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Using multiple joystick systems in computerised enrichment for captive orangutans

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Abstract

*It has been suggested that providing multiple computers with automatic reward dispensers as enrichment to captive orangutans (*Pongo *spp) (as opposed to a single computer, with a care-staff person delivering reinforcers) might help improve behavioural outcomes. The purpose of the current study was to test this hypothesis by providing two computers with automatic reward dispensers to eight orangutans housed in four male-female pairs at Zoo Atlanta, USA. Subjects were observed for ten days during each of three phases: a baseline phase (during which, no computer was provided); immediately followed by Phase 1 (during which, one computer system was provided to each pair of subjects); immediately followed by Phase 2 (during which, two computer systems were provided to each pair). Data were collected in 1-h sessions using instantaneous scan sampling. There was no habituation to the computer system, nor were there any significant increases in aggression, rough scratching, and abnormal behaviours in either computer phase, which indicates that computer-joystick systems are effective as enrichment for captive orangutans. However, a high level of interest in the computer was shown by only a few individuals, which highlights a need to take into consideration individual differences when providing computerised enrichment to captive non-human primates. It would also be advisable to provide other forms of enrichment to increase activity levels for individuals which are not interested in interacting with a computer, as well as to help increase the diversity of behaviours being stimulated by the enrichment.*

Keywords: *animal welfare, automated feeder, computers, enrichment, joystick, orangutans*

Introduction

Environmental enrichment to improve captive animal welfare has traditionally involved providing opportunities for social interaction (eg social housing), and/or providing inanimate objects, which can be used either actively (eg puzzle feeders), or passively (eg television) (for reviews, see Shepherdson 1998; Young 2003; Lutz & Novak 2005). Social interactions are generally considered to be the most effective form of enrichment for group-living animals, mainly because they can be dynamic, unpredictable, and cognitively stimulating (for reviews, see Young 2003; Lutz & Novak 2005; Honess & Marin 2006). However, technological advances in recent decades have made it possible for so-called 'inanimate' devices to be designed in such a way as to provide cognitive challenges through dynamic and interactive experiences, one example being computerised enrichment devices.

In the late 1980s, a joystick-controlled computerised testing system (CTS) was developed by researchers at the Language Research Center (LRC) to test cognitive skills in non-human primates (Rumbaugh *et al* 1989; Washburn *et al* 1989a,b). Although the system was originally designed to test cognitive skills, it was also found to be a useful enrichment device for *singly housed* rhesus monkeys (*Macaca mulatta*) (Washburn & Rumbaugh 1992a,b). These researchers found a lack of habituation to the device, increased activity, and decreased self-directed behaviour (such as over-grooming), cage-directed behaviour (such as shaking/biting the mesh), and stereotypic pacing and rocking.

The LRC-CTS has also been found to be an effective enrichment device for *socially housed* non-human primates. Washburn *et al* (1994) found no evidence of habituation, aggression, or other undesirable behaviours (such as cage-biting and stereotypies), when two devices were provided to pair-housed rhesus monkeys. Similarly, when Lincoln *et al* (1994) provided three computerised testing devices to eight socially housed pig-tailed macaques (*Macaca nemestrina*), informal observations indicated that all individuals were using the devices, and there was no evidence of heightened aggression.

These early studies evaluated the effectiveness of providing *multiple* computers to socially housed non-human primates. Studies have also been conducted on the effectiveness of providing a *single* device to several individuals. For instance, Platt and Novak (1997) provided one computerised testing system to a group consisting of four rhesus monkeys, and another system to a group consisting of three rhesus monkeys. All individuals in each group were observed to use the system. There were no increases in aggression, and no habituation to the system.

More recently, Bloomsmith *et al* (2000) and Ross *et al* (2000) evaluated the LRC-CTS for its use as an enrichment device for socially housed chimpanzees (*Pan troglodytes*). Subjects did not habituate to the device, and the researchers found a decrease in solitary play and self-grooming, and a trend towards increased locomotion when the device was available for use. Some individuals used the device more than others, but no aggressive monopolisation of the device was observed (MA Bloomsmith, personal communication 2012).

The LRC-CTS has also been tested as an enrichment device for orangutans (*Pongo* spp) at Zoo Atlanta, USA (Tarou *et al* 2004). In this study, eight orangutans were housed in male-female pairs, and each pair was given access to one computer. Individuals could solve tasks using a joystick and were reinforced for each correct response. One individual in each pair was found to monopolise the system (ie, there was a 'high user' and a 'low user' in each pair). The researchers found an increase in aggression when the computer was provided, as compared to a baseline phase during which no computer was provided. This is different from previous studies of rhesus monkeys (Platt & Novak 1997) and chimpanzees (Bloomsmith *et al* 2000; Ross *et al* 2000) in which researchers found no aggressive monopolisation of a single computer system. Tarou *et al* (2004) hypothesised that aggression might have increased in their study because of the presence of familiar care-staff who were delivering food rewards as reinforcement for correct responses (ie, there was aggressive competition over food and/or attention from the care-staff, instead of competition over the device). It is to be noted that automatic reward dispensers were used in all previous studies in which there were no increases in aggression with the provision of one computer.

Apart from an increase in aggression, Tarou *et al* (2004) also found a significant increase in rough scratching, which is an indicator of stress or tension (Aureli & de Waal 1997; Baker & Aureli 1997; te Boekhorst *et al* 1991; Maestripieri *et al* 1992; Aureli & Schaffner 2002). They hypothesised that the increase in rough scratching in high users might have been the result of anxiety from the cognitive challenge imposed by the tasks. Previous researchers have found a similar increase in anxiety-related scratching, either with increasing task difficulty during cognitive testing of chimpanzees using match-to-sample tasks (Leavens *et al* 2001; Heintz & Parr 2008), or with an increased delay between trials of a cognitive task (which involved moving a cursor to touch a stationary target) for an orangutan (Elder & Menzel 2001). However, researchers using tasks similar to those used by Tarou *et al* have not reported anxiety-related scratching (Washburn & Rumbaugh 1992a; Lincoln *et al* 1994; Washburn *et al* 1994; Platt & Novak 1997; Bloomsmith *et al* 2000; Ross *et al* 2000). More studies are required to determine whether factors other than cognitive challenge can elicit anxiety-related behaviours during computer-assisted enrichment. For instance, Tarou *et al* hypothesised that the increase in rough scratching seen in their study may have resulted from the stress in competing for food and/or attention from care-staff (and, for low users in particular, scratching might have increased because they were not being reinforced often by familiar care-staff who usually gave them food rewards in other situations).

Despite the increase in some undesirable behaviours in their study, Tarou *et al* (2004) found no evidence of habituation to the system and no increase in any abnormal behaviours (such as stereotypic pacing, regurgitation and re-ingestion, faeces manipulation, hair plucking, and coprophagy). They suggested that using an automatic reward dispenser (as in previous studies) and providing multiple computers might have decreased some of the aggression and anxiety-related behaviours that were seen in their study. The purpose of the current study was to incorporate these suggestions and test whether providing two computers with automatic reward dispensers to pair-housed orangutans at Zoo Atlanta would prevent the occurrence of aggression and anxiety, while maintaining the positive outcomes of computer-assisted enrichment (ie, lack of habituation and an absence of abnormal behaviours).

Materials and methods

Study animals

Subjects were the same four male-female pairs studied by Tarou *et al* (2004). There were two pairs of Sumatran orangutans (*Pongo abelii*), one pair of Bornean orangutans (*Pongo pygmaeus*), and one pair consisting of a female Sumatran orangutan and a male hybrid (*P. abelii* × *P. pygmaeus*). Data were collected from October 2003 to May 2004. At the time of data collection, the subjects were housed at Zoo Atlanta. Subjects lived in social groups (ranging from 2–4 individuals) in outdoor exhibits and were brought into their indoor enclosures as pairs for testing, during data collection. Depending on husbandry needs, group composition in the outdoor enclosures changed occasionally. However, the same pairs were always brought in for testing. They were fed according to their normal daily routine, and water was available *ad libitum*.

This research complied with protocols approved by Institutional Animal Care and Use Committees at Zoo Atlanta and Georgia Institute of Technology, and adhered to the laws of the USA.

Apparatus

The design for the computer enrichment devices was developed at the Language Research Center of Georgia State University, USA (Rumbaugh *et al* 1989; Washburn & Rumbaugh 1992b). Each device consisted of a computer with a monitor and a Mach 3® joystick (CH

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Figure 1

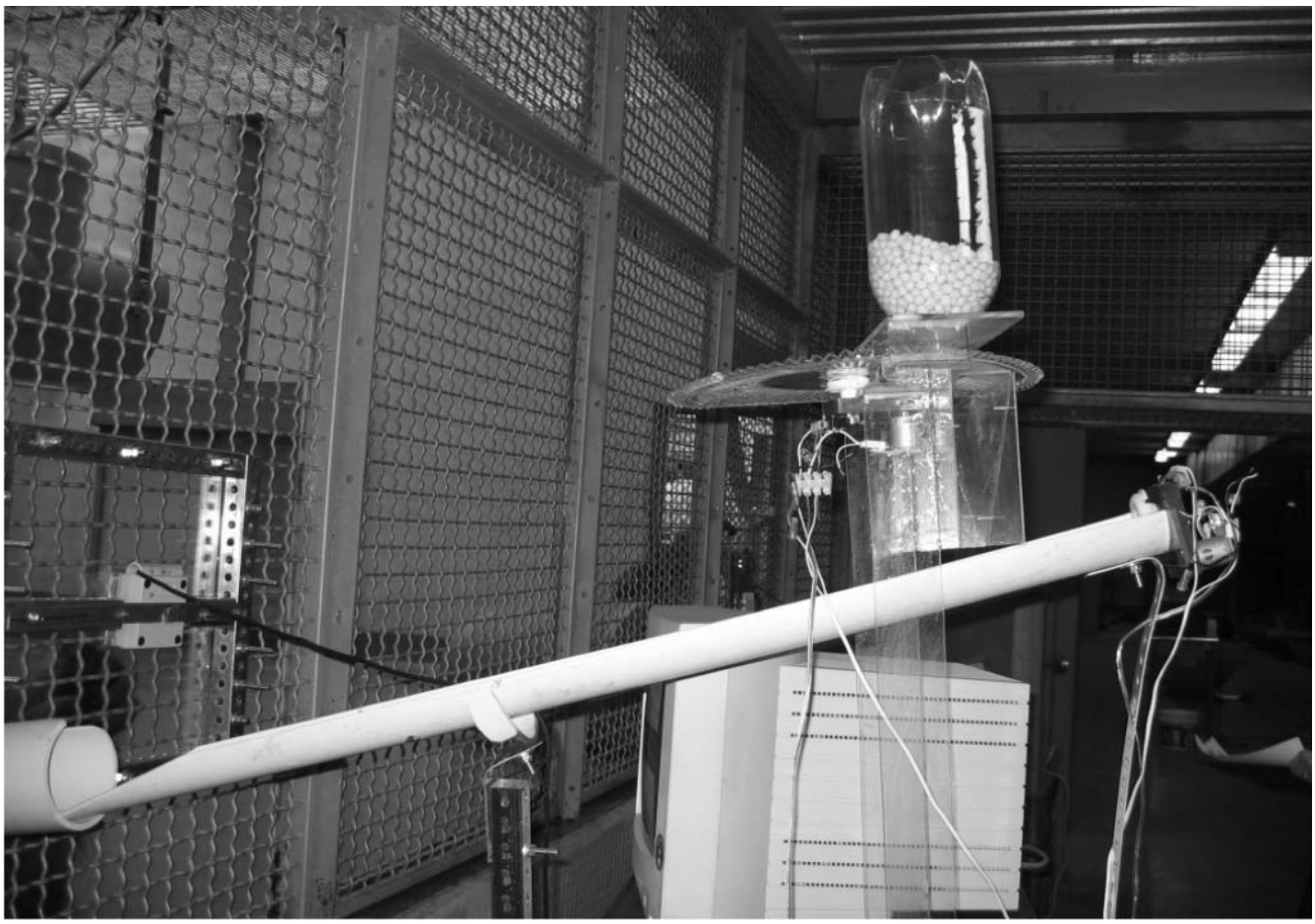

Image showing study apparatus.

Products, Vista, CA, USA), and an automatic reward dispenser. The computer used a programme written in MS-DOS and consisted of tasks that increased in difficulty based on the performance of each individual. The computer running these tasks was placed on a cart outside of the subjects' enclosure. A joystick was mounted to a piece of plexiglass with a hole in the middle, which was then mounted on the wire mesh of the enclosure. Subjects could access the movable tip of the joystick, which controlled a cursor on a computer monitor. The monitor was also placed on the cart outside the enclosure, and was visible to the subjects (see Figure 1).

Procedure

Subjects were observed for ten days during each of three phases: a baseline phase (during which, no computer was provided); immediately followed by Phase 1 (during which, one computer system was provided to each pair of subjects); immediately followed by Phase 2 (during which, two computer systems, 3.65 m apart, were provided to each pair). Thus, 30 h of data were collected on each subject, for a total of 240 h. During the baseline condition, the orangutans were provided with enrichment items, such as, cardboard boxes, blankets, telephone directories, shredded paper, scattered browse, and straw bedding, all of which were usually provided to all the animals on a regular basis. During Phase 1 and Phase 2, apart from the computer system(s), no other enrichment items were provided. Subjects had prior experience with the computer system and tasks, and did not need to be trained to use the joystick.

Four tasks were available to the subjects in Phase 1 and Phase 2: the 'side task'; the 'chase task'; the 'easy maze task'; and the 'difficult maze task'. On each trial of the side task, subjects were rewarded for moving the cursor and touching any one of four rectangular bars, which decreased in size with each correct response, thus making the task progressively more difficult. In the chase task, subjects were rewarded for using the cursor to touch a moving square target on each trial. The easy and difficult maze tasks required the subjects to navigate through a maze to touch a stationary target. The number of correct

Table 1 Ethogram (adapted from Tarou *et al* 2004).

Factor	Description
Proximity measures	
Contact	Physical touching of another animal
Proximate	Within 1 m of another animal
Location	
Arboreal	No limbs on ground
Terrestrial	One or more limbs on the ground
Solitary behaviours	
Feed	Chewing or ingesting food items; includes the action of raising food items towards mouth for ingestion and using hands to look through straw 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
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	
Rough scratching	Rapid, exaggerated scraping of fingernails across any part of body using large arm movements
Yawn	Wide opening of 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 behaviour	
Joystick use	Manipulating the joystick with hands, feet or mouth (individual may/may not be watching the screen)
Social affiliative behaviours	Playing with, grooming, being groomed by, examining, or engaged 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 any other behaviour that is not listed above

responses was recorded by the computer. In each computer phase, the experimenters moved the subjects from one task to another in the following order, if they successfully completed 200 trials of each task: 'side', 'chase', 'easy maze', and 'difficult maze'. Within each phase, once a subject reached the criterion for a given task, he/she was not presented with that task again during the remaining sessions of that phase.

Correct responses on each trial were signaled by a tone, after which the subject was reinforced with a small amount of General Mills Kix® cereal (General Mills, Minneapolis, MN, USA) through an automatic feeding device (no other food was provided during the computer phases). In all three phases, data were collected in 1-h sessions using instantaneous scan sampling with 30-s intervals (Altmann 1974). Data were collected by four observers, with inter-observer reliability maintained at a minimum of 90% throughout the study. The ethogram (Table 1) was adapted from Tarou *et al* (2004).

Data analysis

Wilcoxon signed ranks tests were used to compare the mean percentage of scans that all subjects (as a group) spent in various behaviours, across the three phases. As in Tarou *et al* (2004), subjects were classified as 'high users' and 'low users' depending on the level of computer use. Wilcoxon signed ranks tests were used to compare the mean percentage of scans that high users (as a group) and low users (as a group) spent in various behaviours, across the three phases. Finally, Wilcoxon signed ranks tests were also used to compare the mean percentage of scans that individuals in each pair were observed in proximity and contact, across the three phases of the study.

Mann-Whitney *U*-tests were used to determine whether there were significant differences between high and low users in the proportion of scans spent using the joystick in both of the computer phases. Mann-Whitney *U*-tests were also used to determine whether there were significant differences between high and low users in the proportion of scans spent in other behaviours during baseline, Phase 1 and Phase 2. All statistical tests were two-tailed.

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Table 2 Demographic information and mean percentage of scans in which individuals used the joystick in Phase 1 and Phase 2.

Subjects	Gender	Age (years)	Species	Rearing history	Phase 1	Phase 2
High users						
Chantek	Male	25	*P. abelii* × *P. pygmaeus*	Captive born, hand reared	77.58%	95.33%
Miri	Female	11	*P. pygmaeus*	Captive born, mother reared	35.08%	38.33%
Daisy	Female	21	*P. abelii*	Captive born, hand reared	36.25%	34.50%
Hati	Female	25	*P. abelii*	Captive born, mother reared	29.50%	26.58%
Low users						
Sibu	Female	46	*P. abelii*	Wild born, mother reared	0.17%	12.75%
Alan	Male	32	*P. abelii*	Captive born, hand reared	0.08%	9.50%
JT	Male	14	*P. abelii*	Captive born, mother reared	6.33%	2.50%
Sulango	Male	10	*P. pygmaeus*	Captive born, mother reared	2.33%	11.83%

Results

Computer behaviours

Orangutans used the joystick during a mean of 23.42% of the scans in Phase 1, and 28.92% of the scans in Phase 2. Joystick use was not equivalent and individuals were classified as 'high users' and 'low users' within each pair of orangutans (see Table 2 for the mean percentage of scans in which individuals were observed using the joystick in both phases).

During Phase 1, the high users used the joystick during a mean of 44.6% of the scans. In contrast, low users spent an average of 2.23% of the scans using the joystick. During Phase 2, the same four high users used the joystick during a mean 48.69% of the scans, and the same four low users spent 9.15% of the scans using the joystick. Mann-Whitney *U*-tests indicated that there was a significant difference between high and low users in the proportion of scans in which the orangutans used the joystick in both Phase 1 ($Z = -2.31$, $P = 0.02$, n = 8), and Phase 2 ($Z = -2.31$, $P = 0.02$, n = 8). Wilcoxon signed ranks tests indicated that there was no significant increase in joystick use (from Phase 1 to Phase 2) for high users ($Z = -0.73$, $P = 0.47$, n = 4) and low users ($Z = -1.46$, $P = 0.14$, n = 4). Interest in the computer system did not decrease significantly over time either during Phase 1 or during Phase 2 (see Table 3).

Table 3 Mean percentage of scans in which high users and low users used the joystick during the first and last five sessions of Phase 1 and Phase 2.

	Low users (n = 4)	High users (n = 4)
	First 5 – last 5 sessions	First 5 – last 5 sessions
Phase 1	3.63%, 0.83%	41.83%, 47.38%
	$Z = -1.07$, $P = 0.29$	$Z = -1.60$, $P = 0.11$
Phase 2	5.92%, 12.38%	48.21%, 49.17%
	$Z = -1.46$, $P = 0.14$	$Z = -0.73$, $P = 0.47$

Z scores and *P*-values are the results of Wilcoxon signed ranks tests.

Other behaviours: comparing across conditions

Within each pair of orangutans, time spent both in contact and proximity did not change significantly across conditions (see Table 4). There were significant differences in some behaviours, when comparing across conditions (see Table 5).

Other behaviours: comparing high and low users

During the baseline phase, there were no significant differences between high and low users in any of the behaviours recorded (see Table 6). During Phase 1, low users exhibited a significantly greater percentage of inactivity and a significantly lower percentage of feeding (ie, eating food rewards), when compared to high users. During Phase 2, low users exhibited a significantly greater percentage of inactivity and rough scratching, and a significantly lower percentage of feeding (ie, eating food rewards), when compared to high users.

Discussion

The purpose of this study was to extend the research conducted by Tarou *et al* (2004) and test the effectiveness of providing computer tasks as enrichment to pair-housed orangutans at Zoo Atlanta. One of the goals of the present study was to evaluate the extent to which the computer was utilised. As in Tarou *et al*, one orangutan in each pair monopolised the computer system in Phase 1 (during which, one computer was provided to two individuals housed together), allowing us to classify individuals as high users and low users. The provision of a second computer system during Phase 2 did not change this pattern: individuals classified as high users in Phase 1 continued to exhibit high levels of computer use, and those classified as low users utilised the second computer infrequently. As can be seen from Table 2, three of the four high users were female (and three of the four low users were male). However, we could not perform statistical analyses

Table 4 Mean percentage of scans in which individuals in each pair (n = 4 pairs) were observed in proximity and contact, during baseline, Phase 1 and Phase 2.

Behaviour	Baseline – Phase 1	Phase 1– Phase 2	Baseline – Phase 2
Proximity	21.38%, 33.32%	33.32%, 13.82%	21.38%, 13.82%
	$Z = -1.83$, $P = 0.07$	$Z = -1.83$, $P = 0.07$	$Z = -0.73$, $P = 0.47$
Contact	1.38%, 0.92%	0.92%, 0.83%	1.38%, 0.83%
	$Z = -1.84$, $P = 0.07$	$Z = -0.54$, $P = 0.59$	$Z = -0.18$, $P = 0.85$

Z scores and *P*-values are the results of Wilcoxon signed ranks tests.

Table 5 Mean percentage of scans in which all subjects (n = 8) were observed on and above ground and engaged in different behaviours, during baseline, Phase 1 and Phase 2.

Behaviour	Baseline – Phase 1	Phase 1– Phase 2	Baseline – Phase 2
Arboreal	**14.96%, 8.00%**	8.00%, 10.54%	**14.96%, 10.54%**
	***Z* = –2.52, *P* = 0.01**	$Z = -1.40$, $P = 0.16$	***Z* = –2.52, *P* = 0.01**
Terrestrial	**85.04%, 92.00%**	92.00%, 89.46%	**85.04%, 89.46%**
	***Z* = –2.52, *P* = 0.01**	$Z = -1.40$, $P = 0.16$	***Z* = –2.52, *P* = 0.01**
Aggression	0.07%, 0.14%	0.14%, 0.03%	0.07%, 0.03%
	$Z = -1.07$, $P = 0.29$	$Z = -1.60$, $P = 0.11$	$Z = -1.07$, $P = 0.29$
Social affiliative behaviour	0.44%, 1.69%	1.69%, 0.57%	0.44%, 0.57%
	$Z = -1.69$, $P = 0.09$	$Z = -1.95$, $P = 0.05$	$Z = -0.54$, $P = 0.59$
Rough scratching	1.24%, 1.69%	1.69%, 0.62%	1.24%, 0.62%
	$Z = -1.86\%$, $P = 0.06$	$Z = -1.01$, $P = 0.31$	$Z = -0.34$, $P = 0.74$
Yawn	0.18%, 0.19%	0.19%, 0.38%	0.18%, 0.38%
	$Z = -0.68$, $P = 0.50$	$Z = -1.62$, $P = 0.11$	$Z = -1.37$, $P = 0.17$
Abnormal behaviours	0.12%, 0.30%	0.30%, 0.81%	0.12%, 0.81%
	$Z = -0.73$, $P = 0.47$	$Z = -0.51$, $P = 0.61$	$Z = -0.93$, $P = 0.35$
Object manipulation	8.70%, 7.74%	7.74%, 8.82%	8.70%, 8.82%
	$Z = -0.56$, $P = 0.58$	$Z = -0.42$, $P = 0.67$	$Z = -0.70$, $P = 0.48$
Locomote	6.43%, 5.86%	5.86%, 4.78%	6.43%, 4.78%
	$Z = -0.28$, $P = 0.78$	$Z = -1.54$, $P = 0.12$	$Z = -1.40$, $P = 0.16$
Solitary play	0.58%, 1.64%	1.64%, 1.35%	0.58%, 1.35%
	$Z = -1.48$, $P = 0.14$	$Z = -0.41$, $P = 0.69$	$Z = -1.22$, $P = 0.22$
Self-directed behaviour	3.00%, 4.04%	4.04%, 5.64%	**3.00%, 5.64%**
	$Z = -1.82$, $P = 0.07$	$Z = -1.96$, $P = 0.05$	***Z* = –2.24, *P* = 0.03**
Inactive	33.52%, 31.48%	31.48%, 26.66%	33.52%, 26.66%
	$Z = -0.42$, $P = 0.67$	$Z = -1.40$, $P = 0.16$	$Z = -0.98$, $P = 0.33$
Feed	38.94%, 23.37%	**23.37%, 27.05%**	38.94%, 27.05%
	$Z = -1.40$, $P = 0.16$	***Z* = –2.52, *P* = 0.01**	$Z = -1.26$, $P = 0.21$

Z scores and *P*-values are the results of Wilcoxon signed ranks tests (bold indicates $P < 0.05$).

of possible sex differences in computer use because of the small sample sizes in this study. In addition, from a purely descriptive standpoint, there seem to be no clear relationships between computer use and other demographics, such as, age, species and rearing history.

There was no habituation to the computer system in either phase. This lack of habituation is similar to findings in previous studies of computer-assisted enrichment (Washburn & Rumbaugh 1992a,b; Washburn *et al* 1994; Platt & Novak 1997; Bloomsmith *et al* 2000; Ross *et al* 2000; Tarou *et al* 2004).

Another goal of the present study was to determine whether the presence of the computer system would result in an increase in undesirable behaviours, such as aggression and

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Table 6 Mean percentage of scans in which high users and low users were observed on and above ground and engaged in different behaviours, during baseline, Phase 1, and Phase 2.

Behaviour	Phase of study	High users (n = 4)	Low users (n = 4)	*Z* score	*P*-value
Arboreal	Baseline	8.90	21.02	–1.02	0.31
	Phase 1	1.69	14.31	–1.16	0.25
	Phase 2	2.38	18.71	–1.44	0.15
Terrestrial	Baseline	91.1	78.98	–1.02	0.31
	Phase 1	98.3	85.69	–1.16	0.25
	Phase 2	97.6	81.29	–1.44	0.15
Aggression	Baseline	0.15	0.00	–1.51	0.13
	Phase 1	0.17	0.11	–0.66	0.51
	Phase 2	0.04	0.02	–0.68	0.50
Social affiliative	Baseline	0.38	0.50	–0.29	0.77
	Phase 1	0.34	3.04	–1.31	0.19
	Phase 2	0.10	1.04	–1.48	0.14
Rough scratching	Baseline	2.10	0.38	–1.60	0.11
	Phase 1	2.67	0.71	–1.16	0.25
	Phase 2	**0.10**	**1.13**	**–2.32**	**0.02**
Yawn	Baseline	0.11	0.25	–0.66	0.51
	Phase 1	0.04	0.33	–1.38	0.17
	Phase 2	0.06	0.71	–1.91	0.06
Abnormal	Baseline	0.08	0.17	–0.77	0.44
	Phase 1	0.46	0.15	–0.59	0.55
	Phase 2	0.36	1.27	–0.58	0.56
Object manipulation	Baseline	8.23	9.17	–0.58	0.56
	Phase 1	6.56	8.92	–1.16	0.25
	Phase 2	5.63	12.02	–1.44	0.15
Locomote	Baseline	6.81	6.04	–0.29	0.77
	Phase 1	3.90	7.83	–1.44	0.15
	Phase 2	2.65	6.91	–1.73	0.08
Solitary play	Baseline	0.06	1.11	–0.83	0.41
	Phase 1	0.17	3.10	–1.08	0.28
	Phase 2	0.67	2.04	–0.33	0.74
Self-directed	Baseline	3.06	2.94	0.00	1.00
	Phase 1	4.15	3.94	–0.15	0.89
	Phase 2	5.00	6.27	–0.58	0.56
Inactive	Baseline	31.5	35.56	–0.58	0.56
	Phase 1	**10.8**	**52.13**	**–2.31**	**0.02**
	Phase 2	**10.3**	**43.00**	**–2.31**	**0.02**
Feed	Baseline	39.1	38.73	0.00	1.00
	Phase 1	**38.5**	**8.25**	**–2.02**	**0.04**
	Phase 2	**42.2**	**11.92**	**–2.02**	**0.04**

Mann-Whitney *U*-tests were used to determine whether there were significant differences between high and low users in the percentage of scans spent in these behaviours during baseline, Phase 1 and Phase 2 (bold indicates $P < 0.05$).

stereotypies. In previous studies, researchers did not find increases in aggression when a single computer system was provided to socially housed rhesus monkeys (Platt & Novak 1997) and chimpanzees (Bloomsmith *et al* 2000; Ross *et al* 2000). In contrast, Tarou *et al* (2004) found an increase in aggression when one computer was provided to pair-housed orangutans, and suggested that there might be species differences in competition over a limited resource. In the present study, there were no significant increases in aggression for orangutans in either phase. Similarly, in a recent study by Perdue *et al* (2011), there was no increase in aggression when a single touchscreen computer device was provided to a group of four socially housed orangutans. These findings cast some doubt on the possible explanation that orangutans might behave aggressively when competing over a limited resource such as a computer. Instead, as also hypothesised by Tarou *et al*, it appears more likely that the increase in aggression in their study was due to aggressive competition for food and/or attention from the care-staff individual, delivering food rewards as reinforcement for correct responses.

Tarou *et al* found a significant increase in proximity and contact when one computer was provided, probably because the presence of care-staff providing food rewards near the device attracted both high and low users to the same location. They suggested that this increased proximity was associated with increased aggression. In the present study, time spent both in contact and proximity (within each pair) did not change significantly across conditions. Proximity likely did not increase because of the absence of care-staff at one location, and this may have led to fewer opportunities for aggression. This highlights the potential negative influence of human presence during this kind of enrichment.

As in Tarou *et al*, there was no significant increase in abnormal behaviours (such as stereotypic pacing, regurgitation and re-ingestion, faeces manipulation, hair plucking, and coprophagy) across conditions during the present study. In addition, there were no significant increases in rough scratching in either phase. This is similar to previous studies of computer-assisted enrichment, which did not find an increase in rough scratching in subjects (Washburn & Rumbaugh 1992a,b; Lincoln *et al* 1994; Washburn *et al* 1994; Platt & Novak 1997; Bloomsmith *et al* 2000; Ross *et al* 2000). In contrast, Tarou *et al* (2004) found an increase in rough scratching when one computer was provided to pair-housed orangutans, and suggested that the cognitive challenge imposed by the tasks might have elicited rough scratching in the subjects. This is not likely, given that the present study (and the previous studies cited above) utilised the same tasks as in Tarou *et al*. Instead, as also hypothesised by Tarou *et al*, it is possible that the increase in rough scratching in their study may have resulted from the stress in competing for food and/or attention from care-staff.

Comparing high and low users

During the baseline phase, there were no significant differences between high and low users in any of the behaviours recorded. During both the computer phases, low users exhibited higher levels of inactivity when compared to high users, because low users were not interacting much with the computer. This is similar to Tarou *et al* (2004), who found a significantly higher percentage of inactivity for low users when compared to high users, after the introduction of one computer.

Animal welfare implications

The findings from this study suggest that computer-assisted enrichment is an effective form of enrichment for socially housed captive orangutans. In contrast to Tarou *et al* (2004), there were no increases in aggression and anxiety-related behaviours in the present study. Given that the increase in undesirable behaviours in Tarou *et al* was most likely related to the presence of care-staff providing food rewards, this finding highlights the importance of using automatic reward dispensers during computer-assisted enrichment.

There was a lack of habituation to the computer in the present study. However, the high level of interest in the computer was shown only by a few individuals, which highlights a need to take into consideration individual differences when providing computerised enrichment to captive non-human primates. It is important to note that the lack of interest shown by the low users was probably not because of aggressive monopolisation by the high users. In Phase 2, high users were not blocking access to the second computer, nor were they displacing low users from the second computer (the two computers were 3.65 m apart, which meant that individuals at each computer would not even have been in proximity to each other). Previous researchers have found a similar pattern of high and low users during computer-assisted enrichment (MA Bloomsmith, personal communication 2012; Tarou *et al* 2004). These individual differences in joystick use seem to remain stable over several years; the same individuals who were high and low users in the Tarou *et al* study were categorised as high and low users in the present study (data for the present study were collected almost four years after the first study). These findings suggest that it is important to identify individual differences in computer use, so that informed decisions can be made regarding the provision of multiple devices to social groups.

However, it must be noted that the mean percentage of scans that low users (as a group) spent using the joystick increased from 2.23% (in Phase 1), to 9.15% (in Phase 2), although this difference was not statistically significant. In addition, Table 2 indicates that three out of four low users increased joystick use in Phase 2. Thus, it is possible that the low users in the present study may have utilised the computer to a greater extent had they been given solitary access, or been given access while with a different individual, and these scenarios remain to be explored.

Finally, given the differences in activity levels between high and low users during the computer phases in the present study, it would be advisable to provide other forms of enrichment to increase activity for individuals which are not interested in interacting with a computerised enrichment device. Providing other forms of enrichment would also help increase the diversity of behaviours being stimulated by the enrichment. Behaviours such as general physical activity/locomotion, foraging, exploring, play, etc may best be elicited by

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other types of enrichment (for a review of mixed programmes of enrichment, see Honess & Marin 2006), and would complement the cognitive challenges and problem-solving opportunities provided by computerised enrichment.

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