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Behavioral and Personality Effects on a Cooperative Task for Bottlenose Dolphin (*Tursiops truncatus*) Dyads

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Social species can depend on each other for survival, help in the rearing of young, predator defense, and foraging. Personality dynamics between individuals may influence cooperative behaviors. Bottlenose dolphins (*Tursiops truncatus*) live in social communities and cooperate with other conspecifics to achieve goals both in the wild and in human care. We replicated a test of cooperative problem-solving in dolphins. In addition, we analyzed personality traits and affiliative behaviors that might lead to solving the problem. We tested 5 bottlenose dolphin pairs at the Roatan Institute for Marine Sciences, Honduras, with an apparatus previously used to experimentally test dolphin cooperation. Personality profiles of each dolphin were created using surveys completed by the caretakers, in particular noting 2 different categories of interactions: dolphin to dolphin and dolphin to world. We hypothesized that dyadic success in the cooperative task would differ based on specific personality traits of individuals. We also hypothesized that the most successful dyads would show similar types of conspecific sociality and different means of interacting with objects. Although none of the dolphin pairs cooperated to open the apparatus, individual personalities were analyzed in relation to the dolphins' individual and mutual interactions with the apparatus as well as the pairs' social behaviors. Playfulness, curiosity, and affiliation were positively related to interactions with the apparatus. Our research may be useful in guiding future studies of social problem-solving in dolphins and other species.

Keywords: dolphins, *Tursiops truncatus*, cooperation, problem-solving, personality, affiliative behavior

Cooperation requires animals to anticipate the behavior of other individuals. This ability could encourage high cohesion when engaging in group goal-directed behaviors, such as hunting. The more behavioral variety there is within the group the better equipped the group will be to face challenges, however it also becomes harder to predict individual behavior (Bergmüller et al., 2010). Although cooperation in these groups generally results in a more easily obtained goal than solo attempts, some pairs or groups are more effective than others (Dall et al., 2004). Different roles in the community may necessitate different individual behavioral strategies. Such stable interindividual differences may affect all aspects of the community (Réale et al., 2007; Webster & Ward, 2011). These consistent differences in behavior within individuals may be considered personality types (Bergmüller & Taborsky, 2010).

Personality, or stable interindividual differences that persist over time, is a topic of growing interest within the study of animal behavior, but an in-depth understanding of how personality affects individual social interactions is needed (Gosling, 2008; Webster & Ward, 2011). Personality research with social animals has focused on the effect that individual personalities have on the group as a whole. Different personalities in groups of great tits (*Parus major*) account for high cohesiveness and exploration when foraging (Aplin et al., 2014).

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When studying animals that live in social communities, it is important to consider them not only as a group but also as many individuals with personal relationships. Some personalities are more advantageous than others in specific situations (Aplin et al., 2014; Dall et al., 2004; Gosling, 2008; Sih et al., 2004) and in interactions with other individuals as well (Wolf & Weissing, 2012). Personality affects not only how individuals interact with each other but also how individuals interact with unfamiliar environmental changes. Certain personality traits are correlated with responsiveness to novel objects. Male great tits that are more aggressive tend to be more explorative and interactive with novel situations and objects (Sih & Bell, 2008; Verbeek et al., 1994).

Although much of the research exploring interactions of personalities within groups of social species examines individuals, a less commonly explored dynamic is that of personality similarities and differences within dyads (Webster & Ward, 2011). Whereas some activities require the participation of a group, others only require cooperation between two individuals including rearing of young, conflict resolution, foraging, and mate acquisition (Connor et al., 1992; Gabriel & Black, 2012; Massen & Koski, 2014; Schuett & Dall, 2009).

Variation of each individual's personality within the dyad may influence the outcome of a cooperative task. Steller's jays (*Cyanocitta steller*) tend to partner with mates who display similar behaviors as themselves, and these pairs tend to have more success reproducing and rearing chicks. No matter the parenting strategy used by a breeding pair, the success rate stays high as long as both birds within the pair have similar behavioral repertoires (Gabriel & Black, 2012). Personality also plays a role in cooperative problem solving in rooks (*Corvus frugilegus*). Scheid and Noë (2010) found that a dyad comprised of two shy individuals were less successful in completing a cooperative task for food in comparison to dyads that contained at least one bold individual. When animals forage in pairs, it is often the case that the boldest individual will assume the role of leader and will encourage the dyad to explore more than the individuals would have done alone. Higher rates of exploration results in higher quantities of food acquired; therefore, it is important for shy individuals to find a bolder partner. In stickleback fish, shy individuals are less likely to continue seeking a partner after a proposition has been rejected, whereas bold animals are undeterred and thus more likely to find a conspecific to partner and obtain food (Nakayama et al., 2012).

In the wild, dolphins are social but nomadic and live in fission-fusion societies. In this form of social structure, the individuals in any one pod are constantly changing as multiple pods cross paths (Mann et al., 2000). However, it is common for certain individuals to form long-term bonds with each other and become dyads that travel and change pods together (Connor et al., 1992). Similarly, dolphins in human care also form long-term dyadic relationships (Moreno, 2017). Both types of dolphin populations form social bonds and hierarchies. However, how this social organization is determined among the pod remains unknown (Highfill & Kuczaj, 2010). This consistency in social behavior across wild and managed care populations makes dolphins in managed care ideal subjects for research on cooperation. The similarities of affiliative behavior between the two populations could mean that the relationship variables found among dyads in managed care are generalizable to wild populations as well. Bottlenose dolphins that are kept in human care are often trained to perform behaviors as synchronous pairs; however, experimental inquiries into bottlenose dolphin cooperative behavior are few (Jaakkola et al., 2018; Kuczaj et al., 2015).

Cooperation has been tested in Asian elephants (*Elephas maximus*; Plotnik et al., 2011), chimpanzees (Chalmeau, 1994), orangutans (Chalmeau et al., 1997), and spotted hyenas (*Crocuta crocuta*; Drea & Carter, 2009) by having two animals complete a task in which they must simultaneously pull ropes in order to receive a food reward. Social and cognitive research with bottlenose dolphins suggests that this species should also be able to successfully cooperate to solve a problem (Connor et al., 1992; Kuzcaj & Walker, 2012); however, an experimental method to test spontaneous cooperation through rope-pulling in an aquatic environment was only recently devised (Kuczaj et al., 2015).

Kuczaj et al. (2015) investigated a novel problem-solving task with three populations of bottlenose dolphins in managed care. Each group was presented with a cylindrical apparatus that required the dolphins to pull a rope on either end to release a food reward. This task encouraged cooperation to obtain the fish inside. When the task was presented to a group of six dolphins, two dominant adult males spontaneously learned the task and promptly monopolized the apparatus. Although they cooperated successfully, the reason for their success compared to other populations was not assessed, although personality may have been a factor. Since Kuczaj et al.'s study, other research has investigated dolphin understanding of cooperation (Jaakkola et al., 2018).

We sought to replicate the Kuczaj et al. (2015) experiment with five pairs of dolphins who had previous experience working together and to elaborate on that study by examining if personality differences existed in pairs that cooperate versus those that do not. Personality profiles for each of 10 bottlenose dolphins were compiled using surveys completed by the resident trainers. The dolphin pairs were presented with the apparatus that could be opened cooperatively. Personality traits were correlated with categories of behaviors that were observed during trials. We hypothesized that dyadic success in the cooperative task would differ based on specific personality traits of individuals.

Method

Subjects and Housing

Subjects included 10 Roatan Institute for Marine Sciences (RIMS) dolphins, eight males, two females (see Table 1). In the experiment, dolphins worked in pairs created by the facility comprised of individuals that train together on a regular basis including a training exercise called "tandem create" that requires them to cooperate and perform novel behaviors together in synchrony. Pairs are created by the facility based on birthing season or age.

Table 1

Dolphin pairs with sex and age

Pair Names	Sex	Age in years
Han Solo & Hector	M, M	>6, >13 (wild born)
Ronnie & Mr. French	M, M	14, 12
Bill & Ritchie	M, M	15, 13
Champion & Lenca	M, M	6, 6
Polly & Tilly	F, F	6, 6

The study was conducted at the dolphin housing facility of the RIMS located on Bailey's Key off the coast of Roatan, Honduras (see Figure 1). The lagoon contained 19 dolphins. It was enclosed on all sides by a wooden dock above water and netting below water. The enclosure included a beach and the water ranged from a depth of 0-7 m with an area of approximately 800 m^2. The natural enclosure included sand, coral, sea grass, and free-swimming fish. Testing occurred in the smaller enclosures reserved for individualized training (indicated by arrow in Figure 1).

Figure 1. **An aerial view of Bailey's Key.** Arrow points to testing enclosures.[1]

Materials

Personality Survey

A dolphin personality scale was used to quantify each dolphin's personality. The scale was derived from previous research by Kuczaj et al. (2012) that examined personality traits in two different contexts: dolphin interacts with dolphin and dolphin interacts with object (see Supplemental).

Each trait was rated on a 7-point Likert scale (see Supplemental). An average of the three raters' scores was calculated to give each dolphin one numeric value for each trait. In order to simplify the understanding of the results, trait ratings were reversed so that the most extreme expressions of the traits were represented by the largest value.

Apparatus

The problem-solving apparatus was a 43 cm long PVC pipe sealed on both ends with a cap, one of which was removable (see Figure 2). From each cap, a loop of soft, black rope protruded to allow the dolphins to grip the caps of the apparatus and pull them to open the device. The inside contained herring or capelin fish and ice as the food reward for opening the apparatus. Two GoPro Hero3 cameras were fitted to the apparatus. One GoPro Hero5 underwater and a Sony camcorder above water were used to record the sessions for coding purposes.

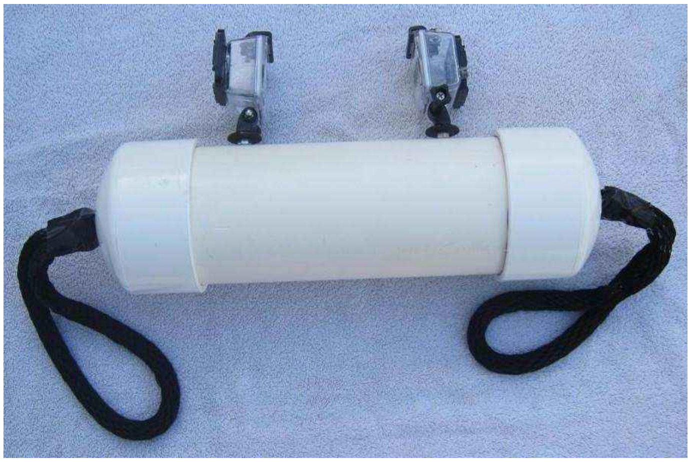


Figure 2. **Cooperative problem-solving apparatus.** (Photo courtesy of K. Winship)

[1] From the Roatan Institute for Marine Sciences. Copyright 2005 by Roatan Institute of Marine Sciences. Reprinted with permission.

Procedure

Personality

Personality surveys (see Supplemental) were distributed through Qualtrics, a web-based survey tool (Qualtrics, Provo, UT). Surveys were completed by the three staff members at the facility who were most familiar with each dolphin. The staff members included the assistant director, the head trainer, and each individual dolphin's primary trainer.

A profile for each dolphin was created by averaging the three ratings of each trait. Profile 1 included average ratings of all traits. Bill was the only dolphin for which none of the raters showed significant inter-rater reliability. To compensate for the lack of agreement and to preclude removing this pair from the study, Bill's profile was comprised of the ratings of Teri Bolton, head dolphin trainer and the rater with the most experience with Bill.

Training

Prior to testing, some dolphins were given a basic introduction to the apparatus to ensure comprehension of the mechanism and to alleviate any neophobia. Due to time restrictions and dolphin availability, only the following dolphins received training, each individually: Polly, 1 session; Tilly, 1 session; Han Solo, 3 sessions; Bill, 3 sessions; Ritchie, 3 sessions; Mr. French, 4 sessions; Ronnie, 5 sessions. A session lasted from 2-10 min based on trainer availability. All dolphins received individual training with the apparatus. Each session began with an exposure in which the dolphin was brought to an upright position in front of the floating platform or the dock. Bill & Ritchie and Mr. French & Ronnie were trained in pairs, side by side. The apparatus was filled with fish and ice in view of the dolphin, and the cap was placed on the end. The trainer then showed the end of the apparatus to the pair of dolphins before pulling on the rope and releasing the contents into the water.

After the exposure, the trainer refilled the apparatus and offered one of the loops to the dolphin. The dolphin was given a secondary reinforcement (whistle acting as a bridge) and primary reinforcement (fish) for touching the rope with his or her rostrum. The dolphin was reinforced for biting down on the rope. Once the dolphin was comfortable with biting the rope, the dolphin was reinforced for allowing the apparatus to free float while holding the rope. In the final training stage, the dolphin received reinforcement for pulling and opening the apparatus while the trainer held the rope on the other end. All dolphins except Polly and Tilly completed the final training stage, biting, and pulling the rope.

Testing

Testing was conducted in one or two sessions per day with each session consisting of one 10-min trial. The number of test trials for each pair varied based on availability and were as follows: Han and Hector, 7 trials; Bill and Ritchie, 6 trials; Mr. French and Ronnie, 7 trials; Champion and Lenca, 5 trials; Polly and Tilly, 2 trials. For each phase of the testing, the selected pair was located in a separate, enclosed training space attached to the back of the lagoon (see Figure 1). Testing was conducted in these training spaces to reduce any stress from displacement to a separate testing area. Activity on the docks surrounding the enclosure were ceased prior to and during the trials. The dolphins were capable of seeing and hearing dolphins in adjacent enclosures and passing boats. The dolphins received no form of reinforcement during trials, no direct communications were given to the dolphins, and trainers did not observe the trials once the apparatus was placed in the water. Prior to the trial, the exposure procedure from the training sessions was repeated. After the contents were consumed, the apparatus was reloaded, thrown into the water, and was retrieved at the end of 10 min. The end of each trial was followed by the opening of the apparatus in front of the dolphins, and the food contents were poured into the enclosure for the dolphins to consume.

Coding

Videos of the trials were scored using all-occurrence sampling for both interactive and affiliative behavior (Altmann, 1974; Kuczaj et al., 2015). Behaviors were grouped into two categories: individual interaction with apparatus and paired interaction with apparatus (see Table 2). Interactions were defined as physical contact with the problem-solving apparatus. Number of behaviors per category were determined for each dolphin. As each pair completed a different number of test trials (see Table S1 for number of trials per pair), the number of behaviors in each category was divided by the number of trials.

Results

Inter-Rater Reliability

For each dolphin's personality profile, inter-rater reliability was determined between the three raters using Kendall's coefficient of concordance (Kendall's W). The analyses showed that all three raters were reliable for nine of the ten dolphins with a $W \geq 0.80$.

Twenty percent of the videos were randomly selected to be coded by the researcher and a research assistant for reliability. Inter-rater reliability for video coding was assessed using Cohen's kappa (κ) and was accepted with a minimum of .80. All videos met the minimum criteria of $\kappa = 0.81$ with an average $\kappa = 0.87$, $SD = 0.04$.

Problem Solving

No dolphin dyads succeeded in opening the apparatus to obtain the food. Dolphin behaviors and traits were analyzed for interactions with the apparatus.

Personality

Personality in relation to interactions between dolphins and the apparatus was analyzed. The average frequency of behaviors in each category for each individual are shown in Table 2. The total frequency of each behavioral category per dolphin is shown in Table S1.

Table 2

Average Frequency of Interactions in Each Category for Each Individual

Dolphin	Individual Interactions with Apparatus	Paired Interactions with Apparatus
Hector	6.29	1.86
Han Solo	5.00	1.86
Mr. French	18.71	3.29
Ronnie	19.86	3.29
Bill	12.17	0.67
Ritchie	14.33	0.67
Polly	44.50	1.00
Tilly	19.00	1.00
Champion	33.20	2.80
Lenca	29.30	2.80

Pseudo-Couple Analysis

To examine the possibility that the individuals in the tested dyads were more or less similar than other potential pairings of individuals, a pseudo-couple analysis was conducted (Kenny et al., 2006). A dyadic index was created for each tested dyad by averaging the difference between individual ratings of traits from the personality surveys. A dyad level measure of pseudo-couple dissimilarity was determined by averaging the dyadic index of all other possible dyads (see Table 3).

A paired-samples *t*-test found no significant difference between the dyadic indices ($M = 0.99$, $SD = 0.44$) and the dyad level measures of pseudo-couple dissimilarity ($M = 1.14$, $SD = 0.27$), $t(4) = -0.37$, $p = 0.60$.

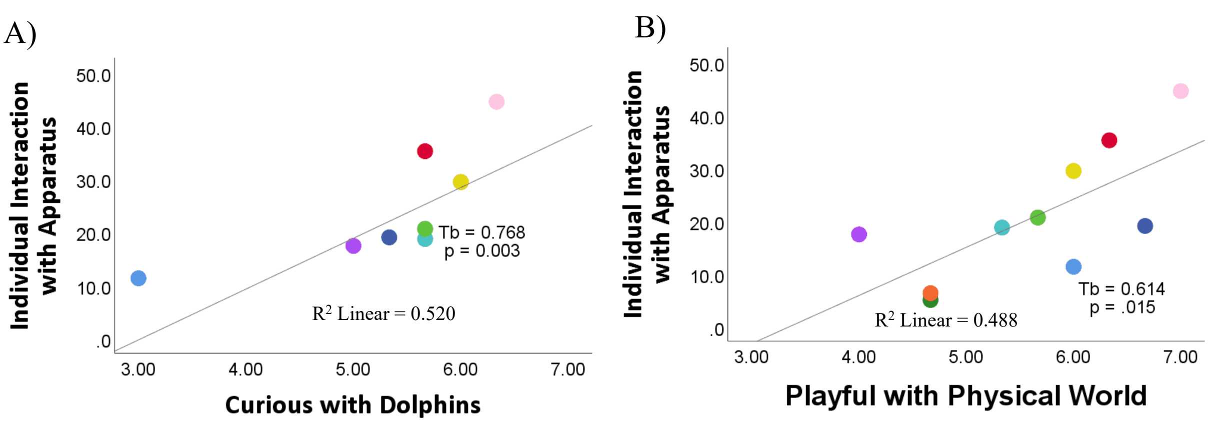
Table 3

Pseudo-Couple Analysis Values

Dolphin	Dyadic Index	Dyad Level Measure of Pseudo-Couple Dissimilarity
Hector and Han Solo	0.90	1.07
Mr. French and Ronnie	0.60	0.87
Bill and Ritchie	1.73	1.49
Polly and Tilly	1.00	0.92
Champion and Lenca	0.71	1.35

Comparison of Behaviors and Personality

Comparisons of personalities to the behavioral contexts in the two behavior categories (Table 2) showed moderate to strong positive correlations between "individual interactions with apparatus" and "playfulness" when interacting with the physical world; "individual interaction with apparatus" and "curiosity" when interacting with other dolphins and "paired interaction with apparatus" and "affiliative" (see Figure 3).



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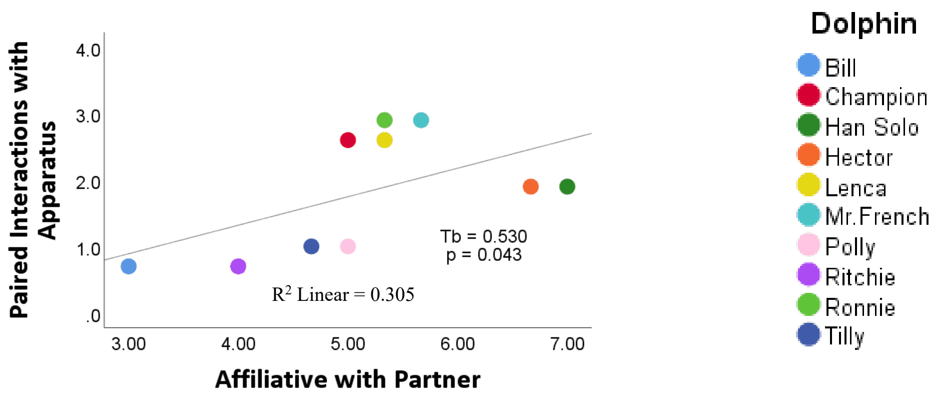

Figure 3. **Scatterplot showing the strength of relationship between (A) individual interactions with the apparatus and the trait curiosity in the context of dolphin interacts with dolphin, (B) individual interactions with the apparatus and the trait playfulness in the context of dolphin interacts with physical world, and (C) paired interactions with the apparatus and affiliation with his/her partner.**

Discussion

We found that none of the dolphin dyads successfully cooperated to solve the task. The dolphins did interact with the apparatus individually and as pairs. We further analyzed these behaviors in light of the dolphins' personality profiles. We found a number of relationships between personalities and behaviors. The more playful a dolphin was with the physical world, the more likely he/she was to interact with the apparatus in their enclosure. Highly affiliative pairs had the highest frequency of paired interactions with the apparatus. There was a positive correlation between individual interactions with the apparatus and curiosity about other dolphins, showing that the more curious an individual was about other dolphins, the more likely he/she was to interact with the apparatus alone. However, there was no correlation between apparatus interactions and curiosity about the physical world. Other dolphins may increase interaction with the apparatus through stimulus enhancement.

We conducted a pseudo-couple analysis to determine if a different dyad composition would have resulted in pairs with different personalities. The analysis showed that none of the possible pairing of dolphins significantly differed in their personality differences from randomly paired dyads. This similarity may be due to restrictions imposed by managed care on the animals' temperaments. As these dolphins are used in a swim-with-the-dolphins program, aggressive or shy behaviors are not reinforced, which might result in individuals that behave more boldly in some contexts and individuals that affiliate more with others. This truncation of the personality range of the dolphins may account for the similarity of any random dyad.

Four of the dolphins showed interesting individual differences. Three dolphins, Mr. French, Ronnie, and Champion, were observed swimming upside down past the apparatus. In addition to Champion's upside-down swims, he and his partner displayed bubble streams when passing by the apparatus. Champion and Lenca were the youngest males used in this study at only 6 years old. The two similarly aged females were not observed blowing bubbles, so another explanation could be a sex difference. However, since only two trials were run with the females, we do not have enough data for a definitive explanation.

There are a few possible reasons why none of the dolphins in this research cooperatively solved the problem. First, there may not have been enough time for the dolphins to solve the problem. Sessions were scheduled to run for four weeks; however, social dynamics and reproductive cycles resulted in a delay of data collection. We supplemented our lost sessions with exposure and training sessions with the individuals that did move to the back pens during the first week. None of the dolphins were taught how to open the apparatus cooperatively; the sessions focused on acclimating the dolphins to the apparatus floating near his/her face as well as teaching them to hold and pull the rope individually.

Second, a possible confound that might have affected the dolphins' failure to open the apparatus was the procedure of dumping the contents immediately before and after each trial. The opening of the apparatus and the expulsion of the fish preceding the trials was similar to the exposure trial used in Kuczaj et al. (2015) and served to show the subjects that there was food inside the tube and how it could be accessed. The dolphins in the Kuczaj et al. (2015) study only received the reinforcement from the task if they were successful. Post-trial emptying of the contents was done in the current study to prevent any undue aggression from frustration. An additional reason for this procedure was that the food contents inside the apparatus were part of the dolphins' daily food intake. The lead trainer also felt that this procedure would act as another example of how the apparatus worked. However, this procedure may have acted as reinforcement that could have taught the subjects that a food reward would be gained following a time delay and that interaction with the apparatus was not necessary for reinforcement. This procedure may have reduced the dolphins' motivation to open it themselves.

Third, the dolphins used in the Kuczaj et al. (2015) study were regularly exposed to non-natural environmental enrichment, such as toys, while the RIMS dolphins rarely received any stimulus that cannot be found naturally (i.e., naturally occurring flora and fauna) in their enclosure. It is possible that this previous exposure to a similar stimulus made the dolphins from the 2015 study more willing to interact with the apparatus (K. Winship, personal communication).

Fourth, the task itself may not require cooperation. King et al. (2016) felt that the task was more competitive than cooperative because it required force to be applied in opposite directions. Previous rope-pulling tasks required force to be applied in the same direction. This is a valid argument; however, the pair that successfully opened the apparatus in Kuczaj et al. (2015) did so while swimming together in the same direction and continued to carry it while swimming together after opening. Further, the pair shared the food with each other, all of which suggests that the task was cooperative (K. Winship, personal communication, March 14, 2018). However, such cooperation has been seen in wild bottlenose dolphins who have been known to herd fish, which sometimes requires them to approach each other from opposite directions, showing that cooperation does not always require movement in the same direction (Gazda et al., 2005).

Further evidence for cooperative problem-solving comes from Jaakkola et al. (2018), who trained dolphins to participate in a cooperative button pressing task. The dolphins were required to push two buttons simultaneously to receive reinforcement. They were capable of waiting for a partner dolphin and inhibited their own response until the partner arrived. These results demonstrated that dolphins were aware of the partner's role during cooperative interactions and adjusted behavior accordingly. Personality differences may not have been evident in this task as the animals were initially trained to work together.

There are several avenues for future research following this study. First, this cooperative problem-solving task should be given to a larger sample of paired individuals. Additionally, this apparatus should be exposed to a wider variety of bottlenose dolphins for a longer period of time. One pair did successfully solve the problem in the original study by Kuczaj et al. (2015), which provides some evidence that this species does have the capability to succeed in this task. Other future studies could continue to examine the relationships between social behaviors and personalities.

Although the dolphins did not cooperate to open the apparatus, the interactive and affiliative behaviors analyzed may be precursors to cooperation. Our research provides information on how personalities can predict affiliative and interactive behaviors in bottlenose dolphins. This information about dolphin personality not only adds to our knowledge about this species but could be useful in dolphin welfare when pairing animals or exposing them to enrichment items.

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