. Transformed data were then used for parametric tests. However, we use untransformed data for graphic presentations.

3. Results

3.1. Changes in behavioural patterns across baseline (A), habituation (B) and test (C)

Fig. 2 presents changes in the rates of each behavioural category as a function of subjects' social rank (dominant/subordinate) and experimental condition A, B, and C. As the figures show, the patterns of behaviour clearly changed with experimental condition. We conducted separate two-way (Social rank X Condition) analyses of variances (ANOVAs) for each behavioural category averaged across sessions for each condition. In categories Chewing and Observation, there were two levels of Condition factor (B and C), while there were three levels (conditions A, B, and C) in all other categories except Transformation and Performance (task-related categories). Since these task-related categories were seen only in test condition C, we conducted two-tailed *t*-tests to determine the effect of social rank.

As shown in Fig. 2, the main effect of Condition was significant for the behaviour categories Inactivity ($F_{2,8} = 55.59$, $P < 0.001$), Social ($F_{2,8} = 6.50$, $P < 0.05$), Manipulation ($F_{2,8} = 15.62$, $P < 0.01$), and Chewing ($F_{1,4} = 14.00$, $P < 0.05$). Fisher's LSD tests further revealed that the amount of time spent inactive was higher in baseline (condition A) than habituation (B) and test (C) (PS < 0.001), and time spent in Social was significantly higher in baseline than test condition C ($P < 0.01$) and marginally higher than habituation ($P = 0.056$). The subjects showed more manipulation of materials during habituation than test condition ($P = 0.051$). There was no effect of social rank on non task-related categories except that subordinates showed marginally more chewing behaviour than dominants ($F_{1,4} = 5.63$, $P = 0.077$).

For the two task-related categories, no difference was found between subordinates and dominants in Transformation of objects ($t_4 = 0.248$), but there was a significant difference in Performance ($t_4 = 3.524$, $P < 0.05$). Dominants spent more time engaged in tool use than subordinates in test condition C.

3.2. Behavioural changes within habituation sessions (condition B)

Some behavioural categories showed positive or negative trends during the three sessions of habituation. Thus, we conducted separate two-way (Social rank (2) X Sessions (3)) ANOVAs for each category. Overall, there was no main effect of Social rank, but we found a significant effect of Session on Manipulation ($F_{2,8} = 13.00$, $P < 0.01$). Object manipulation decreased across experimental days, from 36.57% in the first session to 29.2% in the second session and 8% in the third session.

Although there were no significant trends in other categories, additional analyses revealed that Manipulation and Inactivity were negatively correlated. The Pearson's

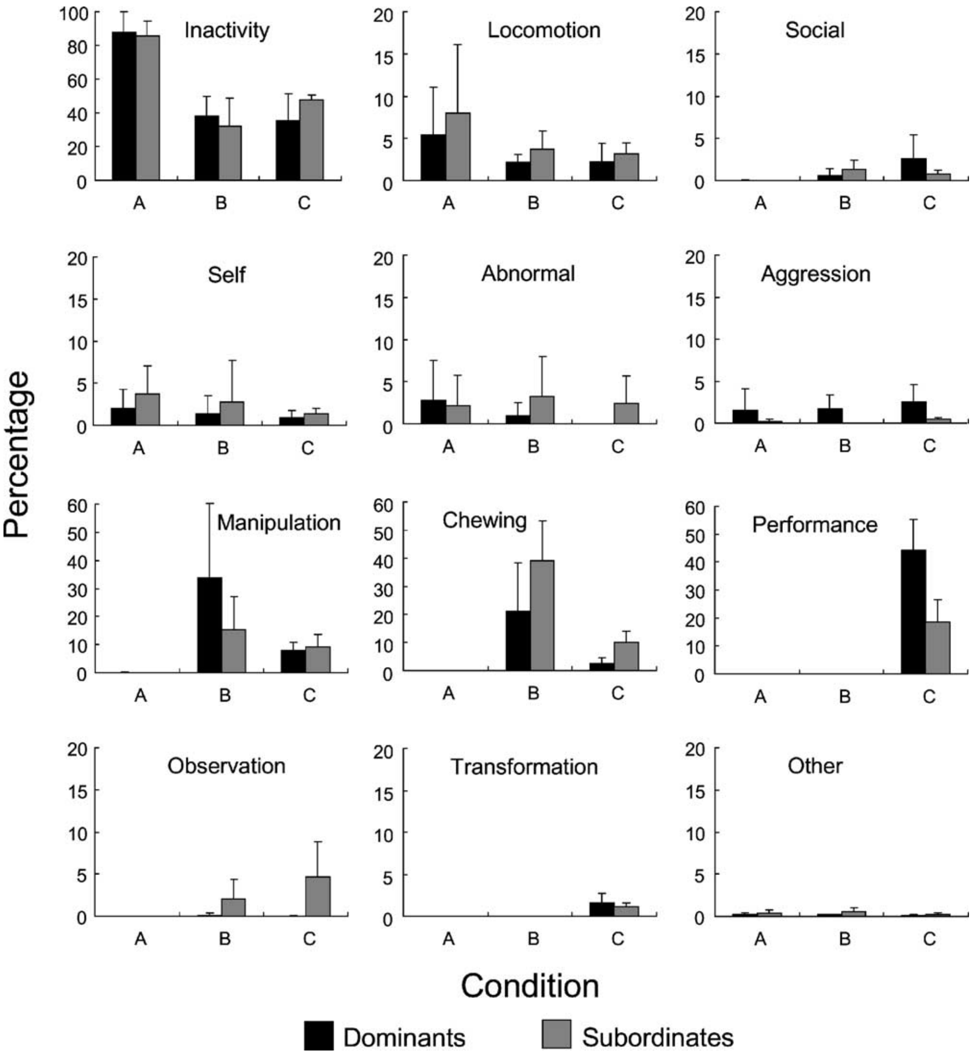

Fig. 2. Percentage of major behavioural category for dominants and subordinates in conditions A (baseline), B (habituation) and C (test). Error bars represent the standard deviation across subjects. Note that the categories ‘‘transformation’’, ‘‘chewing’’ and ‘‘performance’’, could only occur after presentation of materials and task.

correlation coefficient between these two categories was −0.58, showing significant difference from noncorrelation ($t_{16} = 2.849$, two-tailed, $P < 0.05$).

3.3. Activity budget in condition D (subordinates’ test)

During test condition D, the occurrence and duration of the behaviours of subordinates was analysed focusing on honey-fishing performance and categories Transformation and Manipulation, related to the task. Other categories (Table 1) were labelled as ‘‘Other’’.

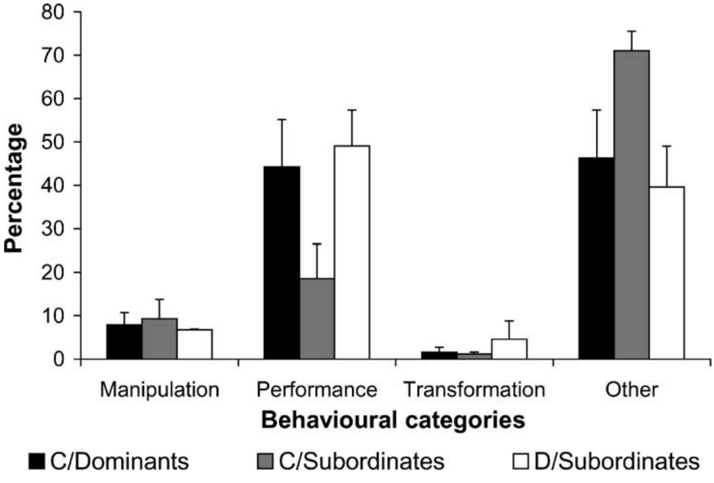

Fig. 3. Comparisons of different behavioural categories for dominants and subordinates in test condition C; and among subordinate subjects in test condition C and D (error bars represent the standard deviation across subjects).

Although the occurrence of behaviours such as performance and manipulation was variable, no specific trends, either increasing or decreasing, within sessions, were found. However, substantial changes in the behavioural patterns of subordinate subjects between the test conditions C and D were found (Fig. 3), and separate one-way (three condition) ANOVAs for each behavioural category were conducted. To compare the behavioural patterns of subordinates, we included the data of dominants in test condition C in these analyses, so that each factor had three levels: dominants in C, subordinates in C, and subordinates in D.

The duration of Manipulation and Transformation was not significantly different between conditions. In contrast, there were significant differences in Performance ($F_{2,6} = 9.84$, $P < 0.05$) and Other ($F_{2,6} = 10.72$, $P < 0.05$). Post hoc LSD tests revealed that the proportion of subordinates' task performance increased significantly from test conditions C to D ($P < 0.01$) and was comparable to that of dominants in C. Not surprisingly, the proportion of Other behaviour by subordinates decreased from C to D ($P < 0.01$), reaching that of dominants in C.

3.4. Other behaviour

Aggressive behaviour occupied a small portion of the subjects' activity budget (0.9, 0.8, and 1.5% on average for baseline (condition A), habituation (B), and test condition C, respectively), but as behaviours were of brief duration, frequency was recorded. From a total of 261 episodes observed, 221 (84.7%) were in the context of possession of the materials (B and C), and only occurred between subjects and non-subjects from neighbouring cages, never among the paired subjects. The non-subjects involved were juveniles with no access to materials, who attempted to reach them and spat water, triggering fights through the bars.

Affiliative behaviours such as social grooming and play were observed at low frequency amongst subjects and between subjects and non-subjects (0.9% during habituation and 1.7% in test condition C, while none was observed during baseline).

Tool use behaviours other than the task were recorded. The introduced materials were used to clean body parts four times (total of 2.2 min). The larger objects previously in the cage were preferred to enhance display, observed 13 times (total of 150 min) and used 20 times (2.8 min), by a subject suffering knee/joint contracture, to aid locomotion.

Abnormal behaviours remained constant through the experiment, but although rates were low (2.5, 2.1, and 2.5% in baseline, habituation, and condition C), they were as high as 15.3% for one subject in one baseline session. Two of the four individuals showing abnormal behaviours, mainly responsible for the data, were subordinates. Limitations to the experimental design prevented careful analyses of activity budget in test condition D, when subordinates had free access to the task, nevertheless stereotypies were also observed then.

4. Discussion

4.1. Behavioural repertoire

Several behaviours emerged with the introduction of the task. Materials were used to fish for honey, similar to ant/termite fishing (Goodall, 1986), and to clean body parts, similar to the observed use of leaf-napkins to wipe dirt from the body (Van Lawick-Goodall, 1968) or sticks to clear the nasal passage (Nishida and Nakamura, 1993) in the wild.

The materials enhanced manipulation patterns throughout the conditions, involving not only the selection of materials and performance of the task per se, but also transformations of materials for their use as tools. All subjects displayed spontaneous interest in manipulating the materials and performing the task.

Maki et al. (1989) also found an increase in aggression after the introduction of a food device that simulated termite fishing. Nevertheless, in this experiment, these episodes were mild and instigated by the juvenile non-subjects, interested in, but with no access to the materials. This led to episodes of sharing (Celli and Tomonaga, submitted) and further social interaction and could be considered a positive stimulation for the individuals (Moodie and Chamove, 1990).

4.2. Activity budget

Although the amount of honey consumed during experimental sessions represents an insignificant portion of the subjects' diets, the task increased the opportunity for the animals to forage in the day cage, previously absent, to an average of 31.4%. Moreover, time allocated to tool use and manipulation increased from the average 0.7% during baseline (condition A) to 8.6% during test conditions. These changes in manipulation, tool use and foraging levels, despite being limited to experimental hours were considered beneficial to developing a species-normative activity budget (see Doran, 1997).

As observed by Paquette and Prescott (1988), presentation of novel objects and task increased the duration of manipulation and simultaneously decreased inactivity levels. Maki et al. (1989) describes a reduction of 74% in mean inactivity time on the phase including the device. Other studies have also described increases in activity (Chamove and Anderson, 1979; Bloomsmith et al., 1988; Boccia, 1989; Brent et al., 1991). In our study, the beneficial results were not equally observed in both groups of subjects. Subordinates showed reduced performance and higher rates of inactivity in test condition C, but not in D, nevertheless the average inactivity time for both groups reduced approximately 52%.

As in other studies, abnormal behaviour was resistant to change (Brent and Eichberg, 1991; Lambert and Bloomsmith, 1994; Lutz and Farrow, 1996). While frustrated competition to access a device led to increased abnormalities (Bloomstrand et al., 1986), some attempts successfully reduced them (Chamove et al., 1982; Bloomsmith et al., 1988; Maki et al., 1989; Bayne et al., 1991). The absence of significant changes here might be due to the relatively short period that the enrichment was tested in comparison with the studies mentioned above, where devices/procedures where employed from 2 to 6 months or longer. Also, because most of the subjects who performed the abnormal behaviours were subordinates who had restricted access to the task, they consequently could benefit less from it.

4.3. Maintenance of the activities

Reduced manipulation rate and consequent increases in inactivity across sessions in condition B demonstrated clear habituation to the materials provided within only three experimental sessions, because the materials were not physically complex enough to sustain high rates of manipulation after the novelty effect wore off. Severe loss of motivation and decreased activity towards toys has been described previously by Line (1987), Paquette and Prescott (1988), Bloomsmith et al. (1990), and Pruetz and Bloomsmith (1992). Line et al. (1991) reported that sticks and toys did not alter rates of activity or abnormal behaviour in aged rhesus monkeys after the second day of presentation, indicating that materials successfully elicit behavioural changes, but are effective only for short periods of time. The reduction of manipulation rates between conditions B to C, besides habituation, can be accounted for by presentation of the task and the learning process itself, as manipulation was more for selection of tools and less in a free-context, than as investigation or solitary play.

Time spent in manipulation and performance was not uniform across sessions of test conditions C and D, but the fluctuation observed could be explained by motivational issues, such as satiation. Reduced use of a feeding board over time was not observed in previous studies, suggesting that tasks with food rewards are more likely to elicit continuous exploitation than other categories of physical enrichment (Bloomstrand et al., 1986; Bloomsmith et al., 1988; Maki et al., 1989; Bayne et al., 1991; Brent et al., 1991; Lutz and Farrow, 1996).

As part of the husbandry procedure, we recommend that the device be made available for longer periods, with larger amounts of reward, to give the animals the opportunity to exploit it at their own convenience. The provision of a second device per cage should also be beneficial, so both can be used simultaneously, reducing undesired monopolisation, which limits the enrichment effect for some animals. Moreover, since proved effective, the device should be made available in all cages and not just to selected pairs.

4.4. Conclusions and animal welfare implications

From an environmental enrichment perspective, the honey-fishing task had several advantages. The introduction of the materials and task increased cage complexity, opportunity for social contact, activity and served as cognitive stimulation (Schapiro et al., 1991). Changes in these features are considered reasonable candidates for the promotion of psychological well-being in nonhuman primates (Bowden, 1988).

The task represented an opportunity to acquire and perform a species-typical behaviour, approximating the repertoire of wild chimpanzees. Although no reduction in abnormal behaviour was noted, the subjects spent more time foraging and manipulating tools and less time inactive in the day cage. These factors alone demonstrate the benefits of the task.

Since subjects engaged in the task consistently over time, it may be practical for long-term implementation. Once available for an extended period, individuals can access the task voluntarily, thus, enhancing their activity budget. Another positive aspect is its practicality, easy maintenance and adaptability in size and shape, making it an efficient source of potentially long-term enrichment at a relatively low cost. The implementation of environmental enrichment techniques has limitations such as budget constraints, hygiene and health concerns, and effectiveness; nevertheless the current captive population requires attention.

We conclude that this simulation of tool use in the wild positively stimulated the subjects, enhancing their psychological well-being and is a feasible form of enrichment for chimpanzees caged in impoverished captive conditions.

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