



Common bottlenose dolphin (*Tursiops truncatus*) problem solving strategies in response to a novel interactive apparatus



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ARTICLE INFO

Keywords:

Emulation
Freeloading
Environmental enrichment
Water flow manipulation
Challenging device

ABSTRACT

The problem solving capabilities of dolphins are suggested to be indicative of advanced cognition. When confronted with a novel problem, dolphins can plan their behavior to create a more efficient strategy than that which was previously modeled. The present study investigated dolphins' ability to plan their behaviors using an interactive apparatus with accompanying weights. Two problems were presented to evaluate dolphins' ability to plan by collecting several weights at once, thus solving the apparatus more efficiently. In contrast to previous findings, dolphins in the present study failed to plan their behavior. Rather, individual differences in problem solving strategies arose throughout the study and are described here. Dolphins engaged in several strategies in order to attempt to obtain the fish reward, including approaches that were not modeled. Strategies for solving the submerged interactive apparatus (SIA) included emulation, freeloading, water flow manipulation, and physical manipulation of the SIA. The SIA was continually solved by a single individual who rarely consumed the food reward, suggesting that she may have been motivated to participate for the challenge itself. Though not indicative of planning, the results of the present study demonstrate the plasticity of dolphin problem solving capabilities and spatial reasoning.

One of the hallmarks of dolphin intelligence is their flexible problem solving skills (Kuczaj et al., 2009; Kuczaj & Walker, 2012). Conscious problem solving occurs when effort is applied to finding a solution that results in achieving a desired state (Holyoak, 1995). One of the least sophisticated forms of problem solving is trial-and-error learning whereby an animal consecutively performs new behaviors until one results in successfully achieving the goal (Baron, 1988). More refined forms of problem solving employ reflection in which the animal develops a mental representation of the problem and has the ability to manipulate these representations to solve the problem (Piaget, 1955). One such cognitively sophisticated form of problem solving involves reflecting on the problem and planning behaviors before physical action occurs (Tolman 1932).

Planning is defined as the ability to “represent and use causal knowledge to create solutions (novel or familiar) that are appropriate for achieving a specific goal in a particular problem environment” (Kuczaj et al., 2009, pp. 102). The ability to plan behavior flexibly is rare among non-human animals (Kuczaj et al., 2006; Reader & Laland, 2003). To plan a solution, an individual must understand the causal relations that are inherent to the problem (Gopnik & Schulz, 2007; Holyoak, 1995). Without causal understanding, no connection can be made between behavior and consequence (Holyoak, 1995). This causal

understanding allows an individual to then determine why some efforts succeed and others do not, allowing him or her to avoid the potential consequences of an error.

A crucial component of planning is the creation of novel behaviors in order to solve novel problems (Kuczaj et al., 2009). Individuals must be able to mentally represent the problem in order to determine the desired outcome (Gopnik & Schulz, 2007; Hauser et al., 1999; Procyk & Joseph, 1996; Tolman, 1932; Washburn, 1936). Planning-resultant behaviors should manifest themselves quickly and entirely when compared to solutions created over time via associative learning or through the accidental discovery of the correct solution (Frye et al., 1996). Additionally, animals must have the ability to mentally represent possible solutions that would achieve the desired outcome (Piaget, 1955).

The ability to express planning skills in diverse situations is cited as a crucial difference between human and non-human planning (Gilbert & Wilson, 2007; Roberts, 2012; Suddendorf & Corballis, 2007). There is significant variation in the capacity to plan physical actions between and within species as well, based on the type of task to be solved (D'Mello & Franklin, 2011; Völter & Call, 2012). Great apes have been documented saving tools for future use (Dufour & Sterck, 2008; Mulcahy & Call, 2006; Osvath & Osvath, 2008) and for use as projectiles (Osvath, 2009; van Hooff & Lukkenaar, 2015), indicating basic

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planning skills, yet the diversity of the species' planning abilities has only recently been explored utilizing cognitive research techniques (Bourjade et al., 2014; Tecwyn et al., 2012).

Generalized planning abilities may have provided an evolutionary advantage to some species by allowing individuals to actively respond to their environment by planning their behavior rather than passively reacting (Tolman, 1932). In the wild, animals will regularly encounter a variety of complex social and physical situations in which the ability to plan behavior facilitates an individual's ability to adapt and thrive (Miyata & Fujita, 2012; Reader & Laland, 2003).

The ability to plan behavior and forecast the possible reactions of conspecifics before acting is beneficial for highly social species (Barth et al., 2004; Povinelli & Cant, 1995). In social non-human primate species living in fission-fusion societies, inhibitory skills are more prevalent, and are suggested to be a result of the need to assess the composition of the party prior to action (Amici et al., 2008). Similarly, bottlenose dolphins (*Tursiops truncatus*) typically live in fission-fusion societies (Connor, Wells, Mann, & Read, 2000; Gowans et al., 2007) in which the ability to assess the situation and the other individuals present may be crucial. Observations of wild dolphin behavior suggest that they may implement plans in a variety of contexts. Cooperation during mate acquisition and foraging/hunting techniques provides evidence that dolphins may engage in planning (see Kuczaj et al., 2009; Kuczaj & Walker, 2012 for a review of potential planning behavior of cetaceans in the wild and under professional care). For example, dolphins intentionally strand to catch fish and sea lions (Hoese, 1971; Guinet & bouvier, 1995), cooperatively herd herring to the surface (Nottestad, Ferno & Axelsen, 2002), and use bubble nets to trap prey (Fertl & Wilson, 1997). However, it is important to note that investigating the planning abilities of wild dolphins is particularly difficult because the full learning history of the individual of interest is unknown (Kuczaj et al., 2009). Therefore, dolphins under human care make excellent research participants because the behavioral and experiential history of the animal is known, enabling researchers to create novel problems.

One method of creating novel problems is through the development of interactive apparatuses. Enriching interactive apparatuses require that the device be an appropriate cognitive challenge and provide tangible or intrinsic reinforcement. While some frustration is necessary when problem-solving, an inappropriate challenge may result in an increase in undesired self-injurious or stereotypical behaviors (Clark & Smith, 2013; Leavens et al., 2001). Non-intrinsically enriching devices must deliver a reward that is of high enough value for unsolicited participation (de Rosa et al., 2003). However, if used in social situations, caution should be taken so that the high-value reward does not elicit aggressive competitive behaviors.

Research at Disney's The Living Seas revealed that bottlenose dolphins were able to create a simple plan in order to solve an apparatus (Kuczaj et al., 2010). The dolphins were presented with several boxes and a single weight. When a weight was dropped inside each box, the dolphin received a food reward. All of the boxes except for one allowed the weight to fall through, effectively returning it to the dolphin. One marked box retained the weight and the dolphin was not able to use it again. To maximize the number of fish they would receive, the dolphin needed to use all the boxes that allowed the weight to fall through first and then drop the weight into the retaining box last. Both subjects arrived quickly and independently at the correct solution, indicating that they could create and follow a rudimentary plan.

Kuczaj et al. (2009) used a multiple weight apparatus to evaluate if dolphins can plan future behaviors to obtain a reward. The dolphins were required to place weights inside the apparatus, designed to release a food reward when triggered by four weights. Scuba divers modeled a method to solve the apparatus by placing each weight into the apparatus one at a time. When weights were placed far away from the apparatus, the dolphins quickly devised a novel solution by retrieving multiple weights in a single trip, thus solving the puzzle with greater efficiency than was modeled. The immediate change in weight retrieval

method suggested that the dolphins could create a rudimentary plan to solve the task and were responding to changes in their environment. Hence, it can be hypothesized that they may have the ability to update their plans based on the resources available.

The purpose of the present study was to investigate dolphins' ability to plan their behaviors using a submerged interactive apparatus. Building on the work of Kuczaj et al. (2009), two problems were presented, with the end goal of examining if dolphins could plan ahead by collecting several weights at once and if they could monitor and modify their planned behavior based on the resources available. The first problem replicated the scenario presented to the dolphins by Kuczaj and colleagues to examine if dolphins would plan their behavior. The second problem introduced variability in the size of the weights to determine if the dolphins would update their plan based on available resources. It was hypothesized that the dolphins would plan their response by creating a new behavior (i.e., carrying multiple weights at one time) to solve the apparatus and that the dolphins would modify their behavior to carry fewer, heavy weights rather than more, light weights.

1. Methods

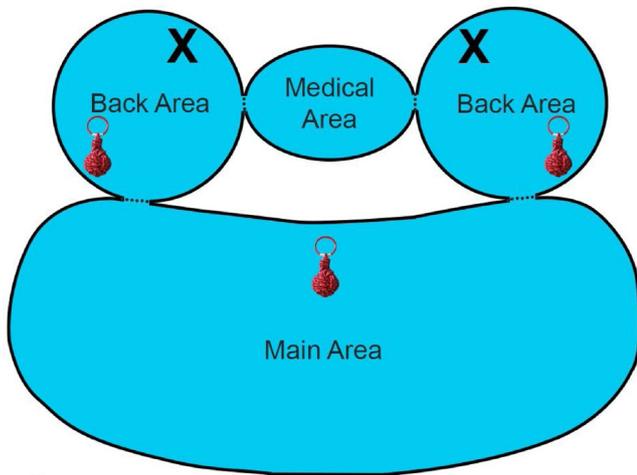
Eight common bottlenose dolphins (*Tursiops truncatus*), housed at the Brookfield Zoo in Brookfield, Illinois, USA were exposed to a submerged interactive apparatus (SIA). The SIA was designed to investigate their ability to plan behavior over a 4-month period. Group 1 consisted of three sub-adult females and one male calf, and Group 2 consisted of one female/male mother-calf dyad and one female/female mother-calf dyad (Table 1). The habitat consisted of four interconnected areas: an oblong main area (33.5 m across, 12.2 m wide, and 6.7 m deep), two circular back areas (10.7 m diameter, 4.3 m deep), and a medical area (7.6 m diameter, 2.4 m deep; Fig. 1). Dolphins were tested in groups, rather than individually as in Kuczaj et al. (2009), because they were not habituated to being separated from the entire group. The dolphins were regularly separated into the two groups used in the study and reunited as part of their normal schedule. The non-participating group was located in the back area or main area that was not being used for the trial.

The dolphins received their regular training sessions and normal daily allotment of food throughout the data collection process. The interactive apparatus (Fig. 2) consisted of a clear Lexan box, submerged two feet beneath the water's surface, containing a shelf that was lowered to release a food reward (four fish) when a given amount of weight was placed inside. Trials were conducted five days a week between 1200 and 1300, directly following a training session in which they were fed. Therefore, the reward acted as an indicator that the correct solution had been found rather than a method of food distribution. The trials were recorded using a handheld Canon Powershot S110 video camera and three GoPro Hero Sessions mounted inside the apparatus. Dolphins were introduced to the 1-lb weights as retrieval objects during training sessions before the habituation phase and were naïve to the apparatus at the beginning of the habituation phase.

The habituation phase was counterbalanced between Group 1 and

Table 1
Demographic information on participants.

Dolphin	Age	Group	Sex
D1	2	1	Male
D2	11	1	Female
D3	13	1	Female
D4	14	1	Female
D5 (calf of D7)	1	2	Female
D6 (calf of D8)	2	2	Male
D7	30	2	Female
D8	34	2	Female



Key

-  Weight placement
-  Apparatus placement

Fig. 1. Location of apparatus and weights in the habitat.

Group 2. For Group 1, the apparatus was placed into the water, with no weights, for 20 minutes a day, for three days. Both the apparatus and the weights were then placed into the water for 20 minutes a day, for three days. For Group 2, the apparatus and the weights were placed into the water for 20 minutes a day, for three days. Next, the apparatus was placed into the water without weights, for 20 minutes a day, for three days.

In each trial, the weights were dropped into the water in a specified location based on the condition (Fig. 1) and then the apparatus was lowered into position on the back wall where the dolphins had the opportunity to solve it. The weights were placed on the opposite side of the back habitat for the habituation phase, modeling phase, and condition 1 and in the front habitat in condition 2 and condition 3 (Fig. 1).

Condition 1 was comprised of 25 trials, condition 2 was comprised of 25 trials, and condition 3 was comprised of 30 trials.

The 'Closed' apparatus is in the pre-trial position without weights resting on the shelf. The 'Semi-open' apparatus is mid-trial with two 1-lb weights partially depressing the shelf. The 'Open' apparatus is post-trial with three 1-lb weights fully depressing the shelf.

In the modeling phase for condition 1, all of the weights were simultaneously dropped into the water followed by the addition of the SIA to the environment. The location of the apparatus and weights are provided in Fig. 1. Then, a trainer wearing SCUBA gear modeled the act of putting a single 1-lb weight in the apparatus while the dolphins were not in session two times for each group. The following trials were modeled by a trainer adding weights from a position the deck. Upon the third weight being added, four fish were released from the apparatus. The apparatus was reset, and the dolphins were given five minutes to solve the apparatus on their own three times (i.e., any dolphin in the group could have added weights). In conditions 1-3, all of the weights were simultaneously dropped in the water. The SIA was then lowered into place. The dolphins were not in session during this time and were free to attend to or ignore the trial set up. If the dolphins did not interact with the apparatus for five consecutive minutes, the apparatus was removed from the habitat. Trainers introduced the yellow, 3-lb weights as retrieval objects before condition 3 began. The dolphins never observed a trainer solving the apparatus with the 3-lb weight. Weight locations and successful weight combinations are given in Table 2.

Videos were coded by a single coder for number of weights added by each dolphin for each trial, the order weights were added in condition 3, and the predominant behavioral state of each individual during the SIA trials. States were classified as 1) actively solving the apparatus by attempting to add weights for more than half of the trial, 2) exploring or observing the apparatus by remaining within 2 m and oriented toward the SIA (without adding weights) for more than half of the trial, and 3) not interacting with or attending to the SIA for more than half of the trial. Individuals were coded for one overarching state for each trial.

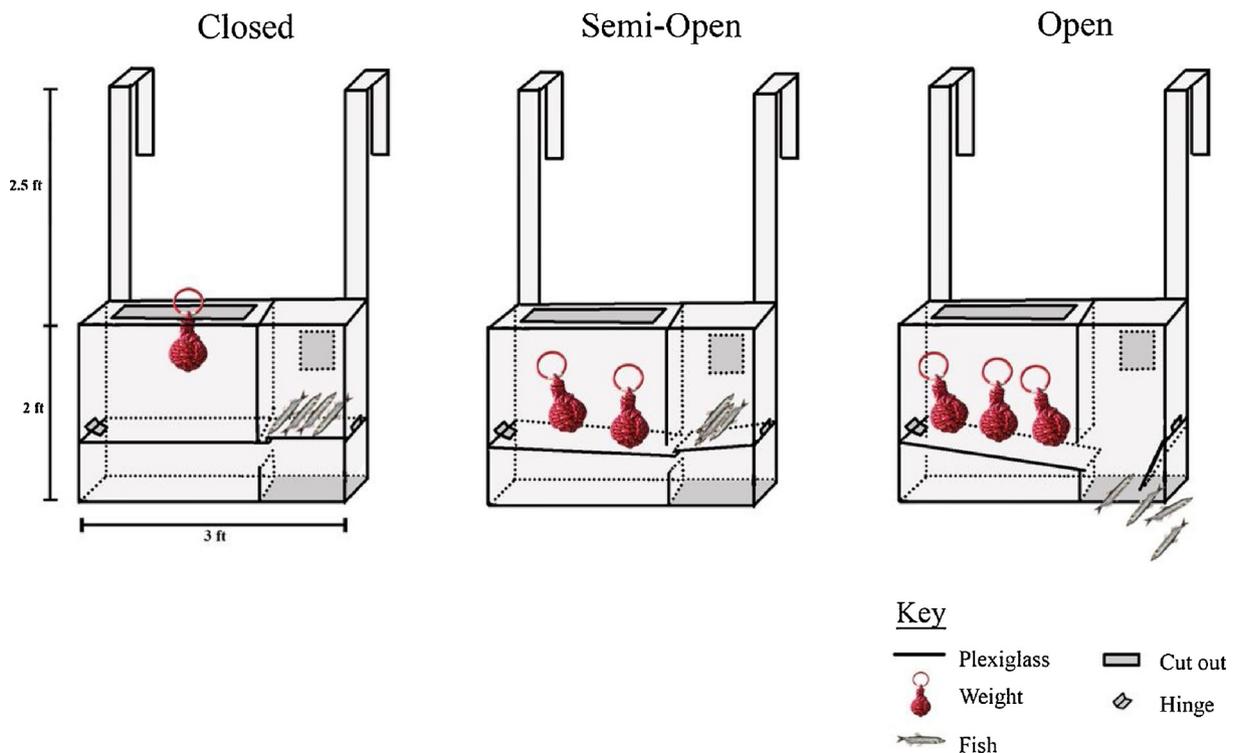


Fig. 2. Interactive apparatus.

Table 2

Condition	Weight location	Combination(s) to solve
1	Back area	Three 1-lb weights
2	Main area	Three 1-lb weights
3	Main area	Three 1-lb weights One 3-lb weight One or two 1-lb weights with terminal 3-lb weight

2. Results

At the end of the modeling phase for Group 1, D4 retrieved two weights in one trip and placed them both in the apparatus. On the first trial of condition 1, D3 placed one weight on top of the apparatus, near the opening. D3 then moved near the location where the food reward was released and nudged the apparatus with her rostrum. This caused the weight to fall in and the fish to be released. After this trial, she adopted physical manipulation by pushing the apparatus as a problem-solving strategy. Pushing the apparatus caused the moving water to lower the shelf and release the fish. The other female dolphins in the group modeled D3 and adopted this strategy as well. To mitigate this issue, the apparatus was modified to include a hidden lever that allowed the researcher to manually release the fish upon the third weight. Despite the modification, the pushing strategy persisted for the three females, and D1 did not interact with the apparatus. Due to three unintended deployments of the food reward on at the beginning of condition 1 as a result of the pushing strategy, Group 1 returned to and remained in the modeling phase for the duration of the testing period. In addition to physical manipulation, D2, D3, and D4 utilized water flow manipulation in their attempts to obtain the food reward. They developed a tail-swishing action and a head-swishing action, in which they rapidly moved water with their flukes or head towards the apparatus, without making contact.

For Group 2, D7 and D8 spent the majority of trials exploring the SIA while observing D5 solve the apparatus. D7 and D8 periodically added weights by dropping them in but never completed trials on their own. Instead, D8 typically remained in the vicinity of the apparatus and approached when D5 arrived with a weight. D7 either remained near the apparatus when D5 was retrieving weights within the back habitat or followed D5 into the front habitat while she was retrieving the weights. Consistent with adding the most weights, D5 was most frequently working to solve the apparatus. D5’s strategy for solving the apparatus was similar to the method modeled, by dropping, pushing, or tossing the weight into the hole at the top of the apparatus. In contrast, D6 seldom spent more than half of the trial interacting with the SIA. The percentage of trials individuals spent engaged in each behavioral state are given in Table 3.

All of the dolphins in Group 2 participated in solving the SIA by adding weights in a minimum of two trials. D5 participated in or solely solved every completed trial. She added 91.1% of the weights placed in the apparatus but only consumed 6.5% of the food rewards, with only one fish total eaten in conditions 1 and 2. D8 added 5.3% of the weights over the three conditions and consumed 75.0% of the fish. D7 added 1.2% of the weights and consumed 18.5% of the fish. D6 added 2.4% of the weights and did not consume any of the food reward. In condition 3, 59% of D5’s weight selections were 1-lb weights and 100% of D8

Table 3

Percentage of SIA trial in each behavioral state.

SIA behavioral state	D7 (%)	D5 (%)	D6 (%)	D8 (%)
Solving	2.50	70.00	6.25	7.50
Exploring/Observing	56.25	7.50	21.25	65.00
No interaction	41.25	22.50	72.50	27.50

Table 4

Number of weights added per condition and number of fish consumed.

Item	Condition	D5 (%)	D6 (%)	D7 (%)	D8 (%)
Weights	1	60 (89.5)	3 (4.5)	2 (3.0)	2 (3.0)
Weights	2	44 (93.6)	1 (2.1)	0 (0.0)	2 (4.3)
Weights	3	49 (90.7)	0 (0.0)	0 (0.0)	5 (9.3)
Fish	1	1 (1.2)	0 (0.0)	14 (16.7)	69 (82.1)
Fish	2	0 (0.0)	0 (0.0)	17 (47.2)	19 (52.8)
Fish	3	13 (13.5)	0 (0.0)	9 (9.4)	74 (77.1)

weight selections were 1-lb weights. Table 4 shows the number of weights added in each condition by individual and the number of fish consumed by individual in each condition.

Participation decreased during condition 2 after the weights were moved farther away. D5 solved the apparatus fewer times and ignored the apparatus in more trials, and D8 consumed fewer of the rewards because she was not present when the fish were released (e.g., she left the apparatus and was swimming in a part of the habitat that was out of view). D7’s reward consumption increased as she consumed the food reward when D8 was not present. D8 displaced D5 or D5 and D7 (a mother-calf pair) using non-contact aggression in order to obtain the food reward in 6.25% of completed trials. In condition 3, three-pound weights were selected first seven times and the 1-lb weights were continually used (Fig. 3).

3. Discussion

The apparatus was engaging for dolphins in Group 2, as demonstrated by their continual interaction with it across 80 trials. Each dolphin regularly interacted with the apparatus by actively solving it, or watching others solve it. Although Kuczaj et al. (2009) found that dolphins planned their behavior on a very similar task, the dolphins participating in the present study did not follow the same pattern. The difference in behavior may be due to previous experiences with problem solving devices as the dolphins who participated in the study by Kuczaj and colleagues had consistently participated in research projects involving different types of apparatuses, while the current participants did not.

At the onset of the trials, D4 retrieved two weights simultaneously and placed them both in the apparatus at the end of the modeling phase. D4 did not have the opportunity to repeat this strategy, however, the rapid change in strategy was reminiscent of the immediate change to a multiple weight strategy by the dolphins in the Kuczaj and colleagues’ study. Unfortunately, without further trials, it is impossible to determine if D4’s multiple weight strategy would have persisted. Although dolphins did not exhibit behaviors indicative of planning, they developed several problem solving strategies in their attempts to obtain the reward including emulating the solution that was modeled by trainers, freeloading (i.e., opportunistically waiting nearby while others were actively solving it), water flow manipulation, and physical manipulation.

D5 developed a problem-solving strategy similar to the process modeled by the trainers. D5 retrieved one weight at a time and placed it into the apparatus. Contrary to the findings of Kuczaj et al. (2009), D5 never added multiple weights simultaneously and did not selectively choose the 3-lb weights rather than the 1-lb weights. Similarly, chimpanzees remain fixed on a single strategy to obtain a food reward despite the introduction of a novel, more efficient strategy being modeled (Hrubesch et al., 2009; Marshall-Pescini & Whiten, 2008). Hrubesch et al (2009) suggested that chimpanzees are conservative, and mastery of a skill constrains further innovation despite observations of other solutions using different strategies. Moreover, chimpanzees maintain their conservatism by retaining their original strategy even when the new strategy involves the same physical actions and would result in a higher valued reward (Hopper et al., 2011). In the present study, one

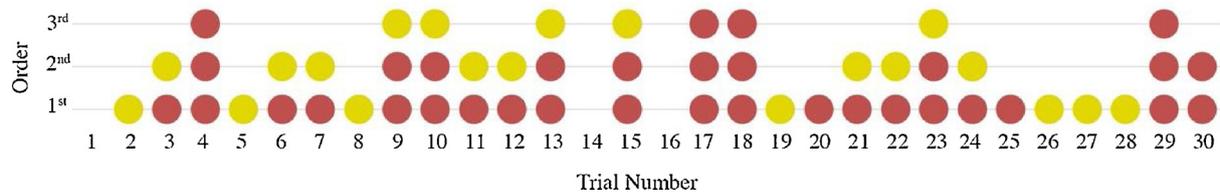


Fig. 3. Order of red 1 lb. weights and yellow 3 lb. weights placed in the SIA in condition 3.

considerable difference between D5's behavior is that D5 rarely consumed the food reward. One explanation of D5's behavior is that she lacked motivation to develop a more efficient behavior because she rarely consumed the food reward. Another explanation is that her behavior was a result of conservatism whereby D5 did not attend to the difference in outcome for the two weight types and simply maintained the physical action of adding weights to solve the SIA. Though either explanation or a combination of the two are plausible, we are unable to speculate further on the basis of her behavior given the data available here.

Although D5 completed the task in a similar manner to the model, it is likely that her strategy was, in actuality, play behavior. Burghardt (2005) defined five criteria for identifying play behaviors: 1) incompletely functional within context; 2) different structurally or temporally from related serious behavior systems; 3) voluntary, pleasurable, or self-rewarding; 4) expressed repeatedly during at least some part of an animal's life span; and 5) initiated in relatively benign situations (pp 382). The behaviors D5 exhibited while solving the SIA met these criteria. She did not add weights to the apparatus in a stereotyped manner and these behaviors were sometimes exaggerated. Methods for adding the weights included behaviors such as directly dropping them in the apparatus, placing them on top and then pushing them in, and throwing them from afar. D5 did not regularly consume the food reward, suggesting that solving the apparatus was self-reinforcing. Finally, these behaviors were initiated when she was well fed and under relaxed conditions, suggesting that D5 may have been engaging in play when interacting with the apparatus. Play provides important opportunities for cognitive development in dolphins, especially calves, by allowing them to create innovative behaviors and practice locomotor skills (Kuczaj & Eskelinen, 2014).

During play, young dolphins commonly mimic the behaviors of their mothers and older conspecifics. In Group 1, the pushing strategy developed by D3 was imitated by D2 and D4 in their attempts to retrieve the fish. In Group 2, D7 and D8 never fully solved a trial despite D5 modeling how to solve the apparatus many times. This is consistent with Kuczaj et al. (2006) in that young dolphins are more likely to spontaneously imitate the behavior of their peers than adults are. Similarly, juvenile chimpanzees frequently innovate new behaviors, but they are less frequently adopted by older, dominant group members (Kendal et al., 2015).

D5 consistently solved the apparatus without regularly receiving a food reward until condition 3, suggesting that the apparatus was intrinsically reinforcing. D5 may have been motivated to solve the apparatus for the challenge itself. D5 did not receive a reward when D7 or D8 were present, marking this as the first report of a dolphin solving a challenging task for an extended period without a tangible reward. Similar results were reported for a sea otter (*Enhydra lutis*) who was able to obtain a food reward but delayed consumption in order to continue interacting with the enrichment device (Hanna et al., 2016). Contrafreeloading (i.e., choosing to work for food even when food is readily available) is common in a number of species (Menzel, 1991). For example, chimpanzees engaged with a challenge device more often when a non-food reward was available than a food reward (Clark & Smith, 2013). Long-tailed macaques (*Macaca fascicularis*), similarly, spent more time manipulating a puzzle maze than attempting to extract the food (Watson et al., 1999).

It is unlikely that D5 participated with the intent of consuming the food reward since she continually solved the apparatus while D7 and D8 were present. Relinquishing food to a higher-ranking member is a least costly method in terms of energy and risk of aggression when the owner is unlikely to be able to defend the food (Wrangham, 1975). As the adult dolphins in Group 1, D7 and D8 consumed the majority of the reward without contest from the calves D5 or D6. Although D5 did not receive the food reward often, D5 may have strengthened her social bond with D8 during this time. D5 and D8 engaged in more social swims during the time period in which the apparatus was presented than before they had access (Lauderdale & Miller, submitted). Dolphins have been shown to exhibit prosocial preferences when provided the opportunity to give access to enrichment to themselves or themselves and a conspecific without request from the conspecific (Nakahara et al., 2017). It is also possible that the fish may not have been an effective reinforcer for D5 because she was regularly nursing and played with the fish before consuming it on the rare occasions that she did obtain the reward.

D7 and D8 did not solve the apparatus, but they added weights in the same manner in which it was modeled. Yet they were still successful in obtaining the food reward by implementing a "sit and wait" strategy. Apart from rarely observed food sharing behavior (Fedorowicz et al., 2003), high-ranking dolphins in the dominance hierarchy consume food prior to low-ranking dolphins (Pryor & Shallenberger, 1998). The lack of aggression exhibited after the release of the food reward suggests they were participating in tolerated food theft, as has been reported in primates societies (Blurton-Jones, 1987; Feistner & McGrew, 1989).

D7 and D8 sporadically added weights to the apparatus but neither solely solved the apparatus and mostly displayed observational and exploratory behaviors. The food reward provided by the apparatus may not have been valuable enough to warrant consistently retrieving the weights. A food reward of higher magnitude or a higher valued type of fish may have elicited more problem-solving behavior from the adult females. In addition, the study sessions were completed directly after a training session in which they were fed. It is possible that providing the opportunity to solve the apparatus before the training session may have increased motivation to solve the apparatus. However, research with common marmosets (*Callithrix jacchus*) revealed that they spent more time extracting and eating food from a puzzle feeder when they were less hungry (de Rosa et al., 2003).

D3 physically manipulated the SIA by developing a pushing strategy that was initially successful at obtaining the food reward. Once pushing the apparatus failed to release the food reward, D2, D3, and D4 implemented water flow manipulation by tail swishing and head swishing. The water flow manipulation of objects observed in the present study is in line with previous reports of similar behaviors. Yamamoto et al. (2014) described dolphins using water flow to lift objects from the floor by opening and closing their mouths repeatedly, moving their heads lengthwise, or making circular head motions. Clark et al. (2013) reported a similar "tail-beating" behavior of a dolphin in response to a challenging underwater maze device, suggesting that this may be a common problem-solving strategy among dolphins. Although D3 did not solve the presented problem using planning, she developed a successful, novel strategy to obtain the food reward that was then repeated by other dolphins in her group.

4. Conclusions

The dolphins in this study did not carry multiple weights that would indicate planning or selectively choose heavier weights to obtain the reward faster. Despite the lack of planning, as observed in Kuczaj et al (2006), the dolphins in this study developed several strategies in order to solve the novel problem that resulted in successfully obtaining the food reward. Dolphins emulated the solution modeled, freeloading by opportunistically waiting nearby while others actively solved the SIA, manipulated water flow, and physically moved the SIA. The SIA was also continually solved by a single individual who rarely consumed the food reward, suggesting that she may have been motivated to participate for the challenge itself. The two adult, dominant dolphins both engaged in a “sit and wait” strategy which resulted in the ability to obtain the food reward without having to exert energy collecting weights. Several dolphins exhibited head-swishing and tail-swishing behaviors that have been reported previously when dolphins were confronted with a novel apparatus.

Though not indicative of planning, the results of the present study demonstrate the plasticity of dolphin problem solving capabilities and spatial reasoning. Participants in this study not only demonstrated their ability to emulate a modeled behavior, but also their ability to solve the problem by innovating novel strategies.

Acknowledgements

The authors would like to thank Dr. Stan Kuczaj for providing the foundation for this study and his guidance during its initial stages. The authors are grateful to Brookfield Zoo, Rita Stacey, Sarah Breen-Bartecki, Bill Zeigler, and the Seven Seas animal care specialist team for their support and assistance during data collection.

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