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Can Dolphins Plan their Behavior?

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The ability to plan one's behavior in novel and appropriate ways when confronted with new problems has been found in members of relatively few species. This ability provides significant evolutionary advantages in that the planner can mentally assess possible solutions prior to implementing one of them, and so need not risk life and limb by muddling though possible solutions to problems via trial and error learning. Although there are instances of wild dolphin behavior that suggest planning, it is difficult to determine if such behaviors were the result of planning, trial and error learning, or even some form of serendipitous discovery. Investigations of problem solving in bottlenose dolphins living in zoological settings can better assess the actual causes of apparent planning, and such controlled studies have demonstrated that dolphins can plan their behaviors in novel contexts. These settings facilitate the assessment of processes that underlie behaviors of interest, while observations from the wild provide invaluable information about apparent planning behavior in various contexts. Integrating findings from both settings is necessary if we hope to fully understand the dolphin capacity for planning.

Recent years have witnessed the discovery of a myriad array of cognitive abilities in a variety of species (see Wasserman & Zentall, 2006). Although many animal species have evolved cognitive abilities to increase individual member's chances of surviving and reproducing, these abilities are often restricted to specific contexts. More flexible cognitive abilities are relatively rare among non-human animals (Hurley & Nudds, 2006; Reader & Laland, 2003; Wasserman & Zentall, 2006). Flexible thinking facilitates an individual's ability to adapt to novel situations (Kuczaj, Gory & Xitco, 2009; Kuczaj & Makecha, 2008; Kuczaj & Walker, 2006; Proust, 2006; Reader & Laland, 2003) and so provides numerous evolutionary advantages for species living in dynamic environments. Thus, evolution seems to have favored two distinct forms of cognitive processing, the relative significance of each depending on the nature of the environmental demands facing a particular species. Cognitive specificity was more heavily weighted for species that benefited from one or more particular abilities, while cognitive flexibility was selected for in species that gained an evolutionary edge by more quickly adapting to novel circumstances. For example, the human ability to plan likely accounts for much of our success as a species.

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This certainly does not mean that humans are perfect. We make mistakes and even continue to engage in behaviors that we know are destructive. We sometimes use trial and error learning to solve problems, but are also capable of using insight and planning to generate novel solutions to novel problems, a remarkable mental capacity that requires the ability to represent the nature of the problem, the desired outcome, and possible ways to achieve the desired outcome (Gopnik & Schulz, 2007; Hauser, Kralik, & Botto-Mahan, 1999; Kuczaj et al., 2009; Procyk & Joseph, 1996; Sloman, 2005; Tolman, 1932; Washburn, 1936). An understanding of causality is also essential for successful planning (Gopnik & Schulz, 2007; Holyoak, 1995; Sloman, 2005). Otherwise, we might struggle to find a solution without understanding why some attempts succeed and others fail. Thus, planning is the ability to represent and use causal knowledge to create solutions for problems. It is one of humankind's most sophisticated forms of problem solving, and has proven difficult to demonstrate in non-human animals.

There are behavioral observations that suggest dolphins and killer whales may engage in planning (Kuczaj & Walker, 2006). Some of these observations come from studies of wild animals. For example, planning may be involved when male dolphins cooperate to herd female dolphins (Connor & Krützen, 2003; Connor, Smolker & Richards, 1992), killer whales cooperate to dislodge seals and penguins from ice floes (Visser et al., 2008), dolphins herd fish into manageable balls while individual animals take turns feeding (Similä & Ugarte, 1993), dolphins intentionally strand to catch fish they have chased onto a bank (Duffy-Echevarria, Connor, & Aubin, 2008; Hoese, 1971), killer whales intentionally strand to capture sea lion pups (Guinet & Bouvier, 1995), or dolphins place sponges onto their rostrums prior to search the ocean floor for prey (Smolker, Richards, Connor, Mann, & Berggren, 1997).

Observations of animals in zoos and aquariums also reveal apparent planning behavior. Some killer whales capture sea gulls for use as play objects (Kuczaj, Lacinak, Garver, & Scarpuzzi, 1997; Kuczaj & Makecha, 2008). The whales use bits of fish to lure the gulls, and the emergence of successful gull catching followed one of two paths, both of which involved observational learning in the whales that were studied. After observing another whale catching and playing with a sea gull, some whales learned to do so themselves via trial and error learning. Other whales seemed to use the information they had obtained via observation to more successfully plan their initial gull baiting attempts. The whales that appeared to plan their behavior based on information they had gained from watching others became successful gull catchers much sooner than did those that depended on trial and error learning. The fact that some whales exhibited rapid learning while others engaged in laborious trail and error learning suggests that the mechanisms involved in the cultural transmission of behaviors within a population varies from animal to animal.

Other examples of apparent planning by dolphins in marine parks come from rough-toothed dolphins that we have studied. One dolphin used a swim fin that had been provided as an enrichment object as a lever. The dolphin would fit its rostrum into the opening of the fin and then use it as a lever to pop open a gate that separated two pools. Another dolphin used a different enrichment object (a buoy) as a tool to knock a walkway off of its mounting. The dolphin would submerge the buoy under the walkway and then release it. The force of the buoy as it rocketed from the water dislodged the walkway. In both cases, the dolphins seemed to use objects as tools to achieve a goal, which suggests planning on their part. However, the goal seemed to be to use the tool to gain control over an aspect of their environment. The dolphin that opened gates with the swim fin did not always swim into the adjacent pool after the gate was open. and so opening the gate seemed more important than actually gaining access to the pool. Similarly, the dolphin that used the buoy to dislodge walkways did not seem interested in the walkway once it was moved. She simply seemed to like using the buoy to alter the walkways position. These dolphins' planning behavior is reminiscent of findings that dolphin calves make their play more complex in order to keep it interesting (Kuczaj, Makecha, Trone, Paulos, & Ramos, 2006). The rough-toothed dolphins were also using play objects in novel ways, specifically as tools that allowed the dolphins to manipulate other aspects of their environment. This play appeared to involve planning, which demonstrates that planning may occur in a variety of contexts.

As impressive as the above examples seem, it is difficult to determine the extent to which each of the above behaviors reflects planning. It has long been known that animals engage in behaviors that appear to involve planning, but are actually instinctive or acquired via serendipity or trial and error learning (Morgan, 1894; Thorndike, 1911; Tinbergen, 1951). Instincts, serendipitously learned behaviors, and trial and error learning do not involve planning since animals that solve problems in any of these ways need not mentally represent the problem and its possible solutions, such mental representation being an essential part of planning (see Kuczaj et al., 2009). However, it is notoriously difficult to determine if and how animals mentally represent their world. How, then, is it possible to decide if an animal's behavior reflects some form of planning?

Detailed information about an animal's behavioral history makes it easier to determine the extent to which the behaviors of interest were the result of some instinctual process, serendipitously learning, trial and error learning, observational learning, or planning. However, such information is difficult to obtain from animals in the wild, particularly from species that are wide-ranging and/or difficult to observe on a regular basis. Animals in zoos and aquariums can be exposed to novel problems, which make it possible to document the complete history of the animals' attempts to solve the problems. This enables researchers to ascertain *how* an animal solves the problems of concern.

We used this approach to assess the planning abilities of two male Atlantic bottlenose dolphins (*Tursiops truncatus*) housed in a large aquarium at The Seas exhibit at Epcot in Lake Buena Vista, Florida (see Kuczaj et al., 2009, for methodological and statistical details). Each dolphin was given two tasks that were designed to allow the dolphins to more efficiently and effectively obtain a goal if they planned their behavior.

One task required the dolphins to drop four weights into an apparatus in order to release a fish that they could then eat. Each dolphin had learned to use weights in this context by watching human divers do so. The human divers always used a single weight at a time, picking up and dropping one weight into the apparatus, then picking up and dropping another weight, and so on until four weights had been dropped into the apparatus. It is important to note that the dolphins *never* observed a human model using more than one weight at a time. Consequently, if the dolphins' behavior relied solely on mimicry of the humans' behavior, we would expect the dolphins to use only one weight at a time. But if the dolphins recognized that gathering and depositing multiple weights on each trip is more efficient, and were able to plan their behavior accordingly, we might expect the dolphins to use multiple weights on each trip despite the fact that they never observed humans using more than one weight and had never used more than one weight themselves. As it turns out, the dolphins proved capable of planning their behavior in this context. When the weights were placed far enough away from the apparatus to make a "multiple weights at a time" strategy more efficient, the dolphins quickly modified their behavior and began to carry multiple weights each trip. Despite the fact that the dolphins were tested individually (and so had no opportunities to observe one another's behavior in this test), each dolphin adopted the novel and appropriate behavior of using multiple weights when it was beneficial for them to do so. This suggests that the dolphins understood that multiple weights were required to release the fish and that they were able to plan their behaviors to achieve their goal more efficiently.

We also wished to assess the flexibility of dolphin planning, and did so by providing the dolphins with another problem that they could solve by using a weight. But in this task the dolphins were provided with only a single weight, which the dolphins had to reuse if they were to obtain all of the fish for a given trial. Specifically, the test involved three boxes different from those used previously. Each box was mounted on a stand with the bottom of the box approximately one meter from the floor of the aquarium. A dolphin could obtain a fish from a box by dropping a single weight into the box. Two of the boxes had open bottoms, resulting in the weight falling to the aquarium floor after a dolphin dropped the weight into the box. This allowed the dolphin to reuse the weight to obtain a fish from another box. However, the third box, which was clearly marked to indicate its difference from the other two boxes, extended to the floor of the aquarium, and so retained the weight after it was dropped into the box, preventing further use of the weight. This meant that a dolphin could obtain all three fish (one in each box) in a given trial by dropping the weight in the retaining box last. If not, the dolphin would receive only one or two fish, depending upon whether it used the retaining box first or second. Each dolphin quickly learned to use the retaining box last, once again demonstrating an ability to plan behavior to more efficiently achieve a goal. The dolphins' behavior in the two tasks described above suggests that they can plan their behavior, even in situations that are quite different from those that dolphins encounter in the wild. The dolphins' performance in the multiple weight test demonstrated that they could create a new behavior (carrying more than one weight at a time) to more efficiently obtain a goal. The fact that each dolphin quickly and independently decided to carry multiple weights when the weights were located at a distance that made multiple trips more costly suggests that the dolphins understood the inherent nature of the task and were able to plan their behaviors accordingly.

The flexibility of the dolphins' planning abilities was demonstrated in the retaining weight box test. In order to solve this problem, the dolphins needed to use a familiar tool (a weight) in a very different context. The dolphins had to both learn to reuse a weight and that one of the boxes did not return the weight for further use. Once again, the dolphins independently and quickly arrived at the correct solution of dropping the weight in the retaining box last. The fact that in both tasks the two dolphins arrived at similar correct solutions suggests that the ability to plan may be common among dolphins.

We should note that the dolphins always received their daily allotment of food regardless of how they performed on the tasks. In addition, the dolphins were fed throughout the day, and the food rewards they obtained on these tests represented a tiny percentage of their daily ration. The dolphins could obtain fish in the multiple weight test by dropping a single weight at a time, and so simple perseverance would have sufficed to produce an equivalent fish reward. Similarly, the dolphins received fish no matter what box they chose in the Retaining Weight Box Test, but they were able to obtain the fish from each box only if they used the retaining box last.

It is unlikely that the dolphins solved the problems solely because they received fish if they did so. Instead the dolphins seemed to enjoy solving the problems that humans provided, perhaps because the problems were cognitively stimulating to the animals. One of the challenges facing aquariums that house marine mammals is the predictability of the animals' environments, and we believe that providing animals with cognitive puzzles is quite enriching for cognitively sophisticated animals such as dolphins. We suspect that the fish the dolphins received when they solved the cognitive puzzles we provided functioned more as indicators that the dolphins had succeeded than as primary reinforcement per se (see Kuczaj & Xitco, 2002, for a more detailed consideration of this idea).

One might ask why it matters if dolphins can plan their behaviors. The fact that dolphins can plan at least some of their behaviors means that they can do more that simply react to their environment. In general, the ability to plan provides individuals with significant evolutionary advantages (Bradshaw, 1993). Successful planning helps animals conserve energy by eliminating the need to engage in costly trial and error learning, and facilitates an individual's ability to adapt to abrupt environmental changes. Planning can also help animals avoid behaviors that could result in injury or death.

The dolphins that we studied were able to create successful plans when faced with tasks unlike any that they would normally encounter in the wild. This suggests a fairly generalized and flexible ability to plan, which in turn suggests that dolphin evolution resulted in a set of cognitive skills that extend beyond those needed to deal with specific problems that dolphins encounter in everyday life, such as mating, foraging and the rearing of young. This may be one reason that dolphins are so playful, for a flexible mind requires stimulation and play is an ideal arena for such stimulation (Kuczaj et al., 2006). An understanding of animal cognition, then, requires an appreciation of both specific niche dependent abilities and more generalized cognitive abilities, in addition to the extent to which species rely on these two types of cognitive abilities. Although the dolphins we studied were able to plan their behavior in novel contexts, the extent to which dolphins can solve novel problems is unknown. Additional work is needed to determine the limits of dolphin planning abilities, which will help to better place dolphin cognition in a comparative context. In order to achieve this understanding, it will be necessary to compare individuals within a species in addition to comparisons across species (Highfill & Kuczaj, 2007; Kuczaj & Walker, 2006; Tolman, 1932). We suspect that studies of wild dolphins will continue to surprise us as observations reveal additional forms of "cognition in the wild", but we also believe that studies of collection animals are essential for a more complete understanding of the processes that underlie the dolphin mind.

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