INTERNATIONAL JOURNAL OF COMPARATIVE PSYCHOLOGY

2018, 31
Heather M. Hill
Editor
Peer-reviewed

Performance on a means-end task by African elephants (*Loxondonta africana*): A replication study

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The current study tested five female African elephants (*Loxondonta africana*) on a means-end behavioral task of pulling a support to retrieve a distant object; a replication of the Highfill, Spencer, Fad, and Arnold (2016) study. Each elephant was tested on three conditions of increasing difficulty. Specifically, subjects were asked to select from a choice of two trays where one tray was baited with a produce item and the other was A) empty; B) baited on the ground next to the tray; and C) baited on the far side of a break in the tray. Results indicated that all five elephants (3 adults, 2 calves) met the criteria established for conditions A and B, and the two calves met criteria for Condition C. The performance by the adults was similar to the performance of the Asian elephants (all adults) in the previous study.

Over the last several decades, animal cognition has been well-studied within the field of comparative psychology and animal behavior. While the majority of these studies have focused on non-human primates, a variety of species have been examined including corvids (e.g., Emery & Clayton, 2004; Heinrich & Bugnyar, 2005), cetaceans (e.g., Marino, 2017; Reiss & Marino, 2001), and canines (e.g., Arden, Bensky, & Adams, 2016). With their large brains and complex social behaviors, elephants serve as an important species to examine. Accordingly, elephants have demonstrated advanced cognitive abilities on a number of tasks (e.g., number discrimination: Irie-Sugimoto, Kobayashi, Sato, & Hasegawa, 2009; Perdue, Talbot, Stone, & Beran, 2012; self-recognition: Plotnik, de Waal, & Reiss, 2006; tool-use: Foerder, Galloway, Barthel, Moore, & Reiss, 2011; Hart, Hart, McCoy, & Sarath, 2001). Furthermore, replication of research is very important, especially when studying exotic animals where previous studies are typically limited to only a few subjects (Agrillo & Miletto, Petrazzini, 2012). Therefore, for the current study, we chose to replicate a study examining the performance of Asian elephants (*Elephas maximus*) on a means-end task (Highfill, Spencer, Fad, & Arnold, 2016), which was a systematic replication of Irie-Sugimoto, Kobayashi, Sato, and Hasegawa (2008) study. Both of the previous studies tested Asian elephants, whereas African elephants *(Loxondonta africana)* were tested in the present study. The task used in all of these studies were based on the classic Piagetian support task (Piaget, 1952). For this task, toys were placed on a towel out of direct reach of an infant, however the toy could be pulled toward the child using the towel underneath. Human infants around 11 months of age were able to complete the task successfully, presumably understanding the spatial relationship between the two features. This type of means-end task has been studied in a variety of non-human animals (e.g., Cotton-top tamarins: (*Saguinus oedipus*): Santos, Rosati, Sproul, Spaulding, & Hauser, 2005; ravens (*Corvus corax*): Heinrich & Bugnyar, 2005, pigeons (*Columba livia domestica*): Schmidt & Cook, 2006).

Both Asian and African elephants are highly social species that live in large herds of genetically related females and their offspring (Poole & Moss, 2008). African elephants are physically larger than Asians and have other physical distinctions such as ear shape, tusk visibility, and number of toenails. Most relevant to this study, is the difference between their trunks. African elephants have trunks with two "fingers" at the end of

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https://doi.org/10.46867/ijcp.2018.31.00.04

their trunks, whereas Asian elephants have only one. However, both species seem to be able to use their trunks similarly. Also, African elephants are taller than Asians, which results in larger distance between their eyes and the ground, which is also relevant for our task (Haynes, 1993). The means-end task used in this study involved placing trays on the ground. Being shorter, Asian elephants may have better visual access to the task. Due to the similarities in environment and training style of the two groups of elephants, we hypothesized that African elephants would perform similarly to the Asian elephants from the previous study, despite their physical differences.

Method

Subjects

Five female African elephants (*Loxondonta africana)*) housed at Zoo Tampa at Lowry Park (ZT) participated in this study. The subjects' ages ranged from 3-35 years old (see Table 1 for ages). The three adult females were wild born and arrived to ZT in 2003. Specifically, El was born in Namibia before being predominantly housed singly at a number of American zoos prior to joining the herd at ZT in 2003. Mt and Mb were both born in South Africa, later transferred to Swaziland, before arriving at ZT in 2003. The two calves, Ma and Mp were both born at ZT to mothers Mt and Mb, respectively. For the majority of their day, the animals socialize as a herd in their outside display area with free access to food and water. All subjects are managed under a positive-reinforcement based, protected contact management program, and are currently trained to participate in husbandry and veterinary care.

Procedure

The study consisted of a means-end task in which the subjects accessed a distant food item. Food items were placed on plastic trays (35 cm x 45 cm) with a small lip. A variety of highly-valued food items from the subject's regular diet (e.g., bananas, papaya) was used as the bait.. The produce was not directly in reach, but could be pulled toward the subject using the end of the tray. All research sessions for the adults were conducted in a stall within the husbandry barn. The barn is where members of the herd frequently have training sessions with the trainers through a husbandry gate. The stalls used were 5.5 m x 7.6 m. The calves were tested in an exterior corridor (3 m wide), which was a path between the barn and outer yard. This location was chosen for the calves because they are smaller and need less space to turn around. For all trials, two trainers stood behind a protective barrier at either side of the area where the subject was located. All trials were conducted mid-afternoon (around 3:00 pm).

Pre-trials

The trunk-reach distance for each subject was measured before any testing took place. To make this measurement, a piece of produce was placed on the ground in front of the husbandry gate. Chalk was used to mark the farthest point the subject could reach with its trunk fully 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 was a novel object to the subjects). The elephants were directed to grasp the tray and slide it closer to reach the produce. All subjects learned to do this sliding motion within 2-3 probe trials.

Experimental Sessions

Each experimental session required two trainers and one experimenter. Trainer 1 and the experimenter were located on one end of the holding stall and Trainer 2 was stationed on the other end. The experimental set-up was on the same side as Trainer 1 and the experimenter. During the initial set-up and after each trial, the subject's attention was held by Trainer 2 at the far side of the stall. Trainer 2 would ask for a series of learned behaviors and reinforce behaviors with chopped produce. The behaviors and reinforcement were designed to prevent the subject from viewing the trays being set-up, but did not detract from their motivation to participate in the experimental task. The same procedure was used for the calves tested in the exterior corridor.

Once the trays were positioned, Trainer 2 would send the subject to Trainer 1. Trainer 1 would simultaneously call the subject to her side of the stall. Trainer 1 stood approximately 40 cm behind the trays. In order to control for inadvertent cuing, Trainer 1 wore dark sunglasses and held a piece of cardboard (50 cm x 30 cm) in her line of sight. This cardboard prevented the trainer from seeing the experimental set-up, so she could remain blind to the correct choice. She was, however, able to maintain visual contact with the subject for safety reasons. During the trial, the experimenter stood to the side, out of the subject's direct line of sight. The experimenter indicated to Trainer 1 when the subject had made a choice by saying "choice." A choice was defined as the first tray with which the elephant's trunk made contact. After the choice was made, Trainer 1 quickly removed the unselected tray from the subject's reach. After the subject either consumed the reward (in the case of success) or investigated the empty tray (in the case of failure), Trainer 1 pulled back the selected tray. Once both trays were out of reach, Trainer 2 recalled the subject to the far side of the stall. The experimenter then cleaned both trays with a disinfectant wipe to remove any previous odors that could serve as cues to the subject, and reset the experiment.

The basic arrangement of the experimental sessions was straightforward. Two trays were placed on the ground at a predetermined distance from the stall gate. This distance varied from subject to subject, based on their individual trunk-reach distance. The two trays were placed next to one another separated by a distance of 38 cm for the adults and 19 cm for the calves. A smaller distance was chosen for the calves as their eyes and trunks were considerably closer to the ground. While setting up each session, chalk was used to outline the tray locations to expedite the resetting process between each trial.

During each trial, the subject was able to choose only one of the two trays per trial. If the subject chose correctly, they gained access to the produce reward that was located on the tray; whereas if they chose incorrectly, they were denied access to the reward (their overall diet was not impacted by their performance on this task). The subject was presented with three conditions of a support task that sequentially increased in difficulty (See Figure 1).

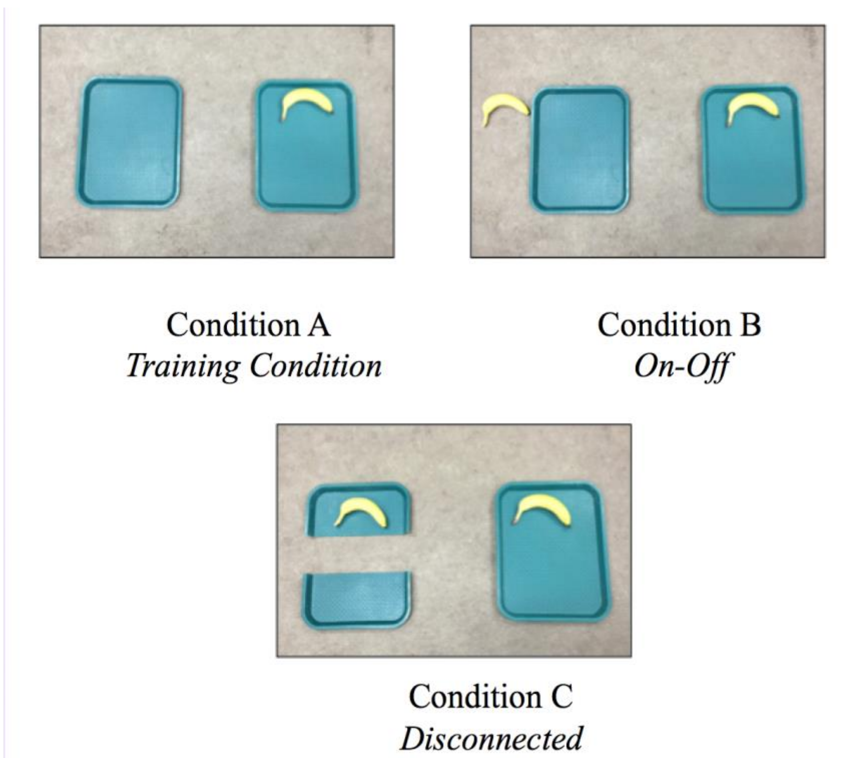

Figure 1. **The three conditions.**

Condition A: Baited vs. Empty Condition. One tray had a piece of produce situated at the far end of the tray (correct choice) and the other tray did not contain any reward (incorrect choice). The produce used varied between trials based on availability.

Condition B: On-Off. A piece of produce was placed on one tray (correct choice) and a piece of produce was placed on the ground, adjacent to the other tray (incorrect choice). During any given trial, the two baits were identical in type (e.g., a slice of papaya) and appearance (e.g., size, shape, positioning). The produce used varied between trials based on availability.

Condition C: Disconnected. Both trays had identical-looking pieces of produce situated at their far ends; however, the middle section of one tray was removed (incorrect choice). The two remaining segments of the disconnected tray, measuring 35 cm x 17.5 cm were placed within the chalk outlines to retain the approximate size of a full tray. The produce used varied between trials based on availability.

The location of the correct choice (left tray or right tray) was counterbalanced in a pseudo-random order, ensuring that the correct tray was not presented on the same side for more than two consecutive trials. One session of 10 trials was completed per subject per testing day. Three sessions were completed per condition. In order to advance to the next condition, the subject had to choose the correct tray for at least 70% of the trials across the first three sessions (binomial test, $p < 0.05$). Consequently, subjects had to make the correct choice 21 out of the 30 trials. Data collection took place from November, 2015 to July, 2016. Testing days were based on the availability of the trainers.

Training Protocol

It was crucial that the subjects' participation in the research trials was enriching and rewarding. In an effort to avoid the subjects becoming frustrated with the protocol, if an elephant chose incorrectly on three consecutive trials, the elephant was presented with an easier condition trial, wherein the elephant was more likely to succeed and gain access to the reward. If such consecutive errors occurred during either conditions B or C, the elephant was presented with a condition A setup. If this occurred while the elephant was completing condition A, the elephant was subsequently presented with a single baited tray. This option was also used it the subject was demonstrating a side bias. Such trials were not included in the data analysis. Binomial tests were conducted for all subjects within each condition. The significance level was set at $p < 0.05$. All statistical analyses were performed using IBM SPSS Statistics 25.

Olfactory Control Trials

It is important to note that an elephant's primary foraging sense is olfaction. However, the means-end task used in this study was designed to rely on visual cues instead of olfactory cues. The subjects could visually access the trays on their approach from the far side of the stall. A recent study determined that elephants can rely on olfactory cues to choose a baited bucket from an empty bucket (Plotnik, Shaw, Brubaker, Tiller, & Clayton, 2014). However, 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. Our task prevented such a close olfactory inspection of the trays. However, to be sure that olfactory cues were not used, all subjects participated in 10 olfactory control trials. During these trials, both trays were baited with opaque, edible paper bags. One bag had a produce reward and the other was empty. Since both trays looked identical, the subjects would need to rely on olfactory cues to perform at levels greater than chance. These trials were conducted in the same manner as the actual experimental trials. None of the subjects performed above chance levels, $M = 5.83$ (out of 10), $p = 0.25$. This result suggests that the subjects were not relying on olfactory cues during the experimental tasks.

Results

For condition A, the average number of days between a block of trials for an individual subject was 3.7 days (maximum of 8 days). For condition B, the average number of days between a block of trials was 6.7 days (maximum of 14 days). For condition C, the average number of days between a block of trials was 5.2 days (maximum of 13 days). None of the elephants demonstrated substantial learning within a condition, in that their performance did not consistently improve across the three trials. Overall, all six subjects reached the criterion (binomial test, $p < 0.05$) for conditions A and B. Two of the subjects (both calves) reached criterion for condition C (See Table 1). It is worth noting that Mt chose correctly 9 out of 10 times during her first block of trials for condition C. However, she did not perform above chance levels during block 2 or 3.

Table 1

Results for all Subjects across the Three Conditions

Subject	Age	Condition A	Condition B	Condition C
Mp	4 y	21/30 (70%)	23/30 (77%)	21/30 (70%)
		***p* = .043**	***p*= .005**	***p*= .043**
Mb	25 y	24/30 (80%)	21/30 (70%)	14/30 (47%)
		***p* = .001**	***p* = .043**	*p* = .86
Ma	3 y	25/30 (83%)	22/30 (73%)	22/30 (73%)
		***p* < .001**	***p* = .016**	***p* = .016**
El	35 y	21/30 (70%)	21/30 (70%)	16/30 (53%)
		***p* = .043**	***p* = .043**	*p* = .86
Mt	25 y	24/30 (73%)	21/30 (70%)	20/30 (67%)
		***p* = .001**	***p* = .043**	*p* = .10

Note. **Bolded =** significant at < 0.05 level

Discussion

Our findings suggest that African elephants are able to demonstrate limited means-to-end problem-solving behavior. All five subjects quickly learned how to pull the tray to acquire the bait and were able to pass conditions A and B within 30 trials. However, only the two calves performed above chance levels for condition C.

Overall, the performance of the adults was similar to what was found with zoo-housed Asian elephants (Highfill et al., 2016). As in the previous study, condition C was the most cognitively complex task of the three conditions, as it required a comprehension of connectedness. Not only does this task require the basic comprehension of such an abstract concept, it also contrasts with experiences elephants may have within their natural environment (e.g., pulling on a tree branch to access the leaves). This incongruity, among other potential explanations could be why the elephants had trouble performing above chance levels for condition C.

Success of the Calves on Condition C

Both calves in this study performed above chance level for Condition C. Furthermore, when compared to the other individuals, Ma (3 y) had the strongest performance on Condition A and Mp (4 y) had the strongest performance on Condition B. In the previous study with Asian elephants, the youngest elephant displayed the strongest performance within all three conditions when compared to the older adults (Highfill et al., 2016). While this subject did not meet the criterion for Condition C, she did choose correctly nine of 10 times during her second block of trials for Condition C. She was approximately 20 years younger than the other adult females in her herd, and approximately 10 years younger than the male. It is worth noting that in the original study by Irie-Sugimoto et al. (2008), the younger of the two subjects performed better overall on the mean-end tasks. However, this study only examined the performance of two elephants, aged 6 and 10.

There are many possibilities for why the younger elephants performed better in the current study. First, the younger animals may be more flexible in their cognitive approach. Research has demonstrated age-related cognitive deficits in both human and nonhuman species. For example, one such study found that dogs show age-dependent deterioration in cognitive function, which was partly due to an increase in behavioral rigidity (Milgram, Head, Weiner, & Thomas, 1994). Another study tested 18 rhesus macaques ranging in ages from 3 to 34 years on a number of different cognitive tasks, including visually guided reaching tasks, and tests of motor skills (Bachevalier et al., 1991). Their results suggested that there were age-related impairments on performance in nearly all of the testing categories, specifically the younger animals performed better than the older individuals. Furthermore, the observed impairments were typically seen on the more difficult versions of the tests and not on the easy versions. A similar trend emerged from the current study, as the adults were able to successfully reach criteria for the easier conditions.

While the calves in this study may be more cognitively flexible, there are other possible explanations for their performance. First, the two trays were positioned 19 cm apart for the calves, versus 38 cm apart for the adults. The difference in configuration was chosen arbitrarily because calves are considerably shorter than the adults. Perhaps the smaller gap between the two trays allowed the calves to compare the two trays more readily than when they were placed farther apart. Additionally, due to their smaller stature, the two calves' eyes are lower to the ground than the adults' eyes. This height difference may have permitted a closer inspection of the trays, which could have contributed to their success. A future study could include using a stand to bring the trays closer to the adult elephants to see if the proximity of the trays could be a determining factor. It is worth noting that the adults in this study were never observed lowering their heads in an attempt to inspect the trays more closely.

Conclusion

Overall, this was the first study to demonstrate means-end behavior in African elephants. When examining the literature on cognitive studies with elephants, the majority has focused on Asian elephants. The results of the current study suggest that African and Asian elephants perform similarly on this type of task. However, further research is needed to determine if African and Asian elephants perform similarly on other cognitive tasks such as number discrimination, cooperation, tool use, and mirror self-recognition.

Acknowledgments

We would like to acknowledge Chris Massaro, General Curator at Zoo Tampa for his support of the project. We also are indebted to the entire elephant team at Zoo Tampa for their enthusiasm and logistical support. Especially Christi Reiter, Audrey Lagemann, Leah Miller, and Heather Pye.

References

Agrillo, C., & Miletto, Petrazzini, M. E. (2012). The importance of replication in comparative psychology: The lesson of elephant quantity judgments. *Frontiers in Psychology*, *3*, 181.

Arden, R., Bensky, M. K., & Adams, M. J. (2016). A review of cognitive abilities in dogs, 1911 through 2016: More individual differences, please! *Current Directions in Psychological Science*, *25*, 307–312.

Bachevalier, J., Landis, L. S., Walker, L. C., Brickson, M., Mishkin, M., Price, D. L., & Cork, L. C. (1991). Aged monkeys exhibit behavioral deficits indicative of widespread cerebral dysfunction. *Neurobiology of Aging*, *12*, 99–111.

Emery, N. J., & Clayton, N. S. (2004). Comparing the complex cognition of birds and primates. In L. J. Rogers & G. Kaplan (Eds.), *Comparative vertebrate cognition* (pp. 3–55). Boston, MA: Springer.

Foerder, P., Galloway, M., Barthel, T., Moore, D. E. III, & Reiss, D. (2011). Insightful problem solving in an Asian elephant. *PLoS ONE 6*, e23251. doi:10.1371/journal.pone.0023251

Hart, B. L., Hart, L. A., McCoy, M., & Sarath, C. R. (2001). Cognitive behaviour in Asian elephants: Use and modification of branches for fly switching. *Animal Behaviour*, *62*, 839–847.

Haynes, G. (1993). *Mammoths, mastodonts, and elephants: Biology, behavior and the fossil record*. Cambridge, UK: Cambridge University Press.

Heinrich, B., & Bugnyar, T. (2005). Testing problem-solving in ravens: String-pulling to reach food. *Ethology, 111*, 962–976.

Highfill, L., Spencer, J. M., Fad, O., & Arnold, A. M. (2016). Performance on a means end task by Asian elephants (*Elephas maximus*) in a positive reinforcement-based protected contact setting. *International Journal of Comparative Psychology*, *29*, 1–10.

Irie-Sugimoto, N., Kobayashi, T., Sato, T., & Hasegawa, T. (2008). Evidence of means–end behavior in Asian elephants (Elephas maximus). *Animal Cognition*, *11*, 359–365.

Irie-Sugimoto, N., Kobayashi, T., Sato, T., & Hasegawa, T. (2009). Relative quantity judgment by Asian elephants (*Elephas maximus*). *Animal Cognition*, *12*, 193–199.

Marino, L. (2017). Cetacean cognition. In L. Kalof (Ed.). *The Oxford handbook of animal studies* (p. 227). Oxford, UK: Oxford University Press.

Milgram, N. W., Head, E., Weiner, E., & Thomas, E. (1994). Cognitive functions and aging in the dog: Acquisition of nonspatial visual tasks. *Behavioral Neuroscience, 108*, 57–68. doi:10.1037/0735-7044.108.1.57

Plotnik, J. M., De Waal, F. B., & Reiss, D. (2006). Self-recognition in an Asian elephant. *Proceedings of the National Academy of Sciences*, *103*, 17053–17057.

Poole, J. H., & Moss, C. J. (2008). Elephant sociality and complexity: The scientific evidence. In C. M. Wemmer & C. A. Christen (Eds.), *Elephants and ethics: Toward a morality of coexistence* (pp. 69–93). Baltimore, MD: John Hopkins University Press.

Perdue, B. M., Talbot, C. F., Stone, A. M., & Beran, M. J. (2012). Putting the elephant back in the herd: Elephant relative quantity judgments match those of other species. *Animal Cognition*, *15*, 955–961.

Piaget, J. (1952). The origins of intelligence in children (M. Worden, Trans.). New York, NY: International Universities Press.

Plotnik, J. M., Shaw, R. C., Brubaker, D. L., Tiller, L. N., & Clayton, N. S. (2014). Thinking with their trunks: elephants use smell but not sound to locate food and exclude nonrewarding alternatives. *Animal Behaviour*, *88*, 91–98.

Reiss, D., & Marino, L. (2001). Mirror self-recognition in the bottlenose dolphin: A case of cognitive convergence. *Proceedings of the National Academy of Sciences*, *98*, 5937–5942.

Santos, L. R., Rosati, A., Sproul, C., Spaulding, B., & Hauser, M. D. (2005). Means-means-end tool choice in cotton-top tamarins (*Saguinus oedipus*): finding the limits on primates' knowledge of tools. *Animal Cognition*, *8*, 236–246.

Schmidt, G., & Cook, R. (2006). Mind the gap: Means-end discrimination by pigeons. *Animal Behaviour*, *71*, 599–608.

Financial conflict of interest: No stated conflicts.
Conflict of interest: No stated conflicts.

Submitted: March 24th, 2018
Resubmitted: May 17th, 2018
Accepted: May 29th, 2018