JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 2005, **83,** 15–29 NUMBER 1 (JANUARY)

SIMULTANEOUS VISUAL DISCRIMINATION IN ASIAN ELEPHANTS

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Two experiments explored the behavior of 20 Asian elephants (*Elephas aximus*) in simultaneous visual discrimination tasks. In Experiment 1, 7 Burmese logging elephants acquired a white+/black− discrimination, reaching criterion in a mean of 2.6 sessions and 117 discrete trials, whereas 4 elephants acquired a black+/white− discrimination in 5.3 sessions and 293 trials. One elephant failed to reach criterion in the white+/black− task in 9 sessions and 549 trials, and 2 elephants failed to reach criterion in the black+/white− task in 9 sessions and 452 trials. In Experiment 2, 3 elephants learned a large/small transposition problem, reaching criterion within a mean of 1.7 sessions and 58 trials. Four elephants failed to reach criterion in 4.8 sessions and 193 trials. Data from both the black/white and large/small discriminations showed a surprising age effect, suggesting that elephants beyond the age of 20 to 30 years either may be unable to acquire these visual discriminations or may require an inordinate number of trials to do so. Overall, our results cannot be readily reconciled with the widespread view that elephants possess exceptional intelligence.

Key words: simultaneous visual discrimination, age effect, cognition, visual acuity, box removal, lid removal, Asian elephants

Although elephants have been closely associated with humankind for thousands of years, and although claims about their exceptional cognitive abilities abound, controlled laboratory studies of their behavior have been infrequent. For many decades, opinions of elephant exceptionality have been based on one zoo study of a 5-year-old elephant, on field investigations, and on casual observations.

The only published (and hence extensively cited) prior study of operant behavior in elephants involved a single 5-year-old Asian elephant at the Munster Zoo (Rensch, 1956, 1957). This subject was presented with two small wooden boxes whose lids were painted with two different stimuli; for example, circle and cross. The subject had to remove the correct lid to secure the reinforcer, a piece of bread. This elephant learned to reliably select the correct stimulus in 330 trials, over a period of several days. By the fourth visual discrimination task, the elephant reached criterion in 10 trials. At the conclusion of the experiment, the subject was given a test that covered 600 trials of 20 acquired discriminations. The test lasted several hours, yet the subject improved toward the end. A year later, the subject made between 63 and 100% correct responses.

The records of Squier's zoo research done in 1964 were destroyed by fire prior to publication; still, given the scarcity of information on the performance of elephants in operant tasks, a few secondhand accounts of this research are worth relating. Squier apparently trained 3 females in a simultaneous light/dark discrimination task, with all 3 responding correctly more than 90% of the time after a few sessions (Stevens, 1978). Eight years after Squier's experiments were abandoned, Markowitz (1982, p. 88) readministered the same visual differential response test to the original subjects. One subject walked directly on her own to the apparatus and pressed the lit panel, making only two errors and reaching criterion of 20 consecutive correct responses in 6 min (Stevens, 1978). The other 2 elephants required thousands of trials to reach criterion, manifesting a puzzling in-

We wish to thank the government of Myanmar and Wayne State University for making this research possible. We are particularly indebted to the Myanmar Department of Forestry and to the Myanma Timber Enterprise for placing their elephants at our disposal and for cheerfully and competently seeing to all technical details. One could not ask for a warmer welcome, nor for a more competent, obliging host. Warm thanks are also due to our dozens of coworkers and staff in Myanmar, especially in Kyet Shar. Among them, we are particularly indebted to U Kyaw Kyaw, who generously shared with us his exceptional skills as elephant trainer and chef. Thanks also to Dr. Elaine M. Hockman, Bulent Ozkan, and Thomas J. Moeller for statistical and software advice.

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ability to recall the task or to relearn it (Markowitz, Schmidt, Nadal, & Squier, 1975).

In more recent studies (Hoefler-Nissani & Nissani, 2004; Nissani, 2004), 2 zoo elephants obtained higher scores than chimpanzees in situations in which they had to choose whether to beg food from a person who could see them or a person who could not (Povinelli & Eddy, 1996), but their performance was still consistent with the notion that they did not know that people see (see also Machado & Silva, 2003). Similarly, both zoo elephants were able to solve a variation of the string-pulling paradigm (securing the end of a retractable cord by means of coordinated trunk/foot action: see Heinrich, 2000; Thorpe, 1956 for a discussion), but the results were open to alternative interpretations. The ability of the 2 elephants to choose whether to suck or blow in a novel competitive tube task (Nissani, 2004) appeared on first sight as an example of grasping the nature of the task, but subsequent informal observations in Burma have placed that interpretation in doubt.

The present experiments explored the performance of elephants in two separate simultaneous discrimination tasks, thereby enriching our meager database and indirectly addressing the controversy about their exceptional mental capacities. To achieve these goals, in Experiment 1 Burmese elephants were presented with a black/white visual discrimination task. In Experiment 2, Burmese elephants were presented with a large/small transposition task.

GENERAL METHOD

Rationale for Analyzing Behavior in the Jungle

The logging elephants of Burma offer an attractive, more ecologically valid alternative to Zoo elephants (Markowitz, 1982; Nissani, 2004). In a typical logging camp, one can study many elephants directly, not across a cable or across a vast expanse of savannah, but at close quarters. Their past history is fairly well documented, and when this research was conducted, included no studies that could confound the interpretation of results. The animals are not confined to a small area, but live in a seminatural state. At night they are released into the jungle to feed on their own, and they often intermingle and breed with surviving populations of wild elephants (Williams, 1950). For example, just prior to our arrival at the Kyet Shar Elephant Camp (see below), 1 of our subjects, Shu Phyo Maung, was captured in perfect condition after spending several months hobbled in the wild in the company of an older wild male.

On the negative side, operant field studies must be adjusted to fit local conditions, relying on makeshift equipment and requiring more improvisations and elaborate controls. For instance, ruling out any experimenter effect—a trivial task in a standardized setting—required as much time and resources as the differential response tasks themselves.

Location and Duration of Experiments

The present experiments were carried out from November 2002 to March 2003 in the forests of central Burma (Myanmar). Although many logging operations and elephants in that country are in private hands, the present experiments were exclusively conducted with government-owned elephants at the following government-owned camps:

Kyet Shar (November 24, 2002 to January 7, 2003). This permanent elephant camp is located in Bago Yoma (Bago Hills), southwest of the town of Toungoo, some 67 km (or 3 hr) by road. The camp is located at the confluence of two streams, Kyet Shar and Kaboung.

Magu (January 14 to January 28, 2003). This temporary camp was especially set up for the present investigations. It was situated about 0.4 km from the permanent village of Magu, about 80 km by road northwest of the town of Toungoo.

Myaing Hay Wun (February 6 to March 1, 2003). This is a permanent research and ecotourism camp at the edge of the forest, about 117 km from the capital city of Rangoon (Yangon).

Subjects

Twenty-one Asian elephants (*Elephas maximus*) served (Table 1), 14 in Experiment 1 and 7 in Experiment 2. At the time of the experiments, some subjects were either resting, too young, too old, or too sick to engage in actual work. The rest, depending on age and size, were either employed as baggage elephants (carrying supplies and personnel to

Table 1

Experimental subjects arranged by age (range, 5 years to 47 years).

Elephant	Initials	MTE registration number	Camp	Sex	DOB	Approximate age at time of experiment (years)	Comments
Tun Thin Thin	TTT	2196	MHW	F	9/11/97	5	Stereotypic rocking behavior
Sit Aye Nyein	SAN	6389	KS	F	7/28/95	7	
Aung Chan Thar	ACT	6349	MHW	M	1993	10	
Shain Shwe Pyi	SSP	6437	MHW	F	1993	10	
Shu Phyu Maung	SPM	6158	KS	M	3/20/91	12	
Aye Dwe Maung	ADM	6413	MHW	M	1991	12	Sore tooth, shoulder, during experiment
Aye Khin Oo	AKO	6412	MHW	F	1993	12	
Moe Mia Kyi	MMK	5751	KS	F	6/22/89	13	
Moe Moe Lay	MML	5811	KS	F	1987	16	Lost part of tail to a poacher
Thit Hnyin Si	THS	5655	KS	F	2/18/86	16	
Moe Moe Aye	MMA	5746	KS	F	1986?	17	
Thit Kyi May	TKM	5654	KS	F	2/16/86	17	
Zaw Oo	ZO	5904	MHW	M	1985	17	
Thit Sein Lay	TSL	5610	Magu	F	9/24/85	18	
Tin Maung Kyaw	TMK	5355	Magu	M	1/12/83	20	
Khain Maung Gyi	KMG	5625	MHW	M	1/1/81	22	
Pan Kyi Yin	PKY	4800	Magu	F	1972	31	Partial vision in right eye
Thaung Tun Aung	TTA	3592	Magu	M	1970	33	
Ngwe Moe Nyo	NMN	3043	Magu	M	1966	37	Lost tusks to poaching; partial vision in left eye
Shwe Win Phyu	SWP	3431	Magu	F	1965	38	
Dawn Phyu	DP	2120	Magu	F	4/7/56	47	

Note. Camp abbreviations: KS = Kyet Shar; MHW = Myaing Hay Wun. DOB is the date of birth, or the estimated date of birth if caught wild. MTE = Myanma Timber Enterprise.

Fig. 1. During breaking, a youngster remains tied to the same tree for days, an experience that may adversely affect the emotional and cognitive development of Burmese elephants (Himmelsbach, 2002).

isolated working camps in the jungle), or logging elephants (dragging logs). The elephants had no background of food-reinforced, instrumental training. Background information about them was obtained from cradle-to-grave government records that were made available to us at the respective camps.

Shortly after capture if wild-caught, or around the age of 4 to 5 years if captive born, all subjects underwent breaking, a time-honored procedure in Burmese logging camps. This procedure involves physical restraint and close contact with human trainers with the objective of producing tractability and submissiveness (see Figure 1) and is considered by some to be harsh and psychologically damaging (Himmelsbach, 2002).

EXPERIMENT 1: BLACK/WHITE DISCRIMINATION

Experiment 1 sought to explore and measure the performance of subjects when pre-

sented with a simultaneous black versus white discrimination task.

Method

Apparatus

Owing to lack of electricity and other conveniences, the present experiments relied on simple equipment and extensive controls.

All black/white discrimination tasks involved the use of one or two hard, green plastic buckets. Each tapered bucket was 32 cm tall, with an internal top diameter of 30 cm and an internal bottom diameter of 25 cm. On one side of each bucket, about 10 cm from its bottom, there was a 10-cm hole—large enough for an experimenter to insert one hand but too small for an elephant to insert a trunk. Each bucket was secured to the ground by means of bamboo stakes.

Each bucket had a green, circular, 33-cm lid made of the same hard plastic material. A white, plastic, semicircular handle was attached to each lid. The distance from the highest point of the handle to the top center of the lid was 19 cm.

In Experiment 1, the discriminative stimuli were distinguished by their brightness; shades were produced by tightly wrapping one lid with white plastic and the other with charcoal-painted canvas. In control tests, painting cardboard disks either black or white and taping the white disk to the black lid and the black disk to the white lid produced the brightness differentials.

In most sessions, a wooden log marked the separation of each subject from the buckets and experimenters. The distance between the edge of each bucket to the nearest part of the log was 64 cm. The log used most often in our experiments was 36 cm in width and 356 cm in length. Because subjects tended to stand as close to the log as possible, the distance from the edge of the buckets to the elephant's feet was usually about 1 m.

Procedure

To prevent fatigue and loss of responsiveness on the part of the elephants, and to obtain as much information as possible, subjects typically took part in a few unrelated experiments in a single session.

In accordance with government regulations, an oozie (elephant handler) was always near his charge during the experiments. In most cases the oozie silently stood or sat by the side of the elephant and did not interact with his charge. As well, a few villagers often gathered at a distance to observe the proceedings, but this seemed to have no effect on the elephants.

All experiments were carried out in full daylight. In early mornings, late afternoons, and cool days, the experiments were carried out in the open. In late mornings, early afternoons, and during spells of uncomfortably hot weather, experiments were carried out under the shade of a tree.

During pretraining and experimental sessions, randomness was achieved by shuffling a deck of 25 red (right) and 25 black (left) cards and writing down the resultant predetermined sequence for that day's experiments. In each session, the numbers of correct choices on either right or left were equal. To overcome position effects, the number of consecutive positive choices on the same side was kept at three or fewer. Despite this, subjects sometimes developed a strong position bias leading, in the absence of experimental intervention, to reinforcers being obtained on 50% of the trials. In such cases, the trial sequence deviated from randomness, and the food was placed on the side opposite to the favored side in over 90% of trials. When the subject abandoned the favored side on three consecutive trials, the experiment returned to a random sequence.

Owing to recurring bouts of malaria and other technical difficulties, interobserver reliability could be assessed for only 78% of the data reported here. Typically, two independent sets of written records were obtained; on some occasions, however, reliability was calculated by comparing one set of observations to a video record.

The experimental schedule for each elephant depended on the needs of our overall experimental program and on the work schedule of a particular elephant. In most cases, an elephant took part in one or two daily sessions: mornings (between 9:00 a.m. and noon) or afternoons (between 3:00 p.m. and 5:00 p.m.). A typical session lasted about 30 min and involved participation in one to three different experiments. When elephants took part in two daily sessions, the intersession interval, which was at least 3 hr, was

spent away from the experimental area. On a few occasions, days passed between one session and the next. On one occasion, an experiment had to be discontinued before meaningful results could be obtained. Such fragmentary data are not reported here.

Burmese logging elephants feed on their own in the forest on rest days or when the day's work is done, and are rarely given any supplementary food. They thus responded eagerly to the assortment of positive reinforcers. For the most part, reinforcers consisted of one or more of the following: (a) a 3- to 8-cm piece of sugar cane, (b) a 1- to 2-cm tamarind ball, or (c) a 3- to 6-cm rice paddy wrapped in banana leaves. On a few occasions when these favorite reinforcers were unavailable, subjects received small portions of the stems of wild banana trees. Our subjects (unlike the 2 Asian elephants of the Detroit Zoo and unlike Rensch's subject) rejected bread products.

Earlier in our work (Nissani, 2004), we noticed that elephants often appear startled and confused by sudden changes in experimental procedures, and that optimal performance depended on step-by-step pretraining:

Pretraining I: Removing a lid to obtain a positive reinforcer from the bottom of a bucket. Here the elephant stood on one side of a heavy log (see Figure 2), directly facing a single bucket on the other side of the log, about 1 m from its feet. A single trainer squatted or sat behind the bucket, directly facing the elephant, and gradually trained the subject to retrieve a reinforcer from the bucket. Once the elephant learned that task, a green, white, or black lid was introduced. At first, the lid just barely covered the bucket opening when the food was placed in the bucket; as the training proceeded, the lid covered an increasingly greater portion of the opening. Once the elephant learned to remove the lid, the trainer held the lid in place and only allowed its removal by the handle.

In the later stages of Pretraining I, the trainer simultaneously inserted the food into the bucket (through the side hole, see Figure 2) with one hand and clicked the lid into place with the other hand. The trainer then removed his hand from the handle, while still holding the food inside the bucket with the other hand. When the elephant grabbed the handle with its trunk and tossed the lid away, the trainer released the food, removed his hand from inside the bucket, and the elephant grabbed the food with its trunk and placed it in its mouth. The performance criterion for Pretraining I was qualitatively defined as the point in which this entire sequence was carried out reliably, smoothly, and rapidly.

Fig. 2. Typical arrangement in Experiment 1 (black/white simultaneous visual discrimination). The white lid is in the foreground and the black lid is in the background. The elephant is about to remove the white lid. Both experimenters are holding an identical food reinforcer in their right hand, partially inserting it into the bucket through the bottom hole.

Pretraining II: Two buckets. The subject faced two identical buckets whose closest points were approximately 50 cm apart. Behind the buckets, a single trainer squatted or sat, holding a single lid. The trainer carried out the same sequence as before with just one of the buckets for five discrete trials. In the next five trials, the reinforcer was placed in the other bucket. The trainer thus kept alternating buckets every five trials until session criterion was reached, with the elephant going to the correct bucket in 9 of 10 consecutive trials, removing the lid, and retrieving the food from that one bucket.

Pretraining III: Single trainer, single lid, two buckets, random placement of the primary reinforcer. This phase was identical to Pretraining II, except that now reinforcer placement (right or left) in one of the two buckets followed a predetermined random sequence. Criterion

was defined as 9 of 10 correct consecutive discrete trials in two separate sessions.

Experimental procedure. Using the same two buckets as in Pretraining III, one experimenter squatted behind one bucket while holding a white lid in one hand and a food reinforcer in the other, and another experimenter squatted behind the other bucket while holding a black lid in one hand and an identical positive reinforcer in the other. A senior experimenter announced the predetermined, randomly selected, reinforced side (right or left) for any given discrete trial. If necessary, the two experimenters exchanged lids, and each placed the lid just behind his bucket so that the elephant could see its color. The experimenters counted "1, 2, 3" and simultaneously clapped the lids on top of their respective buckets with one hand and placed identical reinforcers at the bottom of their buckets with the other hand by inserting this hand through the side holes. Both removed their hands from the lids, but kept the hands with the identical food items inside both buckets (to make sure that the elephant was not choosing the reinforced bucket by smelling its contents). If the elephant chose the correct lid, the experimenter facing that bucket withdrew his hand and left the food behind, while the other experimenter simultaneously withdrew the lid from his bucket with one hand and the food with the other. Both experimenters now waited for the elephant to toss the lid with its trunk, place the food inside its mouth, chew and swallow it. When the subject appeared ready, the experimenters proceeded to the next trial.

If the elephant lifted the incorrect lid, both experimenters withdrew the food-holding hand and the food. Typically, the elephant then removed and tossed that lid, explored the now-empty bottom of the bucket with its trunk, removed its trunk from the bucket, and was ready for the next trial. On some occasions, the elephant made the wrong choice, removed its trunk from that bucket and explored the correct bucket (from which by now the reinforcer and lid had been removed). This was scored as an incorrect choice. Likewise, tossing the correct lid and then inserting the trunk in the wrong bucket was scored as incorrect.

Every 10 to 20 trials, the two experimenters switched positions. To minimize the chance of any experimenter effect, one or two of the experimenters handling the buckets often were replaced in midsession. In each session, the number of trials was typically 50, but at times this varied according to the elephant's performance, work schedule, and participation in other experiments.

For any given session, the session criterion was defined as making 9 of 10 correct consecutive choices. Because elephants that reached this criterion often reverted to chance level in subsequent sessions, an overall learning criterion was defined as the point of reaching 9 of 10 successive correct responses in one session, but only if this was followed by (a) reaching 9 of 10 correct choices within 50 discrete trials in the next session, and (b) obtaining a minimum score of 75% correct responses in all subsequent sessions.

At several points, in an effort to ascertain that switching the lids did not provide the cue for making the correct choice, experimenters acted as if they were switching the lids on every trial, even when no switch was called for.

In most Pretraining III and experimental trials, the reinforced side was read from a predetermined sequence and announced by a senior experimenter. To ascertain that the elephants were responding to the black/white difference and not to these verbal commands (cf. Rensch, 1957), several precautions were taken. Thus, once a discrimination had been acquired, the senior experimenter either switched from the English to the Burmese words for *right* and *left,* or relied on hand and/or head signals. Likewise, on a few trials, after a subject reached learning criterion, experimenters were instructed to silently choose sides on their own.

We took special precautions in all experiments to ascertain that the elephants were learning to respond to the color and not to scent variations. As stated above, both experimenters simultaneously placed identical food reinforcers at the bottom of each bucket. If the elephant first touched the handle of the unreinforced lid, both experimenters simultaneously withdrew lid, hand, and reinforcer. If the elephant first touched the handle of the reinforced lid, hand, reinforcer, and lid were withdrawn from the other bucket, whereas only the hand was withdrawn from the correct bucket, leaving the lid and

reinforcer behind. Thus, until the fate of each trial was decided, both buckets contained an identical primary reinforcer.

Likewise, once some of the elephants learned the black/white discrimination, a control procedure was introduced to ensure that the critical discriminative stimulus they were responding to was color, not some other feature of the correct lid. To achieve this goal, the charcoal-painted lid was fully covered with a white-painted cardboard disk, and the plastic-covered white lid was fully covered with a black-painted cardboard disk. In this case, if subjects were not reacting to the color difference but were reacting instead to another visual cue, to an olfactory cue, or to an auditory cue (e.g., different click sounds), then the change in the black/white materials should have led to a significant decline in their performance. If, on the other hand, they had learned a black/white discrimination, then no decline in performance would be expected.

Upon the completion of the above color shift tests, the size of disks was progressively lowered in a successive series of discrimination tests, from 33 cm to 24, 17, 12, 10, 8, and 6 cm in diameter. In each step, the correct and incorrect lids were alternated; for instance, a lid that served as the S^+ when the pair of disks was 24 cm in diameter, served as the S^- in the next step, when the diameter of the pair of lids was lowered to 17 cm. In each successive step from 24 cm to 6 cm, the lids were fully covered with tan cardboard disks, 33 cm in diameter, which thus served as a background to the white and black disks. The black and white disks were also made of cardboard, with successive pairs either painted black or white or covered with black or white plastic. The disks were temporarily attached to the cardboard with double-sided tape.

One young elephant (TTT; Table 1) learned the discrimination with the buckets but was too destructive and excitable to continue. In her case, a slight modification of the setup was made, employing the same lids but replacing the buckets with two holes in the ground. The switch increased the distance from her eyes to the lid center (from 110 to 125 cm), but had no other observable effect.

Results and Discussion

The distance from the top of either lid to the elephant's eyes depended on the elephant's height and the position the elephant assumed on that day; measurements taken on several occasions suggest that, for the entire black/white group, the distance ranged from 93 to 137 cm.

Once they became accustomed to the setup, all but 1 of the elephants appeared highly motivated, and they were often reluctant to leave the experimental area at the end of the session. The one exception involved Elephant TTA, a healthy, working, 33-year-old tusker that often failed to respond during pretraining and hence did not take part in either Experiment 1 or 2.

When independent records were obtained by two different experimenters, or by one experimenter and a digital video camera, the two sets of records either matched perfectly, or contained very slight discrepancies, usually just a single trial. Such high interobserver reliability is expected, given the clearcut nature of the task.

Data not given here conclusively show that the performance of elephants in this task was neither traceable to verbal signals, nor to their ability to infer the correct lid from the act of switching versus not switching the lid (see Experimental Procedure for description of these two control conditions).

All 14 elephants successfully achieved criterion for Pretraining III (removing a lid placed on top of one of the two buckets and removing food from the bottom of the bucket) within two to seven sessions (Tables 2 and 3). Accurate records of the duration of each session were kept in just one case (Elephant MML), and comprised 125 min. All 14 elephants acquired the task gradually (cf., Thorndike, 1898); however, at the end of pretraining, they all removed the lid competently and smoothly.[1]

The data in Table 2 are arranged by task, and show that 7 elephants reached criterion for the white+/black− discrimination, and 4 for the black+/white− discrimination. Within each task, data are arranged by age of elephant. The two columns on the right give the session number and trial number at

[1] A brief video of a trial can be seen at: www.is.wayne.edu/mnissani/ElephantCorner/disc1.mpg.

Table 2

Experiment 1. Black/white discrimination data for elephants who reached overall learning criterion. Data are arranged by task and, within a task, by age of elephant.

Elephant	Task	Age (years)	Number of pretraining sessions	Position bias? (number of sessions)	Overall learning criterion reached	
					Session number	Trial number
ACT	White+/Black−	10	4	No	1	32
ADM	White+/Black−	12	6	Yes (2)	5	289
SPM	White+/Black−	12	5	No	1	24
THS	White+/Black−	16	5	No	1	10
MML	White+/Black−	16	2	No	3	109
MMA	White+/Black−	16	7	No	1	26
TKM	White+/Black−	17	2	No	6	328
TTT	Black+/White−	5	6	Yes (1)	3	158
SAN	Black+/White−	7	2	Yes (2)	7	375
SSP	Black+/White−	10	5	Yes (2)	7	402
AKO	Black+/White−	12	4	Yes (1)	4	238

which overall learning criterion was reached. Table 3 shows data for the elephants that failed to reach the overall learning criterion.

Tables 2 and 3 show that 11 of 14 elephants successfully mastered this discrimination task, reaching overall learning criterion with means of 3.5 sessions and 181 trials and ranges of one to seven sessions and 10 to 402 trials. Once they reached criterion, and in the absence of intervening discrimination tasks, their performance remained consistent and reliable in all subsequent sessions (reaching the 9 of 10 session criterion by the 9th or 10th trial in over 50% of all sessions).

The results (Tables 2 and 3) raise the possibility of a surprising age effect in learning this discrimination task. The 11 elephants that reached the overall criterion ranged in age from 5 to 17 years, with a mean age of 13.8 years. In contrast, 2 of the 3 elephants that failed to reach learning criterion in any of the sessions (PKY and SWP), and hence to reach the overall learning criterion, were 31- and 38-years-old, respectively. The mean percentage of correct responses for the first six sessions of the 12 young elephants (5 to 17 years of age) was 66.7, as opposed to 49.3 for these 2 older elephants. By the sixth session, the gap between the two groups was significant (Mann-Whitney, $p = .022$). The 1 young elephant (MMK; Table 3) that failed to reach the overall learning criterion seems to have performed better than the 2 older elephants: She reached 9 of 10 session criterion in 5 of 11 sessions and performed correctly in 61% of all trials.

Another difference involved the two colors. Seven elephants achieved the overall learning criterion on the White+/Black− task in 2.6 sessions, whereas 4 elephants achieved criterion on the Black+/White− task in 5.3 sessions. Likewise, the 7 elephants in the White+/Black− group achieved overall learning criterion in 117 trials, whereas the 4 elephants in the Black+/White− group achieved criterion in 293 trials. For the first three sessions for each elephant, the mean percentage of correct responses for the 7 el-

Table 3

Experiment 1. Black/white discrimination data for elephants who did not reach overall learning criterion.

Elephant	Task	Age (years)	Number of pretraining sessions	Position bias? (number of sessions)	Total number of sessions	Correct trials/ total trials (%)
MMK	Black+/White−	13	3	No	11	310/515 (61%)
PKY	Black+/White−	31	4	No	7	194/388 (50%)
SWP	White+/Black−	38	3	Yes (5)	9	271/549 (49%)

ephants performing the White+/Black− task was 76.7%, whereas mean percentage of correct responses for the 4 elephants performing the Black+/White− task was 44.7%. This difference is significant (Mann-Whitney, p = .024). Other lines of evidence seemed consistent with the notion that it was easier for elephants to learn the White+/Black− discrimination than the Black+/White− discrimination. The percentage of correct responses in the first session for the White+/Black− group was 75%, but was 43% for the Black+/White− group. Moreover, the only failure to reach criterion among under 17-year-old elephants (MMK) involved a Black+/White− discrimination task (cf. Mackintosh, 1969).

The most commonly observed error during task acquisition involved the development of positional biases, here operationally defined as choosing the same side, right or left, on nine or more consecutive trials. Only 1 of the 3 subjects that did not master the black/white discrimination showed criterion position biases, and this bias was observed in five separate sessions. Another common error during the learning process involved the occasional removal of the correct lid, immediately followed by placement of the trunk in the wrong bucket (from which the lid and reinforcer had by then been removed).

As mentioned earlier, the jungle setting of our experiments necessitated extensive tests that would have not been required in the laboratory. One control involved ascertaining that the elephants were responding to the color difference, not to such incidental features of the lids as scent. After 6 young elephants (range of ages, 7 to 17 years; mean, 14.2 years) reliably reached the learning criterion for the original task, they were given 13 additional sessions with the same task, in which all 6 rapidly reached the 9 of 10 session criterion in a mean of 10.6 trials. Immediately after each of these 13 sessions, the charcoal-painted lid was covered with a white-painted cardboard disk, and the plastic-covered white lid was covered with a black-painted cardboard disk. Following the switch, the 6 elephants reached criterion in 12 of the 13 sessions (mean, 11.6 trials per session). The same pattern was observed when disk sizes were decreased from 24 to 17 cm, even though both the lids and materials used to

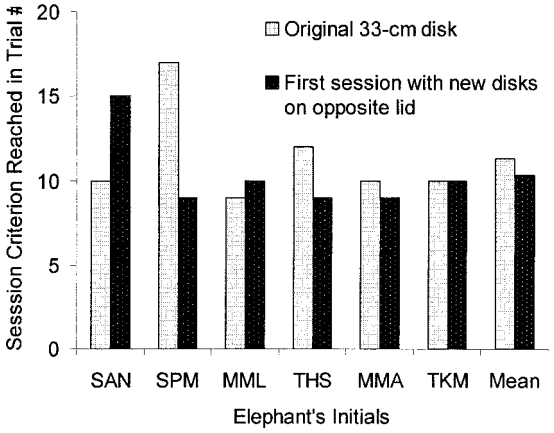

Fig. 3. The results of the first shift of lids and colors for 6 elephants.

produce the white and black shades had been altered. Thus, for the 24-cm lid, elephants reached learning criterion in 27 of 32 sessions, with a mean number of trials to criterion of 15.3, whereas for the immediately following 17-cm phase, the respective values were 26 of 33 sessions and a mean of 15 trials.

Of particular interest are the results of the session in which the first shift of lids and colors took place. In each of the 6 elephants, the session began with the original 33-cm disks. Immediately after each elephant reached learning criterion, the new disks were introduced for the first time, fully covering the opposite-colored lids. Figure 3 shows the results of the first color shift, showing for each elephant the trial number at which the 9 of 10 learning criterion had been reached with the original disk and, then, following the color shift. Clearly, the switch had no effect on the elephants' performances. We may therefore safely conclude that the elephants were indeed responding to the color of the lids, not to some other feature.

A second control condition relied on the progressive decrease in the size of the black and white disks. In this case, one might expect to reach a point in which humans can still distinguish the two colors, whereas elephants, whose visual acuity is considerably lower than that of humans (Rensch & Altevogt, 1955), cannot. If the elephants' performance is traceable to experimenter effect and not to the black/white stimulus control, no threshold should appear, and they should be able to distinguish the smaller disks cor-

rectly, as long as the experimenters themselves could make that distinction. If, on the other hand, elephants rely on the color of disks to make that differential response, as opposed to subtle signals from the experimenters, then a consistent visual acuity threshold should appear for each individual.

The data lend full support to the threshold notion. When data for all 6 elephants are combined, the overall performance of the 6 elephants progressively declined from meeting criterion in a total of 33 of 34 sessions (mean number of sessions per elephant, 5.7) when the diameter of the pair of disks was 33 cm, to meeting criterion in 12 of 28 sessions (mean, 4.7) with 10 cm diameters, to never meeting criterion in 10 sessions (mean, 1.7) with 6 cm diameters. Thus a visual threshold appeared to exist for all of the 6 elephants for which this control was carried out. Because human beings in this exact setup can comfortably distinguish a pair of black/white dots with a diameter of 0.5 cm (personal observations), one may safely conclude that elephants in our discrimination tasks were relying on their own vision, not on discriminative stimuli provided by the experimenter.

This control condition also suggests that elephants see well enough to perform the original discrimination task. In all six cases of progressively lowering disk sizes, the probable point of consistently obtaining a score equal to or lower than 50% sessions correct occurred with disks with diameters of 17 cm or less—roughly one fourth the size of the 33-cm disks used in the original discrimination experiments. This suggests that the original discrimination task was well within the visual acuity range of the younger elephants (Rensch & Altevogt, 1955).

EXPERIMENT 2: LARGE/SMALL TRANSPOSITION

Experiment 2 sought to obtain information about the performance of elephants in relational discrimination tasks and to provide a confirmation of the results of Experiment 1. To achieve these goals, elephants faced a two-stimulus transposition problem (choosing the larger or smaller of a given pair of stimuli; cf. Gulliksen, 1932; Mazur, 2001).

Method

Because the large/small training procedures closely resembled the black/white procedures, only key differences between the two will be highlighted here.

Subjects

Of the 7 subjects that took part in the large/small task, only Elephant ACT (Table 1) had taken part earlier (and attained the overall learning criterion, see Table 2) in the black/white discrimination task. Before and during the large/small task, Elephants ACT and KMG (Table 1) were involved in seeing experiments as described above (Povinelli & Eddy, 1996) and short-term memory experiments, Elephant ZO was involved in seeing experiments, and Elephants DP, NMN, TMK, and TSL were involved in short-term memory experiments.

Apparatus

All large/small relational discrimination tasks involved two circular depressions in the ground and eight specially constructed teak boxes. The depressions were 10 cm deep, 19 to 23 cm across, and 20 to 48 cm apart.

All eight boxes (Figure 4) had roughly equal heights (7 to 8 cm) but differed in surface areas (Table 4). The vertical sides of each box were white. One of the larger surfaces of each box was white and the other was black, allowing us to present elephants, on any trial, with either a black or white combination of the same pair of boxes. To facilitate handling, the two larger surfaces of most boxes had a 2 cm by 2 cm opening at their center.

Procedure

Overall, the mean distance from the elephants' eyes to the boxes was greater than it was in Experiment 1. First, the surfaces of the boxes were only 7 to 8 cm above ground, whereas the lids in Experiment 1 were 32 cm above ground. Second, height in elephants is correlated with age and gender, and the large/small group of elephants was, on average, older than the black/white group (means, 24.4 years vs. 16.7 years), and had a greater proportion of males (71% vs. 21%).

In this experiment (see Figure 5), sometimes the demarcation line between the experimenters and the subject was marked with a heavy log as in the black/white experi-

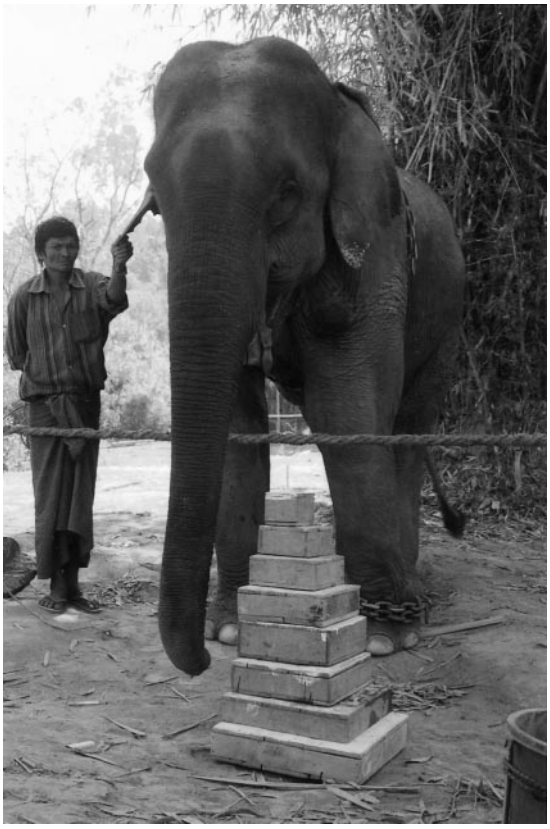

Fig. 4. Boxes used in Experiment 2. Box A is shown here at the bottom and Box G is shown on top (see Table 4). Top, white surface of each box is shown. Not shown is the black surface of each box.

ments. At other times, it was marked by a rope suspended about 1 m off the ground. On a few other occasions, no formal demarcation line was used.

In experimental sessions, both experimenters simultaneously placed an identical reinforcer inside the circular depression with one hand (as opposed to both placing their hands and food through side holes inside the buckets in the black/white setup), and while keeping that hand inside the depression, placed a box over it. The boxes varied in size from 245 to 1681 cm^2 (Table 4).

Following the pretraining phases, and after reaching the overall learning criterion for the large/small task with one pair of boxes, elephants were presented with a total of 21 box-pair combinations of the eight boxes. The use of the different combinations served (a) to ascertain that the critical variable to which the elephants were responding was size, not some other feature of the boxes or experiment, and (b) to rule out any experimenter effect.

[2] A brief video of a trial can be seen at: www.is.wayne.edu/mnissani/ElephantCorner/disc2.mpg.

Table 4

Experiment 2. The size of boxes used in the large/small discrimination task.

Box	Width × length (cm)	Diagonals (cm)	Area (cm^2)
A	41 × 41	58	1681
B	36 × 36	50	1299
C	30 × 31	43	909
X	27 × 28	39	757
D	28 × 26	37	711
E	26 × 26	36	673
F	20 × 20	29	420
G	15 × 16	22	245

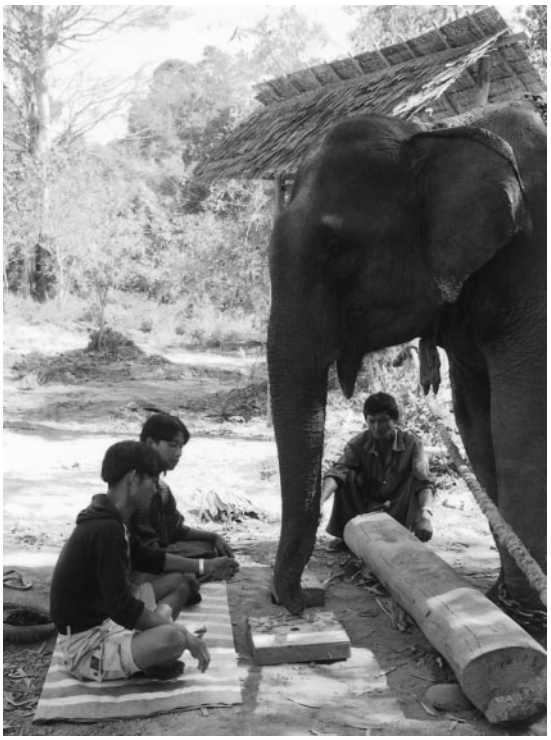

Fig. 5. Experiment 2. Typical experimental arrangement for the large/small relational discrimination. The subject is depicted removing the smaller box and obtaining food in the depression below it. Two experimenters are facing the subject while the oozie (elephant handler) is observing.

Table 5

Experiment 2. Data for the 3 elephants that met the overall learning criterion in the initial large/small relational discrimination task, arranged by age of elephants.

Elephant	Eye distance (cm) to top center of box	Task	Age (years)	Number of pretraining sessions	Position bias? (number of sessions)	Overall learning criterion reached	
						Session number	Trial number
ACT	132	Large+/Small−	10	1	Yes (1)	2	59
TSL	160	Small+/Large−	18	1	Yes (1)	2	96
TMK	164	Large+/Small−	20	1	Yes (1)	1	19

Results and Discussion

Table 5 shows the data for the 3 elephants that reached overall learning criterion, whereas Table 6 displays data for the 4 elephants that did not. Thus 3 of 7 elephants reached the overall learning criterion (achieving 9 of 10 criterion in two consecutive sessions and obtaining over 75% total score in all subsequent sessions) with means of 1.7 sessions and 58 trials.

The results support the age effect observed earlier. The 3 elephants that reached the overall criterion ranged in age from 10 years to 20 years, with a mean age of 16 years. By contrast, the 4 elephants that failed to reach the overall learning criterion ranged in age from 17 years to 47 years, with a mean age of 31 years. Moreover, in the first three sessions for which comparisons can be made, the 2 younger elephants (ZO and KMG) in the group of 4 that failed to reach criterion (Table 6) performed slightly better than the older pair. For example, on the third session, both of the younger elephants passed the 9 of 10 session criterion and had on average a total score of 76%, whereas the 2 older elephants in this group (NMN and DP) failed to meet the 9 of 10 criterion and had an average score of 48% correct.

As in Experiment 1, the most commonly observed error during training and task acquisition involved position bias. This bias was observed in the 3 elephants that met the overall learning criterion (Table 5) and in 2 of the 4 elephants that failed to meet this criterion (Table 6).

Once the 3 elephants met the overall learning criterion, they were presented with up to 21 different pair-wise combinations of boxes, for a total of 109 sessions. Each elephant met the criterion at least twice with five different box pairs, thus showing that learning this task is independent of any particular stimulus combination and demonstrating relative stimulus control in this species. This last conclusion gains further support from a series of control experiments (not shown), which involved shifting the value of a given box (from + to −) in successive box-pair combinations at least once for each of the 3 elephants, for a total of six such switches. For instance, in one of these six switches, Elephant TSL was first presented with the A to C (Table 4) box pair (1681 cm vs. 909 cm^2), for which the

Table 6

Experiment 2. Data for the 4 elephants that did not meet the overall learning criterion in the initial large/small discrimination task.

Elephant	Eye distance (cm) to top center of box	Task	Age (years)	Number of pretraining sessions	Position effect? (number of sessions)	Discrimination data	
						Number of sessions	+ trials/total trials (%)
Z0	159	Large+/Small−	17	4	No	7	154/250 (62%)
KMG	182	Small+/Large−	22	1	No	6	191/300 (64%)
NMN	180	Small+/Large−	37	1	Yes (1)	3	67/148 (45%)
DP	152	Large+/Small−	47	4	Yes (1)	3	107/172 (62%)

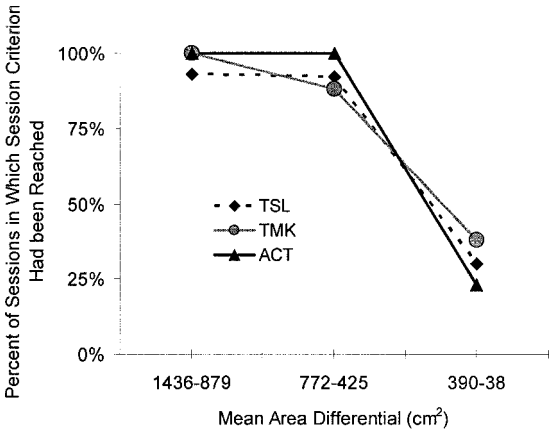

Fig. 6. Individual performance of the 3 elephants that acquired the large/small discrimination task as a function of area differences between boxes.

smaller Box C was the correct stimulus (Table 5), and reached a criterion of 9 out of 10 correct on Trial 10. She then was then presented with the C to F box pair (909 cm vs. 420 cm^2), for which C was the *incorrect* stimulus, and reached the 9 of 10 criterion on Trial 9. For all six switches, the mean number of trials to criterion was 10.5 before the switch and 10.0 after the switch. Clearly, these switches had no effect on performance, again suggesting the presence of relative stimulus control.

When data from eight box-pair combinations whose area differences ranged from 1436 to 879 cm^2 and from 39 sessions were pooled, they show that the 3 elephants reached the learning criterion in 97% of 39 sessions. When data from eight box-pair combinations whose area differences ranged from 772 to 425 cm^2 and from 39 sessions were pooled, they show that the 3 elephants reached learning criterion in 90% of the 39 sessions. In contrast, when data from seven box-pair combinations whose area differences ranged from 390 to 38 cm^2 and from 31 sessions were pooled, they show that the 3 elephants reached learning criterion in 36% of 31 sessions. Figure 6 summarizes some of these data, showing that size differences in the 1436 to 425 cm^2 range had little effect on performance of each individual elephant, but that below 390 cm^2, a precipitous decline occurred. These results provide additional confirmation to the notion that the 3 subjects responded to the relational properties of the stimuli (Reese, 1968). The sharp decline in performance, which occurs between 390 and 425 cm^2, is probably traceable to, and indicative of, the visual acuity threshold of elephants. As in Experiment 1, the existence of a visual threshold argues against experimenter effect.

The 3 elephants acquired the size-discrimination task exclusively with white surfaces. To investigate whether they could immediately generalize that task to other colors, and in an effort to provide additional confirmation to the notion that they were responding to the size relations between the two stimuli and not to other incidental features of the task, they were presented with black pairs of boxes. One elephant (TSL) did not touch either box when facing a black pair of boxes. Because this happened shortly before our scheduled departure, we did not attempt to acclimate her to the black surface. The other 2 elephants showed no visible reaction to the change from white to black and therefore were tested a few times throughout the experiment. In both cases, when a session with white surfaces was immediately followed by a session with black surfaces, no effect on the elephants' overall performance was observed.

GENERAL DISCUSSION

Almost everything that is known at present about the performance of elephants in discrimination tasks comes from Rensch's observations of a single 5-year-old zoo elephant. Our experiments have been based on a pool of 20 working Burmese elephants residing in a more natural setting, with varying ages, both genders, and different histories. Although our experiments are consistent with Rensch's, they present a far more complex and puzzling pattern.

Our experiments demonstrate that food reinforcers can successfully establish and maintain visual discriminations in some elephants, and they show for the first time that elephants are capable of relational discrimination. Our results also point to a remarkable variability. Thus some elephants acquired the white+/black− visual discrimination in the first session and after comparatively few trials, other elephants took several sessions and hundreds of trials, while still other elephants failed to acquire the task. A similar variability

was noted when the elephants responded under relative stimulus control.

The age effect reported here is puzzling because survival in the wild may require a capacity for discrimination learning. The effect cannot be ascribed to senility or lack of motivation—elephants in their twenties, thirties, and forties are at their prime, and our older subjects appeared just as eager as the younger ones. It likewise appears improbable that this effect is ascribable to prior learning. The effect could be ascribed to a sharp decline in the visual acuity of captive adult elephants; indeed, 2 of the older elephants that failed to master a discrimination task had partial vision in one eye (Table 1). Alternatively this effect could be ascribed to differences in the learning abilities of young and mature elephants. Further experiments are needed to confirm the age effect, examine its applicability to the elephant's more primary olfactory sensory modality, place it in an appropriate evolutionary context, and explain it.

Markowitz et al. (1975) reported a preliminary and fragmentary recall study of 3 *Elephas maximus* females. Eight years after the 3 elephants had mastered a light/dark discrimination task (at ages 11, 14, and 17 years), they were presented with the same task again. The now 19-year-old reached criterion of 20 successive correct responses by trial 43, the 22-year-old in 2863 trials, and the 25-year-old in 1240 trials. The authors ascribed the remarkably poor recall of the 2 older elephants to visual anomalies, which in turn were ascribed to the fact that pachyderms in zoos "are maintained indoors for large parts of the year with significantly reduced lighting." In our sample of 20 elephants, the evidence that the oldest elephant to acquire a discrimination was 20 years old and that our elephants spent their entire lives outdoors raises the possibility that the poor performance of Markowitz et al.'s 2 older elephants is traceable to their age. These authors' data thus could be reinterpreted as providing some support to the unexpected age effect reported in the present paper.

More broadly, the performance of even our fastest-learning elephants was unremarkable. Thus our observations are consistent with the notion that elephants can be trained to perform a variety of tasks and that they can meet the daily challenges of life in the wild and captivity by relying on built-in behavioral predispositions, trial-and-error learning (Thorndike, 1898), excellent memory (Markowitz et al., 1975), and extensive social networks (McComb, Moss, Sayialel, & Baker, 2000). However, at the moment, our observations call into question the elephant's reputation for exceptional intelligence and the widespread belief among field and elephant researchers that elephants use their understanding of the world around them to reason their way through the challenges of daily life (cf., Gale, 1974; Gordon, 1966; Poole, 1997; Shoshani & Eisenberg, 1992; Williams, 1953). A subsequent paper will analyze this question experimentally.

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Received May 5, 2004
Final acceptance September 18, 2004