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Assessment of environmental enrichment for Asian elephants (*Elephas maximus*) in zoos, using the maximum price paid concept

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Sammanfattning
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Nyckelord
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2 Introduction
Wild animals experience a constantly changing environment and always have to cope with different challenges, e.g. finding food and water, avoiding predators and socializing with conspecifics. In contrast, zoo conditions are often rather static and the animals have little control over many vital life conditions, such as feeding, the possibility to escape from conspecifics or to avoid sunlight (Swaisgood et al. 2003). With Asian elephants (*Elephas maximus*, Linné 1758), there is a huge difference between their natural habitats, i.e. rainforest and jungle, and the mostly very barren environment offered to zoo elephants. A study on wild Asian elephants showed that they have to spend 12-14 hours per day feeding, to fulfill their energy needs (McKay 1973). In captivity, foraging is often completely lacking and feeding is mostly quickly finished; the elephants are given a large amount of high quality food, which they consume very fast, only a few times a day (Wiedenmayer 1998). The lack of foraging requirements leaves zoo animals with a lot of “empty” time and less

opportunity to express their normal behaviours (Hare et al. 2003). Besides making the animals more inactive, the anticipation of food at regular times often leads to the development of abnormal behaviours, such as stereotypies (Swaisgood et al. 2003).

In addition to feeding behaviour, mud and dust bathing, as well as "ordinary" bathing are common activities among wild elephants. These behaviours are important for e.g. temperature regulation and sun and parasite protection (Rees 2002). According to McKay (1973) wild Asian elephants find water at least once a day and a study by Tehou & Sinsin (2000) on African elephants (*Loxodonta africana*, Blumenbach 1797) showed that they spend 33-38 % of the day drinking or bathing. While young elephants generally lie down in the waterhole, older elephants often just spray themselves with water (McKay 1973). The elephants' access to bathing in zoos is often limited to daily showering and scrubbing by the keepers.

Elephants are highly social animals and live in a matriarchal structure (Schulte 2000). Among both Asian and African elephants the leader female, the matriarch, is accompanied by her female relatives: sisters, cousins, daughters etc, and their young. Usually the females stay in their natal group their whole life whereas the males leave the group at sexual maturity, thereafter travelling alone or in small, unstable groups; they are often found on the outskirts of the female groups (McKay 1973, Douglas-Hamilton & Douglas-Hamilton 1975, Moss 1988).

African elephants have been shown to have remarkably complex social lives, ranging well beyond the family group (Moss 1988). Less research has been conducted on the social behaviour of the Asian elephant, but according to Fernando & Lande (2000) their social life seems to be more restricted to the family group. Like other social animals, elephants have developed a complex communication system (Langbauer 2000). At short distances, e.g. between individuals within a family group, communication can be visual, chemical, auditory or tactile. Elephants also communicate over large distances, using olfaction to some extent, but probably mainly using vocal communication, including infrasound, i.e. sounds below the range of human hearing (< 20 Hz) (Langbauer 2000).

Heffner and Heffner (1980, 1982) found that elephants are more sensitive to low frequencies and less sensitive to high frequencies, compared to other mammals. They determined the lowest audible frequency for the Asian elephant in their study to be 17 Hz at an intensity of 60 dB (re 20 µPa) and the upper hearing limit to be 10.5 kHz at the same intensity. Payne et al. (1986) were the first to describe the use of infrasound in elephants. By recording sounds from captive Asian elephants they found that most of the calls had fundamental frequencies between 14 and 24 Hz. Infrasound has a long wavelength and is less affected by attenuation compared to sounds with higher frequencies (Poole et al. 1988, Garstang et al. 1995). Low frequency sounds might thus travel greater distances and are advantageous for long distance communication (Arnason et al. 2002). These sounds are also less affected by vegetation and hence will work well in forest habitats (Garstang 2004). Only a large animal, though, like an elephant, can generate low frequency sounds with enough energy to carry far (Arnason et al. 2002). Playback experiments conducted by Langbauer et al. (1991) showed that wild African elephants respond to sounds from conspecifics at a distance of at least 2 km. Other studies have shown that low frequency elephant calls can have an audible range of more than 10 km, at optimal atmospheric conditions (Garstang et al. 1995, Larom et al. 1997).

Elephants have a wide repertoire of calls. McKay (1973) describes nine different calls in the Asian elephant, e.g. trumpeting, snorting, growling and rumbling. Many of the sounds are used both in short and long distance communication and most of the calls contain infrasonic frequencies (Langbauer 2000). In African elephants a difference in calling patterns between the sexes has been seen; males seem to have a narrower repertoire of calls compared to females (Langbauer 2000). Poole (1994) explains this difference by the fact that females are group-living and thereby have a need for a high number of vocalizations, for communication both within and between the family groups. Males, on the other hand, are less social and their vocal repertoire seems to be primarily focussed on dominance between males and on reproduction.

In contrast to the comprehensive vocal communication observed in wild elephants, communication among their zoo conspecifics is much more restricted; the zoo groups are often small and no neighbouring groups exist. However, much can be done to stimulate natural behaviours, including acoustic communication, in captive elephants.

Environmental enrichment (EE) can be used to improve the welfare of animals in zoos. Shepherdson (1998 p. 1) defines EE as “an animal husbandry principle that seeks to enhance the quality of captive animal care by identifying and providing the environmental stimuli necessary for optimal psychological and physiological wellbeing”. EE is often used to reduce stereotypic behaviour in zoo animals and has been shown to be successful in doing so (Swaisgood & Shepherdson 2005, Shyne 2006). For an EE to be effective it should promote behaviours that are meaningful for the animal and it is therefore important that the EE offers some biologically relevant resource (Swaisgood et al. 2005). However, even though it is important to look at the species’ wild habitat for guidance in developing EE, functionalism rather than naturalism should be the objective (Newberry 1995, Swaisgood et al. 2003, Hutchins 2006).

Which EEs are effective is of course species-specific. To hide food, or to scatter the food distribution over time during the day, are ways to encourage foraging behaviour and a common EE for zoo elephants (e.g. Wiedenmayer 1998, Morimura & Ueno 1999, Stoinski et al. 2000). Elephants also have other natural behaviours, however, that may be possible to stimulate by EE, e.g. vocal and olfactory communication, bathing behaviour and social behaviour.

As mentioned above, EE aims at improving the welfare of captive animals and to evaluate its effectiveness it is important to have a scientific approach (Newberry 1995, Vick et al. 2000). Animal welfare concerns the subjective feelings of animals and is therefore complicated to evaluate. The term motivation is often used in the context of animal welfare and Toates (2002 p. 31) describes motivation as "an internal process that underlies the tendency to engage in a particular behaviour". Motivation cannot be measured directly though - it must be inferred from behaviour or physiology (Kirkden et al. 2003). Thus, in addition to measuring physical signs of poor welfare, e.g. injuries, corticosteroid levels or abnormal behaviours, various methods of measuring animals' motivational strength have been developed.

Several of these methods are based on consumer demand theory, a model used within microeconomics to describe human choice behaviour (Varian 2006). Kagel et al. (1995) have shown that this model is also valid for measuring animal behaviour. A consumer demand experiment for measuring animals' motivation to get access to a resource typically includes operant conditioning; the subject has to perform a learned task to gain a reward (Warburton & Nicol 1998, Hovland et al. 2006). The cost is experimentally altered and the subject's responses to the different costs are used to evaluate its motivational strength for access to that particular resource (Hovland et al. 2006). Many studies have used a direct operant task, e.g. pressing a lever or a panel to get access to food, straw or social contact (e.g. Matthews & Ladewig 1994, Hansen et al. 2002, Pedersen et al. 2002). Others have had a more indirect approach, where, for instance, the animal has to walk a certain distance or get past an obstacle for access to food (e.g. Sherwin & Nicol 1995, Schütz et al. 2006).

There are mainly three different measurements of motivation used in animal welfare studies; elasticity of demand, consumer surplus and maximum price paid. Dawkins (1983, 1988, 1990) has used demand curves to measure motivational strength in animals. The cost the animal has to pay to get access to a resource is altered and the number of times the price is paid on each cost level, i.e. the demand, is recorded and a demand curve is derived. If the demand is high when the price is low but decreases rapidly as price increases, the animal is said to show an elastic demand. If, on the other hand, the demand is less dependent on price level, i.e. remains high as price increases, then there is an inelastic demand (Dawkins 1988). A resource showing inelastic demand is considered to be of higher value than a resource showing elastic demand. Dawkins' approach has met much criticism though, e.g. Houston (1997) argues that the elasticity of demand is not a valid measurement of motivation. Even though many of the terms originate in microeconomics, they were not properly transferred into animal welfare studies; in economics the elasticity of demand is never used as a measure of resource value (Kirkden et al. 2003).

The second concept, consumer surplus, is based on an inverse demand curve and the experimental design is the same as for an elasticity of demand experiment. For each reward unit in the sequence, the animal has a so-called reservation price, a term used in microeconomics and defined as the highest price a person would be willing to pay for a particular quantity of a specific good (Varian 2006 p.4). Instead of measuring the slope of the demand curve, a series of areas under the curve is measured (Houston 1997, Kirkden et al. 2003). Elasticity of demand is a measure of the rate of change in demand for a resource, whereas consumer surplus estimates how much the animal is prepared to spend on a certain amount of the resource (Kirkden et al. 2003).

Elasticity of demand and consumer surplus both require that the reward can be made available in small units of uniform size or duration, to enable multiple rewards to be earned during a single session, e.g. the animal works for one unit of food, then for another, equal, unit and so on. The reward duration is mostly short and some types of rewards would decline in value if treated in this way, e.g. social contact or nesting. If the animal is interrupted after only a few seconds of social contact, or in the middle of nesting, and has to perform the operant again to get another reward period, the resource would most probably be devalued (Mason et al. 1998, Olsson et al. 2002). In such cases the third approach, maximum price paid, can be used.

Maximum price paid is the same thing as the reservation price for the first reward unit and, accordingly, this measure can also be derived from consumer surplus. The experimental design is the same as for the other two approaches, except that the subject earns only one reward per session (e.g. per day). The price at which demand just falls from one to zero, i.e. the highest price the animal is willing to pay to get the reward, is recorded (Kirkden et al. 2003). Like the consumer surplus, maximum price paid does not give a value of a resource. What can be derived from this measurement is a value of a single access to a specific quantity of a resource, after a given period of deprivation. It is therefore essential to control the deprivation level (Kirkden & Pajor 2006a, 2006b).

A maximum price paid experiment can be conducted using an open or closed economy. In a closed economy the resource is only provided as a reward in the experimental situation, whereas in an open economy the resource is provided also outside the test (Ladewig et al. 2002). In an open economy, a constant deprivation level can be maintained by excluding the resource for a specific period of time preceding the sessions. No matter which type of economy that is used, it is important to keep to the same method for all resources that are being compared (Mason et al. 1998).

To estimate the motivational strength for access to a particular resource, it is necessary to compare with the maximum price paid for a resource of known value (Kirkden & Pajor 2006b). Food is often used as the comparator since its value varies rather predictably, depending on deprivation level. If the maximum price paid for a visit to a resource is at the same level as for a visit to food when hungry, the motivational strength for a single access to that particular resource can be assumed to be strong (Dawkins 1983, Kirkden & Pajor 2006b).

The aim of this study was to design meaningful EE for zoo elephants and to measure their motivation for access to the EE, using the maximum price paid concept. A shower was offered as enrichment to two Asian elephants at Kolmården Wildlife Park. The shower was chosen mainly for three reasons; first, bathing is an important part of wild elephants' lives and such an EE would give these zoo elephants the possibility to express some of their natural behaviours. Second, water was assumed to be something the elephants would find interesting for a long time, with no or small habituation. Hence it could be used frequently as an EE. Third, it is simple to use; the keepers would just have to switch on the water hose. It is important that the EE is not too complicated and does not require a great deal of preparation for the keepers - if so it will not be used. However, according to the keepers[1] (and confirmed during the training sessions), the Kolmården elephants are unwilling to shower if they are not already wet. This might be due to the fact that they were not allowed to decide when to have the shower. Because of that two shower tests were conducted; one when the elephants were dry and one when they were given a short shower by the keepers just prior to the test.

The hypothesis was that the ability to express bathing behaviour is important to zoo elephants and that the availability of a shower would

[1] pers.comm., Thomas Antmar, elephant keeper, Kolmården Wildlife Park

stimulate such bathing-related behaviour. Accordingly, the predictions were that the elephants would 1) use the shower to a large extent, e.g. by standing in the jet or by catching water with their trunks to spray on themselves and 2) be willing to pay a maximum price at about the same level as they would pay for access to a comparator of high value (food when hungry).

Also two other types of EE, both aiming at stimulating vocal communication, were offered to the elephants: playback of elephant calls and a custom designed two-way acoustic internet link to elephants at another zoo. The playback test was conducted as a pre-cursor to the acoustic link, to see if the elephants would at all respond to calls from unknown elephants. The hypothesis for the playback experiment was that hearing the playback of social sounds would elicit a behavioural response. The predictions were that the Kolmården elephants would 1) approach the speaker and show interest in the source of the calls; 2) avoid the speaker and show signs of fear; 3) respond vocally, mainly with sounds expressing excitement and arousal and 4) remain quiet or abort ongoing vocalizations.

The two-way acoustic internet link was created to enable these zoo elephants to communicate vocally with conspecifics at another zoo and thereby to simulate the long distance vocal communication observed in wild elephants. The interactivity offered by the two-way acoustic internet link would provide a more complex resource than the traditional playback experiments. For the acoustic link, the hypothesis was that hearing the live vocal responses from unknown elephants would elicit a dynamic behavioural response. Accordingly, the predictions were that the Kolmården elephants would 1) approach the speaker and show interest in the source of the calls; 2) avoid the speaker and show signs of fear; 3) respond vocally, mainly with sounds expressing excitement and arousal; 4) remain quiet or abort ongoing vocalizations and 5) if responding vocally, produce more diverse calls than in the playback sessions, the type of calls possibly correlated with the type of calls generated by the elephants at the other zoo.

3 Materials and methods

3.1 Subjects

Subjects of the study were two female Asian elephants housed at Kolmården Wildlife Park, Sweden. Both elephants were born at work camps in Thailand and they arrived at Kolmården in 2004. At the start of the study, these elephants, called Bua and Saonoi, were 10 and 11 years old respectively and weighed approximately 2300 kg each. Bua and Saonoi were both trained for hands-on handling.

On November 7, 2007, a 39 year old female Asian elephant, called Saba, arrived at Kolmården Wildlife Park from Zoo Le Pal, France. After an introduction period, when she was housed alone in a smaller section of the indoor exhibit, the three elephants were mostly held together during the day. During the night Saba was kept separated throughout the course of this study, but with the prospect of full integration with the other two.

The Cologne elephant group consisted of one mature and one subadult male, eight adult females and three calves. All elephants were trained using protected contact.

3.1.1 The Kolmården management routines

Normal routines started at 07.30 when the keepers arrived and shortly thereafter the elephants were fed 2 kg of pellets each (for a detailed feeding schedule, see 3.2.1.). They were then chained by one foreleg and one hind leg for a short period of time while they were showered and scrubbed by the keepers. In the summer, the animals were normally kept in the 3000 m^2 outdoor exhibit between 10.30 and 17.30. At 14.00 one or both elephants were led by a keeper to the performance area, situated right next to the exhibit, to give a 20 min educational presentation to the zoo visitors. During the night the elephants were kept in the 250 m^2 indoor exhibit and had occasionally, depending on the weather conditions, also access to a 750 m^2 outdoor back enclosure. When kept indoors they were sometimes separated by an electrical wire but could still have contact with each other. In the late autumn and winter the elephants were released in the outdoor enclosure for a short period of time if the weather allowed, otherwise they were kept indoors throughout the day.

3.2 Experimental procedures

The elephants' motivational strength for the EE was measured by letting them lift weights. Two linked human weight lifting machines for leg training (Nautilus AB, Sweden), installed by Holmgren (2007), were used. The machines were bolted to the concrete floor of the hay loft in the elephant house and a wire, attached to the weights, was led, via a pulley above the weight machines, through a hole in the wall to the indoor exhibit. Via another pulley attached to the ceiling, the wire was suspended down vertically above the elephants' indoor quarters. At the end of the wire a 1.5 m hemp-rope (Ø 30 mm) was attached. In the test situation the elephants were separated by an electrical wire, enabling only one of them to pull the rope. The rope end was lowered to the level of the elephant's head, giving it the opportunity to get a good grip with the mouth and trunk. To lift the weight, and thereby get the reward, the elephant had to pull the rope about

12.5 cm, until the weight magazine hit a beam. If the elephant had not managed to lift the weight within 15 min, the rope was lifted out of reach and the test was terminated.

During a test series the experiment was repeated once every day, at approximately the same time of day and with increasing weights according to a predetermined schedule (Table 1), until the elephant failed to lift the weight. The heaviest weight lifted was considered the maximum price paid for that particular EE. The maximum weight available in the machine was 372 kg and since the elephants managed to pull that weight during the first test weeks the machine had to be remodelled. By fixing one end of a wire to the beam above the weights and adding another pulley which was attached to the elephants' wire, the maximum weight of the machine was doubled. A consequence of this was that the minimum weight of the machine and hence the starting weight for a test series, increased from 27 to 55 kg and the step sizes between the weight levels were changed (Table 1). The alteration also resulted in a halving of the distance the elephants had to pull the rope before the weight magazine hit the beam, to about 6.5 cm.

An open economy was used for both the comparator and the EE tests, i.e. the elephants had access to the resource also outside the test situation. To what extent the various resources were offered is further described in section 3.4.1-3.4.4.

Table 1. Weight schedules used in measuring maximum price paid for environmental enrichment in elephants.

Weight[1] (kg)	Step size	Weight[2] (kg)	Step size
27	1.7	55	1.7
45	1.8	91	1.4
82	1.4	127	1.3
118	1.5	163	1.4
173	1.3	236	1.3
227	1.3	309	1.2
300	1.2	381	1.2
372	1.2	454	1.2
445		563	

[1]Weight schedule 1; used in comparator test 1 (hay test 1) and EE test 1 and 2.
[2]Weight schedule 2; used in comparator test 2 (hay test 2) and EE test 3.

3.3 Training of the subjects

The elephants had previously participated in a similar study conducted by Holmgren (2007) and were already trained to lift weights by pulling a rope. They were also accustomed to the experimental procedure of the comparator test. Each EE test period started with 2-5 introduction days, to make the elephants aware of what they worked for and to get them used to the EE.

3.4 Experiments

3.4.1 Comparator test: 5 kg of hay

Two comparator tests were carried out, one in June 2007 and the other in October 2007. As the comparator the elephants had to lift weights to get 5 kg of hay. Since these elephants were young and growing, it was important to repeat the hay tests close in time to the EE tests, to control for possible increase in their capacity to lift the weights. During the test periods the feeding schedule for each elephant consisted of 2 kg of pellets at 07.45, 5 kg of hay at about 10.00, another 5 kg of hay at about 12.00, approximately 10 branches of browse (*Salix sp*.) in the afternoon and 30-35 kg of seed straw at 16.30. In addition, the elephants were given carrots and pelleted concentrates by the keepers as rewards during training.

The hay test was begun between 10.00 and 10.45 and replaced the ordinary morning hay meal. Before the test started the hay was put into two tarpaulins, which were then winched up to the ceiling and connected to a release mechanism (Holmgren 2007) in an elevated connecting passage along the back wall of the exhibit. During this preparation the elephants were separated from the testing area by an electrical wire, but could still see and smell the hay and follow the preparations. When the tarpaulins were in place, one of the elephants was moved to the test area, while the other remained separated by the electrical wire. The rope was then lowered for the elephant to pull. If she lifted the weights high enough, an IR-sensor activated the release mechanism, which caused one end of one of the tarpaulins to swing down and drop the hay to the floor (Figure 1). 1-2 minutes after the elephant had successfully accomplished this task a keeper went into the enclosure and changed the places of the elephants. The hay obtained by the elephant that had lifted the weight was moved with her so she could continue eating on the other side of the electrical wire. The test was then repeated with the other elephant. On the first day the test order was randomized and thereafter the order was alternated every day. If the elephant did not lift the weights she did not get anything to eat until the 12.00 feeding.

Figure 1. Hay was released from a tarpaulin when the elephant lifted the weight by pulling the rope.

3.4.2 EE test 1: shower outdoors dry

EE tests 1 and 2 were conducted during the summer of 2007. During the test period the ordinary morning shower was cancelled and replaced with a quick shower in the afternoon, given by the keepers. The sessions began between 08.45 and 09.30. Before the test started, an asphalted area (~170 m^2) just outside the elephant house was roped off by an electrical wire. A water hose was put in a stand outside the wire, just out of reach of an elephant trunk, and the water (~14 ºC) was turned on (Figure 2a). The elephants' exit door was opened about 10 cm, as a cue for the elephants, to make them aware of what they were to work for. Since the elephants were very dependent on each other and unwilling to go outdoors alone, both of them were rewarded by being allowed to go outside when one of them had lifted the weights. Therefore, only one elephant could be tested each day. On the first day the subject was randomly chosen and this elephant was tested daily thereafter until she had reached her maximum price paid. Then the experiment was repeated with the other one. During a session, if the subject lifted the weight, the hydraulically operated door was opened. The indoor separating wire was removed as quickly as possible by a keeper, enabling the non-tested elephant to go outside too. The water hose was left on for at least 20 min, depending on the usage, but only the first 15 min were used in the results. Weather conditions and ambient temperature were recorded and the behaviour of the elephants in the outdoor area was video taped during the test.

3.4.3 EE test 2: shower outdoors wet

EE test 2 was conducted as EE test 1 with the exception that the elephants were given a short shower by the keepers just before the test. The sessions were started between 09.00 and 09.30 each morning.

3.4.4 EE test 3: shower indoors wet

EE test 3 was conducted during the autumn of 2007. The elephants were given their ordinary morning shower soon before the test. If the subject lifted the weights, a water hose was manually switched on and fixed in a doorway, spurting water (~14 ºC) through a narrow path into the enclosure (Figure 2b). In contrast to EE test 1 and 2 the elephants were separated during the whole session. The water was on for at least 15 min. If the elephant was still using the enrichment after this period the duration was prolonged but only the first 15 min were used in the results. Both elephants were tested on the same day, one directly after the other. When the test with the first elephant was completed, a keeper made them switch places and the experiment was repeated with the other elephant. The test order was randomized on the first day and thereafter alternated. The behaviour of the elephants was video taped during the test.

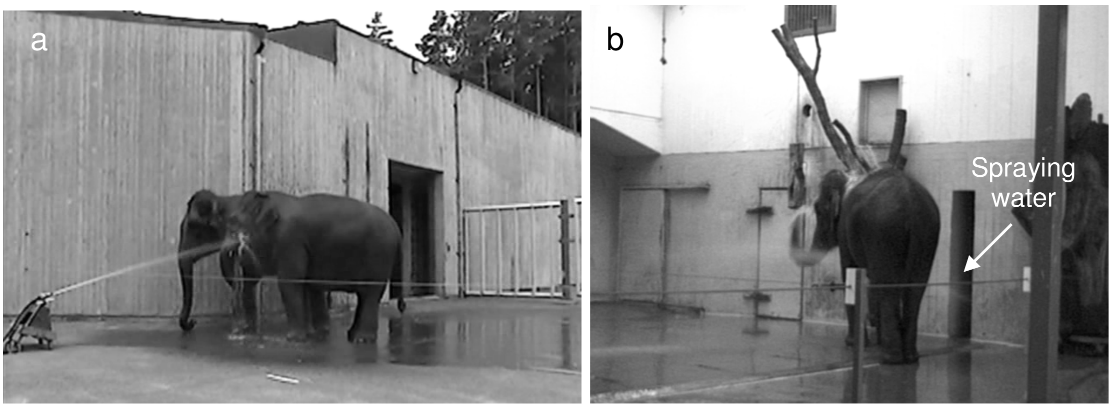


Figure 2. The experimental set up in a) EE test 1 and 2; b) EE test 3.

3.4.5 EE test 4: playback

EE test 4 was conducted in January- March 2008, as a pre-test to the two-way acoustic internet link. Four different loops with recorded elephant calls were used; no 1 contained musth grunts from a male African elephant, no 2 contained four calls from Asian elephants at Berlin zoo, no 3 contained a call from a wild African elephant and two calls from African elephants at Vienna zoo and no 4 contained five calls from wild African elephants. Five to ten seconds of silence was inserted between the different calls in each loop. The sounds were played with a laptop via a JBL GTO2060 amplifier through a GAS METAL 12" subwoofer speaker (frequency spectrum 25

Hz- 3 kHz) installed in a sealed 32 L Quickbazz box. The speaker was placed behind a barred hatch (30×30 cm) in a small room next to the exhibit. Prior to the test the hatch was opened.

Since the objective of the experiment was to observe the Kolmården elephants' reaction to calls from unknown elephants and to prepare them for the acoustic link, the test was conducted in various ways. The elephants were either together during the whole session (any of them were allowed to pull the rope), separated during the whole session or separated from start but let together again when the subject elephant had pulled the rope. One of the sound loops was used at each session and played on repeat for 3-5 minutes. The short duration was chosen to avoid habituation. The test was conducted as a maximum price paid experiment, i.e. the elephants had to lift weights by pulling the rope to start the playback. However, only the three lowest weight levels were used, i.e. the elephants never reached their maximum. The behaviour of the elephants was video taped and sounds were recorded on a laptop using a Behringer ECM8000 electret condenser microphone connected to the unbalanced input of a Behringer Tube Ultragain Mic200 amplifier. The microphone was mounted on a stand, which was placed in the public area of the elephant house, approximately 5 m from the rope and the speaker hatch. The acoustic analysis was done with Adobe® Audition™ 1.0 (Adobe Systems Inc.).

3.4.6 EE test 5: two-way acoustic internet link

EE test 5 was conducted in April and May 2008 in cooperation with Cologne zoo, Germany. A sound pickup and speaker system was installed at each location. The sound pickup system at Kolmården had a Behringer ECM8000 electret condenser microphone connected to the unbalanced input of a Behringer Tube Ultragain Mic200 amplifier and then to the line input of a Sweex SC004 8-channel USB sound card. In Cologne, the same type of microphone and amplifier were used but connected to the line input of a Griffin iMic USB sound card. At both locations, the sound cards were connected to a Linksys NSLU-2 computer operating OpenWRT Linux together with custom made software for synchronously streaming of sound over the internet. At both endpoints, the signal transmitted via the internet was connected to a JBL GTO2060 amplifier and a GAS METAL 12" subwoofer speaker installed in a sealed 32 L Quickbazz box.

The external soundcards were set to a sampling rate of 8 kS/s and the sample resolution was 16 bits. No compression or filtration of the sounds was used. The total system frequency response ranged from 25 Hz to 3 kHz. The speaker sound pressure levels were set to be suitable to the human ear. There was a delay in the transmission of 4.9 s in both directions. This fairly long time was chosen to avoid glitches in the sound caused by varying bandwidth in the internet connections. Especially on the Kolmården side, the transmission speed was limited to ca 0.4 Mb/s upload and 0.6 Mb/s download. This was eventually improved by installing a NMT wireless modem, supplemented with a directional antenna, resulting in an upload speed of ca 1.2 Mb/s and download speed of 2.1 Mb/s.

The sound streaming was going via a Linux server with big storage capacity and high bandwidth internet connection. Streams arriving at the server were recorded to hard disk as WAV-files as well as streamed to the receiving location. The recorded WAV-files could be retrieved from a web page on the same server, each day in a separate directory and each hour named by date and time of the start of the recording. The status of the Linksys computers, i.e. if they were running and connected, could also be viewed on a web page and the computers could be restarted and login access could be set up from the same web page. The acoustic analysis was done with Adobe® Audition™ 1.0 (Adobe Systems Inc.).

As in the playback experiment, the speaker in the Kolmården elephant house was placed behind a small barred hatch (30×30 cm) in the indoor exhibit wall. The experimental set up is shown in Figure 3a. Prior to the test the hatch was opened. A recorded elephant rumble was played as a start sound ("hello") to indicate that the link was open and to stimulate communication. The rumble was recorded at Berlin zoo, was produced by the matriarch there, and it was chosen since the Kolmården elephants had shown a strong vocal response to it during the playback tests.

The microphone and speaker in the Cologne elephant house were placed just outside a large barred gate leading to the 1500 m^2 indoor exhibit, as shown in Figure 3b.

The Cologne elephants were taken indoors and were separated into their individual quarters for training about 30 min prior to the acoustic test. Just before the test started the females and the calves were released into the indoor exhibit, where they were allowed to move freely. The males were kept isolated from the females in an adjacent part of the indoor exhibit, just to the left of the gate shown in Figure 3b. There was a barred door between the males' and females' exhibits, allowing the speaker sounds to be heard by both, and their vocalizations to be picked up by the microphone.

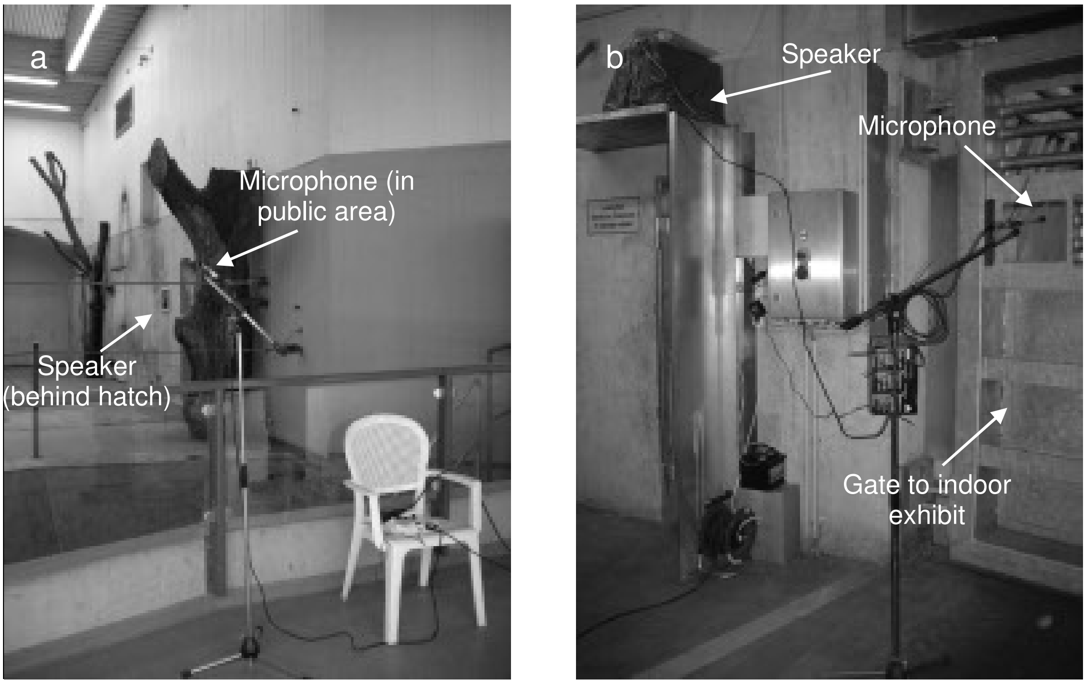


Figure 3. The experimental set up during EE test 5 in a) Kolmården elephant house; b) Cologne elephant house.

3.5 Analysis

The elephants were tested once for each resource, except for the 5 kg of hay, which was tested twice, using the different weight schedules. Since only two animals were available, it was not meaningful to perform any statistical analyses. Maximum price paid was obtained for each resource and elephant. The usage of the EE was presented for each weight level (i.e. each day) during the test period, as percentage of time spent using the EE during the first 15 min. The lifting latency, i.e. the time the elephant needed to lift the weights, was presented as integer minutes for each weight level.

The playback and two-way acoustic internet link experiments were not evaluated using the maximum price paid concept, but only analysed descriptively.

4 Results

4.1 Maximum price paid

The experiments were conducted using two weight schedules and the results for the different schedules are presented separately.

The results from the first hay test and from the outdoor shower tests are presented in Figure 4. No difference could be seen between Bua's maximum price paid to get access to the shower outdoors when she was dry versus when she was wet. Her maximum weight lifted for access to the shower was 0.81 times the weights she lifted for 5 kg of hay. Like Bua, Saonoi did not show any difference in maximum price paid between shower outdoor dry and wet, although she lifted 73 kg less than Bua. Her maximum price for the hay was identical to Bua's, which means that she, for access to the shower, paid 0.61 times the amount she paid for the hay.

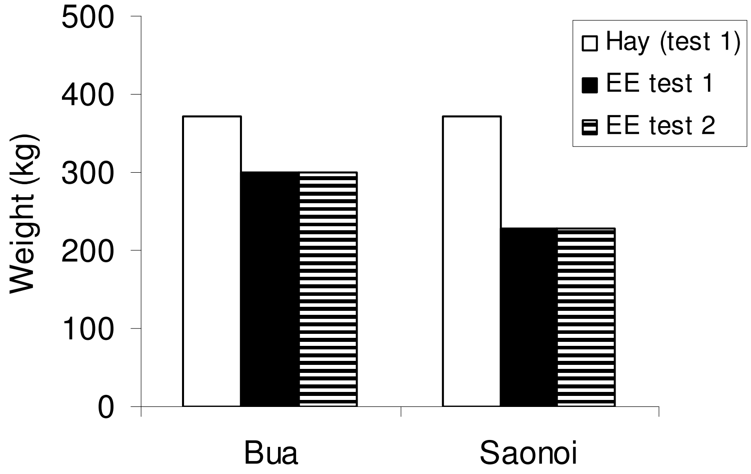


Figure 4. Maximum price paid for access to 5 kg of hay, shower outdoors dry (EE test 1), and shower outdoors wet (EE test 2).

For access to the indoor shower, Bua lifted 0.62 times the weights she lifted for 5 kg of hay (Figure 5). Saonoi showed the same absolute weight difference, 145 kg, between the hay and the indoor shower, but her maximum price for both resources was higher. The proportional difference was therefore lower; for access to the indoor shower she paid 0.68 times the price she paid for the hay. When comparing the outdoor shower with the indoor shower, Bua's maximum weight was higher outdoors, whereas Saonoi showed the opposite result.

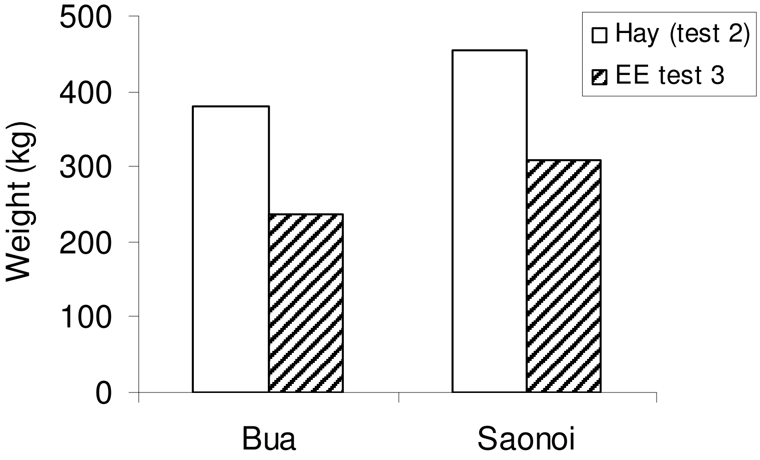


Figure 5. Maximum price paid for access to 5 kg of hay and shower indoors wet (EE test 3).

4.2 Usage of EE

During EE test 1, i.e. the outdoor shower when they were dry at the start, none of the elephants used the shower. They always went outdoors when the door was opened, but in some cases they soon returned indoors. They spent most of the time standing close to each other, sometimes ear flapping and rumbling and they seemed to avoid the water.

In EE test 2, when they were showered by the keepers just before the experiment began, the outdoor shower usage varied between sessions, from 0 to 68 % of the 15 min recording period for Saonoi and from 0 to 38 % for Bua (Figure 6). No correlation between increased weight and usage could be seen. The elephants used the shower in many different ways: they let the jet of water spurt on their head, on the body or in the mouth; they caught water with the trunk and sprayed themselves or drank it; and they walked through the water. Saonoi sometimes kicked against it with her hind legs.

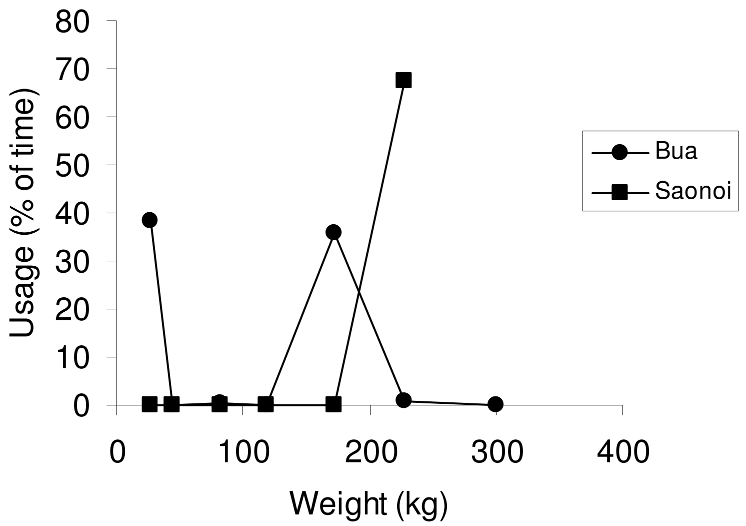


Figure 6. Usage of the shower plotted against the weight lifted during EE test 2.

The ambient temperature ranged between 15 and 22 ºC during EE test 1 and between 16 and 18 ºC during EE test 2 (Figure 7). The weather conditions varied from rainy and windy to sunny. However, no correlation between ambient conditions and the elephants' usage of the shower could be seen.

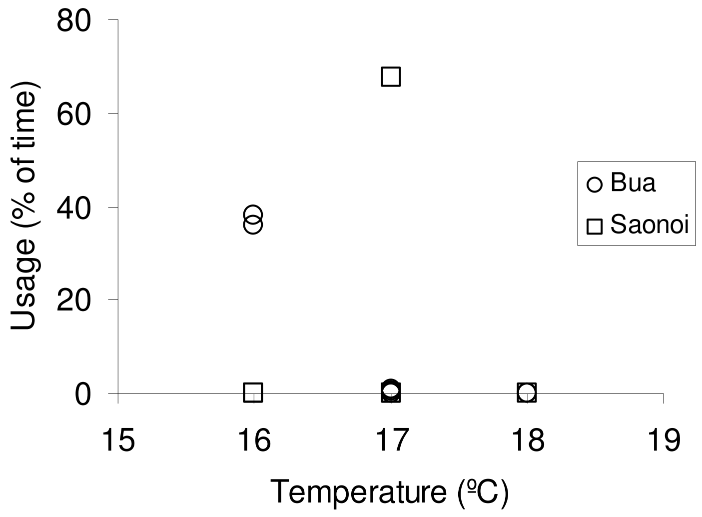


Figure 7. Usage of the shower plotted against the temperature during EE test 2.

A factor that had not been predicted came up during the outdoor shower tests. The area used was adjacent to a back enclosure with a sandy surface. The elephants could stand close to the bordering fence and pick up sand with the trunk to throw it on themselves. This behaviour was only seen in EE test 2, when the subjects were showered before the trials. The magnitude, expressed as the percentage of time spent using the sand, during the first 15 min, is shown in Figure 8 and 9. For both elephants, when sand throwing was occurring, the usage of the shower seemed to be low and vice versa.

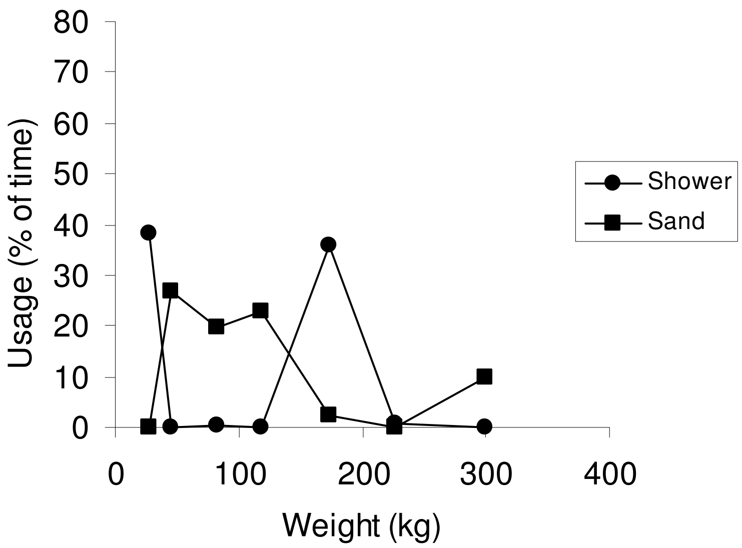


Figure 8. Usage of sand and the shower by Bua during EE test 2.

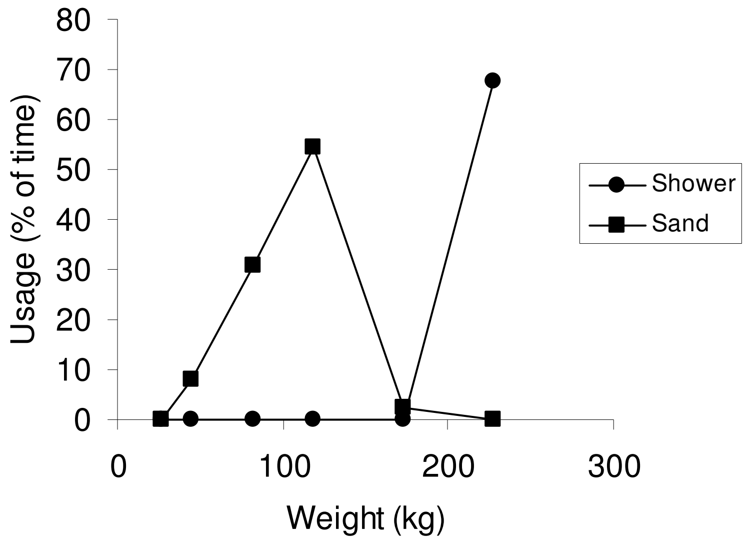


Figure 9. Usage of sand and the shower by Saonoi during EE test 2.

In EE test 3, the indoor shower test, the usage differed a lot between the elephants (Figure 10). Bua did not seem very interested in the shower and also had two days when she did not use the shower at all. Saonoi, on the other hand, had a usage of more than 80 % of the time on all days except for one, when usage was 63 %.

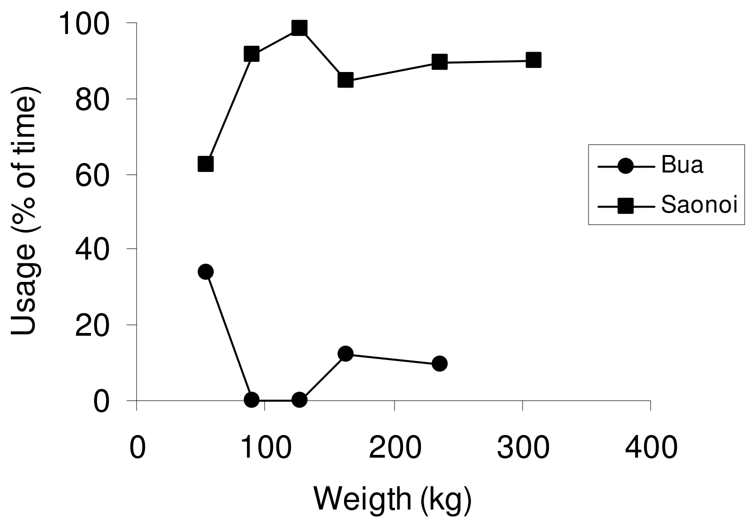


Figure 10. Usage of the shower plotted against the weight lifted during EE test 3.

4.3 Lifting latency

In each session, the elephants had 15 min to lift the weights high enough to hit the weight machine beam. The time they needed varied but for both outdoor shower tests no difference between the EE tests and the hay test could be distinguished (Figure 11 and 12). In the indoor shower test, both elephants showed a weak trend for a longer latency for the shower than for the hay, as weight increased (Figure 13 and 14).

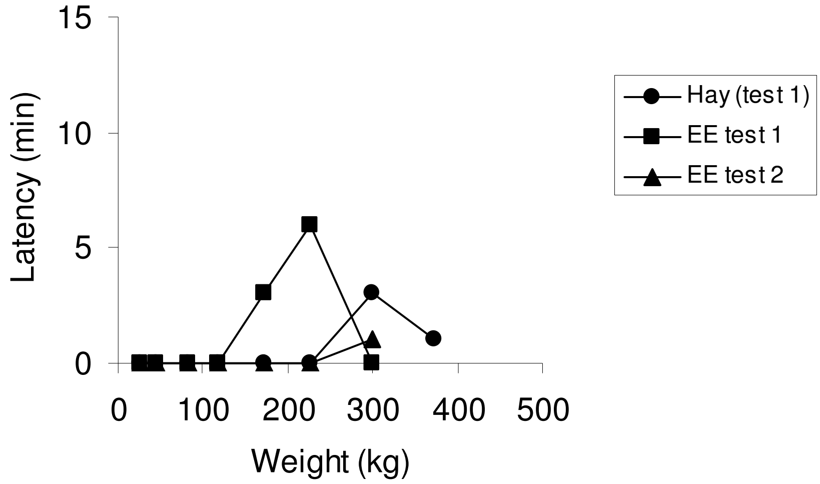


Figure 11. Lifting latency for Bua in hay test 1 and EE tests 1 and 2.

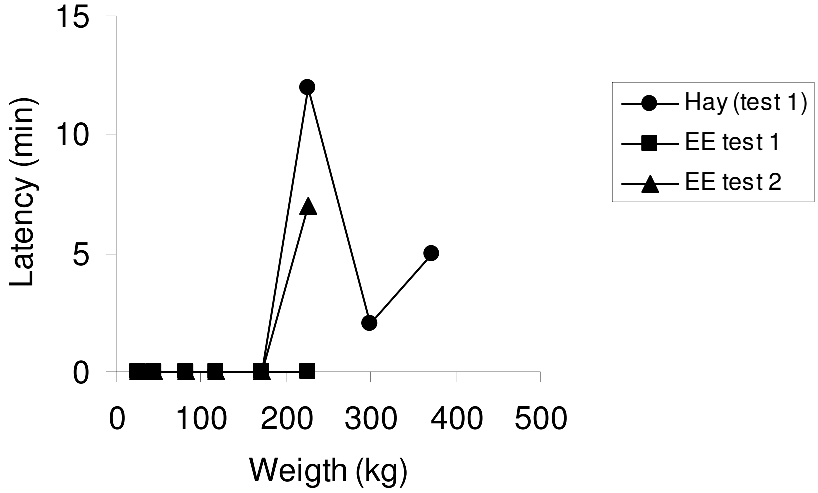


Figure 12. Lifting latency for Saonoi in hay test 1 and EE tests 1 and 2.

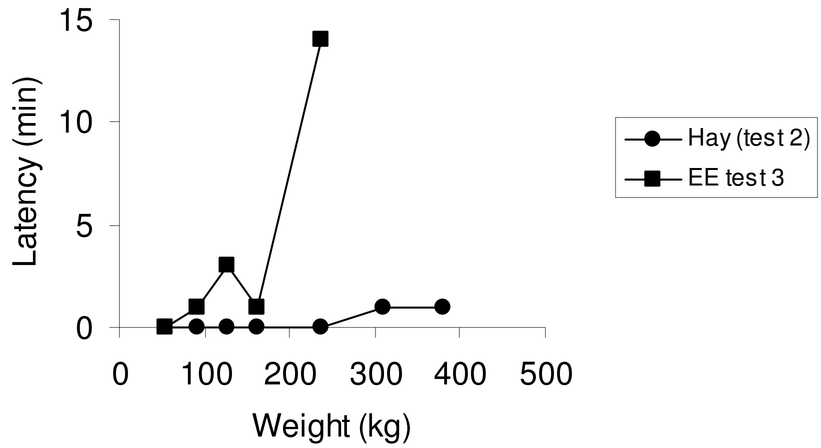


Figure 13. Lifting latency for Bua in hay test 2 and EE test 3.

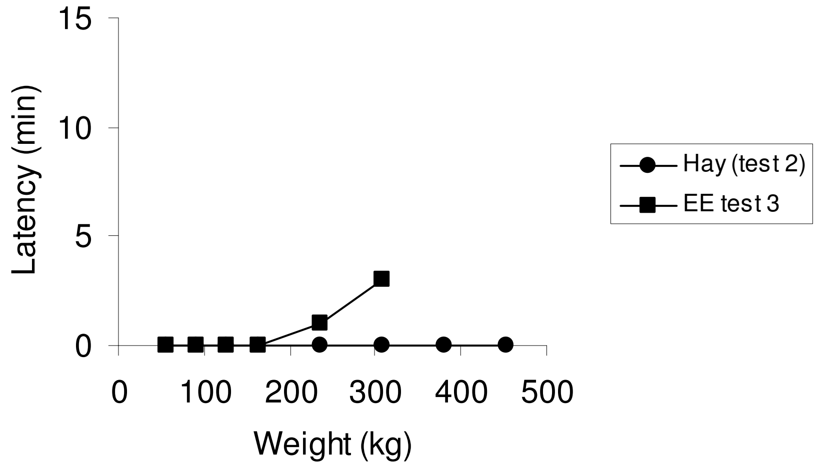


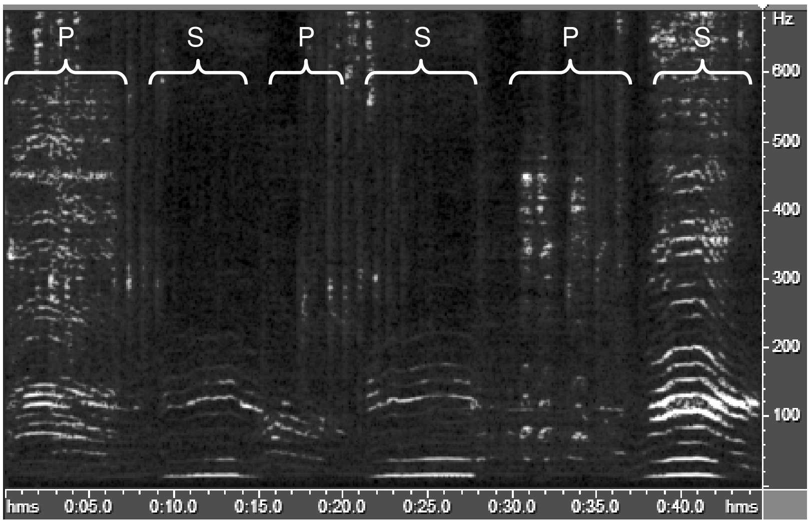
Figure 14. Lifting latency for Saonoi in hay test 2 and EE test 3.

4.4 Playback

Playback experiments were performed 16 times, using different sound loops and elephant constellations, as described in 3.4.5. When the elephants were together during the whole session or were let together directly after the playback was started, they reacted on the sounds, no matter which loop that was played. They responded in several ways: by approaching the speaker, by trumpeting and rumbling, by ear flapping, by coming up close to each other and by raising their tails. When loop no 2 was played there was a particularly strong reaction and during these sessions Bua several times approached the speaker and kicked against the wall. Any difference between the responses to the other sound loops could not be seen. When the elephants were kept separated during the whole test the reaction of both was non-existent or marginal.

Spectrograms of the sound recordings showed that the elephants, mostly Saonoi, responded antiphonally to the playback calls, i.e. they rumbled in the pauses between the playback calls (Figure 15).

At two test occasions the elephants did not pull the rope; once when Saonoi was supposed to pull (Bua separated with an electrical wire) and once when the elephants were together. At both sessions the weight to lift was 127 kg.



P= Playback, S= Saonoi

Figure 15. Spectrogram showing the rumbles from Saonoi in the pauses between the playback calls.

4.5 Two-way acoustic internet link

The two-way acoustic internet link between the Kolmården elephants and the Cologne elephants was open only once during the scope of this study, due to technical problems. Bua and Saonoi responded with excitement and in a similar way as they did to the playback of elephant calls, i.e. they started vocalizing (both trumpeting and rumbling), flapping their ears, bunching together, approaching the speaker and raising their tails. The reactions were more prolonged than during the playback tests, though; they continued to vocalize for at least 15 min after the two-way acoustic internet link was closed. According to the Cologne elephant keepers, their elephants responded by bunching together and approaching the hidden speaker. No rumbles from the Cologne elephants could be seen on the spectrogram.

5 Discussion

The aim of this study was to design and evaluate meaningful EE for Asian elephants in zoos. A shower was used in different contexts and the elephants' motivation for access to it was measured, using the maximum price paid concept. Also two other enrichments were offered to the elephants: playback of elephant calls and a two-way acoustic internet link to elephants at another zoo.

The maximum price paid results for the shower tests did not support the hypothesis; the two subject elephants did not pay an equally high maximum price for access to the shower as they did for access to the comparator, 5 kg of hay. However, one of the elephants used the indoor shower to a large extent, which was in accordance with the prediction.

The elephants' responses to the playback calls of other elephants supported the hypothesis: they responded by vocalizing, approaching the speaker, flapping their ears etc. Also the two-way acoustic internet link caused a similar response in the elephants and the vocalizations and excitement continued also after the link was closed.

5.1 Maximum price paid

The weight lifting machine had to be remodelled because the elephants exceeded its capacity. This had some consequences, e.g. that the lowest weight was doubled. According to Hovland et al. (2006), if the low costs are too heavy it may affect the maximum price paid. It was not considered a big problem in this study, however, since the low weights were still easy to lift for the elephants. More important was probably that the distance the elephants had to pull the rope was halved. How much this affected the results is difficult to say, but it might have been important at the highest weights; when it got really heavy the elephants may have had failed to pull the rope 12.5 cm but still managed to pull it half this distance. Some comparisons between the results, derived from the different weight schedules, will however be made here.

The comparator, 5 kg of hay, was chosen because food was assumed to be of high value to the elephants, since in the wild they engage in foraging and eating for 12-14 hours a day (McKay 1973). Except for the 2 kg of pellets in the morning, the elephants got their latest meal about 17.5 hours prior to the test. According to Holmgren (2007), who used the same animals and set-up, the elephants were without food for at least 12 hours prior to the test. She based this estimate on video recordings of the elephants while they consumed their evening meal. Both elephants lifted heavier weights for access to 5 kg of hay than for access to the shower. The difference was however not very large. For instance, in EE tests 1 and 2, Bua paid a maximum price of 300 kg for access to the shower and 372 kg for access to the hay. The Weber-Fechner law states that changes in the intensity of a stimulus are perceived proportionally (Sinn 2003), i.e. an absolute change at low cost level will be perceived as greater than the same absolute change at a higher cost level. The difference of 72 kg at this weight level corresponds to Bua, for access to the shower, paying 0.81 times the price she paid for access to the hay, which must be considered to be a rather small difference.

This difference would be expected to have been larger since the usage of the shower was low, often non-existent (see 5.2). This raises the question of whether the subjects were actually pulling the rope to get access to the shower or if there was some other reason/motivation behind it. In EE test 1 none of the elephants used the shower at all, but they still lifted the weights: Bua up to 300 kg and Saonoi up to 227 kg. What made the elephants pull the rope in these trials is difficult to say, but it was certainly not the EE. When the subject elephant lifted the weight, the separating electrical wire was removed and the elephants were allowed to be together again. Even though they had only been separated for a few minutes this may have played a role. Female elephants are very social, group-living animals (Shulte 2000) and, even though the electrical wire did not prevent physical contact, it was a barrier and Bua and Saonoi are used to being together most of the time.

Another obvious reason why the elephants may have been prepared to lift the weights in the outdoor shower tests is that they were allowed to go outdoors. Kirkden & Pajor (2006b) tested the motivational strength of sows for access to the last 6.25 % of their daily food intake, i.e. when they were close to satiation. Even though the sows often had food left in their troughs and did not show very much interest in the food they earned, they still were willing to work. This test was used as a comparator to a motivational test for access to a group pen and therefore, when the sows pressed the panel, they did not just gain the food directly, but they opened a door to another pen, where the food was presented. Kirkden & Pajor suggested that the willingness to work may have been, at least partly, due to the opportunity to explore another part of the environment. Also Widowski & Duncan (2000) observed this behaviour of working without using the resource that the study was intended to test. In their experiments, hens had to push open a weighted door to get access to a dust bath. In a number of trials, hens succeeded in opening the door, but did no dust bathing and the authors suggested that this behaviour was caused by the hens wanting to get away from the testing cage and back to their ordinary pen. The outdoor area used in the present study was intended to be rather barren, only offering the EE, but still it offered the elephants more space and stimuli that were not present in the indoor environment. Furthermore, Newberry (1995) has considered the importance of the external environment, i.e. the environment outside the enclosure. She has proposed that a more interesting surrounding can be seen as EE. It is possible that this was a reason for Bua and Saonoi to pull the rope to get outdoors; even though the enclosure in itself was not very interesting, the external environment was.

A third possibility is that the elephants did not know which resource they were working for. If it was unknown to them whether the outcome of lifting the weights would be hay or a shower, they might have been motivated to pull the rope in the EE tests just because they thought they would get hay. However, it is not very likely that the elephants were totally unaware of which resource they worked for, since all tests contained resource cues. In EE tests 1 and 2 the door was opened a few centimetres and the elephants could see the shower and explore the outside with their trunks. During the preparations for the comparator test the elephants could see the hay being put into the tarpaulins and during the test they could see the tarpaulins hanging from the ceiling. So, there should have been no misunderstandings about which resource they would be rewarded with.

A fourth possibility is that the elephants quite simply liked to pull the rope. They lived in a rather barren environment and when something happened, like the rope being lowered, this naturally interested them. As long as it was not too heavy they would have little to lose from lifting the weights. However, this does not explain why they continued to pull the rope for the EE's until rather close to the maximum price paid for hay. If their motivation for the hay was high, as is assumed after 12-14 hours without food, then it is clear that the elephants continued to work for the EE's beyond the point at which the task was easy.

Indoors the results were a bit different. For Bua, the proportional difference in maximum price paid between the EE and the hay increased; for access to the indoor shower she only paid 0.62 times the amount she paid for access to the hay, compared to 0.81 times in the outdoor tests. Her usage of the shower was low indoors and the reduction in the relative value of the EE is consistent with the suggestion that in EE tests 1 and 2 she was lifting the weights just to remove the electrical wire and get together with Saonoi. However, Saonoi used the shower to a much larger extent indoors, and the proportional difference decreased; for access to the indoor shower she paid 0.68 times the price she paid for access to the hay, compared to 0.61 times in the outdoor tests. Both elephants had some kind of motivation to pull the rope in the outdoor experiments and whereas Bua's motivation decreased in the indoor test, Saonoi's increased. The reason for this is further discussed in 5.2.

Bua paid about the same maximum price in both hay tests. The result from hay test 1 was also the same as the maximum price she lifted in the experiments conducted by Holmgren (2007). Saonoi's performance, on the other hand, increased. She lifted 82 kg more in the second hay test than in the first. This was double the weight she lifted in Holmgren's study (227 kg). Since these young elephants are still growing stronger, it is expected that the maximum weight they manage to lift will increase. Saonoi's increasing results may also be explained by her having improved her lifting skills. It is therefore important to conduct the EE test and the comparator test close in time.

5.2 Usage of EE

In EE test 1, none of the elephants showed any interest in the shower. Their unwillingness to use the shower when they were dry might be explained by their adaptation to their natural habitat. Wild Asian elephants are mainly found in rainforest and jungle, which are very humid and mostly hot environments and the skin of the elephants is probably almost always moist. The subjects of this study live in a much drier environment and might experience an unpleasant feeling when they are first hit by the shower. To get the water pressure needed, the taps for both cold and warm water had to be fully opened, which resulted in a water temperature of about 14 ºC. This low temperature may have affected the elephants' willingness to use the shower and it would be interesting to test whether the usage of a warmer shower would be greater.

If the above reasoning is true, it was surprising that the usage was also rather low in EE test 2, when the elephants had been quickly showered by the keepers before the test. A difference in their behaviour with the water could be seen though: in EE test 1 they tried to avoid the water, whereas in EE test 2, even if they were not interested in actually using it, they were not afraid to walk through the spray.

The low usage of the outdoor shower might have been due to the sand-throwing that occurred. Both elephants showed an inverse correlation between usage of the shower and sand throwing; they mainly used only one of the two resources each day. Which behaviour they were most motivated to express seemed to vary randomly from day to day. According to McKay (1973), soil throwing behaviour in wild Asian elephants occurs most frequently after bathing and the same pattern has also been seen among captive elephants (Rees 2002). These observations can explain why the elephants in this study only used the sand when they had been showered before the test and were wet but it does not explain why they only used one of the resources each day.

EE test 3 was carried out indoors, which made it easier to ensure that no other resources were made available when the elephant lifted the weights. There was a huge difference in usage between the two elephants in this test. Bua's usage of the shower was comparable to her usage in EE test

2 and she had two days when she showed no interest at all in the water. Saonoi, on the other hand, showed a much higher interest in the shower indoors and had a usage between 63 and 98 % of the time every day. During EE test 2 the elephants were on some occasions observed pushing each other in the shower, a behaviour that can be seen as competition for the resource. In EE test 3 the elephants were separated during the whole session and therefore did not have to compete for the shower; a factor that might have increased Saonoi's interest for the enrichment. A study conducted by Pedersen et al. (2002) showed that pigs' motivation to work for food or straw depended on the social context. The subject pigs were more motivated if they had a companion pig in an attached pen, who was also rewarded, compared to when they were tested isolated. This result is contrary to Saonoi's behaviour in the present study. However, they may not be really comparable, since the pigs were rewarded separately and did not have to compete, whereas the elephants in EE test 1 and 2 had to share one shower. It may show, though, that it is important to take the social context into consideration in this kind of experiment.

Cooper & Mason (2000) showed that mink pushing through a weighted door for access to e.g. a hay box, a bath or a cylinder used the resource to a greater degree when the cost was high. This result might also have been expected in the present study, but no such correlation was seen; the usage varied unpredictably during the test periods.

In their article about dust bathing in hens, Widowski and Duncan (2000) discuss that the time of the day at which the experiments were conducted may be important. Diurnal rhythms have also been shown to affect the motivational strength in mink for swimming water and a running wheel (Hansen & Jensen 2006). In the present study, all EE tests were carried out in the morning. The elephants might have responded differently if the shower had been offered in the afternoon instead. Another factor that may be important is the temperature. According to Rees (2002) captive Asian elephants show an increased frequency of dust bathing behaviour at higher ambient temperatures and it is possible that the same might apply to water bathing behaviour. The ambient temperature during EE test 2 varied by only two degrees, between 16 and 18 ºC and no correlation between the temperature and the usage could be seen. However, if the shower had been presented during the warmest part of the day, or during a hotter period of the summer, the usage may have been higher. This could not be tested due to public display considerations: the elephants had to be in the outdoor exhibit during the zoo's open hours (10.30-17.30).

5.3 Lifting latency

The elephants were given 15 min to pull the rope, and the latency to do so was predicted to be correlated with the weight, i.e. as the weight increased the latency was assumed to increase. This correlation was observed by Widowski & Duncan (2000) in hens, pushing through a weighted door for access to a dust bath, but could only partly be seen in the present study. At the lower weights the elephants most often pulled the rope within a minute, as expected, but at higher weights the latency varied within a wide range. Neither could any strong difference in latency between the EE tests and the hay tests be seen, except from a trend towards greater latency in EE test 3 compared to hay test 2, as weight increased. The results may have depended much on the current mood of the elephants. Some days they just went to the rope and pulled directly, other days they played with the rope for a while before they attempted to lift the weights.

5.4 Method evaluation

There is a need for good methods to evaluate the effect of EE (Newberry 1995) and maximum price paid has been shown useful in measuring behavioural priorities in animals (Cooper & Mason 2001). However, this study has revealed some difficulties in using maximum price paid as a measurement of elephants' motivation for EE. First of all, elephants are very large and strong animals and the equipment used must be able to cope with their strength. It is also definitely clear that to limit the number of confounding factors there must be an absolute connection between the operant task and access to the EE. Even though resource cues were offered, it is important to make it absolutely clear to the elephants what they are working for. Preferably, no resource other than the EE should be presented, but this may in some cases be difficult to achieve. The indoor shower test was seemingly conducted under these conditions but still Bua lifted the weight without using the shower.

Perhaps this problem could be solved by having two ropes: one for the hay and one for the EE. Even though resource cues were used, this approach might have made it even clearer for the elephants what they were working for. Both ropes would be lowered during the test but only one of them would give a reward. If the elephant was working because she was expecting food, she would pull on the "hay rope", even when only the "EE rope" was activated. No hay would fall down but the elephant would get the opportunity to show which resource she was motivated to work for. Also two activated ropes could be used at the same time, either to make a preference test between two resources or to distinguish what the elephants are really working for. For instance, as discussed above, in the outdoor shower tests, the elephants in some sessions may have lifted the weights just to be able to go outdoors. If there had been one rope for just opening the door and another rope for opening the door and getting access to the shower, the elephants would have been able to show which resource/ resources they were interested in by choosing to pull the appropriate rope.

Another thing that could improve the method is to reduce the time the elephants are given to lift the weights. If the time was reduced from 15 min to 10 min, or maybe even to 5 min, it would have given the elephants less time to get bored and pull the rope because of that. If they were highly motivated, they would probably not need 15 min.

The difficulty of getting enough data to do statistical analyses is another problem with the method. Preferably, more elephants should be used, to increase the sample size. A problem with zoo research in general and with zoo elephants in particular, however, is that there are often a limited number of animals available and even though it is possible to use animals from different zoos it is often hard to replicate the experimental set-up and the animal handling. If more trials of each EE had been conducted, statistics for each animal could have been made. However, since the test can only be conducted once a day, a test period becomes rather long and time consuming; giving only a little amount of additional data. It is also questionable if statistics for each animal is meaningful. To conduct several trials with the same elephant and chose the trial where she pays the highest maximum price may be useful, to really get the maximum, but to take an average of the trials would just be to pseudo-replicate.

5.5 Playback

The hypothesis made for the playback experiments, i.e. that hearing the playback of elephant calls would elicit a behavioural response, was supported by the results; the elephants did respond to the calls in several ways, including vocally. The elephants responded in accordance to prediction 1 and 3; they started vocalizing, bunching together, approaching the speaker, flapping their ears and raising their tails. This was about the same responses as observed by Langbauer et al. (1989), in a playback test with captive African elephants. The social context, which has already been discussed in connection to the shower tests, seemed to be very important. When the elephants were separated during the whole session their reaction to the sounds was weak, whereas they, when together, could show a strong reaction to the same sound loop. Perhaps they were more confident when they were together and thereby dared to approach the speaker and respond to the calls. However, when kept separated they did not show any signs of being frightened or stressed by the sounds; they just continued with what they were doing before the playback started. Another reason for the strong reaction when they were together could be that they quite simply incited each other.

When the elephants responded to the playback calls, the sounds from the speaker and the rumbles from Bua and Saonoi were alternating, i.e. the communication was antiphonal. Wild female African elephants have been shown to respond antiphonally to playback calls from related females (McComb et al. 2003) and in their study on captive African elephants, Soltis et al. (2005) observed that this kind of communication was common between associated females. The calls on the loops played for the Kolmården elephants were recorded from unrelated, unknown elephants, but the way to respond seemed to be the same as in the referred studies.

McComb et al. (2000) showed that wild female African elephants responded differently to long distance, low frequency, contact calls depending on if they come from closely associated individuals or not. If the caller was a member of the family group they responded by producing contact calls and approaching the speaker. If the caller was not a family member, but still rather well known, the elephants just showed a relaxed reaction; they listened to the sound and returned to what they were doing before the call. A third kind of response occurred if the caller was less associated with the elephants. They then bunched up in defence and sometimes moved away from the speaker. The two Asian elephants in the present study showed a mixture of these three reactions. When they were alone their reaction was relaxed, but when they were together they responded vocally, bunched together and approached the speaker. Assuming that Asian elephants react in the same way as African elephants, the animals in this study could be expected not to respond vocally to the calls at all, since they came from unknown elephants. In contrast to the wild elephants in the study of McComb et al. (2000), though, these zoo elephants do not have any neighbouring conspecifics and were totally unused to hearing calls from other elephants. This might have affected their reaction. The speaker was also placed very close to the enclosure and the calling elephant probably appeared to be very near, which might have caused another reaction than if the speaker was further away. Since the speaker was hidden, they could not know if there was a living elephant on the other side of the wall or not.

When loop no 2 was played the elephants reacted stronger than on the other loops. This loop was the only one that contained calls from Asian elephants and that might be the explanation. Even though the calls from the two species probably share similarities, there are easily distinguishable differences, e.g. Asian elephants produce a chirping sound that is typically not made by African elephants (Poole et al. 2005). One of the calls on loop no 2 came from the matriarch of an Asian elephant group in Berlin zoo and was recorded at a moment when she had grabbed the microphone and had it in her mouth[2]. She was probably in an excited mood and the recording was made from a very close distance to the source. Some of these factors, or the combination of them, might explain the stronger reaction to loop no 2.

The fact that the elephants did not pull the rope at two of the playback test trials might suggest that they did not appreciate the playback. At one of these trials Saonoi was the one to pull, but she was not interested in the rope at all. At the other occasion the elephants were together and Saonoi prevented Bua from pulling the rope, by pushing her away from it, which indicates that Saonoi did not want the playback to start. This behaviour has been observed in a previous study, with pellets as the reward (Holmgren 2007). In that case it was believed that the noise from the food dispenser was frightful to Saonoi and that she therefore wanted to prevent Bua from triggering it. However, in this study, already the next day Saonoi did pull the rope herself again, to start the playback, which makes it difficult to conclusively interpret her irregular unwillingness to pull the rope. In the playback test the elephants were most probably aware of that they did not work for hay or for the shower, since there was no resource cues for these resources and also quite some time had passed between since these tests were conducted. There were also resource cues for the playback, just prior to the test the small hatch was opened and the speaker was put on place, fully visible and audible to the elephants and the microphone was set up in the public area.

5.6 Two-way acoustic internet link

Because of technical problems and resulting delays, the two-way acoustic link between the Kolmården elephants and the Cologne elephants was only open once within the course of this study. However, the behaviours observed in the Kolmården elephants during that test support the hypothesis, i.e. that the hearing of calls would elicit a dynamic behavioural response. They did respond by trumpeting and rumbling, bunching together, approaching the speaker, raising their tails and flapping their ears, which is in agreement with predictions 1 and 3. The limited data did not allow the evaluation of prediction 5, i.e. that the vocal response would be more diverse than in the playback test. Still, the elephants' vocal response was prolonged compared to the playback tests, where they usually stop vocalizing rather soon after the sound loop was turned off. In this test, the elephants continued vocalizing, mostly rumbling, for at least 15 min after

[2] pers.comm. Meike Artelt, PhD student, University of Vienna

the two-way acoustic internet link was closed. Since only one trial was conducted, it is impossible to say if this was due to the elephants being more interested in the two-way acoustic internet link or if they were just excited because they were exposed to something new and unknown. Also the response to playback calls was longer during the first trials, although not as long as for the two-way acoustic internet link.

One of the reasons for using a shower as EE was that it is simple to use, which makes it more likely to be used frequently. The word simple does not fit with the acoustic link; technical problems were dominating. This is a problem not unexpected with new techniques and hopefully the system can be made as easy to operate and reliable as e.g. Skype. It is worthwhile to pursue, since the pilot study did show that the link can stimulate vocal communication in zoo elephants. It might help to decipher elephant vocalizations, by studying the type of calls being exchanged and their correlation to other types of behavioural responses.

The link could be applied in many different situations; of course as an ordinary EE, to stimulate vocal communication between elephant groups but also in more specific situations. For instance, an elephant that will be transferred to another zoo can get to know her new group members in advance, and combined with exchange of olfactory stimuli such as faeces, urine and secretions from the temporal glands, this might pave the way for a smother acclimatization. It is also conceivable to allow a transferred elephant to keep the contact with her old group. Whether this would be a positive or stressful option remains to be tested, preferably by the maximum price paid approach. Finally, when artificial insemination is to be used, live vocal communication with a male elephant might get the female in the right mood and possibly enhance her physiological readiness to be inseminated.

5.7 Conclusions

The maximum price paid approach can be used as a measurement to assess EE for zoo elephants, but the number of subjects must be increased to be able to get significant results and draw general conclusions. It is important to take the social context and the external environment into consideration and to make sure that no other resource than the EE is made available when the elephant accomplishes the operant task. In the present study, the motivation of both elephants for the outdoor shower was low or non-existent, whereas they showed diverging results in the indoor test. The shower may be used as an EE for the elephants indoors, but it had no, or little, function outdoors in the present setup.

The elephants responded with excitement and vocally to playback calls from other elephants of both species and to the two-way acoustic internet link. A continuation of this project would be needed to draw valid conclusions about the two-way acoustic internet link. If working properly, the link could be applied in different ways and would also provide a good opportunity to study vocal exchange between Asian elephants, a line of research which has only been explored to a limited extent (Langbauer 2000).

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