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Performance on a Means-End Task by Asian Elephants (*Elephas maximus*) in a Positive Reinforcement-Based Protected-Contact Setting

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The current study tested six Asian elephants (*Elephas maximus*) on a means-end behavioral task of pulling a support to retrieve a distant object; a systematic replication of the Irie-Sugimoto, Kobayashi, Sato, and Hasegawa (2008) study. The paradigm was somewhat modified from the original research to accommodate a protected-contact setting, reduce the total number of trials, and one condition was excluded. Each elephant was tested on three conditions of increasing difficulty. Specifically, subjects were asked to select from a choice of two trays where one intact tray was baited with a highly-valued produce item and the other was A) empty, B) baited adjacent to the tray, and C) baited on the far side of a break in the tray. Results indicated that the elephants met or exceeded the criteria established for conditions A and B, but performed at chance levels on condition C. These data are contrasted with those of the original study where one elephant met criteria for all three conditions. We discuss potentially relevant variables affecting performance including differences in visual access to the trays, motivation levels, and training style.

Elephants have a complex social structure in which they are presented with daily challenges (Poole & Moss, 2008). Their brains are large and complex and lend themselves to the cognitive abilities observed in humans and non-human primates (Jacobs et al., 2011). Accordingly, elephants have demonstrated advanced cognitive abilities both in the wild and under human care. For example, elephants show remarkable ability to use tools and problem-solve. Wild elephants have been observed digging holes to drink water and then ripping bark from a tree, chewing it into a ball, filling in the hole and covering it with sand to avoid evaporation, then returning later to drink again (Bates, Poole, & Byrne, 2008). They often use branches to swat flies or scratch themselves (Chevalier-Skolnikoff & Liska, 1993). Elephants have even been known to drop boulders onto electric fences to turn off the electricity and leave a fenced area (Poole, 1996). Elephants under human care have also been tested on a number of cognitive tasks similar to those which have been administered to primates and dolphins (e.g., number discrimination: Perdue, Talbot, Stone, & Beran, 2012; self-recognition: Plotnik, de Waal, & Reiss, 2006; tool-use: Hart, Hart, McCoy, & Sarath, 2001). For example, Plotnik, Lair, Suphachoksahakun, and De Waal (2011) demonstrated that elephants could learn to coordinate their actions with a partner in a task requiring two individuals to simultaneously pull two ends of the same rope to obtain a reward.

It is important to note that studies examining the cognitive abilities of elephants, or any large exotic animal, are often limited to a few individuals, making it difficult to generalize the results. As such, replication is extremely important when studying animal behavior and cognition (Agrillo & Miletto Petrazzini, 2012). Therefore, for the current study we chose to systematically replicate a study examining the performance of Asian elephants (*Elephas maximus*) on a means-end task (Irie-Sugimoto, Kobayashi, Sato, & Hasegawa, 2008). The nature of the study involved a means-end task, in which elephants could attempt to pull a tray to access a distant food item. The task was based on the classic Piagetian *support* task, where toys were placed out of reach of infants (Piaget, 1952). Specifically, the toys could be pulled toward the subject using a towel placed underneath

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it. Human infants around 11 months of age were able to understand the spatial relationship between the two features. Similar tasks have been used to study the ability of non-human animals to understand means-end relationships (e.g., cotton-top tamarins, *Saguinus oedipus*: Hauser, Santos, Spaepen, & Pearson, 2002; ravens, *Corvus corax*: Heinrich & Bugnyar, 2005). Irie-Sugimoto and colleagues (2008) tested two female Asian elephants on four conditions (A: Baited vs. Empty, B: ON-OFF, C: Transfer, and D: Disconnected). Only one of their subjects was able to complete all four conditions, and both subjects needed a fairly large number of trials to reach criterion levels. The authors concluded that the study needed to be completed with more elephants before solid conclusions could be drawn.

Elephants present an especially unique situation for replication because there are currently two very different ways in which elephants are managed worldwide: protected-contact and free-contact. In protected-contact management, interaction occurs between trainers and elephants through a physical barrier, and is more likely to rely on positive reinforcement operant conditioning; and less likely to use punishment or negative reinforcement to modify behavior, and the elephant's participation in training (and, therefore research) is completely voluntary. Free-contact allows the trainer to have direct physical contact without any barriers such as gates or bollards. This management style includes positive reinforcement, but also allows for punishment and negative reinforcement, specifically the use of a bullhook or ankus, also sometimes referred to as a *guide*. When reviewing the literature on elephant cognition, we found that elephants under both types of management styles have been studied, however the training style is only mentioned briefly as part of the methodology and to our knowledge, differences in learning and cognitive ability in elephants under the two different management styles has not been empirically tested. However, we believe more attention should be paid to this difference as the training techniques to which an animal is exposed to may affect behavior and, thus, the outcome of an experiment.

Practically speaking, protected-contact means there is always a barrier between elephant and human, which may interfere with certain experimental procedures. For example, Foerder, Galloway, Barthel, Moore, and Reiss (2011) tested elephants on their ability to use sticks as tools to reach food items placed opposite of the bars in their indoor enclosure. None of the elephants demonstrated evidence of insightful problem-solving. In a follow-up study, the experimental procedure was modified to be conducted solely on the open habitat and away from the impediment of the bars (Foerder et al., 2011). The elephants were more successful in the new set-up, although the differences in problem solving were attributed to a change in the type of tool and not the change in the enclosure. However, when working with elephants under protected-contact it is important to consider the role the barrier may play in the experimental procedure. There is additional evidence in other species that a barrier may interfere with performance on a task, such as canids showing a decreased ability to respond to human gestures when viewing them through a chain-link fence (Udell, Dorey, & Wynne, 2008).

Furthermore, it is possible that elephants managed under different training styles may vary in their cognitive abilities or performance on tasks. Recent research with domestic dogs has suggested that positive-reinforcement-only training leads to increased cognitive performance on novel tasks (Haverbeke, Laporte, Depiereux, Giffroy, & Diederich, 2008; Rooney & Cowan, 2011). Also, a recent replication of elephant numerical ability suggests that there may be a difference between protected-contact and free-contact trained animals. Irie-Sugimoto, Kobayashi, Sato, and Hasegawa (2009) reported that while the elephants more frequently chose the larger quantity of items in a numerosity task, they seemed to lack the typical magnitude effects observed in other species. Perdue and colleagues (2012) replicated the study and revealed that their elephants did, in fact, exhibit the typical magnitude effects. The original study featured Asian elephants trained under free-contact and the replication featured African elephants (*Loxodonta africana*) trained under protected-contact. The authors Perdue et al. (2012) attributed this difference in performance to various methodological issues present in the original study, which certainly may have been a contributing factor. However, we suggest

that the training history of the animals may have played a role as well—the elephants in the original study were managed under free-contact, while those in the replication were managed under protected-contact. Also, it is important to note that the difference is species could have been a contributing factor.

For our replication, we examined means-end problem solving in Asian elephants managed under protected-contact. The elephants in the original study were managed under free-contact. We hypothesized that our subjects would demonstrate success more quickly (i.e., requiring fewer trials) due to their management/training style. The elephants in the original study needed many trials to achieve criterion performance (up to 250 trials for some of the conditions). To that end, we set our criterion to be limited to a maximum of 50 trials, which was the minimum number of trials presented to a subject in the original study.

Method

Subjects

One male and five female Asian elephants *(Elephas maximus)* participated in this study. All elephants were housed at Busch Gardens, Tampa Bay, FL, USA (BGTB). Ages ranged from 25-48 yrs. Four females were imported from Asia and subsequently transferred to the park in the early 1970s, while the fifth female was born at the park in 1990. The all-female herd was managed under a free-contact system until 2004, when the program transitioned to positive reinforcement based protected-contact behavioral management. Since the transition, the BGTB program has proscribed the use of any punishment or negative reinforcement. The male elephant (also zoo-born) joined the females at BGTB in 2015 and is fully socialized with them. Under the current system, subjects are trained in a choice-based environment to voluntarily participate in husbandry and veterinary care and respond well to trainers and to structured learning opportunities for mental stimulation.

Procedure

The study involved a means-end task in which elephants could demonstrate whether they understood the means to achieving an end goal: accessing distant food. Plastic trays (35 cm x 45 cm) with a small lip were used as the support. An assortment of highly-valued food items from the subject's regular diet (e.g., bananas, honeydew, grapes) were used as the bait. Each subject was given the opportunity to choose one tray from an array of two. Only the near end of the trays was in reach of the elephant's trunk. All research sessions were conducted outdoors on the main habitat at the Elephant Interaction Area (EIA), where members of the herd frequently join trainers for interaction in the form of learning, husbandry, and relationship sessions through a husbandry gate (see Figure 1). The area was constructed to enable guest viewing of these interactions and procedures, although the area remained closed to guests during research trials. Both the top and bottom windows (each 0.91 m x 0.91 m) in the EIA gate were opened for all trials to provide the subjects with a less impeded view of the experimental set-up. A piece of wood was attached to the bottom of the EIA gate to prevent the elephants from sliding the tray into the habitat. Trials were either conducted mid-morning (around 10:00 am) or mid-afternoon (around 3:00 pm). The exact timing varied depending on the daily activities of the herd, but it typically involved the following framework: Elephants shifted off the habitat and into the barn at 7:00 am, returned to the habitat between 9:30 and 10:00 am, shifted back inside at 1:45 pm, and returned to the habitat at 2:30 pm. In most cases, trials were conducted shortly after subjects returned to the habitat.

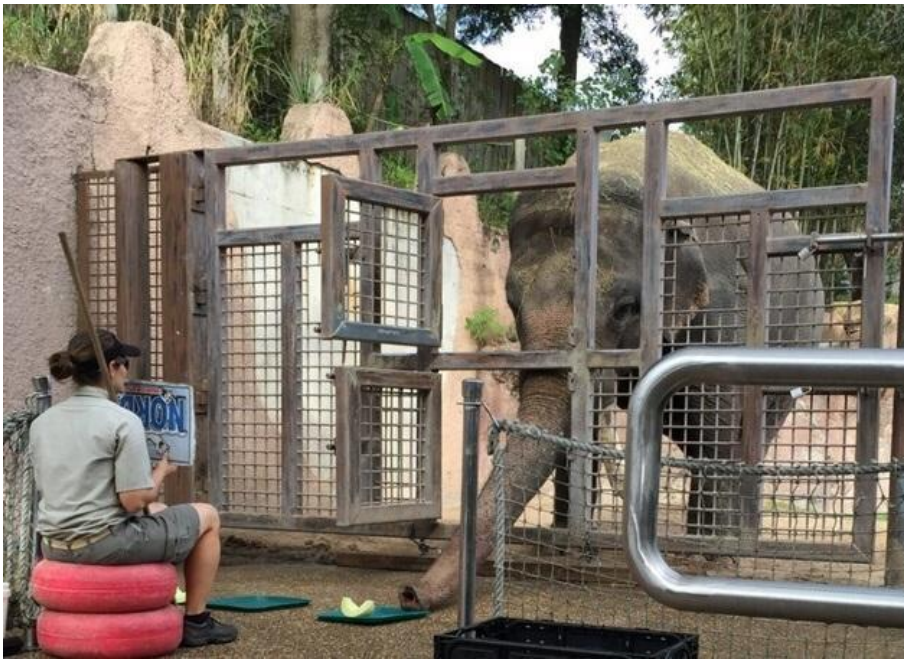


Figure 1. The elephant interaction area (EIA).

Pre-trials. Before starting the research sessions, the trunk-reach distance was measured for each subject. For this measurement, a piece of produce was placed on the ground in front of the EIA window area. Chalk was used to mark the farthest point the subject could reach with its trunk extended. Immediately following the trunk measurement, a single, baited tray was placed on the ground at the measured distance. Each subject was provided 2-3 single tray trials to expose the individual to the tray (which the subjects had never seen before). The elephants were encouraged to grab the tray and slide it closer to reach the produce. All subjects learned to do this sliding motion within 2-3 probe trials. One subject (CA) required several additional training repetitions to learn to leave the tray on the ground after sliding it closer. This helped discourage CA from excessively playing with and breaking the trays once trials began.

Experimental sessions. Two trainers and one experimenter were required for each experimental session (see Figure 2). Trainer 1 was stationed at an overlook adjacent to the EIA. Both Trainer 2 and the experimenter were stationed at the EIA gate. A session would begin when Trainer 1 called the subject to the overlook area. Here, he/she would cue several well-established behaviors and provide primary (a variety of produce items, including small pieces of apples, pears, and sweet potatoes, and browse, including reed grass and banana plant leaves) or secondary (tactile, verbal, cuing object retrieval behavior) reinforcers. Efforts were made to ensure that Trainer 1's interactions were not preferred to the experimental task, yet were still reinforcing enough to encourage the subject to leave the testing area and return to the overlook between trials. When the experimental set-up was ready, Trainer 2 would call the subject over to the EIA gate. During the choice portion of the trial, Trainer 2 remained seated in a neutral position approximately 40 cm behind the trays. To control for unintentional cueing, Trainer 2 wore dark sunglasses and held up a piece of cardboard (50 cm x 30 cm) to block the sight of the tray and to remain blind to the correct choice. For safety reasons, she was still able to see the elephant over the visual barrier, but could not see the array of trays. The experimenter was stationed out of direct sight of the elephant during the choice portion of the trial (hidden from view behind a plant). From her vantage point, the experimenter could see the trays and was responsible for indicating to Trainer 2 when a choice was made by the elephant. A choice was considered to be the first tray with which the subject's trunk made physical contact. Immediately upon hearing a choice was made, Trainer 2 put down the cardboard blinder and quickly removed the unchosen tray. Trainer 2 was also responsible for removing the chosen tray once the bait was consumed. After each trial, Trainer 1 called the subject back to the overlook area so that the next trial could be set up out of sight of the subject. Each trial was set up by the experimenter so Trainer 2 would remain blind. Residual food odors were neutralized between each trial by wiping each tray clean with a disinfectant cloth.

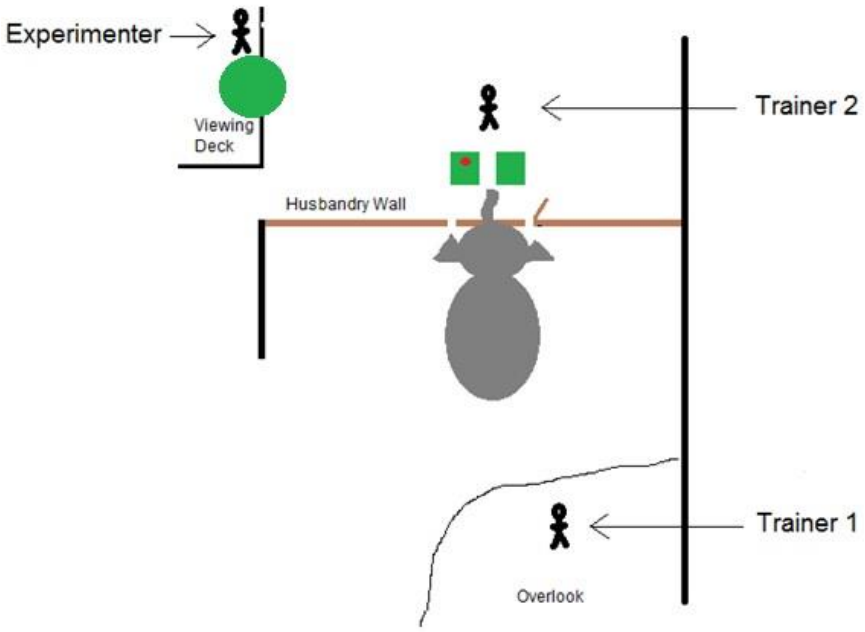


Figure 2. Diagram of the experimental set-up.

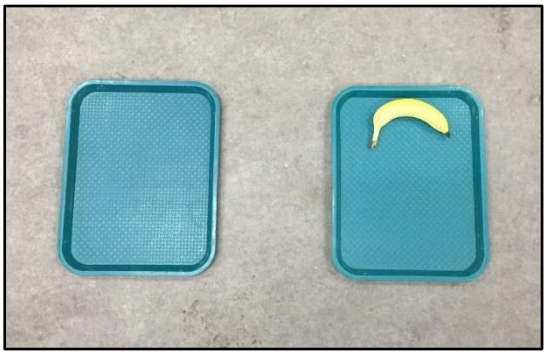
Specifically for the experimental sessions, two trays were presented on the ground in front of the EIA window. Both trays were placed at the same previously measured trunk-reach distance per individual. The two trays were centered with the opened window in the EIA gate and positioned 30 cm apart. Chalk outlines were drawn on the ground at the beginning of each session to facilitate quick and accurate placement. The subject was allowed to choose one tray per trial. If the correct tray was selected, the subject would gain access to the reward and provided the opportunity to consume it. If the incorrect tray was selected, the subject was not able to access the piece of produce (however, the individual's overall diet was not altered). The subject was presented with three conditions of a support-task (See Figure 3). The Transfer condition from the original study was deemed unnecessary and excluded (Irie-Sugimoto et al., 2008).

Condition A: baited vs. empty condition. One tray had a piece of produce placed at the far end of the tray and one tray was empty. Produce type varied between the trials.

Condition B: on-off. One tray had a piece of produce on it (correct choice) and one tray had a piece of produce next to it on the ground (incorrect choice). Within a trial the two baits were identical in type (e.g., two bananas) and appearance (e.g., shape, positioning). Produce type varied between the trials.

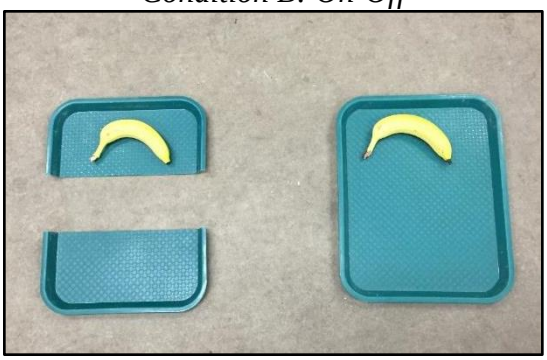
Condition C: disconnected. For this condition, both trays had produce on them, but one tray had a middle section removed, with each remaining segment of the tray measuring 35 cm x 17.5 cm (incorrect choice). Again, within a trial the two baits were identical in type and appearance. Produce type varied between the trials.

In all conditions, the subject's task was to choose a tray, pull it toward itself, and obtain the bait. A trial was considered *correct* when an elephant chose the tray on which the bait was accessible. The left/right location of the correct tray was counterbalanced in pseudo-random order, with the correct tray appearing on the same side in no more than two consecutive trials. Each subject participated in 10 trials per block, per day and at least three blocks per condition, up to a total of five blocks. In order for the subject to move on from one condition, it was required to make a correct choice in at least 70% of trials across the first three blocks of trials (binomial test, $p < 0.05$). Therefore, for three blocks of ten trials, the elephants were required to choose correctly 21 out of 30 trials. If the elephant did not reach this criterion, it was provided up to two additional blocks of 10 trials. Data collection took place from June 2015-January 2016.



Condition A: Baited vs. Empty

Condition B: On-Off



Condition C: Disconnected

Figure 3. The three conditions.

Training Protocol

It was important that the research trials remained an enriching and rewarding experience for the subjects. If an elephant chose incorrectly on three consecutive trials, an easier condition was used on the next trial so that the subject was more likely to succeed. These trials were not included in data analysis. For example, if three consecutive errors were made during Conditions B or C, a trial from Condition A was used on the following trial. If this occurred during Condition A then a single baited tray was presented. A similar protocol was used if the elephant seemed to be developing a side bias. Also, at the discretion of the trainer, on a few occurrences a subject was given a short *mental break* to help increase motivation or performance, which involved the trainer and subject leaving the testing area and engaging in a loosely-structured interaction (e.g., tactile, cuing well-established behaviors).

Results

For Condition A, the average number of days between a block of trials was 5.75 days (maximum of 12 days). For Condition B, the average number of days between a block of trials was 4.23 (maximum of 10 days). However, there was one case in which TI had almost three months between blocks 2 and 3 in Condition B (this was not included in the above average). For Condition C, the average number of days between a block of trials was 3.6 days (maximum of 8 days). None of the elephants demonstrated substantial learning within a condition.

Table 1
Results for all Subjects across the Three Conditions

Subject	Age/Sex	Condition A	Condition B	Condition C
TI	47/F	23/30 (77%)	21/30 (70%)	13/30 (43%)
		$p = 0.005$	$p = 0.043$	$p = 0.585$
KA	25/F	26/30 (87%)	25/30 (83%)	30/50 (60%)
		$p < 0.001$	$p < 0.001$	$p = 0.203$
RO	46/F	23/30 (77%)	21/30 (70%)	14/30 (47%)
		$p = 0.005$	$p = 0.043$	$p = 0.856$
SI	48/F	25/30 (83%)	22/30 (73%)	18/30 (60%)
		$p < 0.001$	$p = 0.016$	$p = 0.362$
CA	44/F	22/30 (73%)	28/40 (70%)	13/30 (43%)
		$p = 0.016$	$p = 0.016$	$p = 0.585$
SP	34/M	21/30 (70%)	28/40 (68%)	13/30 (43%)
		$p = 0.043$	$p = 0.038$	$p = 0.585$

All six subjects reached the criterion (binomial test, $p < 0.05$) for Conditions A and B. None of the subjects reached criterion for Condition C (See Table 1). Two of the subjects (CA and SP) required one additional block of ten trials for Condition B. It is unclear whether the success with the additional block of trials demonstrates learning. Both CA and SP presented a side bias during Condition B. Specifically, CA chose left 10 out of 10 times on her first block of trials within Condition B, and SP chose left 8 out of 10 times on his second block of trials within Condition B. Whether learning occurred or some other unknown variables were negatively impacting performance on these particular blocks is difficult to determine. Within Condition C, all six subjects demonstrated a side bias (8 of 10 trials to one side) in at least 1 of their 3 blocks. Due to their poor performance on the first three blocks of trials, we decided not to present 5 of the 6 subjects with additional blocks to prevent substantial frustration. However, KA (the youngest subject) chose correctly 9 of 10 times during her second block. Since she had this nearly perfect performance, we decided to present her with two more blocks of 10 trials. However, apart from her single block of 9 out of 10, she never again performed above chance levels.

Discussion

Our findings suggest that Asian elephants are able to demonstrate limited means-to-end problem-solving behavior. All six subjects quickly learned how to pull the tray to acquire the bait and were all able to pass Condition A within 30 trials. Four of the six subjects were able to pass Condition B within 30 trials, and the remaining two passed within 40 trials. However, all of the subjects performed at chance levels within Condition C. Only one subject, KA, performed above chance on her second set of ten trials for Condition C. In contrast, one of the elephants in the original Irie-Sugimoto et al. (2008) study succeeded in all three of these conditions.

However, the original study provided many more trials (minimum of 50 and maximum of 250 trials) and an additional condition between the on-off task and the connectedness task. Also, the original study was able to present the research blocks on consecutive days, which was not the case for our study. The additional trials and consecutive learning sessions may have allowed for the elephants in the original study to learn the correct response. Condition C was the most difficult task, involving the relatively complex concept of connectedness. In contrast to the original study, our disconnected tray did not have a separate handle, so both pieces looked identical, which may have increased the difficulty of the task. It could also be argued that Condition C deviates more from the experiences the elephants may have in their environment (e.g., pulling on a tree branch to access the leaves), among numerous other possible explanations.

It is important to note that this task was designed to rely on visual clues, but an elephant's primary foraging sense is olfaction. A recent study determined that elephants can rely on olfactory cues only to choose a baited bucket from an empty bucket (Plotnik, Shaw, Brubaker, Tiller, & Clayton, 2014). However, for this study, the elephants were able to investigate the bucket choices including the one containing the bait (i.e., touching the top of an enclosed bucket with holes, within an 2.5 cm of the bait) before making their choice.

In Conditions A and B the correct choice was the tray with produce on top of it, so it may have smelled differently than the incorrect tray. In Condition C, both trays had produce on them so the two choices may have smelled similar and led to confusion in this condition. However, the elephants were often observed looking at the trays from behind the barrier without putting their trunks through, then immediately choosing a tray without overtly smelling the two choices. This is not to say that the elephants would not be able to detect a difference in smell from behind the barrier. However, the bait for the incorrect side in Condition B was located less than 2.5 cm away from the tray, creating a very small difference in the direction of the scent for the elephants to be able to detect. Furthermore, during testing there were three fans blowing in multiple directions which may have affected the elephant's ability to pick up on subtle olfactory cues.[1]

Potential Effect of Management Style

It is possible that the performance by the elephants in the two studies differed due to management style. The original study examined two Asian elephants managed under free-contact and our study examined six Asian elephants managed under protected-contact. Admittedly, our experimental procedure was hindered by the need to have a barrier between elephant and the experimental set-up. Unlike the original study, the view of the trays in our study was partially obstructed due to the gate at the EIA. This may have led to an increase in overall difficulty in the task. It may be worthwhile to create a means-end task which can be conducted on the open habitat (see Foerder et al., 2011).

However, it is important to note that the elephants in the current study succeeded quickly, requiring fewer than the minimum of 50 trials set by the original study. This was especially evident for Condition B. The elephants in the original study needed 150-250 trials to reach criterion, whereas all six of our subjects reached criterion within 30-40 trials. This finding supports the notion that a positive reinforcement-based training style

[1] At the suggestion of a reviewer, we conducted olfactory control trials. We presented three subjects (KA, SI, TI) each with 10 trials. The subjects were presented with two trays both baited with an opaque paper bag (the subjects regularly receive such bags as rewards). However, only one bag was filled with produce, the other bag was empty. Visually both trays looked identical, so the subjects were required to use olfactory cues to determine which bag was baited. These control trials were presented using the same procedure as in the experiment. None of the three subjects performed above chance levels, $M = 5.66$ (out of 10), $p = 0.75$. This suggests that the subjects were not relying on olfactory cues during the experimental tasks.

can lead to better performance on a cognitive task (Haverbeke et al., 2008). The relationship between training history and cognitive performance in elephants warrants further investigation.

Side Bias and Motivation

Of note is that all of the elephants exhibited a side bias in at least one block of trials during Condition C. This seemed to indicate that the elephants were not understanding the task and simply choosing one side. Anecdotally, during a side bias choice a subject chose quickly and did not seem to be attending to the choices. Two of the subjects (CA and TI) presented side biases during Conditions A and B. Curiously, during Condition A, TI chose correctly 10 out of 10 times during her first block of trials, but on her third block she presented a side bias (she chose her left all 10 times). In this case, her poor performance does not seem to suggest that she did not understand the task, but instead was distracted or unmotivated. When examining the various side biases, no clear pattern emerged. Across all elephants and all Conditions, there were 12 blocks of trials resulting in a side bias (five to left; seven to the right). Four subjects presented a side bias in more than one block of trials. Only one of those subjects presented their side bias exclusively to one side. Specifically, CA presented a side bias once in each condition and she went to her right every time. In future studies, it may be wise to discount trials in which a side bias is presented to eliminate data in which the elephant was potentially unmotivated.

It should also be acknowledged that the availability of food throughout the duration of research sessions may have lessened the subjects' motivation to obtain the bait from the tray, particularly in the more challenging conditions. In order to maintain voluntary participation, which required having the subjects return to the overlook between each trial, the trainers utilized food reinforcers. Therefore, regardless of whether or not the subjects chose correctly and obtained the bait from the tray, they still received produce items shortly after each trial. Furthermore, the bull (SP) required the use of additional pieces of produce almost immediately after making a selection, which were tossed into the habitat to encourage him to direct his trunk back through the window so the trays could be safely removed. This could explain why some of the subjects showed a side bias in the more complex conditions (i.e., B and C); when the task became increasingly difficult, they could select any tray and still receive reinforcement soon afterward, even if it was a smaller amount and of lesser value than the bait on the tray.

Conclusion

Overall, the elephants in the current study demonstrated limited means-end behavior, showing success in Conditions A and B in far fewer trials than the subjects tested in the Irie-Sugimoto et al. (2008) study. Some methodological changes were made from the original to accommodate a protected-contact and positive reinforcement training management style, which in some cases may have hindered (e.g., decreased motivation, visual impairment of barrier) or improved (e.g., increased cognitive function) performance on the tasks. Regardless of the results, this study highlights the need for future research to test elephants living in both free and protected-contact on behavioral and cognitive tasks so that a clearer picture of the potential impacts of these management and training styles can be formed. Likewise, the opportunity to participate in cognitive research projects like this one has the potential to enrich the lives and improve the welfare of elephants managed in either setting, particularly if doing so provides them with increased behavioral choices and mental stimulation. From an animal welfare standpoint as well as academic, further research is needed to learn more about the cognitive abilities of Asian elephants and the factors influencing cognitive performance.

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