

Bottlenosed Dolphins (*Tursiops truncatus*) Comprehend the Referent of Both Static and Dynamic Human Gazing and Pointing in an Object-Choice Task

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The authors tested 2 bottlenosed dolphins (*Tursiops truncatus*) for their understanding of human-directed gazing or pointing in a 2-alternative object-choice task. A dolphin watched a human informant either gazing at or pointing toward 1 of 2 laterally placed objects and was required to perform a previously indicated action to that object. Both static and dynamic gaze, as well as static and dynamic direct points and cross-body points, yielded errorless or nearly errorless performance. Gaze with the informant's torso obscured (only the head was shown) produced no performance decrement, but gaze with eyes only resulted in chance performance. The results revealed spontaneous understanding of human gaze accomplished through head orientation, with or without the human informant's eyes obscured, and demonstrated that gaze-directed cues were as effective as point-directed cues in the object-choice task.

Interest in joint visual attention and the so-called “meeting of minds” has grown dramatically over the last 30 years (Carpenter, Nagell, & Tomasello, 1998; Hare, Brown, Williamson, & Tomasello, 2002; Moore & Dunham, 1995; Povinelli & Eddy, 1996b; Scaife & Bruner, 1975). What was once taken for granted as simply a step in human development is now viewed as a key component of social cognition, communication, language acquisition, and representational theories of mind (Bruner, 1995). *Joint visual attention* has been defined as “looking where someone else is looking” (Butterworth, 1995, p. 29). Like pointing, it is a triadic transaction involving an informant; a recipient; and an object, an event, or a place of interest. In its active form (deictic gaze), it can be used to direct another's attention to something of interest. The spatial-signaling function of gaze, along with associated head and hand orientations, has been viewed as a cornerstone for human referential communication (Argyle, 1978; Butterworth, 1995). Also, gaze can passively (i.e., without the intention of the infor-

mant) draw another's attention to something being observed. Consequently, gaze reading has adaptive value in that it can allow individuals to take advantage of the visual experience of others. Joint visual attention can theoretically inform an observer of another's knowledge state (e.g., Premack & Woodruff, 1978; Tomasello & Call, 1997; Wellman, 1990), which may be used to mediate social interactions and manipulate the behavior of others (Whiten, 1997).

In humans, joint visual attention follows a developmental progression (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; Corkum & Moore, 1995; Scaife & Bruner, 1975). From approximately 2 to 6 months of age, infants begin to look in the direction where another individual gazes; they follow the individual's head movements to locations within their visual field (“gaze following,” after Emery, Lorincz, Perrett, & Oram, 1997). Between 6 and 12 months of age, infants can localize the specific object at which the other is gazing (“joint attention”; Emery et al., 1997). From 12 to 18 months of age, infants can follow another's gaze into space that is outside their own visual field (e.g., behind or above them) and can orient their gaze on the basis of another's eye movements (Butterworth & Jarrett, 1991). Older children can use eye direction alone (i.e., without movement) to infer the attention of another (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995). Thus, joint visual attention in its full form appears to emerge after simpler gaze following.

Over the past several years, several different nonhuman species have been tested for their competence in understanding gaze cues. Perhaps not surprisingly, gaze following has been demonstrated in several primate species (see Emery et al., 1997; Tomasello, Call, & Hare, 1998). At a more advanced level, chimpanzees (*Pan troglodytes*) can follow a human's gaze to an object located behind a barrier or beyond a distractor object, and they can apparently understand that a barrier occludes vision (Povinelli & Eddy,

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1996a; Tomasello, Hare, & Agnetta, 1999). However, chimpanzees and other primates have difficulty understanding the gaze of another within so-called gaze-directed object-choice tasks (Anderson, Sallaberry, & Barbier, 1995). In an object-choice task, the subject faces an informant who orients his or her eyes and head toward one of two containers that is baited. The subject's task is to choose the baited container (theoretically by using the gaze cue). A key issue in object-choice tasks is determining exactly what the subject understands about the gaze cue. Is gaze simply understood as a discriminative stimulus (i.e., a learned arbitrary sign that directs the subject to move in a particular direction until it finds something of interest), or is gaze understood as a true communicative device that indicates the attention and focus of the informant? Accuracy on initial trials with novel gaze problems precludes explanations based on associative learning of specific cues and responses.

For monkeys (*Cebus apella*, *Macaca mulatta*, and *Sanguinus oedipus*), gaze appears to be an ineffective cue in object-choice tasks unless it is presented for a large number of trials or supplemented with other cues, for example, pointing, tapping, or proximity of gaze to the baited container (Anderson et al., 1995; Anderson, Montant, & Schmitt, 1996; Itakura & Anderson, 1996; Neiwirth, Burman, Basile, & Lickteig, 2002).

A lack of accurate first-trial responding also characterizes much of the gaze research on chimpanzees and other apes. Povinelli, Reaux, Bierschwale, Allain, and Simon (1997) found that of 7 chimpanzees, none performed above chance on eight first trials (four using human gaze only and four using gaze-point combinations) in an object-choice task. A similar lack of first-trial accuracy with human gaze alone was shown in 6 chimpanzees by Call, Hare, and Tomasello (1998). Although 1 of 4 chimpanzees tested in an object-choice task by Itakura, Agnetta, Hare, and Tomasello (1999, Study 1) performed above chance in response to gaze-point combinations (17 correct responses in 24 trials), this chimpanzee was at chance levels for the first half of the test, making it likely that this subject learned the proper response over the test trial period. In a subsequent experiment by the same authors, 1 of 5 chimpanzees not previously tested with human gaze performed above chance with this cue. However, first-trial performance was not reported. Finally, the report by Itakura and Tanaka (1998) of spontaneous understanding of human gaze in 2 chimpanzees and an orangutan (*Pongo pygmaeus*) may have been contaminated by prior exposure to conditions in which gaze either accompanied a tap cue on or a point cue toward the correct alternative (see Peignot & Anderson, 1999, for similar confounds in gaze studies with gorillas, *Gorilla gorilla*).

Even in the cases of limited success, it is not clear how precisely apes understand the focus of another's gaze in object-choice tasks. Povinelli, Bierschwale, and Cech (1999) reported that when chimpanzees and children were presented with a human gazing directly at an object versus gazing above it at nothing in particular, only children distinguished between the cues.

In contrast to these largely negative results with primates, results with dogs (*Canis familiaris*) show that they perform well in gaze-directed object-choice tasks. Hare, Call, and Tomasello (1998) found that 2 domestic dogs responded without error, or nearly so, to 18 trials using human gaze cues. Hare and Tomasello (1999) found that 5 of 10 dogs evidenced above-chance performance on 24 trials with human gaze-point combinations (1 dog

was errorless); also, 4 dogs responded accurately to gaze-alone cues given by another dog (body orientation may also have been used). Finally, Soproni, Miklosi, Topal, and Csanyi (2001) found that dogs distinguished between an informant gazing at an object versus gazing above it. Thus, in contrast to the findings of Povinelli et al. (1999) with chimpanzees, these results show that gaze for dogs is target specific.

Bottlenosed dolphins (*Tursiops truncatus*) have also shown proficiency with both human point- and gaze-directed cues. Herman et al. (1999) demonstrated that a dolphin can understand the referential character of human *direct points* (the human's pointing arm is on the ipsilateral side of the referenced object) and *cross-body points* (the pointing arm is on the contralateral side of the object) to each of three objects located 3 m to the left, right, and behind the dolphin. In the context of an artificial gestural language (Herman, Richards, & Wolz, 1984), human points that were substituted for gestural symbols in the language were understood spontaneously (Herman et al., 1999). Tschudin, Call, Dunbar, Harris, and van der Elst (2001) reported spontaneous comprehension of human gaze by dolphins in an object-choice task. On the initial 12-trial test, 2 of 6 dolphins were correct on 10 and 11 trials, respectively. Three others performed above chance after extended trials. We found these results intriguing and believed that an investigation into the basis on which gaze comprehension rests was warranted.

We began this investigation by first testing for spontaneous human-directed gaze comprehension in 2 bottlenosed dolphins. We then examined whether gaze understanding can proceed on the basis of head movements alone (without eyes available), on eye glance alone (without head motion), and without torso information. Finally, we tested for comprehension of static gaze and point to examine whether movement was necessary for accurate interpretation of the referent of these indicators.

General Method

Subjects

Subjects were two 26-year-old female Atlantic bottlenosed dolphins (*T. truncatus*) named Akeakamai and Phoenix. They were housed together with another dolphin in two interconnected seawater pools (each 15.2-m diameter \times 1.8-m deep) at the Kewalo Basin Marine Mammal Laboratory in Honolulu, Hawaii. Each dolphin was tested separately in one of these pools and was fed a portion of a daily diet of approximately 9.1 kg of smelt, herring, sardines, and squid during testing.

Both dolphins had participated in many cognitive studies, including language comprehension (e.g., Herman et al., 1984; Herman, Kuczaj, & Holder, 1993), same-different tasks (Herman, Hovancik, Gory, & Bradshaw, 1989; Mercado, Killebrew, Pack, Macha, & Herman, 2000), television comprehension (Herman, Morrel-Samuels, & Pack, 1990), and vocal and motor mimicry (Herman, 2002; Richards, Wolz, & Herman, 1984). Additionally, in previous studies, both dolphins had revealed spontaneous comprehension of a human's pointing gesture toward a distally placed object as a reference to that object (Herman et al., 1999; Herman, Pack, & Morrel-Samuels, 1993). Phoenix had experience with direct points to laterally placed objects, and Akeakamai had experience with both direct points and cross-body points. Both dolphins also understood points to an object placed behind them. Each dolphin spontaneously understood pointing gestures incorporated within the structure of its respective artificial language (Herman et al., 1999; Herman & Uyeyama, 1999). Neither dolphin had been exposed to any formal training using human gaze. Indeed, during all prior studies with these dolphins, the trainer's head

intentionally remained face forward, and opaque goggles placed over the trainer's eyes prevented eye-gaze cues (e.g., Herman et al., 1984).

Objects

Three objects were used in each experiment. In Experiment 1, they were a surfboard (a 107-cm-long "body board" made of white foam), a hoop (an 81-cm-square hoop constructed from a 1.9-cm-diameter polyvinyl chloride [PVC] pipe), and a pipe (a 117-cm-long \times 1.9-cm-diameter PVC pipe). Because the surfboard tended to drift and was difficult to control, in Experiment 2 we substituted a white-and-black soccer ball for the surfboard.

Actions

Four action commands, each elicited by a single unique gesture of an experimenter's (Adam A. Pack) right arm and hand, were used throughout this study to instruct a dolphin to perform a specified action to a referenced object. The actions were *jump over*, *swim under*, *touch with your pectoral fin*, and *touch with your tail*. Both dolphins were highly familiar with these actions and their associated gestural signs (Herman et al., 1984).

Indicative Cues

Two types of pointing gestures were used: a direct point and a cross-body point. For direct pointing, the experimenter pointed toward the goal object briefly (approximately 2 s), using the arm on the same side as the object. For cross-body points, the experimenter pointed toward the goal object with the arm on the contralateral side from that object; the arm was extended in front of the experimenter's chest with elbow bent and forearm extended horizontally, again for approximately 2 s. During both types of point, the experimenter's head and torso were held steady and facing forward. After a pointing action was complete, the pointing arm returned to the experimenter's side. For the *gaze* cue, the experimenter's arms remained at the experimenter's sides, and the experimenter turned head and eyes until they were oriented toward the referenced object. The experimenter remained staring at the object until the dolphin's response was complete. Gazing was not a conditioned signal in the dolphins' repertoire and was not used to supplement other types of training.

General Procedure

Prior to each trial, the experimenter stood outside the pool wall, facing the dolphin (see Figure 1). Each of two object monitors, positioned 3 m to the left and right of the experimenter, placed a different alternative object on the surface of the water (according to a preplanned schedule) and faced away from the experimenter and dolphin. The object monitors did not know whether their object was the one designated as correct. An assistant located out of the dolphin's view and out of earshot of the object monitors whispered to the experimenter the particular sequence of cues to be given, using the preplanned schedule. The instruction consisted of three items: (a) one of the four action instructions, (b) the indicative cue to be used (direct point, cross-body point, or gaze), and (c) the object to be indicated. The order of the cues—action first, followed by the indicative act—was chosen to ensure that the dolphin would not begin its response until receiving the entire instruction. Theoretically, if the object cue had preceded the action cue, the dolphin could have begun swimming toward the goal object while looking back at the experimenter to receive the action cue. By giving the action cue first, we ensured that the dolphin had to form a representation of this cue while waiting to learn the specific object to be acted on. Once the experimenter received the entire whispered instruction, he then pointed to a small target buoy attached to the pool wall in front of him and jutting out 15 cm. In response, the dolphin rested its rostrum on the buoy and looked toward the experimenter. The experimenter then signed the action

gesture while looking straight ahead. A session coordinator located in the observation tower timed a 3-s interval during which the dolphin was required to keep its rostrum on the target buoy. If the dolphin removed its rostrum from the target buoy during the interval, the trial was aborted and a 45-s intertrial interval commenced. If the dolphin kept its rostrum on the target buoy throughout the delay, the coordinator said "ready" aloud as a signal for the experimenter to perform the second instruction in the sequence (either point or gaze) toward the specified alternative object. The dolphin was rewarded for carrying out the specified action to the indicated object. Figure 1 shows three digital photographs to illustrate the gaze instruction, "Touch with your tail the object being gazed at (the hoop)."

In each trial, an individual having no knowledge of the instruction given to the dolphin (an opaque screen obscured the individual's views of the experimenter but allowed sighting of the dolphin at each alternative) reported aloud the dolphin's choice of object and action. If the report corresponded to the instruction given, the experimenter blew a whistle, fed a fish, and provided social praise. If the dolphin performed incorrectly on part or all of its instruction, no reward was given; the dolphin was simply signaled to return to station. All trials were recorded on digital videotape for postsession review and analysis.

Experiment 1: Testing the Dolphin's Spontaneous Understanding of Human Gaze

We first tested the ability of Phoenix and Akeakamai to respond spontaneously to human gaze in an object-choice task in which a human signed one of four action instructions and then either gazed at or used a direct point to indicate one of two objects. In previous studies, both dolphins had shown comprehension of human pointing (Herman et al., 1999), but neither had been tested before for the comprehension of human-directed gaze.

Method

Procedure

The within-trial procedures were as described above. A total of 24 action + gaze test trials were interposed among 24 action + point trials. Only direct points were used. For each dolphin, two 24-trial sessions were conducted. Each session consisted of 12 gaze trials and 12 point trials organized into three blocks of 8 trials each, with 4 gaze trials and 4 point trials intermixed pseudorandomly. For each block, a different one of the six possible pairwise permutations of the three alternative objects was used. Over the 48 trials, each of the three objects was gazed at eight times and pointed toward eight times. Actions were balanced across objects and indicatives.

Station Training

Normally, in response to an action sign, the dolphins attempt to carry out that action to some object or tank fixture immediately. For the current study, we trained the dolphins, within a single 24-trial session, to remain at station until the appearance of the indicative cue. The dolphin was rewarded for holding its rostrum on the target buoy for a timed 3-s period. No action was required. This training guarded against any speculative movement by the dolphin toward an object before the indicative cue was given. Testing of responses to human pointing and gazing began at the next session.

Results and Discussion

Figure 2 compares Phoenix and Akeakamai's object-selection performance on gaze and point trials. Phoenix was errorless on

both gaze and point trials, and Akeakamai made a single error on the 20th gaze trial, going to the wrong object but executing the required action. There was no significant difference in performance between gaze and point conditions (Fisher's exact test, $N = 96$, $p = 1.0$). Furthermore, each dolphin was correct on the first four trials that a gaze cue was paired with each of the four actions. Thus, the dolphins immediately understood the directive function of human gaze. This finding is similar to that reported by Tschudin et al. (2001), although it is unclear from that report where in the trial sequences the one and two errors, respectively, occurred for the 12 trials, given each of the two dolphins that performed above chance. In the first 12 gaze trials of our study, both dolphins were 100% correct (cumulative binomial test, $p < .01$).

Movement is an important cue used by many species to track prey and predators. In Experiment 1, eye and head movements accompanied the experimenter's gaze cues, and arm movements accompanied his point cues. In the subsequent experiments, we deconstructed the experimenter's gaze and point cues by eliminating or controlling for particular types of movement to investigate their role in the dolphin's understanding of human-directed gaze and pointing. Experiment 2 investigated the importance of head movement versus eye movement. Experiment 3 controlled for any inadvertent torso movements. Finally, Experiment 4 investigated the importance of head and arm movement in gaze and point comprehension, respectively, by eliminating all movement on some trials (static gaze and point) and by contrasting this condition with trials in which movement was allowed (dynamic gaze and point).

Experiment 2: Deconstructing Gaze (Eye Vs. Head Movement)

In this experiment, we tested the effect of eye movement on the dolphin's comprehension of gaze. In Experiment 2A, eye-gaze cues were eliminated (i.e., only head turning toward the referent was allowed). In Experiment 2B, head movement was eliminated, and only eye gaze toward the referent was allowed.

Method

Apparatus and Procedure

For each test, a single 24-trial session was conducted with each dolphin. As in Experiment 1, an action command preceded an indicative cue, and each session consisted of 12 point trials and 12 gaze trials organized into three blocks of 8 trials each. Within-block conditions were as described in Experiment 1. Each unique combination of specific action ($n = 4$), specific indicative cue ($n = 2$), and specific object ($n = 3$) was tested once.

Experiment 2A. At the beginning of each gaze trial and each point trial, the experimenter wore opaque goggles that completely obstructed the experimenter's vision as well as the dolphin's view of the experimenter's eyes. On a verbal cue from the coordinator, the experimenter then gave an action command, and on a second verbal cue, either pointed at or turned his or her head toward one of the two objects.

Experiment 2B. For these trials, the experimenter did not wear the opaque goggles. Each gaze trial commenced as in Experiment 2A, with the dolphin placed on the target buoy and the experimenter signing one of four action commands while facing and looking forward. For the gaze instruction, the experimenter's head remained stationary (i.e., face forward), and only the experimenter's eyes moved in the direction of the referent and remained staring at it. For point trials, the experimenter remained face

forward, with eyes staring ahead throughout the trial. The experimenter signed one of the four action commands and then gave the point instruction, as in Experiment 2A.

Results and Discussion

Figure 3A shows each dolphin's choice accuracy in selecting the indicated object in response to gaze and point cues with the experimenter's eyes obscured (Experiment 2A). As in Experiment 1, both dolphins performed at or near ceiling levels. Phoenix was errorless on point and gaze tests. Akeakamai was errorless on all point trials, but she committed two object selection errors on gaze trials (on the 2nd and 12th gaze trials). Nonetheless, her gaze performance (10 of 12 gaze trials were correct) was significantly above chance (cumulative binomial test, $p < .02$) and not significantly different from her point performance (Fisher's exact test, $N = 24$, $p = .48$). Thus, on gaze trials, human eye movement in the direction of the referenced alternative object was not required for the dolphin to select that object. Lateral head movement by the human toward the object was sufficient to indicate the referent.

Figure 3B shows the percentage of correct object selections for each dolphin on gaze trials in which only the experimenter's eyes moved in the direction of the referent (i.e., the experimenter's head faced forward throughout the trial). In contrast to the high performance levels in Experiment 2A, in Experiment 2B neither dolphin performed significantly above chance on object selection (cumulative binomial test, $p > .05$). Each dolphin's performance on gaze trials was also significantly below its performance on point trials (Fisher's exact test: for Phoenix, $N = 24$, $p = .04$; for Akeakamai, $N = 24$, $p < .01$). Furthermore, the combined performance accuracy of the dolphins in the eyes-only condition (12 of 24 trials correct) was significantly below their performance in either the head-movement-only condition, $\chi^2(1, N = 48) = 8.17$, $p < .01$, or the point trials, $\chi^2(1, N = 48) = 13.4$, $p < .01$. Thus, human eye-gaze cues alone were not sufficient to direct the dolphin's attention toward an object.

Experiment 3: Eliminating Torso

Although in all previous tests, the experimenter attempted to maintain his torso rigid and facing forward, in Experiment 3 we explicitly controlled for any inadvertent torso movements by obscuring all but the experimenter's head on gaze trials and all but his arm on point trials. This procedure thus tested the dolphins' ability to interpret cues from a disembodied head or arm. The dolphins' only previous experience with disembodied body parts was a test of their abilities to understand gestural commands given by the disembodied arms and hands of a trainer appearing on a television that was placed behind an underwater window in their habitat (Herman et al., 1990). Both dolphins interpreted these novel displays with high accuracy. None of the displays involved gazing or pointing at objects.

Method

The procedures were identical to those of Experiment 2A, except that prior to each trial, a white opaque Plexiglas (Atoglas, Houston, TX) board (0.84-m high \times 0.62-m wide) attached to a PVC frame was placed in front of the experimenter. During gazing, only the experimenter's head (with eyes covered by opaque goggles) was visible above the board (Figure 4C).

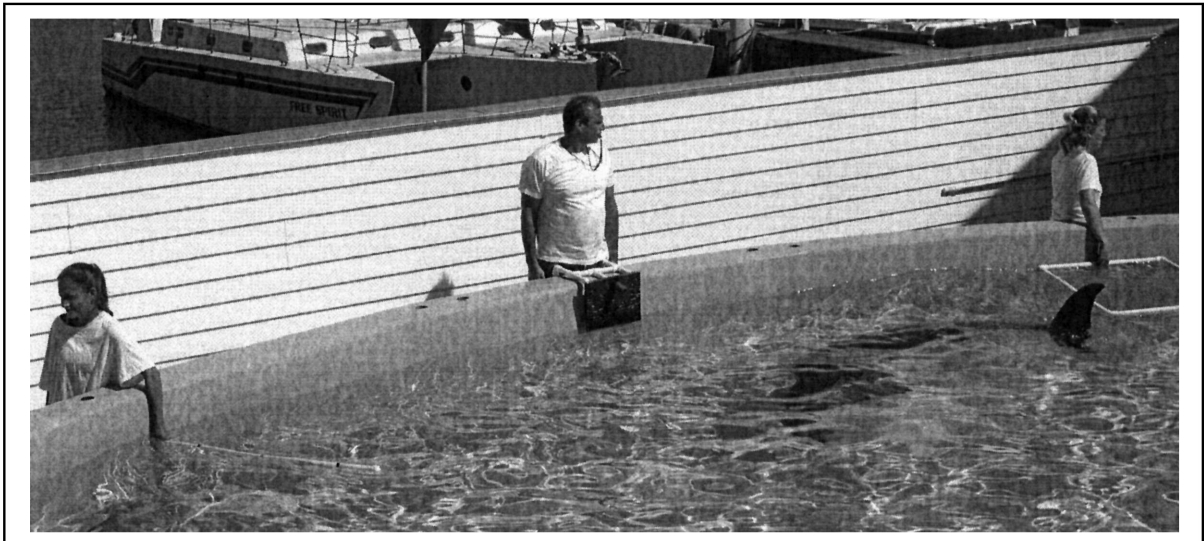
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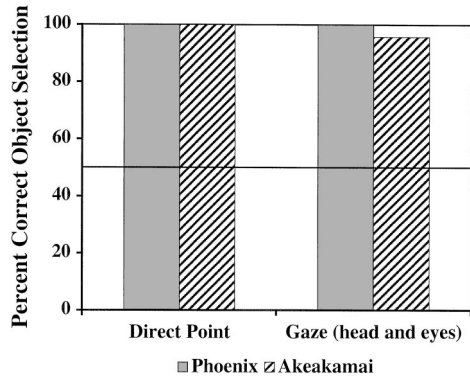


Figure 2. For Experiment 1, the percentage of correct object selections for each dolphin in response to action + point instructions and action + gaze instructions given by the experimenter in the two-alternative object-choice task. Each bar represents 24 trials. A line depicting 50% chance probability is shown. All performance levels are highly significant.

During pointing, only the experimenter’s arm and hand (Figures 4A and 4B), were not obscured.

For both gaze and point trials, the experimenter’s arm reached around the board, signaled the dolphin to station on the target buoy, and was then removed from the dolphin’s view. Once the dolphin’s rostrum was on the buoy, the experimenter again reached around the board and signed one of the four action commands. The experimenter’s arm again disappeared for a 3-s delay. After the delay, the experimenter produced one of three indicative behaviors toward a designated alternative object: gaze (as described earlier), direct point, or cross-body point. For direct point (Figure 4A), the experimenter’s arm on the ipsilateral side of the referent emerged from behind the board and pointed for 2 s at the referent and then returned behind the board and out of view. For cross-body point (Figure 4B), the experimenter’s arm on the contralateral side from the referent emerged from behind the board and, with elbow bent and index finger extended, moved across the front of the board in the direction of the referent until the tip of the experimenter’s finger was near the board’s center, where it was held for 2 s, and then dropped to the experimenter’s side and out of view.

Each dolphin was tested over two 18-trial sessions on 12 trials each of human direct point, cross-body point, and gaze (36 trials total). Three blocks of 6 trials each were completed within a session, each block consisting of one of the six unique two-way permutations of the two side locations (left and right) and the three different alternative objects. Within each block, there were 2 point trials, 2 cross-body-point trials, and 2 gaze trials ordered pseudorandomly. Across all trials, action command, indicative command, and referenced object were balanced.

Before testing the dolphins in this condition, we tested Phoenix’s ability to understand the cross-body point. Although Phoenix had previously been exposed to direct points of a human’s arm and hand (Herman, Kuczaj, & Pack, 1993), she had never experienced cross-body points. Phoenix was tested in a single 24-trial session consisting of 12 action + cross-body-point trials interleaved among 6 action + direct-point trials and 6 action +

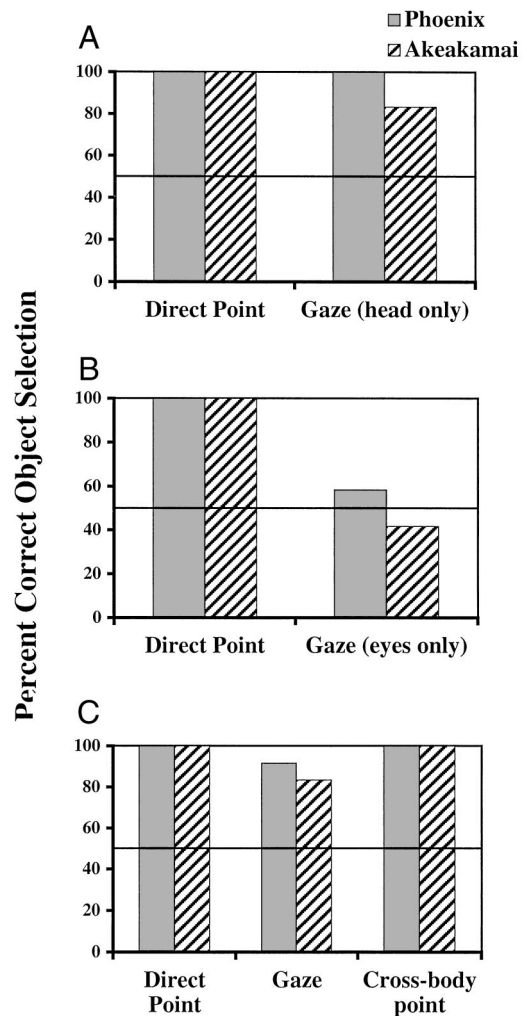


Figure 3. A: For Experiment 2A, the percentage of correct object selections for each dolphin in response to human-directed head gaze of an experimenter with eyes covered by opaque goggles compared with human direct points. B: For Experiment 2B, the percentage of object selections for each dolphin in response to human-directed eye gaze alone (experimenter’s head is stationary), compared with human direct points. C: For Experiment 3, the percentage of correct object selections for each dolphin in response to human direct points, head gaze, and cross-body points, with the dolphin’s view restricted by an opaque board to either an arm alone or the head alone. On head-gaze trials, the board covered all but the experimenter’s head. On direct-point and cross-body-point trials, the board covered the entire body, and the pointing arm emerged from the back of the board. Each bar represents 12 trials, and a line depicting 50% chance probability is shown. The percentage of correct choices is significantly above chance for all but the eyes-only condition.

Figure 1 (opposite). Three digital still images showing a trial sequence for the human-directed instruction, “Touch your tail to the object being gazed at (the hoop),” to the dolphin Phoenix. Pipe and hoop are held to the left and right of the dolphin at a 3-m distance by two assistants, each facing away from the experimenter and therefore unaware of the gaze direction. A: After the dolphin places its rostrum on the target buoy, the experimenter gesturally signs the instruction “Tail touch.” B: The experimenter turns his head and eyes toward the hoop to his left. C: The dolphin’s tail flukes are partially visible above the surface as they make contact with the hoop.

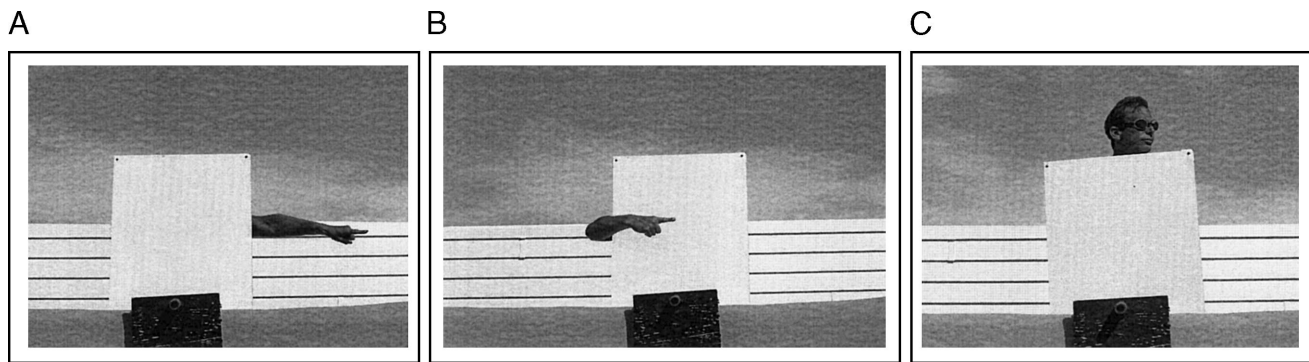


Figure 4. Three digital still images showing the experimenter's indicative cues in Experiment 3, in which an opaque board obscured all of the experimenter except his arm on direct-point trials (A) and cross-body-point trials (B) and all but his head on gaze trials (C). Each image is from the dolphin's point of view and shows the experimenter pointing to or gazing at the object to the dolphin's right. For gaze trials, the trainer wears opaque goggles (C).

gaze trials (with eyes covered by opaque goggles). Within-trial procedures were the same as those of Experiment 2A. No opaque board was used.

Results

Phoenix performed without error on her initial 24-trial test. Thus, like Akeakamai in the Herman et al. (1999) study, Phoenix spontaneously understood the referential function of the cross-body point.

Figure 3C shows each dolphin's choice accuracy in object selection across all conditions of the test, with the view of the experimenter's torso obscured. Phoenix was wholly correct (both on action and object selection) on all direct-point and cross-body-point trials, whereas Akeakamai committed one action error on 12 direct point trials and two action errors on 12 cross-body-point trials. All her object choices were correct, however. On gaze trials, Phoenix selected the indicated object on 11 of 12 trials; her single error occurred on Trial 12. Akeakamai selected the object gazed at on 10 of 12 trials; her two errors occurred on Trials 1 and 6. Both dolphins performed well above chance (cumulative binomial test, $p < .05$). Overall, there was no significant difference in performance levels on object selection between the gaze condition and either the point or cross-body-point condition (Fisher's exact test, $N = 48$, $p = .23$, for each comparison. Additionally, Phoenix was wholly correct on all gaze trials and Akeakamai was correct on 8 of 12 gaze trials (i.e., she committed two action errors in addition to two object-choice errors).

Experiment 4: Static Versus Dynamic Cues

In this final experiment, we investigated the dolphin's ability to interpret a static scene consisting of the experimenter already gazing, direct pointing, or cross-body pointing at one of two alternative objects. Static cues were contrasted with their dynamic counterparts. If the dolphin performed equivalently in both conditions, this result would imply that head or arm movement was not a requisite for the dolphin to understand the referent of human gaze or pointing.

Method

Apparatus

A 0.64-cm-thick brown plywood board (1.2 m high \times 2.4 m long) was used as a blinder to eliminate the dolphin's view of the experimenter. Handles on the rear of the board (i.e., the side facing away from the dolphin) allowed 2 assistants, located behind the board and out of the dolphin's view, to raise the board from behind the pool wall to obscure the dolphin's view of the experimenter or to lower the board to reveal the experimenter. With the board raised, the experimenter adopted a static pose that was revealed when the board was lowered.

Procedure

Each dolphin was tested over three 24-trial sessions. Sessions consisted of 12 dynamic indicative trials (4 direct point, 4 cross-body point, and 4 gaze) and 12 static indicative trials (again, 4 direct point, 4 cross-body point, and 4 gaze). Six 4-trial blocks were run per session (three blocks of dynamic indicative trials and three blocks of static indicative trials ordered pseudorandomly). Each block used two of the three objects in a different permutation. Trials were ordered pseudorandomly. Each action and referenced object was balanced across sessions.

Within-trial procedures were identical to those of Experiment 2A, except that after the experimenter completed his action command, the assistants raised the blinder from behind the tank wall, completely obscuring the dolphin's view of the experimenter. On static trials, the experimenter adopted the gaze position, direct-point position, or cross-body-point position while behind the blinder and remained immobile for the remainder of the trial. After 3 s, the blinder was lowered behind the pool wall, revealing the experimenter. The dolphin was required to perform the action command to the object indicated by the experimenter's static posture. On dynamic trials, the experimenter remained face forward while the blinder was raised and lowered, and then, as in Experiment 2A, produced the indicative instruction in full view of the dolphin. On all trials, the experimenter wore opaque goggles.

Results and Discussion

Figure 5 (top) shows the percentage of correct object selections for each dolphin in response to human dynamic direct point, dynamic cross-body point, and dynamic gaze. Figure 5 (bottom)

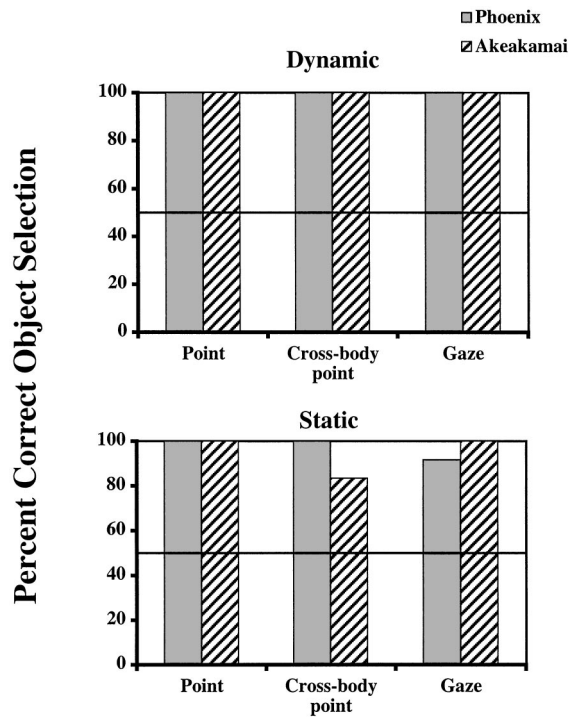


Figure 5. The percentage of trials in Experiment 4 in which the dolphins selected the indicated object in response to the experimenter's direct pointing, cross-body pointing, and gazing presented dynamically (top) and statically (bottom). Each bar represents 12 trials. The 50% chance probability line is shown. All performance levels are highly significant.

shows the corresponding results for the static condition. Each dolphin was errorless in selecting the indicated object across all dynamic trials. Phoenix was wholly correct (on both action and object selection) on all dynamic trials, whereas Akeakamai made a single action error on a dynamic cross-body-point trial.

On static indicative trials, Phoenix was errorless in selecting the indicated object on all static direct-point and cross-body-point trials and made only one error (on Trial 6) on 12 static gaze trials (cumulative binomial test, $p < .01$). She made no action errors on any trial. Akeakamai was errorless in selecting the indicated object on all static direct-point and static gaze trials and made only two errors (on Trials 3 and 6) on the 12 static cross-body-point trials (cumulative binomial test, $p = .02$). In addition, Akeakamai made one action error on the static cross-body-point trials and one action error on the static gaze trials. Overall, a Fisher's exact test revealed no difference between static and dynamic conditions in the combined object selection performance levels for the 2 dolphins ($N = 144$, $p = .25$).

On the first occasion that Phoenix experienced a static gaze, static direct point, and static cross-body point with each of the four actions (12 trials total), she performed without error. Akeakamai was wholly correct on 9 of these 12 first trials, committing two action errors and one object error (on a cross-body-point cue). Thus, both dolphins performed significantly above chance on object selection on these initial 12 trials (cumulative binomial test, $p < .05$). These results indicate that the dolphins spontaneously understood the object being attended to through human static gazing, static direct pointing, and static cross-body pointing.

General Discussion

The current findings establish that the dolphins Phoenix and Akeakamai spontaneously understood (i.e., on the first trials) the gaze direction of a human in an object-choice task. That is, each dolphin was errorless on its first trials of human gaze paired with each of the four actions: jump over, swim under, touch with your pectoral fin, and touch with your tail. Errorless first-trial performance cannot be explained by associative learning of an arbitrary discriminative cue (in this case, directional head turning with attention to the object under scrutiny by the informant). Our findings, therefore, argue that gaze is understood as a reference to the object lying in the direction of the gaze. Tschudin et al. (2001) similarly demonstrated high levels of human gaze comprehension in an object-choice task by 2 of 6 dolphins. However, as we noted previously, the researchers did not report the location within the test sequence of the few errors that occurred, which limits an assessment of the initial spontaneity of gaze comprehension.

The claim that Phoenix and Akeakamai interpreted human gaze spontaneously derives from the history of these animals. Neither had been exposed to any formal training using human gaze. In all of our other cognitive studies with these 2 dolphins (e.g., Herman et al., 1984, 1989, 1999; Mercado et al., 2000), the research protocol required the trainers to keep their heads oriented face forward and still. In addition, the trainers wore darkened goggles to prevent the possibility of eye-gaze cues. Although the dolphins likely experienced a human looking at an object or location informally, gaze was never used to accomplish or supplement training. Any prior knowledge the dolphins may have had of human gaze, therefore, would have been derived from informal observation of humans.

Given the dolphin's understanding of human-directed gaze, a key issue was for us to determine the basis for this ability by deconstructing the human gaze response into its more primitive elements. First, we examined whether human eye movement alone was essential to or could be used exclusively to direct the dolphin's attention. In humans, even the slightest glance (without head or torso turning) at an object, individual, or event can direct an observer to focus his or her attention on that sight (e.g., Butterworth, 1995; Butterworth & Jarrett, 1991; Itakura & Tanaka, 1998; Povinelli et al., 1999). Moreover, neurons specialized for processing gaze information, including head orientation and eye direction, have been found in the cortical and subcortical brain regions of humans (e.g., Hoffman & Haxby, 2000) and monkeys (Perrett et al., 1985; Perrett, Hietanen, Oram, & Benson, 1992). *Eye-gaze following*—the ability of an observer to follow an informant's eye direction to a location in space—has been demonstrated in chimpanzees (Povinelli & Eddy, 1996a), adult (but not juvenile) pig-tailed macaques (*Macaca nemestrina*; Ferrari, Kohler, Fogassi, & Gallese, 2000), and baboons (*Papio papio*; Fagot & Deruelle, 2002). However, evidence for spontaneous comprehension of directed eye gaze in an object-choice task has been documented in only one study (with 2 chimpanzees and an orangutan; Itakura & Tanaka, 1998). Others have failed to find this effect in either chimpanzees (Povinelli et al., 1999), gorillas (Peignot & Anderson, 1999), or capuchin monkeys (*Cebus apella*; Vick & Anderson, 2000).

Dogs also have difficulty following human eye gaze in object-choice tasks. Soproni et al. (2001) demonstrated dogs' compre-

hension of human head + eye gaze toward a target but reported only chance performance with eye-gaze cues alone. Similarly, Hare et al. (1998), using an eye-gaze condition in which the eyes alternated between the baited cup and the dog, found no evidence for comprehension of the cue.

To what degree is the dolphin's comprehension of human gaze controlled by movement of the informant's eyes? Our studies show that head turning without eye information is sufficient for accurate responding, but eye gaze alone (with the head held facing forward) is insufficient, yielding only chance performance. Thus, the directionality of the human head alone appears to be the only salient cue for the dolphin in its response to gaze. This finding is not unexpected, perhaps, given that dolphins, unlike humans, primates, and dogs, have eyes laterally placed rather than positioned forward on their face. Consequently, the movements of the dolphin's head and any accompanying eye movements cannot be correlated. For example, as the head turns toward the right, the right eye moves to the left to fix on a target to the right. Furthermore, other than when dolphins are frightened or excited, little of the white sclera is visible, resulting in a largely uniform dark background. Thus, dolphins' eye movements are more difficult to detect than those of other species and may not be a salient directional cue in the dolphin's natural world (although they may communicate emotional state).

Clearly, movement of the head or arm was not required for the dolphins' understanding of human gaze and pointing. Although these movements may be a helpful cue for eliciting an attentional response, the terminal position of the movement was sufficient, of itself, for the dolphins to locate the object of attention. *Static gaze*—observing a human head already turned left or right—was as effective as dynamic gaze. Similarly, static direct points and static cross-body points were as easily understood as their dynamic counterparts. Importantly, the dolphins understood these static forms of gaze, direct point, and cross-body point on their first trials, hence spontaneously. Spontaneous understanding of static gaze cues has been found with children but not with chimpanzees (Povinelli et al., 1997) or dogs (Hare et al., 1998). Inspection of the combined results of four static gaze trials and four static gaze-point combinations given to 7 chimpanzees (Povinelli et al., 1997, Table 1) has revealed that no subject was above chance. However, in a later study (Povinelli et al., 1999), 2 of these 7 subjects were eventually successful in interpreting static gaze. Hare et al. (1998) found that 2 dogs were only 50% correct during their first 18-trial session of static eye + head gaze trials, but both performed significantly above chance with dynamic pointing and dynamic gaze cues, and one of the dogs performed above chance with static pointing.

The dolphins in the present study are thus the first nonhuman animal shown to be spontaneously and reliably attentive to both static head orientation and static arm and hand orientation. Each dolphin was able to "read" the static cue spontaneously and respond with the designated behavior to the referenced object. However, how precisely dolphins can follow human gaze to specific objects located in the same direction as others has yet to be determined. Chimpanzees can follow dynamic human gaze to locate objects around barriers and past distractors (e.g., Tomasello et al., 1999), and dogs can distinguish between dynamic gaze at an object and dynamic gaze above an object (Soproni et al., 2001).

Given the findings of gaze comprehension in such distantly related species as primates, dogs, and dolphins, an obvious question is what social and/or evolutionary mechanisms led to these abilities. Hare et al. (2002) found little evidence that rearing history affected dogs' comprehension of human gaze. Similarly, the wide variation in gaze comprehension abilities demonstrated by apes despite similar human-rearing backgrounds implies that human rearing is not responsible for gaze understanding (Call et al., 1998; Itakura et al., 1999; Itakura & Tanaka, 1998; Povinelli et al., 1997). Herman et al. (1999) considered the dolphins Akeakamai and Phoenix to be enculturated because of their long history of contact with humans in daily social interactions and in cognitive problem-solving activities. However, the high levels of gaze comprehension observed by Tschudin et al. (2001) in dolphins without this extensive social and cognitive history leads us to argue that enculturation is not necessary for sophisticated comprehension abilities.

Moore and Corkum (1994) hypothesized that the selection pressures favoring the evolution of conspecific gaze following would require dominance of the visual modality in the species at least, as well as forward-facing eyes (so that gaze direction can be reliably indicated by head orientation) and a sophisticated social structure. Compared with nonhuman primates and dogs, dolphins do not appear to meet this set of requirements very well. As noted previously in this article, dolphins do not possess forward-facing eyes. Furthermore, although dolphins' visual system is well developed (e.g., Herman, 1990; Madsen & Herman, 1980) and dolphins show roughly equivalent proficiencies in some cognitive tasks using their visual and auditory senses (e.g., Herman, 1987; Herman et al., 1984, 1989; Pack & Herman, 1995), the dominance of their visual system over their auditory system (see Au, 1993) is unlikely. The only criterion they meet well is a sophisticated social structure (Mann, Connor, Tyack, & Whitehead, 2000; Pryor & Norris, 1991; Reynolds, Wells, & Eide, 2000).

Although dolphins do not possess forward-facing eyes, another sense, echolocation, is strongly associated with head orientation. *Echoic emission* involves a stream of broadband short-duration clicks that are projected in a narrow (approximately 10°) directional beam from the portion of the dolphin's head above its rostrum (see Au, 1993). Echoes from objects differing in density from the aquatic transport medium can provide dolphins with detailed information about their spatial structure and overall global shape (e.g., Pack, Herman, Hoffmann-Kuhnt, & Branstetter, 2002). In the wild, dolphins use echolocation to locate food (Rossbach & Herzing, 1997), as well as to "probe" each other (Herzing, 1996). Herman et al. (1999) suggested that attending to another's distal interrogation of an object through echolocation may be a natural part of the dolphin's behavior and may generalize to other types of functionally equivalent distal referencing. The directionality of the echoic emission may in effect point at the object being investigated, although not necessarily with an intention to inform or direct others. Nevertheless, a dolphin observing another dolphin echolocating may understand that the echolocator is attending to something. In fact, it has been shown that by listening to the echoes returning from a target being inspected through echolocation by another dolphin, the "eavesdropping" dolphin can identify the target (Xitco & Roitblat, 1996). Thus, joint attention to the echoes reflecting off an object, in conjunction with an understanding of the identity of the emitter of the original echolocation beam,

may provide a general foundation for the dolphin's spontaneous understanding of the referent of human point and gaze.

In trying to reconcile the differences in gaze comprehension abilities between primates and dogs, Hare and Tomasello (1999) noted that dogs have likely benefited from cognitive traits selected for in their closest ancestor, wolves (*Canis lupus*; Vila et al., 1997). They speculated that gaze comprehension may have been selected for in wolves because of its adaptive value in group hunting, which often requires close monitoring of conspecific gaze and body orientation. Hare and Tomasello reasoned that primates do not require this same type of group coordination in foraging activities because they are primarily frugivores and herbivores; thus, their well-developed ability to gaze follow may derive from the pressure to monitor the social activities of individuals (Hare, Call, Agnetta, & Tomasello, 2000). However, in a recent study, Hare et al. (2002) found little evidence for gaze comprehension in an object-choice task performed by human-reared wolves compared with that performed by dogs. Inasmuch as both species performed well in a nonsocial cognitive task and dogs' use of human social cues did not vary with age or rearing history, Hare et al. concluded that dogs most likely developed their abilities for gaze comprehension through the historic process of human domestication.

Dolphins, of course, are not domesticated animals. Their well-developed skills of gaze comprehension, therefore, are likely the result of different evolutionary pressures converging on the same cognitive solution. For individual dolphins, the ability to monitor the directionality of another's body or head orientation (both in the presence and absence of echoic emission) has clear adaptive value for monitoring activities related to food localization, group hunting, and social behavior (for a description of these activities, see, e.g., Bel'kovich, 1991; Connor, Heithaus, & Barre, 1999; Connor, Wells, Mann, & Read, 2000). In a highly social species such as the bottlenosed dolphin, it is likely that the functional use and benefits of vision and/or echolocation, in conjunction with the close coordination of individual dolphins in groups, would favor the evolution of joint attention. Xitco, Gory, and Kuczaj (2001) showed that in the presence of human observers, 2 dolphins spontaneously pointed their rostrums toward baited containers and often gazed back and forth between a human observer and a container. Presumably, these responses were intended to direct and monitor the human's attention, suggesting that joint attention in dolphins is robust and symmetric.

Finally, Tomasello et al. (1999) distinguished between low-level and high-level models of how individuals understand the gaze of others. Under the low-level model, an observer moves in the direction that another is looking until it encounters an object of interest. Under the high-level model, the individual comes to understand that when another looks in a direction, he or she is observing something (i.e., having a mental experience). The findings with chimpanzees, dogs, and human infants suggest that their knowledge of gaze extends beyond the low-level model but falls short of the high-level model (Butterworth & Jarrett, 1991; Soprani et al., 2001; Tomasello et al., 1999). That is, in at least some circumstances chimpanzees, dogs, and human infants appear to process gaze "geometrically" (i.e., they can locate the terminal point of an informant's gaze around barriers and past distractors), but this does not necessarily mean that the informant understands what he or she has been observing. At the time of our research, we

could certainly include the dolphin's response to human gaze in the low-level model of gaze comprehension (Tomasello et al., 1999). Clearly, human gaze is not perceived simply as an arbitrary cue that the dolphin learns to associate with moving in a particular direction. If this were the case, the dolphins would not have demonstrated spontaneous understanding of gaze, particularly static gaze. Gaze does appear to be object oriented in that the dolphins, almost without error, performed the required actions to the designated objects. On the other hand, tests have yet to be conducted on whether the dolphin can follow another's line of sight to a particular object among several objects located in the same general direction.

References

- Anderson, J. R., Montant, M., & Schmitt, D. (1996). Rhesus monkeys fail to use gaze direction as an experimenter-given cue in an object-choice task. *Behavioural Processes*, *37*, 47–55.
- Anderson, J. R., Sallaberry, P., & Barbier, H. (1995). Use of experimenter-given cues during object-choice tasks by capuchin monkeys. *Animal Behaviour*, *49*, 201–208.
- Argyle, M. (1978). *The psychology of interpersonal behaviour*. Middlesex, England: Penguin Books.
- Au, W. W. L. (1993). *The sonar of dolphins*. New York: Springer-Verlag.
- Baron-Cohen, S., Campbell, R., Karmiloff-Smith, A., Grant, J., & Walker, J. (1995). Are children with autism blind to the mentalistic significance of the eyes? *British Journal of Developmental Psychology*, *13*, 379–398.
- Bel'kovich, V. M. (1991). Herd structure, hunting, and play: Bottlenose dolphins in the Black Sea. In K. Pryor & K. S. Norris (Eds.), *Dolphin societies: Discoveries and puzzles* (pp. 17–77). Los Angeles: University of California Press.
- Bruner, J. (1995). From joint attention to the meeting of minds: An introduction. In C. Moore & P. J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 1–14). Hillsdale, NJ: Erlbaum.
- Butterworth, G. (1995). Origins of mind in perception and action. In C. Moore & P. J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 29–40). Hillsdale, NJ: Erlbaum.
- Butterworth, G., & Cochran, E. (1980). Towards a mechanism of joint visual attention in human infancy. *International Journal of Behavioral Development*, *3*, 253–272.
- Butterworth, G., & Jarrett, N. (1991). What minds have in common is space: Spatial mechanisms serving joint visual attention in infancy. *British Journal of Developmental Psychology*, *6*, 255–262.
- Call, J., Hare, B., & Tomasello, M. (1998). Chimpanzee gaze following in an object-choice task. *Animal Cognition*, *1*, 89–100.
- Carpenter, M., Nagell, K., & Tomasello, M. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development*, *63*, (4, Serial No. 255).
- Connor, R. C., Heithaus, M. R., & Barre, L. M. (1999, February 18). Superalliance of bottlenose dolphins. *Nature*, *397*, 571–572.
- Connor, R. C., Wells, R. S., Mann, J., & Read, A. J. (2000). The bottlenose dolphin: Social relationships in a fission–fusion society. In J. Mann, R. C. Connor, P. L. Tyack, & H. Whitehead (Eds.), *Cetacean societies: Field studies of dolphins and whales* (pp. 91–126). Chicago: University of Chicago Press.
- Corkum, V., & Moore, C. (1995). Development of joint visual attention in infants. In C. Moore & P. J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 61–83). Hillsdale, NJ: Erlbaum.
- Emery, N. J., Lorincz, E. N., Perrett, D. I., & Oram, M. W. (1997). Gaze following and joint attention in rhesus monkeys (*Macaca mulatta*). *Journal of Comparative Psychology*, *111*, 286–293.
- Fagot, J., & Deruelle, C. (2002). Perception of pictorial eye gaze by

- baboons (*Papio papio*). *Journal of Experimental Psychology: Animal Behavior Processes*, 28, 298–308.
- Ferrari, P. F., Kohler, E., Fogassi, L., & Gallese, V. (2000). The ability to follow eye gaze and its emergence during development in macaque monkeys. *Proceedings of the National Academy of Sciences, USA*, 97, 13997–14002.
- Hare, B., Brown, M., Williamson, C., & Tomasello, M. (2002, November 22). The domestication of social cognition in dogs. *Science*, 298, 1634–1636.
- Hare, B., Call, J., Agnetta, B., & Tomasello, M. (2000). Chimpanzees know what conspecifics do and do not see. *Animal Behaviour*, 59, 771–785.
- Hare, B., Call, J., & Tomasello, M. (1998). Communication of food location between human and dog (*Canis familiaris*). *Evolution of Communication*, 2, 137–159.
- Hare, B., & Tomasello, M. (1999). Domestic dogs (*Canis familiaris*) use human and conspecific social cues to locate hidden food. *Journal of Comparative Psychology*, 113, 173–177.
- Herman, L. M. (1987). Receptive competencies of language-trained animals. In J. S. Rosenblatt, C. Beer, M. C. Busnel, & P. J. B. Slater (Eds.), *Advances in the study of behavior* (Vol. 17, pp. 1–60). Petaluma, CA: Academic Press.
- Herman, L. M. (1990). Cognitive performance of dolphins in visually guided tasks. In J. A. Thomas & R. A. Kastelein (Eds.), *Sensory abilities of cetaceans: Laboratory and field evidence* (pp. 455–462). New York: Plenum.
- Herman, L. M. (2002). Vocal, social, and self-imitation by bottlenosed dolphins. In C. Nehaniv & K. Dautenhahn (Eds.), *Imitation in animals and artifacts* (pp. 63–108). Cambridge, MA: MIT Press.
- Herman, L. M., Abichandani, S. L., Elhadj, A. N., Herman, E. Y. K., Sanchez, J. L., & Pack, A. A. (1999). Dolphins (*Tursiops truncatus*) comprehend the referential character of the human pointing gesture. *Journal of Comparative Psychology*, 113, 347–364.
- Herman, L. M., Hovancik, J. R., Gory, J. D., & Bradshaw, G. L. (1989). Generalization of visual matching by a bottlenosed dolphin (*Tursiops truncatus*): Evidence for invariance of cognitive performance with visual or auditory materials. *Journal of Experimental Psychology: Animal Behavior Processes*, 15, 124–136.
- Herman, L. M., Kuczaj, S., III, & Holder, M. D. (1993). Responses to anomalous gestural sequences by a language-trained dolphin: Evidence for processing of semantic relations and syntactic information. *Journal of Experimental Psychology: General*, 122, 184–194.
- Herman, L. M., Morrel-Samuels, P., & Pack, A. A. (1990). Bottlenosed dolphin and human recognition of veridical and degraded video displays of an artificial gestural language. *Journal of Experimental Psychology: General*, 119, 215–230.
- Herman, L. M., Pack, A. A., & Morrel-Samuels, P. (1993). Representational and conceptual skills of dolphins. In H. R. Roitblat, L. M. Herman, & P. Nachtigall (Eds.), *Language and communication: Comparative perspectives* (pp. 273–298). Hillsdale, NJ: Erlbaum.
- Herman, L. M., Richards, D. G., & Wolz, J. P. (1984). Comprehension of sentences by bottlenosed dolphins. *Cognition*, 16, 129–219.
- Herman, L. M., & Uyeyama, R. K. (1999). The dolphin's grammatical competency: Comments on Kako (1999). *Animal Learning and Behavior*, 27, 18–23.
- Herzing, D. L. (1996). Vocalizations and associated underwater behavior of free-ranging Atlantic spotted dolphins, *Stenella frontalis*, and bottlenose dolphins, *Tursiops truncatus*. *Aquatic Mammals*, 22, 61–79.
- Hoffman, E. A., & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience*, 3, 80–84.
- Itakura, S., Agnetta, B., Hare, B., & Tomasello, M. (1999). Chimpanzee use of human and conspecific social cues to locate hidden food. *Developmental Science*, 2, 448–456.
- Itakura, S., & Anderson, J. R. (1996). Learning to use experimenter-given cues during an object-choice task by a capuchin monkey. *Current Psychology of Cognition*, 15, 103–112.
- Itakura, S., & Tanaka, M. (1998). Use of experimenter-given cues during object-choice tasks by chimpanzees (*Pan troglodytes*), an orangutan (*Pongo pygmaeus*), and human infants (*Homo sapiens*). *Journal of Comparative Psychology*, 112, 119–126.
- Madsen, C. J., & Herman, L. M. (1980). Social and ecological correlates of vision and visual appearance. In L. M. Herman (Ed.), *Cetacean behavior: Mechanisms and functions* (pp. 101–147). New York: Wiley Interscience.
- Mann, J., Connor, R. C., Tyack, P. L., & Whitehead, H. (2000). *Cetacean societies: Field studies of dolphins and whales*. Chicago: University of Chicago Press.
- Mercado, E., III, Killebrew, D. A., Pack, A. A., Macha, I. V. B., & Herman, L. M. (2000). Generalization of same-different classification abilities in bottlenosed dolphins. *Behavioural Processes*, 50, 79–94.
- Moore, C., & Corkum, V. (1994). Social understanding at the end of the first year of life. *Developmental Review*, 14, 349–372.
- Moore, C., & Dunham, P. J. (1995). *Joint attention: Its origins and role in development*. Hillsdale, NJ: Erlbaum.
- Neiworth, J. J., Burman, M. A., Basile, B. M., & Lickteig, M. T. (2002). Use of experimenter-given cues in visual co-orienting and in an object-choice task by a new world monkey species, cotton top tamarins (*Sanguinus oedipus*). *Journal of Comparative Psychology*, 116, 3–11.
- Pack, A. A., & Herman, L. M. (1995). Sensory integration in the bottlenosed dolphin: Immediate recognition of complex shapes across the senses of echolocation and vision. *Journal of the Acoustical Society of America*, 98, 722–733.
- Pack, A. A., Herman, L. M., Hoffmann-Kuhnt, M., & Branstetter, B. K. (2002). The object behind the echo: Dolphins (*Tursiops truncatus*) perceive object shape globally through echolocation. *Behavioural Processes*, 58, 1–26.
- Peignot, P., & Anderson, J. R. (1999). Use of experimenter-given manual and facial cues by gorillas (*Gorilla gorilla*) in an object-choice task. *Journal of Comparative Psychology*, 113, 253–260.
- Perrett, D. I., Hietanen, J. K., Oram, M. W., & Benson, P. J. (1992). Organization and functions of cells responsive to faces in the temporal cortex. *Philosophical Transactions of the Royal Society of London: Biological Sciences*, 335, 23–30.
- Perrett, D. I., Smith, P. A. J., Potter, D. D., Mistlin, A. J., Head, A. S., Milner, A. D., & Jeeves, M. A. (1985). Visual cells in the temporal cortex sensitive to face view and gaze direction. *Proceedings of the Royal Society of London B*, 223, 293–317.
- Povinelli, D. J., Bierschwale, D. T., & Cech, C. G. (1999). Comprehension of seeing as a referential act in young children, but not juvenile chimpanzees. *British Journal of Developmental Psychology*, 17, 37–70.
- Povinelli, D. J., & Eddy, T. J. (1996a). Chimpanzees: Joint visual attention. *Psychological Science*, 7, 129–135.
- Povinelli, D. J., & Eddy, T. J. (1996b). What young chimpanzees know about seeing. *Monographs of the society for research in child development*, 61, (3, Serial No. 247). Chicago: University of Chicago Press.
- Povinelli, D. J., Reaux, J. E., Bierschwale, D. T., Allain, A. D., & Simon, B. B. (1997). Exploitation of pointing as a referential gesture in young children, but not adolescent chimpanzees. *Cognitive Development*, 12, 423–461.
- Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, 1, 515–526.
- Pryor, K., & Norris, K. S. (1991). *Dolphin societies: Discoveries and puzzles*. Los Angeles: University of California Press.
- Reynolds, J. E., Wells, R. S., & Eide, S. D. (2000). *The bottlenose dolphin: Biology and conservation*. Gainesville: University Press of Florida.
- Richards, D. G., Wolz, J. P., & Herman, L. M. (1984). Vocal mimicry of computer-generated sounds and vocal labeling of objects by a bottle-

- nosed dolphin, *Tursiops truncatus*. *Journal of Comparative Psychology*, 98, 10–28.
- Rossbach, K. A., & Herzog, D. L. (1997). Underwater observations of benthic feeding bottlenose dolphins (*Tursiops truncatus*) near Grand Bahama Island, Bahamas. *Marine Mammal Science*, 13, 498–503.
- Scaife, M., & Bruner, J. S. (1975, January 24). The capacity for joint visual attention in the infant. *Nature*, 253, 265–266.
- Soproni, K., Miklosi, A., Topal, J., & Csanyi, V. (2001). Comprehension of human communicative signs in pet dogs (*Canis familiaris*). *Journal of Comparative Psychology*, 115, 122–126.
- Tomasello, M., & Call, J. (1997). *Primate cognition*. Oxford, England: Oxford University Press.
- Tomasello, M., Call, J., & Hare, B. (1998). Five primate species follow the visual gaze of conspecifics. *Animal Behaviour*, 55, 1063–1069.
- Tomasello, M., Hare, B., & Agnetta, B. (1999). Chimpanzees, *Pan troglodytes*, follow gaze direction geometrically. *Animal Behaviour*, 58, 769–777.
- Tschudin, A., Call, J., Dunbar, R. I. M., Harris, G., & van der Elst, C. (2001). Comprehension of signs by dolphins (*Tursiops truncatus*). *Journal of Comparative Psychology*, 115, 100–105.
- Vick, S., & Anderson, J. R. (2000). Learning and limits of use of eye gaze by capuchin monkeys (*Cebus apella*) in an object-choice task. *Journal of Comparative Psychology*, 114, 200–207.
- Vila, C., Savolainen, P., Maldonado, J. E., Amorim, I. E., Rice, J. E., Honeycutt, R. L., et al. (1997, June 13). Multiple and ancient origins of the domestic dog. *Science*, 276, 1687–1689.
- Wellman, H. M. (1990). *The child's theory of mind*. Cambridge, MA: MIT Press.
- Whiten, A. (1997). The Machiavellian mindreader. In A. Whiten & R. W. Byrne (Eds.), *Machiavellian intelligence II: Extensions and evaluations* (pp. 144–173). Cambridge, England: Cambridge University Press.
- Xitco, M. J., Jr., Gory, J. D., & Kuczaj, S. A. (2001). Spontaneous pointing by bottlenose dolphins (*Tursiops truncatus*). *Animal Cognition*, 4, 115–123.
- Xitco, M. J., Jr., & Roitblat, H. L. (1996). Object recognition through eavesdropping: Passive echolocation in bottlenose dolphins. *Animal Learning and Behavior*, 24, 355–365.

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