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Self-Recognition in the Asian Elephant and Future Directions for Cognitive Research With Elephants in Zoological Settings

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The field of animal cognition has grown steadily for nearly four decades, but the primary focus has centered on easily kept lab animals of varying cognitive capacity, including rodents, birds and primates. Elephants (animals not easily kept in a laboratory) are generally thought of as highly social, cooperative, intelligent animals, yet few studies—with the exception of long-term behavioral field studies—have been conducted to directly support this assumption. In fact, there has been remarkably little cognitive research conducted on Asian (*Elephas maximus*) or African (*Loxodonta africana* or *L. cyclotis*) elephants. Here, we discuss the opportunity and rationale for conducting such research on elephants in zoological facilities, and review some of the recent developments in the field of elephant cognition, including our recent study on mirror self-recognition in *E. maximus*. Zoo Biol 29:179–191, 2010. © 2009 Wiley-Liss, Inc.

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INTRODUCTION

There are two remarkable facts about the history of human/elephant relations: (1) elephants are one of the few (if not the only) animals currently employed by man without any history of formal, systematic domestication or artificial selection [Lair, 1997] and (2) elephants are widely accepted as an intelligent and socially complex species, even though relatively few controlled cognitive studies have been conducted to support this [cf. Bates and Byrne, 2007; Plotnik et al., 2006]. Here, we focus on the latter fact as being a rationale for increased behavioral and cognitive research with elephants in zoological facilities. African elephants [primarily *Loxodonta africana*, i.e. the savannah elephant; e.g. Poole, 1996, but see also *L. cyclotis*; Roca et al., 2001] have been studied in the wild continuously for more than 30 years [e.g. Douglas-Hamilton and Douglas-Hamilton, 1975; Moss, 1988; Poole, 1996], almost entirely within the fields of elephant population and social dynamics [e.g. Douglas-Hamilton and Douglas-Hamilton, 1992; Moss and Croze, 2008] and vocal communication [e.g. Moss and Croze, 2008; Payne et al., 1986; Payne, 2003; Poole, 1996]. The Asian elephant (*Elephas maximus*) has received less attention, with very little evidence of their behavioral repertoire available in peer-reviewed scientific journals [but see Olson, 2004; Schulte 2000; Sukumar, 1989].

Elephants are long-lived, highly-social and large-brained [Schulte, 2000; Shoshani, 1998; Shoshani et al., 2006], and the long-term ethological research conducted by Douglas-Hamilton and Douglas-Hamilton [1992], Poole [1996], Moss [1988], Payne [2003], for example, has provided substantial evidence of elephant cooperation and data on social dynamics. However, social behavior research from an ethological perspective provides only a glimpse into their minds and experimental research is necessary to gain a better understanding of their cognitive capacities [Griffin, 1976]. For instance, the vast number of ethological studies on nonhuman primate behavior [e.g. de Waal, 1982; Van Lawick-Goodall, 1968] are complemented by the equally large number on primate cognition [e.g. Kappeler and van Schaik, 2006; Tomasello and Call, 1997 for reviews]; the study of the latter helps us to assess the cognitive mechanisms that underlie an animal's natural behavior. A field for elephant cognition research has only recently begun to take shape. Here, we review recent developments in this field, while noting that any comprehensive review of elephant cognition is, thus far, premature. In addition, we discuss the relevance to and implications of elephant cognition research for zoological parks, as well as potential future directions for this promising field.

ELEPHANT COGNITION: 1957–2008

The idea of the elephant as a highly cognitive animal is by no means a new topic of study [Nissani, 2004; Romanes, 1882; Rensch, 1957; Schulte 2000; Williams, 1950]. Multiple anecdotes discuss the elephant's remarkable sense of memory [e.g. Markowitz, 1982; Rensch, 1957], problem-solving skills [an African elephant using a self-made tool to plug and cover a water source—Gordon, 1966], attention to dead conspecifics and the covering-up of carcasses with debris [e.g. Douglas-Hamilton and Douglas-Hamilton, 1975; Moss, 1988; McComb et al., 2006], and potential deception [reports of Asian elephants stuffing the bells around their necks with dirt to silence the bells and perhaps avoid being heard—Williams, 1950]. Perhaps one of the most recognized and well-documented examples of advanced cognitive capacity in elephants stems from observations of elephants' attention to others in need [Bates et al., 2008a,b]. De Waal [1996, 2008] terms this "targeted helping," or help fine-tuned to another's specific situation and goals. Douglas-Hamilton et al. [2006] described a family's attempts to assist and lift a fallen matriarch, whereas Moss [1988] related an elephant family's response to the mortal wounding (by gunshot) of a family member:

> "Teresia and Trista became frantic and knelt down and tried to lift her up. They worked their tusks under her back and under her head. At one point they succeeded in lifting her into a sitting position but her body flopped back down. Her family tried everything to rouse her, kicking and tusking her…(pg. 73)."

Such demonstrations of targeted helping also seem to be linked to empathic perspective-taking, or the capacity to take another's perspective [de Waal, 2008]. Such a capacity for "cognitive empathy" [defined as: "empathy combined with contextual appraisal and an understanding of what caused [an individual's] emotional state"—de Waal, 2008, p 4.5] is extremely rare in the animal kingdom, seemingly limited to the great apes [chimpanzees—*Pan troglodytes*, bonobos—*P. paniscus*, orangutans—*Pongo pygmaeus*, and gorillas—*Gorilla gorilla*, see de Waal, 1996 for a review], bottlenose dolphins [*Tursiops truncatus*, Caldwell and Caldwell, 1966; Siebenaler and Caldwell, 1956], and elephants [e.g. Bates et al., 2008a,b; Moss, 1988; Poole, 1996]. Suggestions of advanced elephant empathy led Gallup [1983] to predict that these animals would make good candidates for mirror self-recognition (MSR) and complex self-awareness, a prediction verified and discussed by Plotnik et al. [2006].

The first systematic investigation of elephant cognition was undertaken by Rensch [1957] on one 5-year-old Asian elephant housed at the Münster Zoo in Germany, and remarkably, no other comprehensive study of elephant cognition via controlled experiments was conducted in more than 40 years following its publication. Although it took the elephant more than 300 trials to reach criterion on a single-pair discrimination task (i.e. it was trained to choose one of two shapes—a circle and a half-circle, for example—to obtain food), it eventually learned to discriminate consistently between more than 20 pairs of different shaped stimuli [Rensch, 1957]. Visual discrimination tasks are among the most common types of laboratory cognition studies conducted on a wide variety of species, including primates and birds [cf. Vallortigara, 2004], but many of the species tested use vision as a primary or secondary sensory modality; elephants, on the other hand, seem to primarily use their auditory, olfactory and seismic senses when interacting with their environment and when communicating with conspecifics [Moss and Croze, 2008]. Many have hypothesized, however, that the vision of the elephant may be highly underestimated [e.g. Lair, 1997], and although there have been a few studies on the physiology and anatomy of the elephant eye [e.g. Murphy et al., 1992; Stone and Halasz, 1989], we know of only one other cognition study on elephant vision, and it too was a basic assessment of shape and color discrimination [Nissani et al., 2005].

One additional area of research focuses on tool-use, often mentioned as one of the first markers of complex cognition [cf. de Waal, 2001; McGrew, 1992; Shettleworth, 1998; van Schaik et al., 1999], and is exhibited across animal taxa.

Corvidae—the family of birds that includes crows, ravens, rooks, and magpies—manipulate tools in various ways to obtain food [see Emery and Clayton, 2004 for a review]. Tool-use is extensive and well documented in chimpanzees, orangutans, and a few other primates [see van Schaik et al., 1999 for a review]. Bottlenose dolphins have been observed to carry sponges when foraging on the sea floor for fish and it has been suggested that they use the sponges to protect their sensitive beaks when they probe for prey in the sandy substrate [Krützen et al., 2005; Smolker et al., 1997]. Tool-use and tool manufacture has also been documented in the Asian elephant, where branches are used, stripped, and further manipulated to swat insects [Chevalier-Skolnikoff and Liska, 1993]. In addition, it has been postulated that the prehensile trunk enables elephants to engage in complex manipulative behaviors quite similar to those of primates [Hart et al., 2001]. These authors explain that such evidence "would appear to place [elephants] in the category of great apes in terms of cognitive abilities…" (p 839).

In fact, some researchers have already begun to synthesize the literature on elephant social complexity to assess the basis for these claims of advanced cognition [using neuroscience, anatomy, and neuroethology as a starting point—Bradshaw and Schore, 2007; Hart et al., 2008, or using anecdotal evidence from long-term social behavior research—Bates and Byrne, 2007], but cite little experimentally based literature because of its relative scarcity. However, a select few studies have attempted to reinvigorate the field of elephant cognition within the past 3 years. Bates et al. [2007] demonstrated that wild African elephants are capable of classifying potential predators (in this case, the Maasai of Kenya, who hunt them, and the Kamba, who do not) by both visual (shirt color discrimination) and olfactory cues (smells associated with each of the two ethnic groups). The authors hypothesize that such an ability to classify a same-species predator into subcategories based on their relative threat is likely related to their cognitive capacities. Bates et al. [2008a,b] subsequently looked at the ability of elephants to understand the locations of family members through olfactory cues. Not only did the authors demonstrate that elephants are capable of recognizing up to 30 family members from cues available to them in a mix of urine and earth, but when experimentally presented with these urine–earth mixes of specific, out-of-sight family members, the elephants displayed differential behavior depending on the location of these particular individuals. In particular, elephants spent more time investigating urine when the individual was either absent or behind them—thus making it impossible for the sample to have been deposited there—than when they were present or in front of them. The authors suggest that the known social complexity of elephants and the need to keep track of large numbers of individuals may require complex cognition.

Three recent studies investigated elephant cognitive capacity in a captive setting. Nissani [2006] reported that elephants were unable to successfully accomplish what he termed "a causal reasoning" task by transferring knowledge of a lid/bucket paradigm across experimental conditions. When presented with a bucket of food with a lid, the elephants would remove the lid and obtain the food, but continued to remove, or flip the lid even if it was placed beside the bucket and thus was irrelevant to obtaining food. Although the author argued this suggests an inability to reason causally, the strong indication that the elephants were heavily trained by their handlers and that this training may have unduly affected their performance suggests further investigation is necessary before any conclusion on elephants' causal reasoning abilities can be reached. In this particular experiment, the elephants were first trained to ''flip'' or remove the lid and then expected to forget this training when subsequently presented with a paradigm with the lid beside the bucket, and as far as we can tell, the elephants were handled throughout the experiment without controls in place to prevent the caretakers from influencing the elephants' responses. Because Asian elephants in Southeast Asian countries are often handled daily either for work (in Nissani's case, logging in Myanmar) or for tourism (as in Thailand and Cambodia), controls must be implemented in cognition experiments conducted in these countries to ensure the results are not influenced by the behavior of the elephants' handlers.

Asian elephants have also been shown to demonstrate the ability for making relative quantity judgements (RQJ), which is a dichotomous judgment of numerical inequality ordered in magnitude [Irie-Sugimoto et al., 2008]. In this study, two experiments were conducted to test whether elephants would choose the larger quantity of bananas (1–6 items) when they could compare two visible quantities and when the two quantities were presented in sequence. In one experiment, five elephants were each simultaneously presented with two baited baskets that contained different amounts of food and were tested to determine whether they would select the one containing the larger quantity. The authors reported that all the elephants chose the larger amount ''at significantly greater frequency than the smaller'' without prior training. In a second experiment, four other elephants were sequentially presented with baited baskets, which could not be seen by the elephants in their total quantities. The authors reported that the elephants selected the larger amount more ''frequently than could be ascribed by chance.'' Eight of the nine elephants did not exhibit disparity or magnitude effects in which performance declines with a smaller difference between quantities in a two-choice task, or as the total quantity increases. The authors suggest that these findings are inconsistent with previous reports of RQJ in other animals, and suggest that elephants may be using a different mechanism to compare and represent quantities than previously suggested for other species.

In another study, Irie-Sugimoto et al. [2007] used a simple yet compelling tray-pull task to investigate elephants' ability for understanding means–end relationships. When presented with two trays so that only one of the two, when pulled, would result in success and thus yield a food reward, one elephant performed significantly above chance, suggesting goal-directed behavior driven by an ''understanding that pulling the tray was the 'means' for achieving the 'end' of obtaining the bait'' (p 1). Such performance is similar to that demonstrated in nonhuman primates [e.g. Hauser et al., 2002], and suggests that some experimental designs detailed in the extensive cognition literature on nonhuman primates may be adaptable to studies on elephants.

Nonhuman primates in particular are being tested across cognitive facilities: for instance, they have been tested for individual and kin recognition with computerized tasks [Parr and de Waal, 1999], cooperation and between species differences [Melis et al., 2006], imitation and cultural transmission [e.g. Horner et al., 2006; Whiten et al., 2005], planning for the future [Mulcahy and Call, 2006], and their tendencies to be altruistic [Warneken et al., 2007] or sensitive to inequity [Brosnan and de Waal, 2003]. This literature is growing rapidly and beginning to inspire work on large-brained birds, canids, dolphins, and so on. The practicality of conducting similar tests with elephants may be limited, especially as these animals cannot be brought into a laboratory situation, but many of the test paradigms can be adapted for outdoor use, and are actually extremely simple and straightforward.

The most promising areas of research on primates try to address cognitive questions related to behavior observed under naturalistic conditions, such as the testing of imitation skills related to the evidence for cultural traditions in wild chimpanzees—traditions thought to be socially learned [Whiten et al., 1999]—or the testing for reciprocity related to the evidence for cooperation among unrelated chimpanzees [de Waal, 1997]. Similarly, cognition research on elephants should receive its main inspiration from natural elephant behavior, and thus aim to elucidate suspected but as yet unproven cognitive capacities.

MIRROR SELF-RECOGNITION

Our recent contribution to elephant cognition research involved testing the elephant's ability to use a mirror for self-investigation, or MSR. The human proclivity to recognize oneself in a mirror has long been considered a hallmark of intelligence and considered a measure of self-awareness. MSR emerges in children between 18–24 months of age [Amsterdam, 1972] and is associated with the emergence of other cognitive abilities related to theory of mind [Lewis, 1986; Piaget, 1952]. In a seminal paper, Gallup [1970] demonstrated that we shared this ability with our closest relatives, the chimpanzees. Gallup [1970] exposed the chimpanzees to a mirror and recorded their behavioral responses. The animals exhibited three basic stages of behavior. Mirror naïve animals initially showed *exploratory behavior* to the mirror itself and *social behavior*, as if viewing a conspecific. This stage was followed by *mirror* (*or contingency*) *testing* behavior characterized by highly repetitive acts as if one were testing the contingencies of their behavior with that of the reflected image. This stage was often difficult to separate from another stage considered to be *self-directed behavior* in which the animal would use the mirror to view parts of its body that could not be seen in the absence of the mirror. Once self-directed behavior was observed, Gallup conducted what he considered a more objective measure of self-directed behavior, the mark test. In the mark test, the subject is marked with an odorless mark that the subject can only see in the mirror. The test is passed if the subject touches the mark on itself at the mirror or, in the case of nonhanded animals such as dolphins [Reiss and Marino, 2001], orients immediately to the marked area while at the mirror. The MSR test has been used as a comparative measure of cognition and the basis for a provocative debate regarding the phylogenetic and ontogentic development of self-awareness [Parker et al., 1994]. Subsequent studies confirmed the ability for MSR in other chimpanzees and all the other anthropoid apes (i.e. bonobos, gorillas, and orangutans, but notably failed to demonstrate it in primates or other species other than the Hominoidea, i.e. humans and apes [see Anderson and Gallup, 1999]. Studies with old and new world monkeys failed to demonstrate this ability. One study with capuchins, *Cebus apella*, reports that they may reach a level of self–other distinction intermediate between seeing their mirror image as other and recognizing it as self [de Waal et al., 2005]. Such a "middle-stage" of MSR suggests a possible cognitive continuum across animal taxa.

Gallup [1982, 1983] first hypothesized a phylogenetic connection between MSR and expressions of empathy. He suggested that future candidates for MSR tests would be other large-brained, highly social animals that exhibit empathetic behavior, including elephants and dolphins. MSR has in fact been recently demonstrated in two nonprimate species that possess these traits, the bottlenose dolphin [Reiss and Marino, 2001] and the Asian elephant [Plotnik et al., 2006]. Reiss and Marino [2001] first demonstrated MSR in dolphins and presented it as evidence for cognitive convergence in Hominoid species and dolphins and Plotnik et al. [2006] provide further evidence for such convergence between these species and Asian elephants. Importantly, both studies were conducted in zoological facilities in which careful experimental controls could be employed and a rich collaboration between researchers and the zoo or aquarium staff enabled this research to be accomplished.

In our study demonstrating MSR in an Asian elephant [Plotnik et al., 2006], our goal was to test whether three adult female elephants at the Bronx Zoo would exhibit behaviors indicative of MSR and pass the mark test. We viewed this study as both an opportunity to conduct this comparative cognitive test in elephants within their normal social context at the zoo and an opportunity to provide the elephants with a jumbo-sized mirror—a novel and potentially effective enrichment device. With the support of the management and staff, we constructed an elephant-safe mirror made of two 4 ft × 8 ft sheets of plexi-mirror, which were glued to plywood to produce a full 8 ft × 8 ft mirror with a negligible yet fully braced seam down the middle (Fig. 1). The mirror was then framed with steel support and soldered to the yard wall ~30 cm off the ground. The mirror had a cover (i.e. a metal door painted with flat, nonreflective brown paint) that was either locked in an open or closed position depending on the experimental procedure. The mirror was bolted to a wall of the elephants' outdoor yard.

The three adult female elephants that we tested at the Bronx Zoo included Maxine (35 years of age), Patty (35 years of age), and Happy (34 years of age). A fourth younger female, Samuel R, who resided with Happy was exposed to the mirror but not tested. During the study, one pair of elephants was shifted from their indoor holding facilities to their outdoor yard for 1 hr (0915–1015) for observation and testing before they were shifted into the public exhibit area. From 1115 to 1215

Fig. 1. "Happy" the elephant at the mirror. Bronx Zoo, NY, NY.

the other pair of elephants was shifted from their holding facilities to their outdoor yard for observation and testing [see Plotnik et al., 2006 for a detailed description of equipment and procedures]. There were five experimental phases/conditions during which each elephant pair was observed: baseline (no mirror present, 1 hr per day for 4 days), covered mirror control (1 hr per day for 3 days), open mirror (1 hr per day for 4 days), covered-mirror sham control in which each elephant was sham-marked with glow-in-the-dark face paint, which is not visible under normal sunlight (the sham controlled for olfactory and tactile cues—1 hr for 1 day), and the mark test in which a visible mark (white nontoxic face paint) was applied to one side of the elephants forehead and the invisible sham mark to the other (1 hr for 3–4 days, see Fig. 2).

A quantitative and qualitative analysis of the elephants' behavior revealed that all three elephants exhibited strikingly similar stages of behavior and a number of similar behaviors as those exhibited by apes and dolphins in MSR studies. Initially, the elephants exhibited exploratory behavior toward the mirror that included attempts to look behind the mirror by standing on their rear legs and looking over the wall, attempts to look under the mirror by kneeling on their front legs to look under the bottom edge of the mirror, and apparent sniffing with their trunks behind the mirror. These exploratory behaviors decreased after initial exposure. Notably, no social behaviors, visual or vocal, were directed toward the mirror. After the initial stage of exploratory behavior subsided, a second stage—contingency or mirror-testing behavior—was observed in which the elephants exhibited highly repetitious (but not stereotypic) behaviors at the mirror similar to those reported in apes and dolphins. These included nonstereotypic trunk and body movements in front of the mirror and rhythmic head movements made by moving the head in and out of mirror view; such behavior was not observed in the absence of the mirror. A third stage of self-directed behavior was observed in which elephants performed the following behaviors: positioning at the mirror with one side of the head and eye in close proximity to the mirror surface, exploration of the inside of the mouth using the trunk in close proximity to the mirror, and bringing food to and eating right in front of the mirror. In another instance, one of the elephants used her trunk to pull her ear

Fig. 2. "Happy" the elephant with an X-shaped, visual mark on the left side of her head (in this session, the invisible sham mark is on the right side).

slowly forward toward the mirror. These behaviors were absent in the baseline and closed mirror conditions and provide behavioral evidence that the elephants were using the mirror as a tool to investigate their own bodies.

One of the elephants, Happy, reached the behavioral criteria for moving to the mark test after 3 hrs/days of mirror exposure, whereas the other two elephants reached criteria after 4 hr/days of exposure—a similar time frame as reported for chimpanzees [Gallup, 1970]. Only Happy passed the mark test, although all three elephants exhibited behavior consistent with mirror-testing and self-directed behavior during the open mirror condition. Happy was tested three times. She passed the mark test on the first day of testing. During the first mark test, Happy showed a clear increase in head touching early in the session. She touched her head 14 times, with 12 of these touches directed to the marked area and during or within 90 sec after proximity to the mirror (Fig. 3). Happy's overall rate of head touching was significantly higher in this session as compared with her rate of head touching across the three other conditions [i.e. there was a significant difference between (i) the first mark test, (ii) the open-mirror tests before marking, and (iii) all nonmirror conditions combined ($\chi^2 = 130.83$, df = 2, $P \leq 0.001$)]. However, in two subsequent mark tests, Happy failed to touch the mark or show overt interest in the marked area. The other two elephants, Maxine and Patty, were marked twice and failed to show increased touching or interest in the mark on themselves in both tests.

These results are not inconsistent with data reported in other species showing MSR such as the extensively tested chimpanzees in which not all individuals pass the mark test [Povinelli et al., 1993; Swartz and Evans, 1991]. Happy, Maxine, and Patty continued to show self-directed behavior at the mirror, suggesting that they may have lacked interest in the mark but not in their own reflection. Future studies examining the ability for MSR in both Asian and African elephants and developmental studies with elephants of different ages are critical to further elucidate the distribution of this ability across elephant species and factors that may contribute to MSR. Zoological facilities and elephant sanctuaries are optimal facilities for such research and our results indicate that mirrors can serve as effective enrichment devices for the elephants as well.

Fig. 3. This image, taken from the camera embedded directly behind the mirror, shows Happy touching the mark on her head while in full view of the mirror.

FUTURE DIRECTIONS AND THE IMPLICATIONS OF COGNITION RESEARCH IN ZOOS

With the publication of our research on MSR in elephants we discovered there was an enormous interest by the press and public in the discovery that we humans share this ability with elephants. This abundant interest by the public in animal cognition and learning more about animal minds not only offers zoos a unique opportunity to further educate their visitors about discoveries about animal cognition but to actively participate and contribute to this active area of research. There are already well-established fields of nonhuman primate and bird cognition research [see Tomasello and Call, 1997; Emery and Clayton, 2004 for reviews] and an increasing number of such studies being conducted in zoological parks [e.g. Shillito et al., 2005; Stoinski and Whiten, 2003] including an introduction of research paradigms, such as computer testing, to the general public [e.g. Reiss and McCowan, 1993; Turner, 2007]. Cognitive research with bottlenose dolphins and other cetaceans conducted in research laboratories and in aquariums [cf. Herman, 1980; Marino et al., 2007; Reiss et al., 1997; Reiss and Marino, 2001] have led to advancements in the elucidation of their sensory and learning abilities and these findings in conjunction with behavioral field observations have provided a richer picture of the cognitive lives of these mammals. Clearly, there is room for such expansion of elephant cognition research as well, considering the public's fascination with these large, intelligent mammals [Lair, 1997].

For modern zoos and aquariums, it is important to educate an increasingly well-educated public as well as to participate in both field research and research on animals in human care. This broad education and research mission requires an integrated and collaborative approach to research by wildlife biologists, veterinarians, small population ecologists, behavioral ecologists, conservation biologists, and cognitive scientists alike. Although there has been basic reproductive, veterinary, and behavioral research conducted in zoos to increase our knowledge of wild species biology and applied wildlife management, there is a paucity of published work on animal cognition research conducted in zoos [Hardy, 1996; Kleiman, 1992]. One way to successfully engage and inspire the public is by linking them to the results of zoo-based research that clearly demonstrates the cognitive abilities of magnificent animals like elephants, thus inspiring individual people to take conservation action [Fraser et al., 2006].

Although several animal protection groups and animal welfare scientists have recently criticized the keeping of elephants in captivity—e.g. Clubb et al. [2008]—few objections have been aimed at noninvasive cognitive research that has increased our overall knowledge of and appreciation for elephants. Indeed, captive animals may be more appropriate for cognitive, veterinary, and other studies because of recent advances in husbandry training by zookeepers and zoo-training staff that allow these personnel to habituate the animals to the presence of outside researchers. These husbandry-training techniques apparently increase trust of humans in their mixed social groups [e.g. Mellen and Ellis, 1996], and facilitate easier movement of animals for experimental manipulation of the animals' environments. For example, keepers at Smithsonian's National Zoo and other zoos have used husbandry-training techniques to easily move animals from one habitat to another, and to habituate female elephants to voluntarily stand (no chemical restraint, etc.) for ultrasounds, vaginal exams, and artificial insemination.

The logistics of conducting cognitive studies with the requisite experimental controls with free-ranging elephants is extremely challenging. In contrast, cognitive research can be more practically facilitated in the zoo and aquarium environments. However, animal training takes time and effort and significant challenges to researchers may exist even if they are working with cooperative curators and keepers with significant background knowledge in animal psychology. Zoo animals, like wild animals, also may present a challenge simply by being predictably unpredictable. Nonetheless, collaborative cognitive research efforts between scientists and zoo staff can result in cognitive research programs that not only lead to scientific advances but may also serve to stimulate the physical and mental health of animals themselves. This is especially true for large-brained mammals like elephants, that are embraced by keepers and curators in AZA-accredited zoos and that are required by accreditation standards to have viable research programs. Animal cognition research on elephants is thus a welcome advance in an overall zoological scientific research program, and will help to stimulate a vibrant zoo research community as we move forward.

Zoo curators, whether trained in animal behavior, nutrition, or general wildlife biology and applied husbandry techniques, may not have the expertise to design rigorous cognitive experiments, or may have the expertise but not the time because of competing demands. But zoos are outstanding resources for collaborating researchers, and those researchers will benefit from the collaboration if they can design their research to be accessible to the zoo visitors through graphics and other educational materials or if it can be applied to the management needs of the zoo. The more the relationship is mutually beneficial, the more the zoo professionals will embrace the collaboration for the benefit of scientific knowledge and the animals themselves.

Elephants, therefore, are an optimal species for cognition research in zoological parks. Their size, social complexity, potentially diverse cognitive capacity, and the attention they garner from the scientific and zoological communities as well as the general public make the need for their conservation, through the combination of direct in- and ex-situ conservation work, and research in the areas of animal behavior and cognition, both realistic and necessary.

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