

Bottlenose Dolphins' (*Tursiops truncatus*) Theory of Mind as Demonstrated by Responses to their Trainers' Attentional States

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The present study examined the ability of dolphins to follow the gestural signs presented by human trainers in various attentional states in order to understand the social cognition of dolphins. The human trainers enacted the gestural signs by orienting their bodies and heads in different directions. If the dolphins were attending to the attentional state of the human trainers, their performances would be affected by the orientation of the head only. Results showed, however, that the dolphins' behaviors were controlled by the orientation of the trainers' bodies rather than that of their heads. Two additional tests further supported the minimal impact of head orientation on responses to human gestural signs. The present results might be influenced by the current experimental setting, thus we need further efforts to accumulate empirical evidence on social cognition in dolphins.

Since the proposal of the "theory of mind" by Premack and Woodruff (1978) and the "Machiavellian Intelligence Hypothesis," or social intelligence hypothesis, by Byrne and Whiten (1988), many researchers have focused on cognitive abilities in the social domain (i.e., social cognition and/or social intelligence; e.g., Whiten & Byrne, 1997). In particular, studies with nonhuman primates such as great apes have demonstrated the extent and limits of the social-cognitive abilities of these species (Call & Tomasello, 2008; Tomasello, Call, & Hare, 2003; see also Penn & Povinelli, 2007; Povinelli & Vonk, 2003). Recently, the number of empirical studies on different primate taxa has gradually increased, with the majority of comparative social cognition studies limited to nonhuman primates, primarily because the social intelligence hypothesis is based on the long-term efforts of many primatological studies (e.g., Humphrey, 1976). However, the social intelligence hypothesis is not anthropocentric. If several criteria are met in a given species, social intelligence can be expected to evolve in that species. These criteria include large brains relative to body size, large and relatively permanent

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social groups, and a long life span. In addition to some primate species, corvids, bats, elephants, hyenas, and cetaceans meet those criteria (Bugnyar, 2007; Byrne & Whiten, 1997; Clayton, Dally, & Emerey, 2008; Kuczaj, Gory, & Xitco, 2009; Marino, 1996; de Waal & Tyack, 2003; Wilkinson, 2003).

Needless to say, this social intelligence hypothesis remains controversial with regard to many species (great apes: Call & Tomasello, 2008; Penn & Povinelli, 2007; Povinelli & Vonk, 2003; Tomasello et al., 2003; dolphins: Manger, 2006; Marino et al., 2008; hyenas: Holekamp, 2007; dogs and wolves: Hare & Tomasello, 2005; Topal et al., 2009; Udell, Dorey, & Wynne, 2008). These controversies might be attributable to the lack of empirical evidence collected in reliable experimental contexts, especially with respect to non-primate species such as dolphins. Experimental studies on social cognition/intelligence in nonhuman primates have been based primarily on the framework developed in Baron-Cohen's (1995) "mindreading system," which focuses on whether animals understand the meaning of the direction of another's gaze, whether they understand the meaning of another's intentionality, how they share attention with others, and whether they have a (representational) "theory of mind." Empirical data on each specific research question have been obtained from captive individuals (e.g., Tomonaga, 2006). For example, chimpanzee infants exhibit a direct-gaze preference at around 2 months of age (Bard, Myowa-Yamokoshi, Tomonaga, Tanaka, Costal, & Matsuzawa, 2005; Myowa-Yamakoshi, Tomonaga, Tanaka, & Matsuzawa, 2003), leading to the ability to follow human gaze at around 1 year of age (Okamoto, Tomonaga, Ishii, Kawai, Tanaka, & Matsuzawa, 2002). Adult captive chimpanzees have a much more sophisticated ability to follow gazes and engage in joint attention (Call, Hare, & Tomasello, 1998; Itakura & Tanaka, 1998; Tomasello, Hare, & Agnetta, 1999), but are limited in comparison with humans (Okamoto, Tanaka, & Tomonaga, 2004). Chimpanzees also adapt their behavior in reaction to the perceptual and/or attentional states of humans and conspecifics. They change their behaviors when the other individual cannot see what they can see (Hare, Call, & Tomasello, 2001; Povinelli, Boysen, & Nelson, 1990; Povinelli & Eddy, 1996). Interestingly, these abilities are more prevalent in competitive than in cooperative situations (Hare & Tomasello, 2004; Hare et al., 2001). This tendency is known to be opposite to that demonstrated by dogs, a species whose behavioral traits in a social domain (such as cooperation or less aggressiveness) have been selected by humans through breeding (e.g., Hare & Tomasello, 1999; Wobber & Hare, 2009). Research on sensitivity to the attentional state of the others, including human experimenters, has shown that chimpanzees demonstrate differential requesting behaviors that vary according to human attentional states (Hattori, Tomonaga, & Fujita, in press; Hostetter, Cantero, & Hopkins, 2001; Hostetter, Russell, Freeman, & Hopkins, 2007; Kaminski, Call, & Tomasello, 2004; Povinelli & Eddy, 1996). For example, Hattori et al. (in press) found that chimpanzees engaged in more requesting behaviors when the human experimenter held the food and gazed directly at them than when he looked away from them or did not hold the food items (*cf.* Hattori, Kuroshima, & Fujita, 2007, 2009).

In contrast to the substantial number of laboratory studies on social cognition/intelligence in nonhuman primates, data on captive delphinid cetaceans such as bottlenose dolphins are quite limited, especially in comparison with the data obtained from these animals with respect to other research topics such as vocal communication, echolocation, and visual cognition (see Kuczaj et al., 2009; Morisaka, 2007, 2009; Pack & Herman, 2006). Within this relatively circumscribed literature, Pack and Herman (2004, 2007; Herman, Abichandani, Elhajj, Herman, Sanchez, & Pack, 1999) successfully demonstrated that well-trained bottlenose dolphins utilized human pointing and gaze cues during the object-choice task that is frequently used with nonhuman primates (e.g., Itakura & Tanaka, 1998; Okamoto-Barth, Tomonaga, Tanaka, & Matsuzawa, 2008). Tschudin, Call, Dunbar, Harris, and van der Elst (2001) also reported that dolphins understood untrained directional cues presented by a human trainer. Furthermore, Xitco, Gory, and Kuczaj (2001) reported that the two captive dolphins at Walt Disney World spontaneously emitted pointing-like responses to human trainers by moving their own heads in the direction of an object of interest. Xitco, Gory, and Kuczaj (2004) also tested the same dolphins under conditions similar to those used in studies of sensitivity to human attentional states in nonhuman primates (e.g., Hattori et al., in press; Kaminski et al., 2004). When the trainer looked at the dolphins, the dolphins pointed more frequently to the baited jar than when the trainer showed his back to the dolphins; these results are comparable to those obtained from chimpanzees.

These experimental situations are, however, rather exceptional, applying to captive dolphins living in the Port of Nagoya Public Aquarium in Japan. As a result of well-controlled husbandry training, these dolphins have always followed the trainers' explicit gestural signs. For example, as shown in Figure 1, one trainer apparently controlled two dolphins simultaneously by using an explicit gestural sign (with the right hand) with the right individual and by using "eye contact" with the left individual. This picture seems to present a good example of the dolphin's ability to follow human attentional states, an ability that may lead them to a "theory of mind." Indeed, the role or importance of eye contact is sometimes emphasized in the training of dolphins (e.g., Pryor, 1981), and some trainers believe that eye contact serves a special function. However, no experimental studies have demonstrated the critical role of eye contact during performance training using gestural signs. Thus, this study used a similar experimental condition but a different functional context from that used for chimpanzees (Hattori et al., in press; Kaminski et al., 2004) to test how dolphins responded to the signs presented by human trainers with various attentional states. The attentional states of the human trainers were manipulated with changes in the orientation of their bodies and/or heads; these were positioned either synchronously or independently in relation to the dolphins.



Figure 1. A trainer controlling two dolphins at the Port of Nagoya Public Aquarium. He used his right hand to show the sign for “hold” to the dolphin on the left in the picture while making eye contact with the dolphin on the right.

Method

Participants

Four captive adult male bottlenose dolphins (*Tursiopus truncatus*), Eagle, Tino, Quick, and Peace, participated in the present experiment. They were all wild-born and had lived in the Port of Nagoya Public Aquarium (PNPA) in Nagoya City, Japan for approximately six years. Their estimated ages ranged from 9 to 12 years, and they lived as a group in a pool (elliptical shape, 16 m × 11 m and 6.5 m in depth). They usually received four 15-minute sessions of husbandry, performance, and cognitive training, including matching-to-sample training, per day (Saito et al., 2007, Uwano, Saito, Kamiya, Minami, Tomonaga, & Uchida, 2008). However, they did not participate in public performances during the study period. The participants were fed approximately 9 kg of fish during the training sessions, which were routinely conducted by nine trainers.

Procedure

Preliminary training. During the regular daily training sessions, one trainer controlled one or more dolphins. In the present experiment, however, two trainers led the experimental sessions in which the dolphins were initially trained to follow the basic experimental procedures. As shown in Figure 2, two trainers, A and B, stood at opposite sides of the pool. At first, one or more dolphins waited at trainer A’s side in response to the “hold” gesture enacted by A (see Fig. 1). A then instructed one of the dolphins swim to trainer B’s side while the other dolphin(s) waited. When the dolphin arrived at B’s side, B presented a gestural sign to the dolphin. If the dolphin performed an appropriate action in response to the sign, trainer A whistled and the dolphin swam back to A’s side,

where he was rewarded with a piece of fish. Dolphins alternated in their participation in training trials, and 10 gestural signs, all of which had been learned during the standard training (see Fig. 3), were presented randomly to the dolphins. This preliminary training continued for approximately one month.

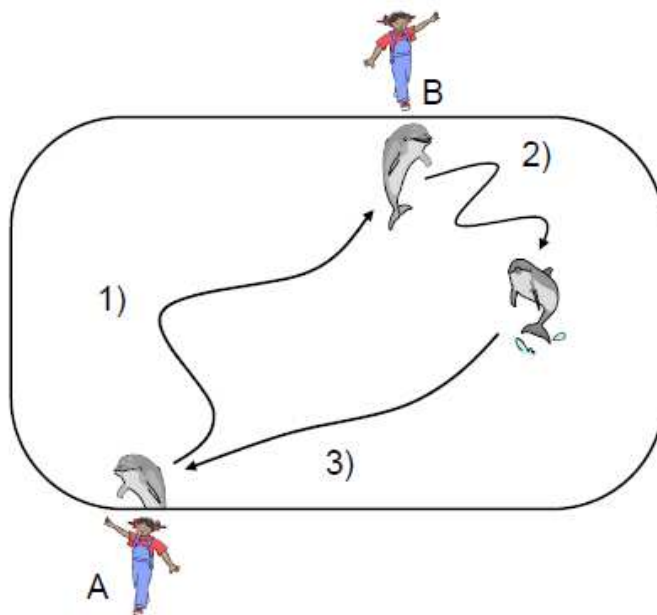


Figure 2. Schematic flow of the trial. 1) A dolphin swam from trainer A to trainer B in response to the gestural sign by A; 2) B presented a gestural sign to the dolphin, and the dolphin performed the corresponding action; and 3) following a correct response, A whistled, and the dolphin returned to B's side and was rewarded with a piece of fish.

Rotation test. The first and main test series, the rotation test, was started following the preliminary training. This testing involved preparation of one baseline and three test conditions that differed according to the body and/or head orientations of trainer B *vis-à-vis* the dolphins. During the baseline trials, B stood in front of the dolphin, facing him straight on (0°). Figure 3 shows several examples of baseline and test trials. Under the *body + head* condition, B's body and head were synchronously oriented away from the dolphin at an angle of 45° , 90° , or 180° . Under the *body rotation* condition, B's body was directed away from the dolphin at an angle of 45° or 90° , his head was directed toward the dolphin, and he maintained constant eye contact with the dolphin. Under the *head rotation* condition, B's body was always oriented to the dolphin but his head was positioned 45° or 90° away from the dolphin. It should be noted that 0° baseline trials were randomly assigned to 0° trials for each test condition. Each session consisted of 12 baseline and 4 test trials, and each dolphin received 28 sessions (336 baseline and 112 test trials). The dolphins received 16 trials under each rotation condition in the test trials. Trainer A judged the correctness of the dolphins' actions, and two types of error responses were possible. The first type of error occurred when the dolphin performed an action that differed from that signaled by the gestural sign, and the second occurred when the dolphin returned to trainer A's side without performing any action. If the dolphin made an error, the whistle was not sounded and the trainers stepped 1–2 m away from the side of the pool. This contingency was applied during both baseline and test trials.

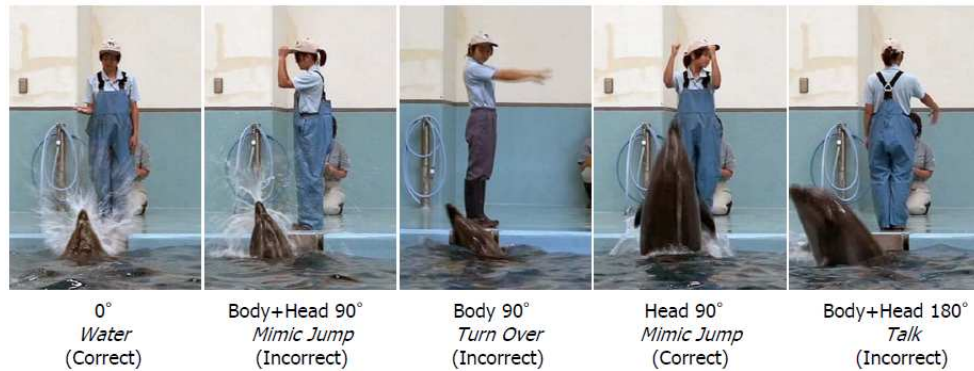


Figure 3. Examples of gestural signs during the baseline (leftmost panel) and test trials. Correct and incorrect designate whether the dolphins' actions were appropriate responses to the signs.

Bucket test. To further test the role of head cues, two of the dolphins (Eagle and Tino) received an additional test series comprised of the Bucket Test, in which trainer B's head was fully covered by an opaque blue bucket while his/her body was oriented toward the dolphins (Fig. 4, cf. Povinelli & Eddy, 1996). This test was conducted to completely remove gaze information. To habituate the participants to the bucket in this setting (it had previously been used to contain the fish reward), it was placed near trainer B during the baseline trials. Each session consisted of 12 baseline and four test trials. Each dolphin received six sessions (i.e., 24 test trials in total).

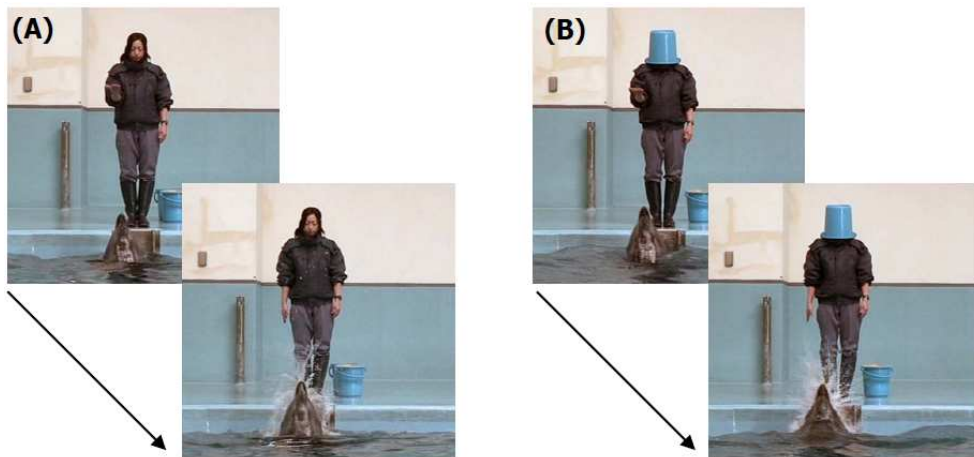


Figure 4. Examples of the bucket test. (A) baseline trial, (B) test trial.

Two-person test. All four dolphins also received a series of control tests in the form of the two-person test. During these tests, the two trainers stood close together (see Fig. 5C), and the trainer in the back presented gestural signs while the trainer in the front was oriented 0°, 90°, or 180° away from the dolphins (Fig. 5A, B). In this test, especially under the 180-degree condition (Fig. 5B), normally oriented gestures were presented with the front-side trainer's head (also with body) rotated at a 180° angle to verify the role of head orientation in this test setting. Each dolphin received 20 sessions of testing, consisting of 12 baseline trials (in which the trainer in front stood toward the dolphin) and four test trials. The dolphins received 40 trials under each angle condition (90° and 180°).

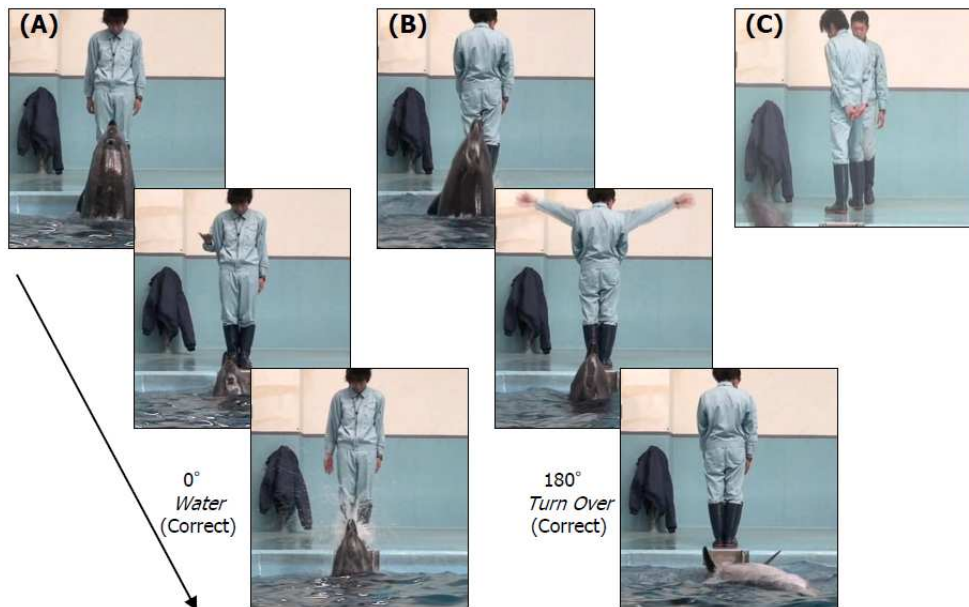


Figure 5. Two examples of the two-person test. (A) 0° test, (B) 180° test, (C) two trainers stood together in these trials.

Inter-rater reliability

All behaviors of the dolphins were video-recorded. Another coder who was unaware of the main purpose of the current study used these video clips to check the dolphins' behaviors in 16% of the trials. The main and the additional coders agreed in 96% of the cases, and Cohen's *kappa* was 95%, which is regarded as excellent.

Results

Rotation test

All dolphins exhibited very accurate responses when trainer A presented the gestural signs at 0° (96% correct). Figure 6 shows the mean percent of correct responses under each condition. All dolphins exhibited clearly better performances under the head-rotation condition than under the other two conditions. The horizontal dotted lines on the left graph show the significance levels ($p = 0.05$) of the binomial tests when the chance level was set conservatively at 50% (correct or incorrect). The right part of this figure shows the results averaged across dolphins. Statistical analysis was initially conducted only on the data obtained in the body + head condition because only this condition included four different rotation angles (0°, 45°, 90°, and 180°). Repeated-measure two-way [4 rotation angles \times 2 testing blocks (first and second halves)] analysis of variance (ANOVA) showed a significant main effect for rotation angle ($F(3,9) = 6.46, p < 0.05$), but no significant main effect for testing block ($F(1,3) = 1.40, p = 0.322$) (67% vs. 61%), or two-way interactions ($F(3,9) = 1.65, p = 0.247$). *Post-hoc* multiple comparisons

using Ryan's method showed that the dolphins performed significantly better in the 0° (baseline) trials than in the 90° and 180° rotation trials ($p < 0.05$).

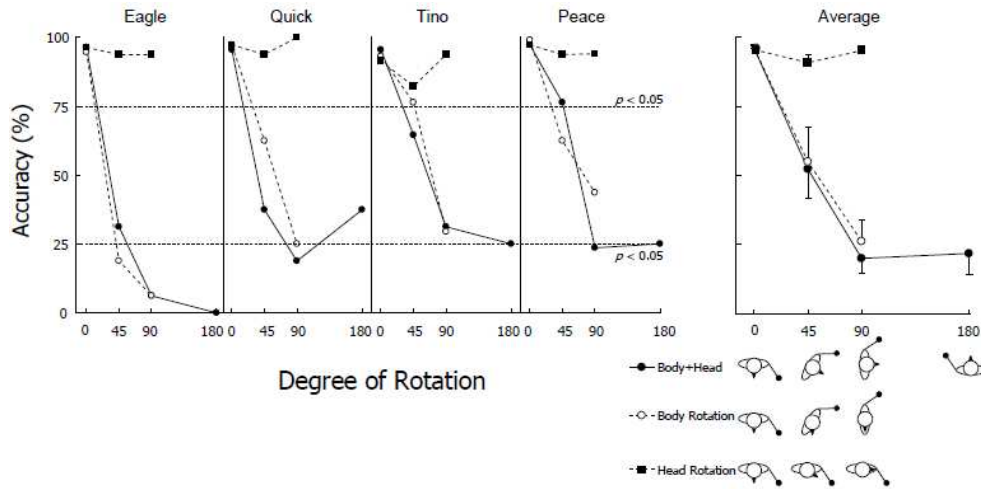


Figure 6. Individual and mean accuracies of the rotation test. Horizontal dotted lines represent the significance level ($p < 0.05$) of binomial tests.

The second statistical analysis included all the conditions, but the 180° trials under the body + head condition were excluded. The results of three-way [3 conditions \times 3 rotation angles (0°, 45°, and 90°) \times 2 testing blocks] ANOVA showed significant main effects for testing condition ($F(2,6) = 14.93, p < 0.01$) and rotation angle ($F(2,6) = 21.51, p < 0.01$), but no significant effect for testing block, ($F(1,3) = 5.56, p = 0.10$ (83% vs. 75%)). Furthermore, the two-way interaction between condition and rotation angle was significant ($F(4,12) = 14.98, p < 0.001$), but the other two-way interactions ($F_s(2,6) < 3.94, p_s > 0.08$) and the three-way interaction ($F(4,12) = 1.55, p = 0.251$) were not. *Post-hoc* tests of simple main effects revealed that the effect of rotation angle was significant under the body + head ($F(2,18) = 29.62, p < 0.001$) and body conditions ($F(2,18) = 25.30, p < 0.001$), but not under the head-rotation condition ($F(2,18) = 0.19, p = 0.828$).

As shown in the left part of Figure 6, some individual differences in performance also emerged. Eagle committed more errors (42%, excluding the 0° baseline trials) than did the other three dolphins (62% on average). To analyze the individual differences further, Figure 7 shows the patterns of errors under all test conditions (averaged across rotation angles, excluding the 0° trials) for each dolphin. This figure shows that all dolphins exhibited the same error patterns under the body + head and body-rotation conditions. Furthermore, Eagle showed more “return” errors (77% of all errors, $p < 0.01$, binomial tests) than did the other dolphins (46%, not significant, binomial tests).

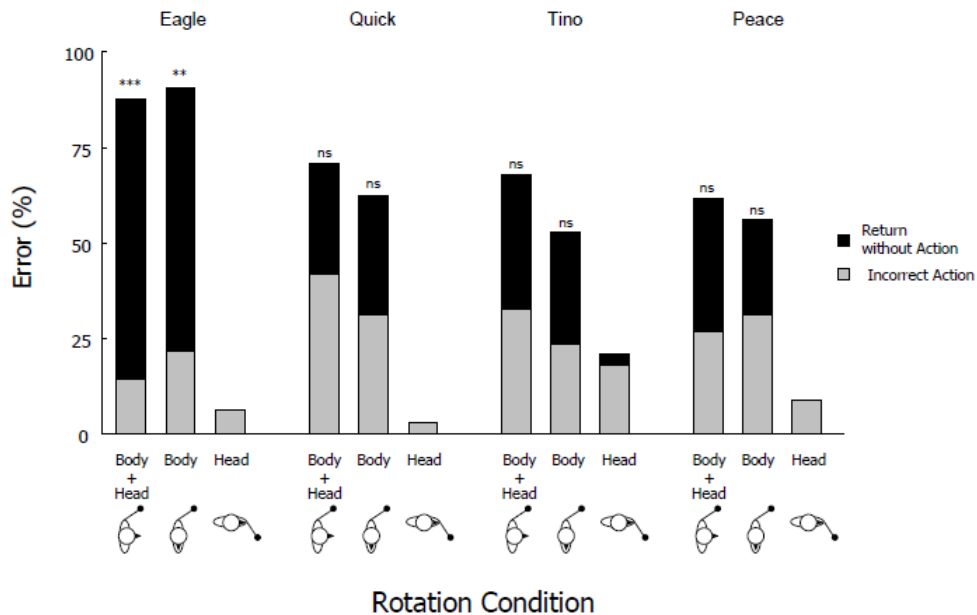


Figure 7. Error analysis of the rotation test for each dolphin. ***, $p < 0.001$; ns, not significant (binomial tests).

Bucket test

Having the trainer wear the bucket did not affect the dolphins' performances. Eagle achieved a 99% correct response rate in the baseline and a 100% correct response rate in the test trials, and Tino performed at 100% and 92% correct, respectively.

Two-person test

Figure 8 shows the results of the two-person test. The results are superimposed on those from the rotation test. Horizontal dotted lines show the significance level ($p = 0.05$) of the binomial tests when the chance level was set conservatively at 50%, as in the rotation test. No dolphin changed his performance from that exhibited in the standard baseline trials when the two trainers stood in front. Furthermore, three of the four dolphins (Quick, Tino, and Peace) performed very accurately during the test trials. Mean accuracy for the test trials averaged across these three dolphins was 91%, which strongly suggests that the head-orientation cues had very little impact on their responses to the gestural signs. In contrast, Eagle's performance deteriorated when the trainer in front was not oriented to the front (11% correct on average). With only one exception, Eagle returned to trainer A without performing any action and thereby committed 71 errors during the 80 test trials. Eagle might have learned to distinguish contextual differences between baseline and test trials as a result of repeated exposures.

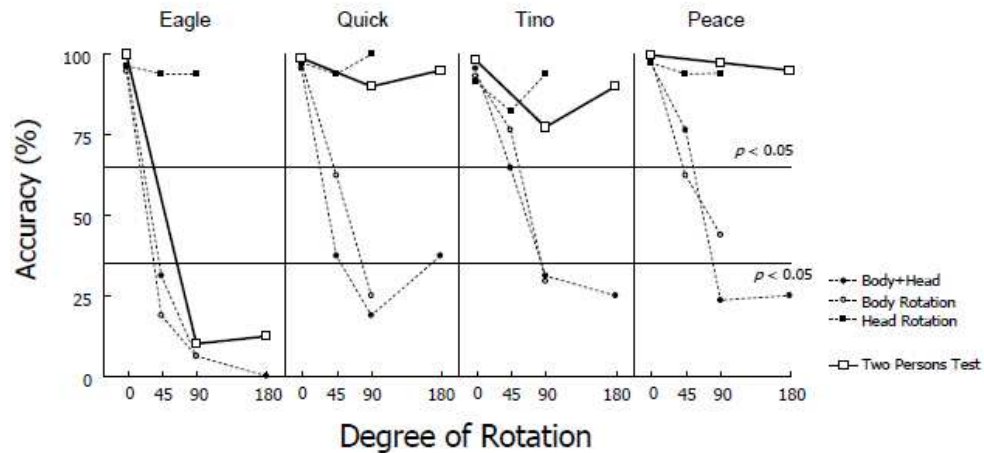


Figure 8. Individual scores on the two-person test. Horizontal dotted lines represent the significance level ($p < 0.05$, binomial tests) below and above chance (50%) level for the two-person test data. For comparison, the results from the rotation tests were also superimposed.

Discussion

In the present study, we tested the sensitivity to the human attentional state by captive dolphins when they followed the human signs for actions. Although some degree of individual differences emerged, the results of the first test of the experiment were quite decisive. Captive bottlenose dolphins in the PNPA paid no attention to the attentional states of the human trainers during the positive reinforcement training. Even when the trainer's head was directed away from the dolphins, they successfully followed the signs if they were presented at the right direction. Conversely, if the gestural signs were presented with averted directions, the dolphins' performance became worse even when the trainer's head was directed toward the dolphin. Furthermore, when the head was covered by the bucket to remove all the social information from the head, the dolphins' performances were still accurate. When the two trainers stood in alignment, whilst the trainer closest to the dolphin faced away and the other trainer stood facing the dolphin whilst simultaneously gesturing (Two-persons test), performances of the three of four dolphins were still unchanged. These results indicated that the dolphins seemed to only attend to the direction of the gestural signs but not the head direction of the trainer. These results are rather inconsistent with those of previous studies on dolphins in Western facilities (Herman et al., 1999; Pack & Herman, 2004, 2007; Tschudin et al., 2001; Xitco et al., 2001, 2004), which indicated that dolphins attended to human attentional states more carefully than did our dolphins. This discrepancy might be attributable to the differences in experimental contexts. All three previous studies were conducted under special conditions, whereas our experimental context was quite similar to that in which the daily husbandry and performance training were conducted, and it used the same basic gestural signs within a strict positive reinforcement procedure. Thus, our dolphins may have been extensively trained to follow only the gestures and not the

other subtle social cues exhibited by human trainers. Furthermore, Xitco et al. (2004) measured the occurrence of spontaneous responses to the human trainers, whereas our dolphins were supposed to follow the gestural signs made by an ostensibly inattentive trainer. This difference in experimental contexts might also have affected our results. Indeed, the dolphins tried to perform certain learned actions even when the trainers looked away from them, and three of four dolphins (excluding Eagle) performed *some* (correct or incorrect) actions during 79% of the test trials. Due to the limitation of the activities of the public aquarium, we could not prepare the special testing situations. If we test these dolphins not under the similar situation to the daily training but under the situations where the dolphins could show some spontaneous reactions, for example, playful interaction with humans, they would show the different patterns of results. Needless to say, this possibility should be tested in the nearest future.

The present results also illuminate the non-social but perceptual abilities of dolphins. Their performances deteriorated as a function of the rotation of gestures, which seemed related to their ability to engage in mental rotation (Herman, Kuczaj, Shaw, & Morrel-Samuels, 1990; Murayama & Tobayama, 1995; Shepard & Metzler, 1971) and to the viewpoint dependence and/or independence in visual object recognition (Biederman & Gerhardstein, 1993; Peissig, Young, Wasserman, & Biederman, 2000; Friedman, Spetch, & Ferrey, 2005; Spetch & Friedman, 2003; Watanabe, 1997). It is well known that object recognition deteriorates in both human and nonhuman animals when objects are rotated in a direction that differs from that depicted by the usual and familiar viewpoint. Herman, Morrel-Samuels, and Pack (1990) and Murayama and Tobayama (1995) preliminarily reported that bottlenose dolphins and beluga also showed evidence of mental rotation. Furthermore, Jokisch, Daum, and Troje (2006) used biological motion stimuli and reported viewpoint dependence among humans in perceptions of walking motions. In the present experiment, the performances of all the dolphins deteriorated when the gestural signs were presented at unfamiliar angles (i.e., other than 0°). These results can be considered as evidence for the viewpoint-dependent recognition of human actions by dolphins. Although Herman et al. (1990) reported that dolphins responded appropriately to degraded video images of gestural signs, including point-light displays, the processes by which dolphins recognize human gestural signs remain incompletely understood. Our results might contribute to the understanding of action recognition by dolphins. Future studies are necessary to further the understanding of dolphins' ability to recognize human actions (see also Kuczaj, Solangi, Hoffland, & Romagnoli, 2008). The results of this line of research will also benefit dolphin trainers (Herman et al., 1990).

Though preliminary, our results suggest that our bottlenose dolphins pay less attention to the trainer's attentional state under the typical training situation. However, it is still unclear whether such inattention is always observed in the other, less controlled situations. It is necessary to accumulate the empirical data of dolphin's attention in a various kind of social situations to address these issues.

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