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Tool use, problem-solving, and the display of stereotypic behaviors in the brown bear (*Ursus arctos*)

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Recent studies suggest that bears have relatively high cognitive capabilities. However, cognitive processes and problem-solving abilities remain relatively unexplored in bear species. We studied the capacity for 8 captive brown bears (*Ursus arctos*) to move and use inanimate objects to obtain a food reward. We recorded their behaviors during the problem-solving process using a behavioral ethogram. Three items, a large log, a small log, and a box, were placed in an outdoor enclosure. As the bears progressed through 3 stages of trials, they would need to manipulate the objects and displace them into the proper location and orientation to climb atop to reach a suspended food reward. Completion of the third and final stage was deemed to be evidence of tool use. Six of the 8 bears were capable of tool use. Most bears (>90% of trials) were successful in completing the final stage in <100 seconds. Bears exhibited behaviors such as head flips, pacing, and jumping as the trial length progressed and failure rate increased. Individual bears exhibited different tool preferences and techniques. The bears were capable of applying previously learned skills to novel items. The 2 bears that did not succeed at tool use were both free range before their relocation to the Washington State University Bear Research and Education Center; their prior history may have contributed to their inability to use tools.

Introduction

The ability to use tools is often used as an indicator of advanced cognition in animals. Extensive studies of the intelligence of social animals such as great apes (Schaik and Burkart, 2011) and non-primate social animals such as corvids (Cheke et al., 2011), canids (Overall, 2011), and elephants (Foerder et al., 2011) continue to reveal an association between social living and problem-solving behaviors, including tool use. Studies suggest that social carnivores outperform nonsocial animals when presented with a problem requiring innovation (Borrego and Gaines, 2016). Brown bears (*Ursus arctos*) are raised for the first 2 to 3 years in a social environment and then lead minimally social lives communicating with one another primarily through physical and scent marking of their environment as adults (Clapham, et al., 2013; Clapham et al., 2014; Sato et al., 2014). Interestingly, even polar bears (*Ursus maritimus*), which live almost entirely solitary lives as adults, still exhibit long distance social communication through scent marking (Owen et al., 2014). This makes the classification of bears as social or nonsocial difficult.

American black bears (*Ursus americanus*) and brown bears are highly adaptable in seeking food (Lesmerises et al., 2015). Both black and brown bears learn their foraging strategies primarily through social interactions with their mothers during the first years of their life (Mazur and Seher, 2008; Gardner et al., 2014). In areas near human settlements, black bear cubs are tutored by their mothers to seek human-associated foods. They show great variability in specific strategies used depending on the individual litter and environmental factors (Mazur and Seher, 2008). This pattern of living in proximity to humans suggests plasticity in both learning and behavior when encountering a situation requiring problem-solving. Likewise, brown bears range widely across North America, Europe, and Asia and, therefore, are highly adaptable in exploiting a variety of habitats and foods (Haroldson et al., 2005;

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McCarthy et al., 2009; Ware et al., 2012; Fortin et al., 2013). The high level of resource adaptability by a relatively nonsocial species may require cognitive abilities most often associated with more social species (Finn et al., 2009).

Bears are most closely related to canids, mustelids, and procyonids (Choi et al., 2010), which are known for their relatively high-level cognitive abilities (Hall and Schaller, 1964; Michener, 2004; Overall, 2011). Similarly, bears have unusually large brains relative to their body size, even when compared to close phylogenetic relatives (Gittleman, 1999; Rushton and Ankey, 2000; Ware et al., 2013). Empirical research supports some relationship between a carnivore's relative brain size and problem-solving ability (Benson-Amram et al., 2016). Black bears have been recently shown to perform at a similar level to primates with respect to quantification, estimation, and counting (Vonk et al., 2012). These data raise the question of whether selective pressures beyond social living play a role in developing highly functioning cognitive capabilities. The great adaptability seen in black bears prompts additional questions about the cognitive capacity and capabilities of bears, which remain relatively unexplored.

The most widely accepted definition of tool use is the revision of Alcock's definition (1972) by Beck (2011) that states the following: "tool use is the external employment of an unattached environmental object to alter more efficiently the form, position, or condition of another object, another organism, or the user itself when the user holds or carries the tool during or just prior to use and is responsible for the proper and effective orientation of the tool." According to this definition, tool use has been demonstrated in many species including corvids which manufactured tools out of wires to retrieve food (Bird and Emery, 2009; Cheke et al., 2011), elephants which positioned a box as a stepping stool to reach suspended food (Foerder et al., 2011), beavers which use sticks for communication (Thomsen et al., 2007), and bottlenose dolphins (*Tursiops sp.*) which manipulated sponges to create foraging opportunities ('Krützen et al., 2014). Many other mammals shown to use tools include mustelids (Hall and Schaller, 1964; Michener 2004) and primates (Gruber et al., 2010; Boose et al., 2013). Some species which rarely use tools in the wild readily use tools in a captive environment with ability that rivals that of chimpanzees' (*Pan troglodytes*) (Emery and Clayton, 2009). Köhler (1925) described several stages of tool use and manufacture in chimpanzees and suspected problem-solving behavior when approaching novel problems. Suspected tool use has been documented in a free-ranging brown bear; however, the purpose and objective remain uncertain (Deecke, 2012).

This study assessed whether captive brown bears have the ability to solve a problem by manipulating freely moveable objects to reach a food reward. Our observations in captive bears reveal that bears very often use physical force when approaching new problems which will lead to trial and error problem-solving. This type of learning is often observed when testing bear-resistant products (http://igbconline.org/bear-resistant-products/; http://www.grizzlydiscoveryctr.org/research/product-testing/). When force does not work, bears often appear to demonstrate insight-like behavior, with individual variability. We hypothesized that brown bears have the ability to manipulate objects in their captive environment using them as tools to achieve a goal. We predicted that (1) bears would position large objects (logs and boxes) to obtain a food reward; (2) bears would initially go through trial and error until the concept was learned and, if successful, transfer this skill to different conditions and tools; (3) bears would show behaviors consistent with impatience and eventually abandon the experiment if unsuccessful at obtaining the food reward. We discuss evidence of tool usage in captive brown bears from a proximate perspective, with respect to the immediate environmental factors that may influence the behaviors.

Methods

Subjects

Eight brown bears (N = 8) were included in this study: 5 adult females, LU, KI, PE, CO, and OA (11-15 years of age) and 3 subadult males, RO, PA, and TA (3 years of age). Three of the adult females (LU, KI, and PE) were born in captivity and 2 (CO and OA) were relocated from free-ranging locations 3 years before this study. The subadult males were born in captivity. Three of the adult captive-born females (LU, KI, and PE) had previous experience with positive reinforcement training for husbandry purposes. The remaining 5 bears did not. All animals were housed at the Washington State University Bear Research, Education, and Conservation Center and maintained in compliance with American Society of Mammologists guidelines (Sikes and Gannon, 2011) and the *Bear Care and Colony Health Standard Operating Procedures* approved by the Washington State University Institutional Animal Care and Use Committee (IACUC) (ASAF #3054).

Enclosure and materials

The bears were tested in 1 section of a large outdoor grassy 0.56-ha enclosure. A corner of the enclosure was used to construct four 7.6 m × 7.6 m zones and one 15.2 m × 1.8 m zone which were used to identify animal location and movement (Figure 1). The zones were marked on the shorn grass with white commercial paint (High Performance Enamel, Rust-Oleum Corporation, Vernon Hills, IL). An adjustable rope was suspended across the corner of the yard so that a food reward could be suspended above the center of zone 1 at heights ranging from 2 to 3 m. The height of the suspended food reward was adjusted to be 0.5 m beyond the reach of each individual bear when it was standing on the ground bipedally. Zone 1 contained the tools necessary to complete each trial including: a 0.57 m × 0.57 m × 0.57 m plastic enrichment box, a 0.33 m tall × 0.64 m diameter large log round and a 0.4 m tall × 0.5 m diameter small log round. A surveillance camera (Pan/tilt/zoom Esprit HD camera, Pelco, Surrey, BC, Canada) above the fence at zone 2 filmed the testing area. The behaviors were recorded using video that recorded the bears' activity while in or near the 5 zones. The large log round was placed in the enclosure 1 week before beginning trials to habituate the bears to the new stimulus. The large log was the only item used for stages 1 and 2. The small log and box were added in stage 3 to determine if bears would apply previously learned knowledge to new or novel items.

Procedures

The trials began when the bear entered the enclosure in zone 5 and were terminated when the bear was no longer interested in the task and left the test area for >10 minutes, an arbitrary determination but appeared a rational cutoff as when (primarily the 2 previously free ranging) bears gave up on the test area, they did not return to interact for that trial set up. Trial success rate for stages 2 and 3 was based on intentional objective movement to retrieve reward. Intentional movement of the object was defined as the bear looking at the reward and object in succession followed by deliberate manual displacement and positioning of the object in the appropriate direction and location that would allow successful retrieval of the reward. If the bear did not obtain the reward through intentionally manipulating the object, the trial was considered a failure. The experimental design was divided into 3 stages.