

The Dolphin's (*Tursiops truncatus*) Understanding of Human Gazing and Pointing: Knowing *What* and *Where*

Adam A. Pack and Louis M. Herman

The Dolphin Institute, University of Hawaii at Manoa, and Kewalo Basin Marine Mammal Laboratory

The authors tested whether the understanding by dolphins (*Tursiops truncatus*) of human pointing and head-gazing cues extends to knowing the identity of an indicated object as well as its location. In Experiment 1, the dolphins Phoenix and Akeakamai processed the identity of a cued object (of 2 that were present), as shown by their success in selecting a matching object from among 2 alternatives remotely located. Phoenix was errorless on first trials in this task. In Experiment 2, Phoenix reliably responded to a cued object in alternate ways, either by matching it or by acting directly on it, with each type of response signaled by a distinct gestural command given after the indicative cue. She never confused matching and acting. In Experiment 3, Akeakamai was able to process the geometry of pointing cues (but not head-gazing cues), as revealed by her errorless responses to either a proximal or distal object simultaneously present, when each object was indicated only by the angle at which the informant pointed. The overall results establish that these dolphins could identify, through indicative cues alone, what a human is attending to as well as where.

Keywords: dolphin, gazing, pointing, joint attention

Joint attention is considered an important component of social cognition (e.g., Carpenter, Nagell, & Tomasello, 1998; Eilan, Hoerl, McCormack, & Roessler, 2005; Moore & Dunham, 1995). Understanding the attention of another regarding prey, predators, or social events is adaptive for many species, especially those that rely on cooperative and/or competitive behaviors. Joint attention has been studied primarily through two types of tasks, *gaze-following* tasks and *object-choice* tasks. Gaze following occurs when the observer orients in the direction of an informant's head and/or eye movements to a location without moving toward the indicated location or retrieving or acting on an object in that location (Emery, Lorincz, Perrett, Oram, & Baker 1997). Object choice occurs when the observer selects the particular one of several objects being pointed to or gazed at by an informant (Anderson, Sallaberry, & Barbier, 1995). A key issue in both of these tasks is determining what the observer understands about the focus of the informant's attention. Does the observer understand that a particular object, location, or event is being attended to by

the informant, or does the observer simply attend to the general direction of regard of the informant, perhaps moving in that direction and selecting the first item of interest encountered (see, e.g., Butterworth, 1991, 1995; Morissette, Ricard, & Decarie, 1995)?

Until recently, most animal studies examining an observer's understanding of an informant's pointing or gazing cues were conducted with nonhuman primates. Perhaps not surprisingly, all great ape species can follow the head-gaze direction of a human informant (i.e., head and eyes move simultaneously to the locus of attention). Moreover, apes understand the locus of attention even if the target lies behind a barrier or lies beyond other distracting places or objects (e.g., Braüer, Call, & Tomasello, 2005; Tomasello, Hare, & Agnetta, 1999). Chimpanzees may even check back to a human informant if they find nothing at the terminal destination of the informant's line of head gaze (Call, Hare, & Tomasello, 1998). An understanding of the geometry of gazing or pointing occurs when an observer is able to locate the indicated place or object by processing the vertical angle at which the informant is gazing or pointing. Butterworth (1995) studied this ability in human infants and described their developmental progression toward such understanding. However, juvenile chimpanzees tested in object-choice tasks failed to understand the geometry of a human informant's head gaze (Povinelli, Bierschwale, & Cech, 1999), and adolescent chimps and adult chimps failed to reliably locate the distal object being pointed at by the human informant (e.g., Barth, Reaux, & Povinelli, 2005; Povinelli, Reaux, Bierschwale, Allain, & Simon, 1997). Surprisingly, perhaps, these same capabilities are present in dogs (Soproni, Miklósi, Topál, & Csányi, 2001; see also the summary in Miklósi & Soproni, 2006). The ability of dogs to respond accurately to pointing and head-gazing cues has been hypothesized to derive from selection for those traits during the long process of domestication (Hare, Brown, Williamson, & Tomasello, 2002).

Adam A. Pack and Louis M. Herman, The Dolphin Institute, Honolulu, Hawaii; Department of Psychology, University of Hawaii at Manoa; and Kewalo Basin Marine Mammal Laboratory, Honolulu, Hawaii.

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Correspondence concerning this article should be addressed to Adam A. Pack, The Dolphin Institute, 420 Ward Avenue, Suite 212, Honolulu, HI 96814. E-mail: pack@hawaii.edu

The discovery of convergent or divergent cognitive traits, like joint attention, among distantly related species can help reveal the underlying foundations of those traits, the ecological and/or social pressures selecting for them, and how they are adaptive (see, e.g., Herman, 1980, for an early discussion of the values of comparisons of diverse species on cognitive traits). In keeping with this dictum, several recent studies (summarized in Pack & Herman, in press) have concentrated on the abilities for joint attention in bottlenose dolphins, a highly social species that engages regularly in many cooperative and some competitive behaviors (Connor, Wells, Mann, & Read, 2000). For example, if human head gazing and pointing in object-choice tasks are understood by dogs but not primates, does that implicate domestication as necessary for that ability? But what if dolphins demonstrate such understanding?

Herman and colleagues (e.g., Herman et al., 1999; Herman, Pack, & Morrel-Samuels, 1993) first demonstrated that dolphins understood human indicative pointing to distally placed objects to the left, to the right, or behind the dolphin. Spontaneity of understanding of single human points to left and right objects was also shown by Tschudin, Call, Dunbar, Harris, and van der Elst (2001) with test-naïve dolphins. Using combinations of points, Herman et al. (1999) demonstrated that a dolphin understood the referential aspect of the human pointing gesture by responding spontaneously to the incorporation of human pointing gestures within the framework of a familiar gestural communication system. Within the system, human symbolic gestures referenced different objects, and sequences of these gestures instructed the dolphin to transport one object to another. For example, the inverse grammatical sequence of three symbolic gestures glossed as “surfboard hoop fetch” instructed the dolphin to transport the hoop to the surfboard (see Herman, Richards, & Wolz, 1984). When either direct points or cross-body points were substituted for the gestural symbols for particular objects within these types of sequences—for example, “point directly at the surfboard, cross-body point at the hoop, fetch”—the dolphin immediately understood the instruction, as evidenced by a correct transport response of the hoop to the surfboard. The dolphin’s high levels of accuracy with such combinations of brief points (circa < 1 s on average per point) allowed the inference that it formed mental representations of the indicated objects. That is, the object pointed to first (the destination object) had to be retained in memory while the second object (the transport object) was pointed to and then the fetch sign given (the type of relation to be constructed between the two objects). This representational ability as well as an understanding of the referent of symbolic gestures was noted in the studies of the dolphin’s understanding of a symbolic language-like system (see, e.g., Herman et al., 1993). Such understanding was hypothesized to extend to human pointing.

Comprehension by dolphins of the referential character of human gazing was examined by Tschudin et al. (2001) and Pack and Herman (2004). Both studies showed spontaneous understanding of human head gazing to distal objects within an object-choice task. Pack and Herman (2004) also showed first-trial transfer to static gazing and pointing from earlier experience with dynamic forms of these cues. These authors concluded that human head gazing was object oriented and not simply interpreted as a cue to move in a particular direction.

In the current study, we investigated more specifically what dolphins may understand about the focus of an informant’s point-

ing or head-gazing cue. In Experiment 1, we asked whether a dolphin could explicitly report the identity of an object being gazed at or pointed to by a human informant by finding a match for the indicated object elsewhere. Specifically, the dolphin was required to attend to the particular one of two sample objects indicated by pointing or head gazing by the human informant and then find an identical match for it among two remotely located alternative objects.

In Experiment 2, we tested whether the dolphin was able to process different symbolic instructions about the actions to be taken in regard to the object indicated by human head gazing. Separate symbolic gestures were used to indicate to the dolphin that it should either match the object indicated by the human informant or take a direct action to it. Although the dolphin already understood a variety of gestural signs for actions to objects (over, under, tail touch), this new procedure required that the dolphin first learn a new gestural sign for the concept of *match*. If the dolphin carried out an action when so signed and matched only when so signed, this would indicate that the match sign (as well as the action signs) was understood semantically.

Finally, in Experiment 3, we investigated the dolphin’s understanding of the geometry of human indicative cues. Specifically, we tested whether the dolphin could identify the object at the terminal destination of a human’s pointing or head-gazing cue when a distractor object lies nearer along the same path as that to the terminal destination.

Experiment 1

Method

Subjects

Two 26-year-old female Atlantic bottlenose dolphins (*Tursiops truncatus*), named Akeakamai and Phoenix, participated in this study. Both were housed with a male dolphin in two interconnected seawater pools (each 15.2 m in diameter and 1.8 m in depth) at the Kewalo Basin Marine Mammal Laboratory. Each dolphin was tested separately in one of these pools and was fed a portion of a daily diet of 9.1 kg of smelt, herring, sardines, and squid during testing.

Previously, both dolphins had revealed spontaneous understanding of human direct pointing (the human’s pointing arm is on the ipsilateral side of the referenced object) and cross-body pointing (the pointing arm is on the contralateral side of the referenced object) as well as human-directed head gazing toward one of several distally placed objects as a reference to that object (Herman et al., 1999, 1993; Pack & Herman, 2004). Both dolphins also understood direct pointing to an object placed behind them, and each spontaneously understood direct or cross-body pointing gestures incorporated within the structure of its respective artificial language (Herman et al., 1999; Herman & Uyeyama, 1999). Furthermore, each of the three cues (direct point, cross-body point, and head gaze) was understood spontaneously when the informant presented them statically (Pack & Herman, 2004).

Each dolphin also had previous experience with making judgments of similarity or identity between objects. Phoenix had demonstrated first-trial transfer with novel objects in both an identity matching-to-sample task as well as in a same-different task with

successively presented sample and probe (Herman, Hovancik, Gory, & Bradshaw, 1989; Herman, Pack, & Wood, 1994). Akeakamai had demonstrated first-trial transfer in same-different tasks with simultaneously presented objects (Herman et al., 1994; Mercado, Killebrew, Pack, Macha, & Herman, 2000). However, neither dolphin had ever experienced matching tasks involving more than one sample, nor had they ever encountered humans pointing or gazing at objects to be matched or judged as same or different.

Objects

Six objects were used. They were an orange terra-cotta flowerpot, a green fiberglass grating, a sand-filled PVC X, a letter "I" constructed from aluminum I beams, a stainless steel bowl, and a black hard-rubber roller (see Herman & Pack, 1992, Figure 3, Set 1, for computer renditions). The objects differed from each other in size, material composition, and shape. During trials, each object was presented above the water surface by a monitor wearing a white T-shirt (to provide a uniform background). Objects held in the air are available to the dolphin's visual sense but not to its echolocation sense (Pack & Herman, 1995).

Indicative Cues

Pointing. Both direct points and cross-body points were used to indicate an object to the left or right of the dolphin. Points were brief, approximately 5 s in duration. During both types of pointing, the experimenter's head and torso were held steady, facing forward. After a point was complete, the pointing arm was returned to the experimenter's side. Opaque goggles were worn over the experimenter's eyes during pointing trials.

Head gazing. For the head-gazing cue, the experimenter's arms remained at his sides and he turned his head to the side until it was oriented toward the referenced object. After the head-gazing cue was complete, the experimenter again faced forward. As with pointing, the experimenter wore opaque goggles, so that eye gazing was never used. Pack and Herman (2004), in fact, showed that eye gazing was not effective for the dolphin but head gazing was.

Procedure

Figure 1 is a schematic of the poolside setup. At the beginning of each trial, the experimenter stood outside the pool wall facing the dolphin. Two sample monitors, wearing opaque goggles to prevent them from observing the dolphin's responses, were positioned 3 m to the left and right of the experimenter. Each held a sample object behind the pool wall and out of view of the dolphin. An assistant located out of the dolphin's view and out of earshot of the sample monitors whispered to the experimenter the sequence of cues to be given, using a preplanned schedule. The instruction consisted of two items: first, the indicative cue to be used (direct point, cross-body point, or head gaze), and second, which object was to be indicated (the one to the experimenter's right or left). Once the experimenter received the instructions, he tapped a small buoy in front of the dolphin. In response, the dolphin placed her rostrum on the buoy and looked at the experimenter. The experimenter then placed opaque goggles over his eyes. Thus, the experimenter did not know which two sample objects were posi-

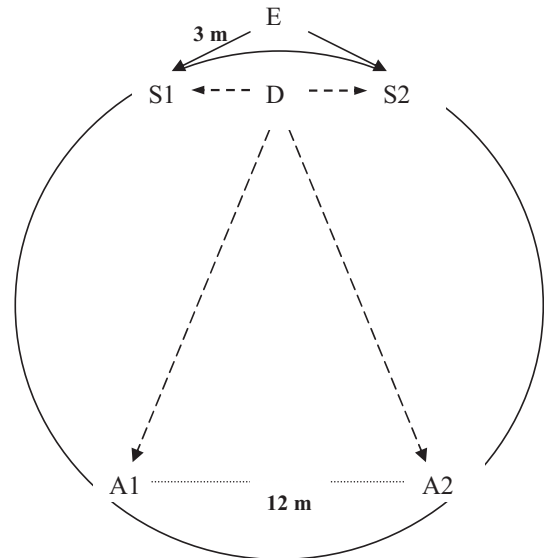


Figure 1. Schematic diagram (not to scale) showing the arrangements of sample objects (S1 and S2) and alternative objects (A1 and A2) relative to the experimenter (E) and the dolphin (D). Solid arrows show possible directions for an indicative cue from the experimenter. Dashed lines with arrows show the dolphin's possible responses depending upon the experimenter's indicative cue and instruction. In Experiment 1, the dolphin attended to whichever sample object was cued by the experimenter and then found a match for this object from among the two alternative objects. In Experiment 2, the dolphin either responded directly to the indicated sample object with a designated action or simply attended to the indicated sample object and then found a match for it, with each type of response dependent on the gestural signal given by the experimenter after the indicative cue.

tioned in the pool nor the location of the matching alternative object.

Once the experimenter's goggles were in place, a session coordinator located in an observation tower adjacent to the pool signaled the sample monitors to simultaneously bring their sample objects into the dolphin's view, by holding them in air about 30 cm above the water surface. Each object was held diagonal to the pool wall so that the dolphin turning toward an object would view it face forward. After a required 3-s hold by the dolphin on the buoy (to indicate her attention and readiness), the experimenter gave the appropriate indicative signal toward either of the sample objects and held the signal for 5 s (timed by a digital clock held by the coordinator). The end of the interval was signaled by the vocal command "out" from the coordinator. The experimenter then terminated his indication, the sample objects were removed from view, and two assistants, also wearing opaque goggles, each presented an alternative object. The alternative objects were presented on the opposite side of the pool (circa 15 m distant from the samples), face forward at about the same height above water as were the samples. The alternative objects were separated by 12 m, and one matched the sample that had been indicated by the experimenter (the S+) and the other matched the alternate sample (the S-). The dolphin was rewarded for swimming across the pool and stationing in front of the S+ for 3 s.

An individual in the observation tower who had no knowledge of the instruction given to the dolphin nor the identity of the

indicated sample viewed the alternatives only and reported aloud the dolphin's choice of alternative object. If the dolphin chose correctly, the experimenter blew a whistle and rewarded the dolphin with social praise and a fish. For an error, the dolphin was simply signaled to return to the experimenter's station. All trials were videotaped for post-session review and analysis.

Training. During training, no indicative cues were used by the experimenter, whose task was simply to station the dolphin in front of him and to administer reward as required. Both dolphins were already familiar with matching single samples to two alternatives presented on the same side of the pool as the sample (e.g., Herman et al., 1989), but neither had performed matching with samples and alternatives located on opposite sides of the pool. Therefore, the dolphins were trained first to select a match for a single sample object from among two alternatives located at the opposite side of the pool. The single sample was held by either sample monitor, with only one monitor present at each trial. The monitor showed the sample to the dolphin on instruction from the session coordinator, and then an assistant positioned between the alternative objects and hidden behind the pool wall tapped on the outside of the wall with a plastic pipe. This acoustic cue guided the dolphin to swim across the pool (in the direction of the cue). Once there, the dolphin, who was already familiar with choosing between the alternative objects, spontaneously stationed in front of one of them. The choice of a match or nonmatch initiated the same response contingencies as described earlier. The acoustic tap cue was then faded out rapidly over trials as the dolphin began to spontaneously swim to the side of the pool opposite the sample upon hearing the coordinator's verbal signal "out" for the sample to be removed and the alternatives to be presented.

For the next step, both sample presenters were positioned on each side of the experimenter but with only one or the other displaying the sample. The alternative objects were again presented. Each session of training consisted of 15 trials, one session per day. After the dolphin reached a performance criterion of 80% correct responses or better in a single session with this final step, we proceeded directly to testing the two-sample object-matching procedure, described earlier.

Testing. Here, for the first time, both sample objects were presented, and the experimenter indicated the specific sample to be matched by using either a pointing cue or a head-gazing cue. Test trials were run according to the procedure described earlier. For each dolphin, each combination of two of the six objects (15 combinations) was tested twice with each of the three indicative cues—direct point, cross-body point, and head gaze—once with one member of a pair as sample and once with the other member of a pair as sample. Thus, a total of 90 unique trials were tested—30 with direct point, 30 with cross-body point, and 30 with head gaze. Fifteen trials were conducted per session, 5 trials with each indicative cue, with cue types ordered quasi randomly. Sample identity and alternative locations were balanced across two consecutive sessions. All variables were balanced across the six sessions required to complete the test. One session was run per day. The intertrial interval was approximately 60 s. Although trial duration (i.e., the time from the presentation of sample objects to the dolphin's choice of alternative) was controlled in part by the response speed of each dolphin, it was nonetheless similar for both dolphins (for Phoenix, $M = 23.1$ s, 95% confidence interval [CI] = ± 0.59 s; for Akeakamai, $M = 21.7$ s, 95% CI = ± 0.77 s).

Results and Discussion

Training

Training was completed for Phoenix in three sessions (45 trials in total). She matched correctly on 43 trials (96%). Akeakamai required five sessions (75 trials in total) to complete training. She matched correctly on 61 trials (81%).

Testing

Table 1 compares matching accuracy of each dolphin when the experimenter indicated the sample object by a direct point, a cross-body point, or a head gaze. Chance performance of a wholly correct response was .25 (.5 probability of following the informant's cue to the correct sample object multiplied by .5 probability of choosing the alternative that matched the indicated sample). Phoenix was 87% correct or better ($p < .0001$, cumulative binomial test with chance = 0.25) with each of the three indicative cues. There were no significant differences across the three cuing conditions, $\chi^2(2, N = 84) = 0.21, p > .05$.

Akeakamai performed less reliably than Phoenix but still significantly above chance levels on each indicative condition ($p \leq .003$ by cumulative binomial test). However, her overall response accuracy was significantly lower than Phoenix's on all three indicative tests, $\chi^2(1, N = 60) \geq 7.70, p < .01$. As with Phoenix, there were no significant differences across cuing conditions, $\chi^2(2, N = 52) = 0.50, p > .05$.

The videotaped record of behavior during each test trial allowed us to separate the accuracy in responding to the indicative cue from the accuracy in responding to the matching alternative. On seeing the indicative cue provided by the experimenter, each dolphin spontaneously began swimming toward one of the samples and then waited in front of that sample until both samples were removed and both alternatives presented at the opposite end of the pool. Each dolphin then swam to the alternatives and stationed in

Table 1
Experiment 1: Number of Correct Responses by Phoenix and Akeakamai to Each Portion of the Two-Sample Indicative Matching Task

Subject and indicative cue	Correct responses		No. approaches to indicated sample ($n = 30$)	No. matches to approached sample ($n = 30$)
	First trials ($n = 6$)	All trials ($n = 30$)		
Phoenix				
Direct point	6	29	30	29
Cross-body point	6	29	30	29
Head gaze	6	26	28	27
Akeakamai				
Direct point	1	19	30	19
Cross-body point	3	18	30	19
Head gaze	4	15	21	16

Note. Correct responses for first trials and all trials are the numbers of trials on which the dolphin selected the indicated sample and selected the matching alternative object. A first trial is the first time a particular object of the six altogether was pointed to (by either method) or gazed at. Number of matches to approached sample is the number of matches to the sample approached, regardless of whether it was the indicated sample.

front of the one selected. No attempts were made to touch or to perform any action to the indicated sample object.

The last two columns of Table 1 show, respectively, each dolphin's accuracy in selecting the indicated sample and in selecting a match for the sample chosen (regardless of whether it was the indicated sample). Both Phoenix and Akeakamai were errorless in selecting the sample object pointed to either directly or through the cross-body gesture. Akeakamai was significantly less proficient than was Phoenix in selection through head gaze, $\chi^2(1, N = 60) = 4.00, p < .05$, although still well above chance levels ($p < .05$, cumulative binomial test, chance = .5). In the matching portion of the task, Phoenix was nearly errorless, whereas Akeakamai performed at chance levels (60% overall; $p > .05$, cumulative binomial test, chance = .5).

We measured the dolphin's ability to spontaneously report the identity of the sample cued by the informant by examining overall performance accuracy on the first test trial with each of the six objects as the indicated sample. Recall that during training, a single sample was used and no indicative cues were used. Phoenix responded correctly to both portions of each trial (i.e., she responded accurately to the indicated object and matched correctly) using direct points (6 of 6 correct), cross-body points (6 of 6 correct), or head gaze (6 of 6 correct). Thus, from the outset, Phoenix was able to report accurately on the identity of an object pointed toward or head gazed at by a human informant.

In contrast, Akeakamai was correct on only 8 of the 18 first trials with each of the six objects as the indicated sample. These included one correct match on the 6 direct point trials, three on the 6 cross-body point trials, and four on the 6 head-gaze trials. An analysis of Akeakamai's behavior during these trials revealed that she had no difficulty selecting the sample object indicated by the experimenter. She approached the indicated sample on all 18 trials. Her difficulty was therefore in encoding the identity of the indicated sample, maintaining an accurate mental representation of the sample once both samples were removed from view, choosing the matching alternative, or a combination of two or more of these factors.

Experiment 2

In Experiment 2, we tested whether the dolphin was able to process different symbolic instructions about the actions to be taken in regard to the indicated object. Two different categories of actions were contrasted: (a) *matching*—find a match for the indicated object, as in Experiment 1; and (b) *acting*—perform a requested behavior directly to the indicated object. The dolphin's ability to perform the second type of response reliably has been demonstrated previously (e.g., Herman et al., 1999; Pack & Herman, 2004) but was never contrasted with a matching-requirement option. Matching requires that the dolphin attend to the indicated object but take no direct action to it, other than the implicit response of mentally representing it to allow for the subsequent identity match. Acting requires attending to the indicated object and acting directly on it, such as touching it with the pectoral fin or leaping over it. The key element of contrast then is the instruction that follows the experimenter's indication. That is, the indication alone does not tell the dolphin what to do about the object. Instead, the dolphin must wait for the succeeding symbol: match or act. The dolphin's ability to reliably carry out the instruction given

implies that the contrasting match and act symbols are processed semantically. It also implies that the indication by the experimenter is understood as a reference to a specific object, rather than to a location where an object may be found. Roughly, it is the difference between "look at that" versus "look there." The former, if understood, implies that the dolphin is sharing in the experimenter's attention to an object rather than to a place.

A crucial step in developing the indicated contrast was to teach the dolphin a new gestural symbol glossed as "match," which could then be contrasted with three familiar action symbols requesting unique behaviors to an object. Note that in Experiment 1, the matching task was the only task, and no explicit symbol for *match* was used or was necessary.

Method

Subject

Because Phoenix had performed in Experiment 1 at near ceiling levels and Akeakamai appeared to have difficulty in the matching portion of the task, we selected Phoenix to participate in this second experiment.

Objects, Actions, and Indicative Cues

The same six objects used in Experiment 1 were used again. Three direct action commands, each elicited by a different single unique gesture of an experimenter's right arm and hand, were used throughout this study to instruct the dolphin to perform a specified action directly to a referenced object. The actions were glossed as "jump over" (OV), "swim under" (UN), and "touch with your pectoral fin" (PT). Phoenix was highly familiar with these actions and their associated gestural signs (e.g., Herman et al., 1993). In addition to these signs, the new symbolic gesture "match" was taught to Phoenix. In response, Phoenix was to select the alternative object (of two) that matched the indicated sample object, as in Experiment 1. The matching instruction was now explicit rather than implicit. The same indicative cues (direct point, cross-body point, and head gaze) used in Experiment 1 were also used here.

Procedure

The physical conditions and control conditions of Experiment 2 were identical to those of Experiment 1 (see Figure 1). As in Experiment 1, the dolphin faced the experimenter at the start of each trial. However, the instruction whispered to the experimenter by an assistant now consisted of three items: first, which object (right or left) was to be indicated; second, the indicative cue to be used (direct point, cross-body point, or head gaze); and third, which one of the four behaviors was to be signed (OV, UN, PT, or match). The order of the cues—indicative cue followed by the behavioral cue—was selected so that the initial cue (indicative) would not prompt any particular action other than attending to the indicated object and looking back toward the experimenter for further instruction.

After the experimenter received the set of three instructions, the procedure followed as in Experiment 1, except that in response to the session coordinator's signal, all four objects—the two sample objects and the two alternative objects—were presented simultaneously over the pool wall. (In Experiment 1, the two samples

appeared first, and the two alternatives appeared only after the samples had been withdrawn.) After all four objects were presented, the experimenter gave the indicative cue as in Experiment 1, held it for 5 s, and then gave the behavior instruction gesturally (OV, UN, PT, or match). In response, the dolphin either carried out the designated action to the indicated sample object or, if the match sign was given, swam to the opposite side of the pool and selected one of the two alternative objects. Reinforcement contingencies were as in Experiment 1.

Training. To train Phoenix to respond to the new match sign, we conducted trials in which a single sample was presented to either the left or right of the experimenter. No indicative cue was given. The experimenter simply presented the new match sign, and on a verbal cue from the coordinator, the alternative objects were presented at the opposite side of the pool (as in Experiment 1). Over trials, the delay in presenting the alternatives was gradually reduced until both the single sample and the alternatives appeared simultaneously. Phoenix quickly learned to respond to the match sign and matched correctly on 44 of 48 of the training trials. We then proceeded to testing using indicative cues.

Testing. For the first time, the two sample objects and the two alternative objects were presented simultaneously, and for the first time in this context the indicative cues were used. There was no prior specific training for this context. A total of 180 unique trials were given across 12 sessions of 15 trials each. Each of the 15 combinations of object pairings (from the set of six objects) was tested 12 times, 6 times with Object A of a pair member as the cued sample and 6 times with Object B of a pair member as the cued sample. Of each set of 6 trials with a particular pairing, 3 trials were act trials in which each of the three action gestures (OV, UN, and PT) was tested once, and 3 trials were match trials. Thus, there were a total of 90 match trials (30 with direct point, 30 with cross-body point, and 30 with head gaze) and 90 action trials (30 with direct point, 30 with cross-body point, and 30 with head gaze). Locations of samples (right or left of the experimenter) and locations of alternatives relative to each other and to the locations of the sample objects were balanced. As in Experiment 1, all trials were videotaped. Intertrial intervals were approximately 60 s.

Results and Discussion

Phoenix never confused the match sign with any of the act signs. Table 2 therefore examines her performance separately for these two conditions, match and act, as a function of the type of indicative cue given: direct point, cross-body point, or head gaze. It is apparent that act trials were easy for her: She made only seven errors over the 90 trials. All seven errors were an approach to the wrong object. On one of these errors, Phoenix also carried out the wrong behavior. For overall response accuracy, chance was calculated as .17 (i.e., .5 for sample choice multiplied by .33 for action choice). For each indicative cue, Phoenix's overall performance was well above chance levels ($p < .0001$ by the cumulative binomial test). There was no significant difference in overall performance among the three types of indicative cues, $\chi^2(2, N = 83) = 0.17, p > .05$.

Match trials were clearly more difficult. Here, Phoenix made 32 errors over the 90 trials, significantly more than on the act trials, $\chi^2(1, N = 180) = 20.46, p < .001$. For match trials, chance for overall response accuracy was calculated as .25 (.5 probability of following the informant's cue to the correct sample object multiplied by .5 probability of choosing the alternative that matches the indicated sample). Phoenix's overall performance on match trials was 73% correct with direct point, 67% with cross-body point, and 53% with head gaze, each significantly above chance levels ($p < .001$, cumulative binomial test, chance = .25). Her performance accuracy did not differ significantly across the three indicative cues, $\chi^2(2, N = 90) = 2.72, p > .05$.

Trial duration differed for act and match trials, due to the different response requirements for these trials. For act trials, Phoenix's mean trial duration was 10.90 s (95% CI = ± 0.66 s). For match trials, her mean trial duration was 20.15 s (95% CI = ± 0.88 s).

The videotape record, used to separate out errors attributable to choice of the nonindicated sample and errors attributable to choice of a nonmatching alternative, was difficult to interpret on 29 of the 90 trials. Hence, Table 2 (number of approaches and number of matches), shows only the performance levels on the remaining 61 trials: 23 for direct point, 21 for cross-body point, and 17 for head

Table 2

Experiment 2: Phoenix's Responses on Act Trials and on Match Trials as a Function of Type of Indicative Cue Given

Type of trial and cue	Overall response accuracy ($n = 30$)	No. approaches to indicated sample	No. matches to approached sample	No. correct actions (OV, UN, PT, or match) ($n = 30$)
Direct action trials				
Direct point	28	28 (30)	NA	30
Cross-body point	29	29 (30)	NA	30
Head gaze	26	26 (30)	NA	29
Match trials				
Direct point	22	23 (23)	19 (23)	30
Cross-body point	20	20 (21)	16 (21)	30
Head gaze	16	16 (17)	11 (17)	30

Note. Number of matches to approached sample is the number of matches to the sample approached, regardless of whether it was the indicated sample.

Numbers in parentheses indicate the number of trials of 30 altogether that could be evaluated from the video record. OV = jump over; UN = swim under; PT = touch with pectoral fin; NA = not applicable.

gaze. On those 61 trials, it is clear that errors were mainly choice of the nonmatching alternative to the approached sample (75% correct overall) and not choice of the nonindicated sample (97% correct overall), $\chi^2(1, N = 122) = 9.84, p < .01$. Interestingly, Phoenix matched less reliably in Experiment 2 than in Experiment 1, $\chi^2(1, N = 151) = 9.87, p < .005$.

For the 61 trials that were amenable to videotape analysis, Phoenix's matching accuracy on direct point (83%) and cross-body point (76%) trials was significantly above chance levels ($p < .05$, cumulative binomial with chance = .5). However, her matching accuracy of 65% with head gaze did not differ significantly from chance ($p = .17$, cumulative binomial test, chance = .5). An analysis of the 15 matching errors reported in Column 4 of Table 2 revealed that 14 errors were committed by choosing the S- alternative after approaching the S+ sample, and only one error (on a head-gaze trial) resulted from choosing the S+ alternative after approaching the S- sample. The implication of these results is a difficulty with remembering the sample on match trials.

There were no significant differences in matching performance for direct point or cross-body point when comparing results for Phoenix in Experiment 1 with those of Experiment 2 ($p \geq .07$, Fisher's exact test). However, performance with head gaze was significantly better in Experiment 1 than in Experiment 2 ($p = .05$, Fisher's exact test).

It is not clear what factors may account for Phoenix's poor performance with human head gaze in the matching portion of Experiment 2 relative to her performance in Experiment 1 with the same cue. Although Experiment 2 was more complex in its requirements than Experiment 1 (i.e., matching and acting were contrasted in Experiment 2, whereas there was only matching in Experiment 1), this did not seem to impact matching performance following pointing cues. Clearly, further research would be necessary to examine the reliability of this effect and, if reliable, to determine the contributing factors to observed decrements in performance.

Experiment 3

In Experiment 3, we investigated the dolphin's understanding of the geometry of human direct pointing and head gazing. Would the dolphin attend to the particular object of regard by the experimenter when there are two objects lying in the same plane, one near (proximal) and the other far (distal)? To choose appropriately, the dolphin must attend to the particular angle of regard by the experimenter.

Method

Subject

The subject was Akeakamai. As was noted earlier, she was the subject in the Herman et al. (1999) study in which her understanding of sequences of points to objects was contrasted with her understanding of more familiar sequences of symbolic gestures referring to objects, as in the Herman et al. (1984) study. We wished to use this contrast again, this time to compare Akeakamai's understanding of head gaze or direct points to objects near and far with her understanding of symbolic gestural references to those same objects. In each case, the reference to an object, either

indicative or gestural, was followed by a familiar gestural symbolic reference to an action to be taken to the object. Because Akeakamai normally performs at a high level with the wholly symbolic object plus action task, that task provided a baseline against which performance with indicative cues could be compared.

Objects

Four objects were used, two ordinary white plastic Frisbees floating on the water surface and two streams of water from garden hoses suspended 73.3 cm above the water surface. For each pair of identical objects, one object was located to the dolphin's left and the other to her right, at equal distances from the dolphin.

Procedure

Both direct pointing and head gazing were used in this test and were presented as described in Experiments 1 and 2. Each point or head-gaze cue was followed by one of three familiar gestural action commands: "go over" (OV), "touch with your tail" (TT), or "touch with your pectoral fin" (PT). The familiar wholly symbolic gestural sequences consisted of three sequentially given semantic elements: location (left or right with respect to the dolphin), object (Frisbee or water), and action (OV, TT, or PT). For example, the sequence "right + Frisbee + OV" instructed Akeakamai to jump over the Frisbee to her right and not the one to her left. The same response would be required if the experimenter instead pointed at or head gazed at the Frisbee to the dolphin's right and then signed OV. Figure 2 is a schematic of the experimental setup. The Frisbees were positioned on the surface of the water 0.8 m to the left and right of the dolphin and constituted near objects. The garden hoses were attached to a metal railing on the top of the pool wall 3.7 m to the left and right of the dolphin and constituted far objects. A slow stream of water from each hose poured continuously into the pool. The experimenter's extended arm with pointed index finger was about 0.61 m from a Frisbee and 2.85 m from a hose. The angle subtended by the experimenter pointing or head gazing toward the top of the hose and toward a Frisbee lying on the water surface on the same side as the hose was approximately 60°.

On each trial, an assistant located out of view of the dolphin whispered the trial instructions to the experimenter that included, sequentially, type of cue (direct point or head gaze), location (left or right), object (Frisbee or water), and action (OV, PT, or TT). Alternatively, the instruction could be to give the whole sequence symbolically (e.g., "left + water + over"). The experimenter then tapped the stationing buoy, and when the dolphin stationed, the experimenter produced the required instruction. Reinforcement was contingent on all elements being carried out correctly by the dolphin. A minimum intertrial interval of 60 s was used. Trial duration (i.e., the time from the beginning of the first gestural sign or cue from the experimenter until the completion of a response recognizable to the blind observer) was relatively brief. For references to near objects, $M = 5.46$ s (95% CI = ± 0.62 s). For references to far objects, $M = 5.87$ s (95% CI = ± 0.67 s).

Each unique combination of object (Frisbee, water) plus location (left, right) plus referential symbol (direct point, head gaze, gestural name of object) plus action command (OV, PT, TT) was tested once, for a total of 36 unique trials given over two sessions

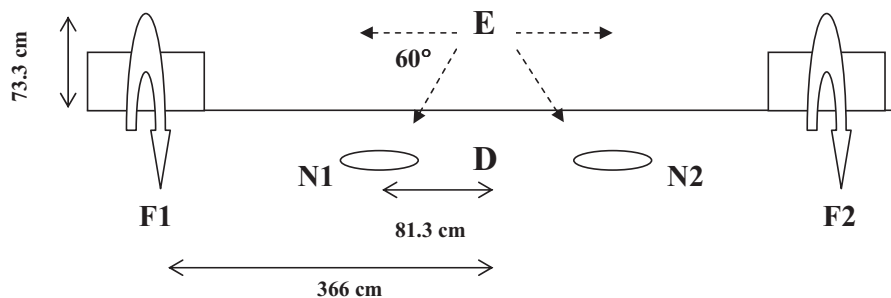


Figure 2. Schematic diagram (not to scale) showing the arrangements of near objects (N1 and N2; two Frisbees) and far objects (F1 and F2; two streams of flowing water) located to the right and left of the dolphin (D) and experimenter (E). Dashed arrows show the two lines of regard to a near or far object by the experimenter, with the angle between being approximately 60°.

(24 trials on Day 1 and 12 trials on Day 2). There were a total of 6 “object-far” trials per referential symbol and 6 “object-near” trials per referential symbol.

Results and Discussion

Akeakamai was wholly correct on 11 of the 12 familiar symbolic gestural sequences, indicating that she recognized that valid responses could be performed to both near and far objects. Her only error was in response to the sequence “left + water + TT,” in which she performed a correct tail touch but to the stream of water on her right. Akeakamai was 100% correct on all 12 trials in which a direct point was used to indicate either a near or far object. This indicated that she understood the terminal destination of the direct point. She was not simply responding to human pointing in this new experimental context by moving in the direction of the point until she discovered an object (in which case she should have selected one of the near objects, depending upon which arm was used for pointing, when the experimenter pointed to the distal object). Rather, when the informant pointed to far objects, Akeakamai disregarded the distractor (proximal) object lying along the same path as the distal object. That she responded correctly to the distal object on the first trial to the left and the first trial to the right, and on all trials thereafter, indicates that specific learning was not involved. Rather, comprehension was immediate.

In contrast to the errorless performance observed with human pointing, Akeakamai responded to human head gazing by always choosing the near object, although always responding on the indicated side (left or right) and always performing the requested action. Thus, side and action choices were always correct, but object choices were only 50% correct. Akeakamai’s performance in this regard was similar to results for human infants tested for comprehension of pointing versus head gazing at objects near and far (Butterworth, 1995), and the dolphin’s difficulty may be interpreted in a way similar to interpretations for infants. Butterworth (1995, p. 35) noted, “For any given angular distance between targets, the long ‘lever’ of the arm undergoes a greater lateral displacement between alternative targets than does the head.” Consequently, relatively large angular differences traced by the human arm, compared with the head, are likely more salient to the dolphin as well. Thus, the relative extent of the human head, compared with the extended pointing arm, combined with a rela-

tively small angular difference between the location of the proximal and distal objects likely made resolution of the terminal destination of head gaze difficult. The same type of explanation may apply to the findings of Povinelli et al. (1997), who presented 2-year-old children with two objects that were placed near and far from an informant and within the child’s visual field. Povinelli et al. found that children performed less accurately in selecting the far object when it was gazed at by the informant than when the informant used pointing or a combination of pointing and gazing toward this object.

Finally, a videotape analysis revealed that Akeakamai responded relatively quickly regardless of object position. Across cue type, the difference in her response time (i.e., time from completion of experimenter’s instruction to performance of a response recognizable to the blind observer) to near objects ($M = 2.79$ s, 95% CI = ± 0.56 s) versus far objects ($M = 3.02$ s, 95% CI = ± 0.44 s) was not significant, $t(34) = 0.18$, $p > .05$.

General Discussion

Findings from the present study indicate that dolphins can understand *what* a human is attending to, as well as *where*. The suite of experiments reported, in conjunction with earlier work (Herman et al., 1999; Pack & Herman, 2004), establish that indicative cues provided by a human informant were processed by the dolphin at referential, semantic, and syntactic levels. Syntactic processing in this case refers to the ability to take into account the sequential order rules of a symbolic communication system to organize a meaningful response. This was seen in the Herman et al. (1999) study showing that sequences of pointing gestures were understood within the framework of an inverse grammatical structure that had been used previously with symbolic (as opposed to indicative) gestures. In this sequence of points, the order in which the pointing gestures were given—which object was pointed to first and which object was pointed to second—dictated which object was to be brought to which object. The rule followed by Akeakamai during sequential indicative pointing—bring the second referenced object to the first—was inferred spontaneously from her previous experience with the use of the inverse grammar with wholly symbolic gestures (Herman et al., 1984). For example, in Akeakamai’s prior experience, there were specific gestures for “hoop,” “surfboard,” and “pipe,” such that the sequence “hoop +

pipe + fetch” was interpreted correctly as an instruction to take the pipe (the object referenced second) to the hoop (the object referenced first). Reversing the order of appearance of hoop and pipe symbols would also reverse the instruction, which Akeakamai reliably understood. When pointing at objects was substituted for the symbolic gestures, Akeakamai immediately interpreted the instruction in the same way as she did symbolic instructions.

In the current study, referential processing was demonstrated through the dolphin’s attention to the specific object indicated by the informant through pointing or head gazing and not just to the direction in which the informant was pointing or head gazing. This was shown most convincingly by the matching test (Experiment 1), in which the indicated object, the sample, was not itself the object to which the response was to be made but instead was the referent to which the dolphin’s attention was to be paid, with the response to be carried out elsewhere to an identical (matching) object. To match successfully, the dolphin had to encode the characteristics of the referenced sample in memory (i.e., mentally represent the sample), because the sample was no longer visibly accessible while the dolphin viewed the two alternative objects, seeking to find a match. Referential processing was also shown in Herman et al. (1999) through the use of combinations of pointing gestures, as described earlier, in which the initial pointing gesture directed the dolphin Akeakamai to attend to and remember the indicated object without immediately acting upon that object.

Finally, semantic processing refers to the ability to take into account the meanings or referents of individual symbols. In the current study, semantic processing of the indicative cue was demonstrated by the establishment of a semantic contrast between the imperatives of *act on* versus *match*. This contrast revealed that the indicative cue was not treated simply as a releasing signal to respond directly to whatever object was indicated but was processed as an instruction to attend to an object and wait for a further conditional gesture clarifying the type of response (direct or indirect) to take to the object.

To our knowledge, the only study similar to the current study of two-sample matching appears in a brief description by Premack (1988) who reported that the language-trained chimpanzee Sarah could accurately select which one of two alternative objects was identical to the particular sample object being gazed at by a human. As described by Premack (no methodological details and no detailed data were given), the informant gazed at one of two sample objects. Sarah was then required not to choose that object but instead to go to and choose the matching object from among two alternatives that were exact replicas of the two samples. Thus, human gaze at a specific sample provided the only cue for selection of a corresponding alternative. Unlike the current study, however, in which match and act were contrasted (Experiment 2), there was no semantic contrast to the matching response in the Premack study. Hence, Sarah’s response was constrained to matching by the unvarying context in which the gaze cue was used. Other than the Premack study and the current one with dolphins, no others have required specifically that the observing animal encode and remember the characteristics of the object of regard by the informant. Encoding and remembering the object’s characteristics are necessary, of course, for the act of subsequently matching those characteristics among offered alternative objects.

In addition to these conclusions about the dolphin’s understanding of human indicative cues, the final study reported here showed that the dolphin appeared to understand human pointing geometrically. The dolphin was able to successfully and spontaneously locate an object at the terminal destination of a human’s point, where the object indicated lay beyond a distractor object. However, she did not show this same geometric skill with near and far objects in response to human head gaze. As noted earlier, this may not have been as much a conceptual limitation of comprehension of head gaze, which was found to be well within the dolphin’s capability in Experiment 1 as well as in earlier work (Pack & Herman, 2004), as it was a practical perceptual difficulty with reading the fine angular differences of head gaze compared with the more salient leverlike arm and hand motions involved in pointing (cf. Butterworth, 1995; Povinelli et al., 1997).

There are abundant data in earlier work (Herman et al., 1999, 1993; Herman & Uyeyama, 1999; Pack & Herman, 2004; Tschudin et al., 2001) showing that the dolphin’s comprehension of human pointing and head gazing is not necessarily directly or explicitly learned but can apparently occur as a consequence of informal exposure to human indications in facilities or conditions in which dolphins are in close contact with humans. In the studies reported here, and also in the earlier studies just cited, dolphin responses to human pointing or head gazing when tested in formal experimental conditions were shown to be immediately correct and were not dependent on explicit formal training. Herman et al. (1999) suggested that dolphins may “point” in their natural world through the narrow directed beam of their echolocation signal. In this regard, Xitco and Roitblat (1996) showed that a listening dolphin positioned next to an echolocating dolphin can identify what the echolocator is targeting by listening to the returning echoes. During echolocation, not only is the echolocation beam acting like an outstretched arm pointing to a target but the dolphin’s entire body, with its fusiform shape, is oriented in the direction of the target. In this sense, the “informant” dolphin is pointing, and the listener and the informant dolphin are engaged in an act of joint attention. By this, we do not mean to infer that an intention to inform is involved; however, the evidence offered by Xitco, Gory, and Kuczaj (2001) of the dolphin’s whole-body pointing with head forward and looking back at the human swimmer, who alone had access to the object desired by the dolphin, is strongly suggestive of intention to inform the human of the dolphin’s object of attention.

Moore and Corkum (1994) hypothesized that selection pressures favoring the evolution of conspecific gaze following would require dominance of the visual modality, forward-facing eyes (so that head orientation could reliably indicate gaze direction), and a sophisticated social structure. Dolphins do not fulfill the first two requirements, yet as our studies abundantly illustrate, they can and do attend to the object indicated through head gaze by the human informant. Thus, the generality of Moore and Corkum’s hypothesis is not supported. However, a sophisticated social structure dependent on attention to others may be necessary for any species showing sensitivity to gaze, or general bodily orientation, with the particular form, function, and mechanisms of attentional behavior selected for by the constraints of the specific biological and ecological traits and conditions of the particular species.

To the extent that parallel studies in joint attention have been conducted with dolphins, dogs, and apes, there are several notable

differences in demonstrated abilities.¹ First, dogs (Hare, Call, & Tomasello, 1998; Miklósi, Pongrácz, Lakatos, Topál, & Csányi, 2005), and dolphins (Herman et al., 1999) spontaneously (i.e., on the first trials) understand human dynamic indicative pointing to distal objects, but chimpanzees do not (reviewed in Miklósi & Soproni, 2006; see also Povinelli et al., 1999). Second, it has been relatively difficult to demonstrate with apes accurate first-trial use of information provided by dynamic human head (and eye) gaze in an object-choice task (e.g., Call, Agnetta, & Tomasello, 2000; Call et al., 1998; Itakura, Agnetta, Hare, & Tomasello, 1999), as contrasted with the relative ease of such use in dogs (Hare et al., 1998; Hare & Tomasello, 1999; Soproni et al., 2001) and dolphins (Pack & Herman, 2004; Tschudin et al., 2001).

Third, studies of geometric understanding of pointing, carried out as in Experiment 3 of this article, do not seem to have been applied to nonhuman primates or species other than dolphins (see recent review by Miklósi & Soproni, 2006). However, some studies have shown that apes can accurately follow the gaze direction of another (i.e., look where another is looking) geometrically to specific locations around barriers and past distractors (e.g., Braüer et al., 2005; Tomasello et al., 1999) and that both chimpanzees and dogs understand that opaque barriers can occlude another's vision (Braüer, Call, & Tomasello, 2004; Hare, Call, Agnetta, & Tomasello, 2000; Povinelli & Eddy, 1996). (Dolphins have not been tested with barriers.) In object-choice tasks, dogs and 3-year-old children distinguished the geometry of an informant's gaze at an object versus above the object, but chimpanzees do not make this distinction (Povinelli et al., 1999; Soproni et al., 2001). (Again, dolphins have not been tested with this type of task.)

Fourth, production of pointing accompanied by gaze alternation between the object of interest and the recipient (presumably to ensure its attention) may emerge in apes (e.g., Greenfield & Savage-Rumbaugh, 1990; Krause & Fouts, 1997; Leavens, Hopkins, & Bard, 1996; Miles, 1990), dogs (Hare et al., 1998; Miklósi, Polgárdi, Topál, & Csányi, 2000), and dolphins (Xitco et al., 2001) under various conditions in which the subjects have extensive human contact. In orangutans (Call & Tomasello, 1994, Experiment 3) and dolphins (Xitco, Gory, & Kuczaj, 2004), subjects appear to understand the importance of the attention of the audience and consequently point more often when the recipient is face forward than when it has its back turned or is away from the area.

Finally, dolphins have demonstrated spontaneous (i.e., first-trial) comprehension of static head gaze (no eyes) and static point cues to distal objects (Pack & Herman, 2004), but chimpanzees (Povinelli et al., 1997) and dogs (Hare et al., 1998) have not. Two of 7 chimpanzees tested by Povinelli et al. (1997) for an understanding of static cues were eventually successful in interpreting static head gaze (and eyes), as shown later by Povinelli et al. (1999; see also Barth et al., 2005). Likewise, 1 of the 2 dogs tested by Hare et al. (1998) showed eventual understanding of static head gaze (and eyes) as well as eventual understanding of static human points.

Clearly, these differences, as well as the similarities, are intriguing, and further studies are needed to clarify the conditions (biological, ecological, social, and experiential) under which these various joint attentional characteristics may emerge. However, domestication is one process that has been suggested to account for the understanding by some species of human pointing and gazing cues. As was noted earlier, the abilities of dogs for understanding

of human-given indicative cues has been attributed by Hare et al. (2002) to the historic process of human domestication, a hypothesis supported by the lack of evidence for an understanding of these cues in object-choice tasks by human-reared wolves (Hare et al., 2002). Also lending support to the domestication hypothesis are findings that several other domestic species (e.g., domestic goats, Kaminski et al., 2005; domestic cats, Miklósi et al., 2005) respond appropriately to some types of gazing and pointing cues. That domestication is not a necessary condition in some other species is shown through the studies with dolphins (summarized in Pack & Herman, in press), some of the studies with apes (e.g., Braüer et al., 2005; Hare & Tomasello, 2004; Itakura & Tanaka, 1998; Tomasello et al., 1999), and, to the extent that they have been tested, the studies with seals (Scheumann & Call, 2004; Shapiro et al., 2003).

The sensitivity of dolphins and apes to indicative cues of others may derive in part from the requirements of the complex societies in which they live. Within the structure of these societies, individual identification is crucial, long-term associations are common, the formation of male–male alliances and female–female affiliative behavior has been documented (reviewed in Baker & Smuts, 1994; Connor & Mann, 2006; Connor, Read, & Wrangham, 2000), and both competitive and collaborative behaviors may occur. It seems likely that the advantages of monitoring, coordinating, or even manipulating the behaviors of other individuals in one's group would select for close attention to the behaviors of these others. Recognizing such cues as gazing or body orientation can alert the observer to events of importance or allow the observer to predict the behavior of others. Similarly, offering these indicative cues to others may act in one's own interest, such as by alerting others to events of importance. As noted by Pack and Herman (in press), "Recognizing attentional cues of others and what they connote, and 'knowing' how to project attentional cues to others (subsumed respectively under the domains of declarative and procedural intelligence—Herman, 2006) represent exceptionally useful skills for manipulating one's peers" (see also Byrne & Whiten, 1988; Whiten & Byrne, 1997).

¹ Other less extensively studied species (e.g., cats, Miklósi et al., 2005; seals, Shapiro, Janik, & Slater, 2003; goats, Kaminski, Riedel, Call, & Tomasello, 2005; and monkeys, Anderson, Montant, & Schmitt, 1996, and Anderson et al., 1995) show some responsiveness to human-given indicative cues but are not considered here in detail.

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