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Computer-assisted enrichment for zoo-housed orangutans (Pongo pygmaeus)

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Abstract

*The study of environmental enrichment has identified a variety of effective forms of enrichment, but there are widespread problems associated with their use. Few forms of enrichment are cognitively challenging, and even the most effective often result in rapid habituation. This study examined the use of a computer–joystick system, designed to increase in complexity with learning, as a potential form of enrichment. Eight orangutans (*Pongo pygmaeus*), housed in male/female pairs, were observed for 120 h during a baseline period and 120 h when the computer–joystick apparatus was available. Data were collected in 1 h sessions using instantaneous group scan sampling with 30 s intervals. The orangutans spent 25.9% of the scans using the joystick system. One member of each pair monopolised the computer system: 'high users' spent 48.9% of scans using the joystick system compared with 2.9% by 'low users'. Behavioural changes associated with the provision of the computer included increases in aggressive behaviour, anxiety-related behaviours, solitary play, contact with and proximity to a social partner, and decreases in feeding. The lack of habituation by the high users, both within and across sessions, indicates that computer-assisted tasks may be a useful form of environmental enrichment for orangutans. However, the significant increase in aggression indicates that this form of enrichment may be more suitable for singly caged animals, or that the provision of multiple apparatuses should be tested for the ability to eliminate potential competition over the device.*

Keywords: *animal welfare, enrichment, great apes, non-human primates, orangutans, psychological well-being*

Introduction

The importance of environmental enrichment for improving the welfare of captive non-human primates is well known. Enrichment for such species can range in form from simple cage toys (Bloomsmith *et al* 1990a) or feeding devices (Bloomsmith *et al* 1988) to complex social groupings (Reinhardt *et al* 1987, 1988; Bramblett 1989) and visual stimulation through the use of videotapes (Bloomsmith *et al* 1990b; Bloomsmith & Lambeth 2000) and television (Brent *et al* 1989). Increases in the occurrence of species-typical behaviour (Markowitz 1982; Tripp 1985; Bloomstrand *et al* 1986; Paquette & Prescott 1988; Britt 1998; Markowitz & Aday 1998; Chang *et al* 1999), decreases in aggression (Desmond *et al* 1987; Bloomsmith *et al* 1988, 1994), the reduction of social deficiencies (Joines 1977; Fritz 1989; Schapiro & Bloomsmith 1994) and the reduction of stereotypic behaviours (Boccia 1989; Laule & Desmond 1998) as a result of these types of environmental enrichment have been observed in non-human primates. However, there are limitations with many forms of environmental enrichment: many lead to rapid habituation (Platt & Novak 1997), whilst few, other than social housing, offer any real cognitive challenge to the animal.

It has been suggested that the ideal captive environment should be complex, allow the animal some level of control or the ability to obtain rewards for appropriate action, and have some element of unpredictability (Poole 1998). The same might be said for enrichment devices. The often-unavoidable habituation to enrichment items that is inherent in most enrichment programmes, particularly for non-human primates, has created a demand for new and creative techniques for effective environmental enrichment. Owing to its dynamic and interactive nature, computer-based enrichment may have certain advantages over other types of enrichment. The infinite number of tasks and levels of complexity that can be programmed into a computer can provide animals with daily cognitive stimulation and the continual opportunity to solve novel problems. Moreover, the complexity of a task can be programmed to increase on the basis of individual performance. It has been shown that animals provided with enrichment that leads to differential outcomes, based on their responses, recover more quickly from physiological stress than those that do not have such an experience (Line *et al* 1991). Therefore, it is possible that computerised enrichment could serve to improve not only psychological, but also physiological well-being in animals.

Computer–joystick systems have been used in a variety of studies to investigate the cognitive skills of non-human primates (Washburn *et al* 1989a,b; Andrews & Rosenblum 1993, 1994; Washburn & Hopkins 1994). However, such apparatuses have not been thoroughly evaluated from the perspective of environmental enrichment. There is some evidence that access to computerised video games may be beneficial to captive primates. A computerised speed game that allowed mandrills (*Mandrillus sphinx*) to play against either zoo visitors or the computer, increased overall animal activity and led to decreased aggression (Markowitz & Aday 1998). Although their research was not conducted for the purposes of enrichment, Washburn and Rumbaugh (1992) state that rhesus macaques (*Macaca mulatto*) seemed to be particularly motivated by the control, competition, and challenge inherent in computerised tasks. To our knowledge, only two studies have scientifically examined the use of video games as a form of enrichment for captive primates. Platt and Novak (1997) presented rhesus macaques with a video game device that involved the manipulation of a joystick to solve an on-screen problem and receive a food reward. They found that both individually and socially housed individuals made use of the video game and showed no sign of habituation to the device. Furthermore, they became more active when the device was present. The authors concluded that video games may serve as an appropriate form of enrichment for captive non-human primates.

Given that great apes have such tremendous cognitive capabilities (Savage-Rumbaugh 1986; Boysen & Bernston 1990; Miles 1990; Call & Tomasello 1994; Call & Rochat 1996), they may be particularly suitable subjects for enrichment involving computerised tasks. Several years ago, some members of our laboratory initiated a study of computer-assisted enrichment for chimpanzees (*Pan troglodytes*) (Bloomsmith *et al* 2000) using a hardware system designed for the Georgia State University Language Research Center (Rumbaugh *et al* 1989; Washburn & Hopkins 1994). The chimpanzees attended to the task and learned without any formal training, spending a mean of 13% of their time using the computer. There was no evidence of habituation as exposure to the device increased (Ross *et al* 2000). One of the purposes of enrichment is to increase overall activity levels. Excluding time spent interacting with the computer, the activity levels of the chimpanzees did increase. Furthermore, their levels of auto-grooming and solitary play were reduced, indicating a shift towards species-typical behaviour patterns (Bloomsmith *et al* 2000). Following this initial success, we decided to apply a similar approach to examining the enrichment value of computerised tasks for orangutans (*Pongo pygmaeus*) at Zoo Atlanta.

In captivity orangutans are often housed in small groups (Maple 1980) because of their solitary nature in the wild compared to that of other apes (Reinhardt *et al* 1987, 1988; Bramblett 1989). Environmental enrichment initiatives may be particularly important for such solitary species when in a captive environment. Few studies have been conducted to assess the effects of any form of enrichment on the behaviour of orangutans. Wilson (1982) and Perkins (1992) found that the number of movable objects in orangutan enclosures (defined as those objects that were attached to the enclosure but moved within the space of the cage) and the number of animals in the environment correlated positively with activity levels. Perkins (1992) also found that the amount of usable surface area and enclosure volume correlated positively with activity levels.

Tripp (1985) experimentally manipulated the enclosure of a group of zoo-housed orangutans, collecting behavioural data under conditions when no enrichment items were present, or when manipulable items were present, or when both manipulable and edible items were present. Increasing activity was observed as the level of complexity increased. Similarly, Wright (1995) found that enrichment devices requiring high levels of manipulation elicited the greatest increases in object manipulation, investigation and play. Computerised tasks differ from other challenging tasks, such as those offered by Wright (1995), in that they are more dynamic and can be programmed to increase in complexity in response to the behaviour of the animal. Elder and Menzel (2001) found that a computer task identical to the one used in the current study increased frustration-related behaviours such as scratching and forceful manipulation of objects by one singly housed orangutan. However, salivary cortisol levels were reduced during the performance of the task, suggesting that the task can reduce stress in laboratory-housed great apes. The purpose of the current study was to extend the behavioural research conducted by Elder and Menzel (2001) to include both frustration-related and general behaviours in order to test the appropriateness of a computer game system as a form of enrichment for captive orangutans.

Methods

Subjects

The subjects were two male and three female Sumatran orangutans (*Pongo pygmaeus abelii*), one male and one female Bornean orangutan (*Pongo pygmaeus pygmaeus*), and one male hybrid housed at Zoo Atlanta in stable male/female pairs. They ranged in age from 6 to 43 years. The four pairs of orangutans were rotated independently on a bi-weekly basis through three large natural outdoor exhibits and one non-naturalistic indoor/outdoor enclosure that was not accessible to the public. All observations were made in the indoor areas of the enclosure, which were furnished with ropes for climbing and swinging, and with sleeping platforms. Animals in the indoor/outdoor enclosure were regularly provided with additional enrichment including cloth, boxes, phonebooks, parachutes, straw bedding, and scattered food.

Apparatus

The computer system used for this study was modelled on a system designed for and used in cognitive research at the Language Research Center of Georgia State University and the Yerkes National Primate Research Center. It consisted of a computer capable of running tasks in the DOS programming language. The computer was placed on a mobile computer cart, which was rolled up to the enclosure for the tasks. A Mach 3® joystick was mounted to a 30 × 30 × 3 cm piece of Plexiglas™ with a hole in the middle. The Plexiglas™ was then bolted to wire mesh. This design allowed the orangutans access to only the movable tip of the joystick and prevented them from removing the joystick or accessing the cord.

The computer system ran a software programme consisting of tasks that increased in difficulty based on the performance of each individual orangutan. The joystick controlled a cursor on the computer screen (Rumbaugh *et al* 1989). Two basic tasks were presented to the orangutans: the 'side task', and the 'chase task'. In the side task, the subjects were rewarded for moving the central cursor to touch any of the four walls. The walls decreased in size with each correct answer, making the task more difficult. The chase task required the subject to move the central cursor to touch a moving square target. Correct moves in both tasks were signalled by a tone, after which the orangutan was reinforced with a small amount of a preferred food or drink (fruit, cereal, or juice). When the computer was present, a zookeeper familiar to the orangutans provided reinforcement for correct responses. Reinforcements supplemented the orangutans' normal diet; they were not food deprived prior to observations. Subjects were moved from the side task to the chase task once they were able to successfully complete 200 trials during the 1 h study period.

Procedure

The orangutans were observed five days per week for 1 h (between 1200h and 1300h), both during a baseline phase, and after the introduction of the computer. Behavioural data (see ethogram in Table 1) were collected on each pair using an instantaneous scan sampling method (Altmann 1974) with 30 s intervals. Fifteen hours of data were collected on each pair of orangutans in the baseline condition, in which they were provided with normal enrichment items such as cardboard boxes, blankets, simple toys, and climbing ropes, as well as scattered browse. Immediately following the baseline period, 15 daily 1 h observation sessions were collected on the pairs while they had access to the computer system. No additional enrichment was provided during the sessions when the computer system was available. A total of 240 h of data were collected, including both the baseline and the computer phases of the study. Each pair was observed for 3–5 weeks in the baseline condition, followed by 3–5 weeks of observation in the computer condition. Data were collected by four trained observers, and inter-observer reliability was maintained at 90% or greater throughout the study.

The data were analysed as the estimated mean proportion of scans devoted to various behaviours across all subjects using Wilcoxon signed-ranks tests. For some tests, subjects in each pair were categorised into high computer use or low computer use (those spending less than 10% of scans using the computer), and individual Mann-Whitney *U* tests were conducted to compare individuals within each group. All statistical results were considered significant at $P < 0.05$.

Results

During the computer phase, the orangutans used the joystick during a mean of 25.9% of scans and watched the monitor during a mean of 4.1%. Therefore, an overall mean of 30% of scans involved time spent actively or passively engaged with the computer system. However, computer use was not equivalent across individual subjects. Within each pair of orangutans, one individual monopolised the computer and was, therefore, deemed a 'high user'. Three of these high users were female and one was male. The high users interacted with the joystick during a mean of 48.9% of scans and watched the computer monitor during a mean of 2.9%, spending an average of 51.8% of scans engaged with the computer (see Figure 1). Low users, on the other hand, spent a mean of 2.9% of scans interacting with the joystick and a mean of 5.4% of scans watching the computer monitor, giving a mean total of only 8.3% of scans engaged with the computer system. Mann-Whitney *U* tests indicated that the difference between high and low users in the mean proportion of scans spent interacting with the joystick ($Z = 2.31$, $P = 0.02$) was significant. However, the mean proportion of scans during a session that the high and low users spent watching the computer monitor ($Z = 0.73$; $P = 0.47$) was not statistically significant. As can be seen in Table 2, there were no significant differences between the high and low users in any of the other behaviours recorded, with the exception of the proportion of scans spent inactive, either prior to or following the introduction of the computer system.

Interest in the computer enrichment device did not decrease significantly over time for the high users ($Z = 0.0$; $P > 0.05$), which spent an average of 38.4% of scans using the computer in the first five sessions of the study, and a mean of 39.1% of scans using the computer in the last five sessions. In contrast, computer use by the low users decreased from 12.6% in the first five sessions to 0.96% in the last five sessions. This difference approached but did not reach significance ($Z = –1.83$; $P = 0.07$).

The mean percentage of scans spent engaged in several behaviours changed significantly following the introduction of the computer enrichment device. Table 3 presents the mean percentage of scans during which the orangutans were observed on and above the ground, and engaged in different behaviours, both before and after access to the computer system, as well as the results of the Wilcoxon signed-ranks tests used to identify statistically significant changes in behaviour.

As can be seen from Table 3, the availability of the computer caused a decrease in the mean percentage of scans in which feeding was recorded ($Z = –2.52$; $P = 0.01$). This was true both for high users (a mean of 56.6% before and 18.6% after introduction of the computer) and for low users (a mean of 52.8% before and 13.2% after introduction of the computer). The mean percentage of scans in which the orangutans engaged in solitary play increased significantly when the computer system was available ($Z = 2.20$; $P = 0.03$). Anxiety-related behaviours increased significantly after the introduction of the computer ($Z = 2.10$;

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Table 1 Operational definitions of behaviours.

Proximity measures	
Contact	Physical touching of another animal.
Proximate	Within 1 m of another animal.
Distant	Greater than 1 m from another animal.
Location	
Arboreal	No limbs on the ground.
Terrestrial	One or more limbs on the ground.
Solitary behaviours	
Feed	Chewing or ingesting chow or other food items; includes the action of raising food items towards mouth for ingestion and using hands to look through grass or hay to find food items.
Self-directed behaviour	Scratching, picking at nose or skin, genital manipulation or auto-grooming.
Object manipulation	Handling, touching, moving, smelling, or mouthing an object (not food, faeces, or joystick) with hands, feet or mouth.
Carry/hold	Grasping, but not manipulating an object (not food, faeces, or joystick).
Locomote	Movement from one place to another; does not include pacing.
Solitary play	Play behaviour that does not involve another animal.
Inactive	Sitting or lying, engaged in no other behaviours.
Anxiety-related behaviours	
Scratch	Fast scraping of fingernails across any part of the body.
Yawn	Wide opening of the mouth, involuntarily accompanied by deep inhalation.
Abnormal behaviours	Regurgitation and re-ingestion, hair plucking, faeces ingestion or manipulation, pacing or other idiosyncratic repetitive movement.
Computer behaviours	
Watch monitor	Eyes directed towards the computer monitor.
Joystick	Touching or manipulating the joystick with hands, feet or mouth while eyes directed towards the computer monitor.
Social affiliative behaviours	Playing with, grooming, being groomed by, examining, or engaging in sexual behaviour with another animal.
Social agonistic behaviours	
Non-contact aggression	Non-physical displaying at or threatening of another animal.
Contact aggression	Physical aggressive contact, including hitting, tugging, grabbing, biting, stomping on, or rolling the victim.
Other	Exhibiting behaviour that is not listed here.

P = 0.04). As can be seen in Figure 2, an increase in yawning and scratching occurred both in high users (a mean of 0.49% before and 4.1% after introduction of the computer) and low users (a mean of 0.44% before and 1.3% after introduction of the computer). Other forms of stereotypic behaviour did not change significantly after the introduction of the computer.

Although aggression occurred at very low levels throughout the study, levels of non-contact and contact aggression significantly increased after the introduction of the computer ($Z = -2.20$; $P < 0.03$). This increase in aggression occurred in both high and low users of the computer system for non-contact and contact aggression (see Figure 3). Proximity measures also changed significantly following exposure to the computer, with orangutans spending less time distant from each other when the computer was available ($Z = -2.52$; $P = 0.01$). Within a pair, time spent both in contact with, and proximate to, the other individual increased after the introduction of the computer ($Z = 2.1$; $P = 0.04$ and $Z = 2.53$; $P = 0.01$ respectively).

Discussion

This study has shown that captive orangutans were able to use a joystick-controlled computer apparatus with food reinforcement and to learn two simple tasks with no explicit training. The orangutans did not habituate to the computer system. An assessment of the first and last five days of the computer phase revealed that the use of the computer by those orangutans that spent the most time interacting with it did not decrease during the course of the study, possibly because of the flexibility of the computer system. The programme increased in complexity and the tasks changed over time, maintaining the attention and interest of these orangutans. The lack of habituation to the computer system that was observed in this study in the high users distinguishes it from other, similar, types of enrichment that have been used for great apes in the past, such as television, videotapes and slides (Sackett 1966; Brent *et al* 1989; Bloomsmith *et al* 1990b; Andrews & Rosenblum 1993, 1994; Bloomsmith & Lambeth 2000). Interactive enrichment techniques, in which reward rates are determined by performance

Table 2 Mean percentage of scans in which high user and low user orangutans were observed on and above ground, and engaged in different behaviours, before and after access to the computer system. (*Z* scores and *P* values are the results of Mann-Whitney *U* tests [* $P < 0.05$]).

Behaviour	Phase of study	High user (n = 4)	Low user (n = 4)	*Z* score	*P* value
Arboreal	Baseline	11.57	14.28	–0.30	0.77
	Computer	4.42	12.18	–1.44	0.15
Terrestrial	Baseline	85.40	85.37	0.00	1.00
	Computer	91.83	76.72	–0.87	0.39
Aggression	Baseline	0.37	0.30	–0.33	0.74
	Computer	1.44	1.60	0.00	1.00
Social behaviour	Baseline	1.86	2.09	–0.29	0.71
	Computer	0.54	1.71	–0.58	0.56
Abnormal behaviour	Baseline	2.95	1.81	–0.30	0.77
	Computer	4.14	1.40	–0.29	0.71
Anxiety-related behaviour	Baseline	0.66	0.51	–0.57	0.56
	Computer	4.57	1.86	–0.57	0.56
Carry/hold object	Baseline	1.68	3.19	–1.16	0.25
	Computer	0.26	0.38	–0.15	0.88
Object manipulation	Baseline	9.02	9.68	–0.29	0.77
	Computer	3.79	8.19	–1.16	0.25
Locomote	Baseline	9.08	7.67	0.00	1.00
	Computer	4.76	8.07	–1.73	0.08
Solitary play	Baseline	0.65	0.40	–0.30	0.77
	Computer	1.58	1.89	–0.15	0.89
Inactive	Baseline	18.64	21.44	–0.87	0.39
	Computer	8.00	39.68	–2.31	0.02*
Feed	Baseline	56.56	52.79	–1.16	0.25
	Computer	18.64	13.22	–1.16	0.25

on a task, have been found to hold the interest of primates for long periods of time (Markowitz & Aday 1998).

One orangutan in each pair dominated the computer system, interacting with the computer in almost half of the scans during which it was available. Despite the fact that the orangutans did not make equal use of the computer system, it was a focal point for all subjects. This resulted in an increase in the amount of time the orangutans spent in contact with, and in proximity to, their social partners. Although low users rarely touched the joystick, they spent a large amount of their time near the system and the high user, either watching the computer screen, or begging for food from the zookeeper who was delivering reinforcers to the high user. The increase in proximity was accompanied by an overall increase in aggression, initiated by both low users and high users. High users often drove low users away from the computer for brief periods of time, and were rarely displaced from the computer system. This increase in aggression was not expected in this study. Research conducted on chimpanzees and macaques in a similar social setting has reported no aggressive monopolisation of the computer system (MA Bloomsmith, personal communication 2002). The observed increase in aggression in this study may have been the result of competition over the limited resource, which is common when food sources or enrichment devices are highly desirable and defensible (Boccia *et al* 1988; Maki *et al* 1989). This problem is typically addressed by adding and dispersing food sources or by providing additional enrichment devices for groups of primates. However, neither Bloomsmith *et al* (2000) nor Platt and Novak (1997) observed an increase in aggression or monopolisation of the computer system by any one individual when socially housed chimpanzees or rhesus macaques were given access to a computer task. The fact that this type of competition has not been reported in other studies suggests that there may be species differences in competitive behaviour.

Orangutans are generally more solitary, and presumably have less well-established hierarchical systems than the more social great apes (Maple 1980). In the wild, orangutans aggregate only in the presence of trees that are rich in fruit (Utami *et al* 1997). They appear to adjust their behaviour specifically to eliminate the possibility of competition by forming groups only when food availability within a tree is high. However, dominance relationships between orangutans affect access to large fig trees: a

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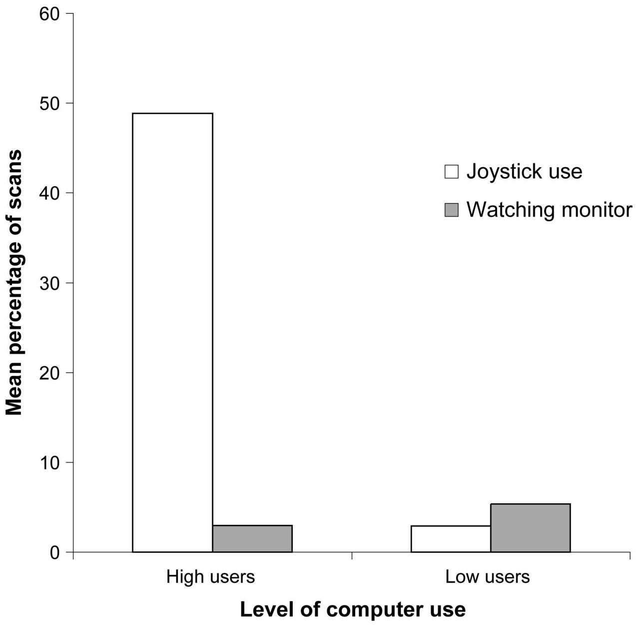
Table 3 Mean percentage of scans in which orangutans were observed on and above the ground, proximate to their social partners, and engaged in different behaviours, before and after access to the computer system. (*Z* scores and *P* values are the results of Wilcoxon signed-ranks tests [* *P* < 0.05]).

Behaviour	Pre-computer (n = 8)	Post-computer (n = 8)	*Z* score	*P* value
Arboreal	12.92	8.30	–1.40	0.16
Terrestrial	85.40	84.30	–0.28	0.78
Aggression	0.23	1.40	–2.20	0.03*
Social behaviour	1.97	1.13	–1.26	0.21
Abnormal behaviour	2.38	2.77	–0.85	0.40
Anxiety-related behaviour	0.58	3.22	–2.24	0.03*
Carry/hold object	2.44	0.32	–2.52	0.01*
Object manipulation	9.40	5.99	–1.40	0.16
Locomote	8.40	6.42	–0.98	0.33
Solitary play	0.52	1.74	–2.20	0.03*
Inactive	20.0	23.8	–0.28	0.78
Feed	54.70	15.93	–2.52	0.01*
Proximate	13.95	35.58	–2.53	0.01*
Contact	5.80	12.04	–2.11	0.04*
Distant	78.50	48.25	–2.52	0.01*

Figure 1



Mean percentage of scans that high user and low user orangutans spent using the joystick and watching the computer monitor when the computer was available.

dominant individual will sometimes displace a subordinate from a tree. Once displaced, a male subordinate is rarely allowed to return. Utami *et al* (1997) attribute this to sexual competition rather than to food competition because dominant females are more tolerant in allowing subordinate females to return after being displaced than are males. Sexual competition in the current study is an unlikely explanation for the monopolisation of the computer system because the pairs were male/female and it was more often the female that was excluding the male from access to the computer. Therefore, it is more likely that the increase in aggressive behaviour was a result of limited resources. In our study, there was only one enrichment device and one zookeeper, encouraging competition over the computer system. This type of situation would not occur in the wild because orangutans would adjust their behaviour such that they would remain solitary when food sources were limited. Therefore, our study may have induced unnatural circumstances that orangutans in the wild would not normally experience.

Another possibility for the increased aggression when the orangutans had access to the computer system was our use of familiar zookeepers to deliver reinforcement for correct responses. The zookeepers provided similar reinforcers as those used in the research sessions for correct responses during training sessions for routine husbandry practices. Therefore, the animals were confronted with an unusual situation: keepers were present at the front of the enclosure, as they would be for the purposes of training, but were ignoring behaviours that would normally have been reinforced (eg presenting body parts for inspection). It is, therefore, possible that the measured increase in aggression was displaced frustration on the part of the low users as a result of not receiving food and/or attention from the zookeepers, rather than being due to competition over the computer–joystick system itself. The presence of familiar humans has been shown to increase agonism in chimpanzees (Lambeth *et al* 1997). Zookeepers were not present during baseline sessions, preventing separate analyses of the effects of the computer system and keeper presence. We are currently expanding this study by developing and implementing an automated reinforcement system for the orangutans in an effort to remove the possible influence of humans on the behaviour of the animals. We will also test the effect of multiple computer systems on behaviour in

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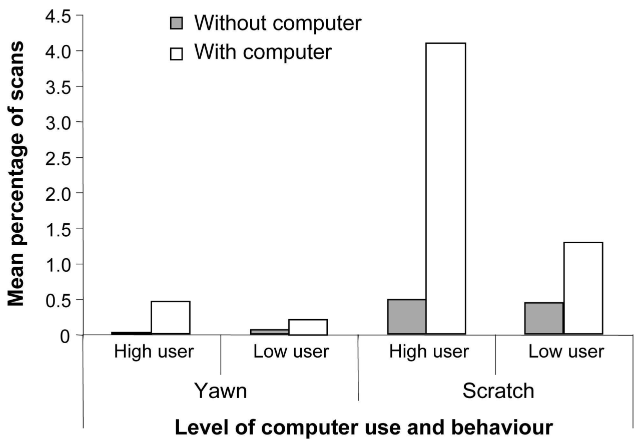
order to determine whether increasing the availability of this resource will reduce or eliminate the negative effect of aggression and perhaps allow high levels of computer use by each member of the social group.

There was a significant increase in anxiety-related behaviours (scratching and yawning) when the computer system was available. Research suggests a relationship between scratching and anxiety in several species of primate (Troisi *et al* 1991; Baker & Aureli 1997; Das *et al* 1998), including orangutans (Elder & Menzel 2001). In this study, high users performed much higher levels of scratching behaviour. Whilst scratching also increased in low users when the computer was available, the difference was not nearly as pronounced as that observed in high users. The increased scratching associated with the availability of the computer system in high users may be attributable either to the tension involved in defending their location in front of the computer from their social partner, or to the cognitive challenge associated with the tasks. Elder and Menzel (2001) found similar increases in self-directed behaviour in a singly housed female orangutan that was given access to a video game system similar to the one used in the current study, suggesting that increases in frustration-related behaviour are not necessarily a result of competition. Rather, they found that aspects of the task itself, such as increases in the delay period between trials, resulted in an increase in frustration-related behaviour. Scratching has been shown to increase during computerised cognitive tests in both chimpanzees (Leavens *et al* 1997) and orangutans (Elder & Menzel 2001). As the system is designed to continuously increase in difficulty as subjects master lower-level tasks, it becomes increasingly challenging, which may elicit anxiety- or frustration-related behaviours. We did not record the levels of performance achieved by the orangutans in these tasks or alter aspects of the system. Further research would be necessary to clarify whether the increase in scratching was associated with some aspect of the game itself, such as delay between trials or an increase in the cognitive challenge. Low users did not spend enough time on the computer to experience the increases in complexity of the task. Therefore, increases in scratching observed in low users may have resulted either from their not being allowed access to the computer or from the fact that the keepers providing positive reinforcers were ignoring their behaviour.

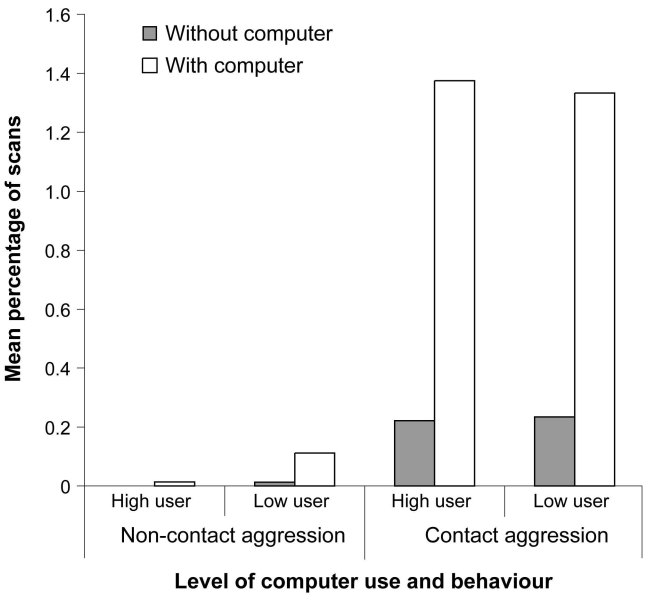
The increase in scratching observed after the computer system was made available was not accompanied by any significant increases or decreases in abnormal behaviours. Enrichment programmes are often conducted with the goal of not only increasing activity, but also decreasing the occurrence of abnormal behaviours (Bloomsmith 1989; Chamove & Anderson 1989; Markowitz & Line 1989). Some studies have found that complex tasks can actually cause an increase in abnormal behaviours in at least some animals (Bloomstrand *et al* 1986). However, Washburn and Rumbaugh (1992) observed a decrease in the prevalence of stereotypic and self-directed behaviours in rhesus macaques that were given access to the same computer task used in our study. No changes were found in any of the abnormal behaviours that were recorded in the present study; however, they occurred at very low levels throughout the study making it difficult to draw any definitive conclusions.

Figure 2



Mean percentage of scans that the orangutans spent engaged in anxiety-related behaviours as a function of level of computer use (high versus low), both with and without access to the computer system.

Figure 3



Mean percentage of scans that the orangutans spent engaged in aggressive behaviour as a function of level of computer use (high versus low), both with and without access to the computer system.

Computer-assisted enrichment decreased the time the orangutans spent feeding in this study. Many enrichment programmes are initiated with the goal of increasing the time required to search for and/or process food without increasing overall consumption (Bloomsmith *et al* 1988). In the baseline sessions of our study, small food items were often scattered throughout the enclosure as enrichment, requiring the orangutans to spend large amounts of time foraging. Although they spent less time feeding when the computer system was available, computer-assisted enrichment seemed to be able to sustain interest without requiring large amounts of food and reinforcers. This could be important for great apes in a captive environment, where inactivity and over-consumption of food can lead to obesity, resulting in increased health problems and, therefore, decreased well-being (Brent 1995).

In conclusion, our research suggests that a computerised system may be a good form of enrichment for captive orangutans. Although the cost of this form of enrichment may be initially higher than other simpler forms of enrichment (approximately $100 plus the donation of an out-dated computer), the value of the enrichment device may be amortised over long periods. The sustained interest in an interactive computer system, as observed in the high users in the current study and others, suggests that it might be an appropriate form of long-term enrichment. However, given the increase in aggression and scratching observed in this study, caution should be taken when considering the use of computer-assisted enrichment with orangutans. These are not desirable behavioural responses to enrichment. Future research will be conducted with the goal of minimising the negative changes in behaviour observed in our study. One explanation for the increases in aggression and frustration-related behaviours may be the presence of the zookeeper who provided reinforcement. Studies will be conducted using automated devices that will provide reinforcers to the orangutans, thereby removing the possible influence of keepers on the behaviour of these animals during the computer phase. Another possible explanation for these results is that the presentation of a single computer system to pairs or larger groups of orangutans may create competition over the limited resource and therefore increase aggression. In the wild, if a tree is large enough and contains enough fruit to accommodate several individual orangutans, the presence of a dominant individual in the same fig tree does not seem to adversely affect foraging behaviour or foraging efficiency in the tree (Utami *et al* 1997). Therefore, the effects of multiple computer systems for groups of orangutans will be tested in order to determine whether increasing the availability of the resource decreases aggression and increases the level of computer use by all members of the social group.

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