

Dolphin Social Cognition and Joint Attention: Our Current Understanding

Adam A. Pack^{1,2} and Louis M. Herman^{1,2}

¹*The Dolphin Institute, 420 Ward Avenue, Suite 212, Honolulu, HI 96814, USA*

²*Department of Psychology, University of Hawaii at Manoa, 2430 Campus Road, Gartley Hall, Honolulu, HI 96822, USA*

Abstract

Recent intense interest in social cognition in dolphins reflects findings that wild dolphins live in complex societies that rely on individual recognition, a protracted period of development, coalition formation, and cooperative, as well as competitive, social behaviors. Laboratory studies have revealed a host of cognitive skills that can support such complex behaviors—for example, broad imitative abilities, abilities to understand another’s indicative cues, and spontaneous use of pointing to communicate with human companions. *Joint attention* is recognized as a key element of social cognition that extends from simply following another’s gaze to using pointing or gazing cues of another to select objects or locations. Studies of bottlenose dolphins (*Tursiops truncatus*) have revealed that they understand (1) human-given direct and cross-body points; (2) human-given dynamic and static pointing and gazing cues within object-choice tasks; (3) the geometry of pointing cues; (4) the referential character of pointing and gazing cues; (5) sequences of direct and/or cross-body points that were instructions to transport one object to another; (6) how to produce pointing cues and the importance of audience attention; and (7) possibly the belief state of another that is engaged in a joint attention task. The evidence suggests that joint attention skills in dolphins are robust and to some degree symmetric across comprehension and production. Comparative analyses indicate that in some areas of joint attention, abilities of dolphins exceed the demonstrated skills of apes. Possibly, a dolphin’s capacity for joint attention may be related to the adaptive benefits of being able to attend to the focus of another dolphin’s echolocation beam in conjunction with a sophisticated social structure dependent on attention to others.

Correspondence: A. A. Pack, The Dolphin Institute, 420 Ward Avenue, Suite 212, Honolulu, HI 96814, USA (E-mail: pack@hawaii.edu)

Key Words: dolphins, joint attention, pointing, social cognition, gazing, *Tursiops*

Introduction

Interest in social cognition in dolphins has surged in recent years, largely because of positive findings from both laboratory and field studies. First, laboratory studies with bottlenose dolphins (*Tursiops truncatus*) have revealed an impressive array of cognitive and communicative skills (reviewed in Herman, 1980, 2006; Herman et al., 1993), including skills that require social attention such as imitative capabilities (Herman, 2002), abilities to understand and produce indicative pointing (Herman et al., 1999; Xitco et al., 2001, 2004), and abilities to understand the focus of another’s gaze (Tschudin et al., 2001; Pack & Herman, 2004, 2007, in press). Second, field studies over the past two decades have provided growing evidence that bottlenose dolphins have highly complex social networks that rely on individual recognition, a protracted period of care-giving for young, long-term associations within fission/fusion societies, coalition and alliance formation, and close coordination of social activities (e.g., Connor et al., 2000; Connor & Mann, 2006). The relationship between the findings of these two avenues of study is intimate and synergistic. For example, Herman (1980) suggested that the array of cognitive skills demonstrated by bottlenose dolphins are likely “derived from the demands of social living, including both cooperation and competition among peers, expressed within the context of the protracted development of the young” (p. 421). Thus, a full understanding of dolphin social behavior in the wild demands an understanding of dolphin social cognition.

An important component of social cognition is shared attention, often referred to as *joint attention*. Joint attention is a triadic transaction between an informant; a receiver; and an object, a place, or an event of interest and may involve the informant gazing and/or pointing at the item of interest. A key feature of joint attention is the degree of “sharedness” between the informant and the receiver. The “full flower” of joint attention is realized when both the informant and the receiver

are cognizant of not only each other's shared attention towards the item of interest but also each other's shared knowledge state regarding that item. This is the difference between "I see that you see X" versus "I know that because you and I both see X we are both cognizant of X." Joint attention can benefit the receiver, the informant, or both. It can provide the receiver with enhanced perceptual alertness to predators and prey, or more generally, to events of biological or social significance. Further, the receiver may gain information about the informant's beliefs or desires that, in theory, could be used to manipulate the informant's behavior to the benefit of the receiver (e.g., see Premack & Woodruff, 1978; Tomasello & Call, 1997). Similarly, the informant can benefit from the receiver's assistance in monitoring, obtaining, or defending against the informant's focal subject. By directing the receiver's attention, the informant is in effect manipulating the receiver's behavior, which may be to the benefit of the receiver or not (e.g., see instances of deceptive manipulation of behavior in various chapters in Whiten & Byrne, 1997; Johnson & Karin-D'Arcy, this volume). Consequently, directed pointing and gazing have significant communicative value for both the receiver and the informant. Of course, gazing (and in some cases pointing) may not necessarily be intended to engage the attention of another.

In this paper, we review the accumulated data on the understanding by bottlenose dolphins of human-directed pointing and gazing as examined through laboratory studies.¹ We also cover the more limited data available on a dolphin acting as the informant. These findings, although bridging across a wide species barrier, nevertheless involve a joint social act. The positive and often unique findings of the cross-species interaction suggest that the bases for joint attention and its social and adaptive offshoots lie within the capability of dolphins, are very general, and may play a significant role in social exchanges in the dolphins' natural world.

Subjects

The dolphin subjects were from three different laboratory facilities and had different experiences and varying degrees of enculturation through their interactions with humans at the time of their initial tests of joint attention. Tombi, Khanya, and Affrika (3 females, 6 y old or younger) and Kelpie, Kani, and Jula (3 males, 16 y old or younger) were housed at SeaWorld, Durban, South Africa (Tschudin et al., 2001). They were trained to perform in public shows, but pointing and gazing were not signs in their learned repertoires nor were they used to supplement training. Akeakamai and Phoenix were two adult female dolphins housed

at the Kewalo Basin Marine Mammal Laboratory in Hawaii. They had been exposed informally to humans pointing at an object and then giving the sign "fetch" as an instruction to bring the indicated object to the trainer (Herman et al., 1999). Before the formal studies of their understanding of sequences of points and of human gaze, however, there was no specific training or deliberate exposure to these cues (Pack & Herman, 2004). Bob and Toby were two adult male dolphins that together with humans in SCUBA gear used a large underwater keyboard to symbolically make requests or specify "named" objects or locations (Xitco et al., 2001, 2004). In one paradigm, the dolphins observed humans using the keyboard and followed them to objects or locations named by the divers through key presses. The dolphins were neither trained to produce nor comprehend pointing or gazing.

Issues Addressed in Studies of Joint Attention

Studies of joint attention generally focus on several empirically testable issues:

1. Can a receiver follow the gaze or points of an informant to locations within and outside the receiver's visual field?
2. Can a receiver select a particular object among several distal objects being gazed at or pointed to by an informant?
3. What components of indicative cues (e.g., arm movement, eyes open, etc.) are attended to and/or required by a receiver to understand an informant's deliberate or inadvertent communication?
4. Are gazing and pointing cues understood geometrically² and referentially³?
5. Can an individual act as an informant, pointing or gazing to communicate referentially

¹ From here on we use the word "dolphin" alone to refer to the bottlenose dolphin.

² "Geometric" refers to projecting and following an informant's line of sight to an object even when another (distractor) object or a visual barrier may lie along the same path (Butterworth, 1995; Tomasello et al., 1999).

³ "Referential," as used in gazing or pointing studies, usually means an understanding by the subject that the cue or symbol used by the informant represents or refers to an object lying in the direction of the cue rather than merely the direction.

with others? Are these cues imperative and/or declarative?⁴

6. To what extent do the informant and the receiver “know” about their common mental state towards the object, location, or event of joint attention?

Development of Joint Attention in Humans

These six questions vary in complexity and loosely reflect different stages of development of joint attention in humans. Because humans are the most well-studied species with regard to joint attention (e.g., Eilan et al., 2005), we briefly review some of the early stages of development and complexity of joint attention in humans (see various chapters in Moore & Dunham, 1995) to set a framework for understanding joint attention in dolphins.

Kaminski et al. (2005) suggested that “gaze following” is the most fundamental skill of social cognition and a precursor to fully developed joint attention. Emery et al. (1997) defined gaze following as looking in the direction where another individual is looking (i.e., following the head and/or eye movements to that location without any requirement for retrieving or acting on an object in that vicinity). In human infants, the developmental progression from gaze following to fully developed joint attention has been well-documented (e.g., Scaife & Bruner, 1975; Butterworth & Cochran, 1980). Thus, from about 2 to 6 mo of age, infants start looking in the direction where another gazes, following another’s head movements to locations within their visual field, but halting their head turning at the first object they encounter, which may not be the target of the other human. From 6 to 12 mo, the infant localizes the specific object at which the other is gazing. Between 12 and 18 mo, most infants can follow another’s gaze to objects that lie behind or above the infant (i.e., out of the infant’s visual field) (Moll & Tomasello, 2004). Infants can also do this based on eye movements alone (Butterworth & Jarrett, 1991).

The understanding of the referential function of the human manual pointing gesture also follows a developmental progression in infants, although commencing at a later stage of development (e.g., Butterworth, 1991; Morissette et al., 1995). At about 9 mo of age, infants direct their attention to the pointing finger of another or to objects close to the finger (ca < 50 cm), but they do not understand points to distant objects (Lempers, 1979). Between 10 and 15 mo, infants begin to point their finger to attract the attention of another to distal objects and also to alternate their gaze between the object and the adult, checking back to ensure the other’s attention. By 12 mo, many infants engage in both “imperative pointing” and

“declarative pointing” (Liszkowski et al., 2004). Imperative pointing (after “protoimperatives” described by Bates et al., 1975) involves the infant using pointing as a request to obtain a desirable. Declarative pointing (after “protodeclaratives,” Bates et al., 1975) involves the infant pointing with the goal of simply sharing attention and interest. Although these two types of pointing appear to emerge in near synchrony, the functional distinction between them may be seen in children with autism who readily engage in imperative pointing but fail to use declarative pointing (Baron-Cohen, 1991), and also in human-reared apes who learn to point imperatively but do not engage in declarative pointing (Call & Tomasello, 1996). Finally, between 15 and 18 mo, infants understand the referent of another’s point to distal objects and can disregard distracting objects in the path of the point. They also understand that the informant who is pointing to an object is subjectively attending to that object, a possible precursor to their development of a “theory of mind” (Povinelli & Preuss, 1995).

Gaze Following in Nonhumans

Aside from humans, the ability to follow the head gaze (head and eyes moving in concert) of conspecific informants to something that is out of an observer’s direct view has been demonstrated in several ape species—for example, chimpanzees (*Pan troglodytes*) (Tomasello et al. 1998) and orangutans (*Pongo pygmaeus*) (Kaplan & Rogers, 2002); a few monkey species—for example, sooty mangabeyes (*Cercocebus torquatus*); several macaque species (*Macaca mulatta*, *M. nemestrina*, and *M. arctoides*) (Emery et al., 1997; Tomasello et al., 1998; Anderson & Mitchell, 1999); and domesticated goats (*Capra aegagrus*) (Kaminski et al., 2005). Chimpanzees will even look back to a human informant (“checking back”) when finding nothing at the terminal destination of the informant’s line of gaze (Call et al., 1998). Also, eye-gaze following—the ability of a receiver to follow an informant’s eye direction to a particular location in space—has been shown in chimpanzees (Povinelli & Eddy, 1996), adult pigtailed macaques (*Macaca nemestrina*) (Ferrari et al., 2000), and baboons (*Papio papio*) (Fagot & Deruelle, 2002). At a more sophisticated level, all great ape species (*Pongo pygmaeus*, *Gorilla*

⁴ “Imperative pointing” refers to pointing that is used as a tool to request something desired. “Declarative pointing” refers to pointing used to share attention and interest in something. The goals of declarative pointing in human infants are to direct attention and obtain a reaction (e.g., a comment), thus confirming shared attention and interest (Liszkowski et al., 2004).

gorilla, *Pan paniscus*, and *Pan troglodytes*) have been shown to accurately follow the gaze direction of another geometrically to specific locations around barriers and past distracting objects (e.g., Povinelli & Eddy, 1996; Tomasello et al., 1999; Brauer et al., 2005). Dolphins have not been directly tested on head-gaze or eye-gaze following or its natural extension, point following (i.e., the ability to follow the pointing gesture of another to a location, object, or event out of direct view).

Object Choice in Response to the Directed Pointing and Gazing of an Informant

In contrast to the few animal species tested for gaze following, many species have been examined for their ability to understand directed gazing and pointing in "object-choice" tasks. These include monkeys (e.g., *Cebus apella*, *Macaca mulatta*, and *Sanguinus Oedipus*), apes (*Pan troglodytes*, *Pongo pygmaeus*, and *Gorilla gorilla*), dolphins, seals (*Arctocephalus pusillus* and *Halichoerus grypus*), goats (*Capra sp.*), dogs (*Canis familiaris*), wolves (*Canis lupus*), and cats (*Felis domesticus*) (see Pack & Herman, 2004, and Miklosi & Soproni, 2006, for partial reviews). In the basic form of this task, a subject observes a human informant who orients his or her head and/or eyes for directed gazing or his or her arm and hand for directed pointing toward one of several objects. The subject's task is to select the object indicated by the informant (in theory, by using information from the informant's gazing or pointing cue). For example, human infants, 18 mo and older, can accurately select the particular container (of two) indicated by an informant using dynamic pointing, head gazing, or eye glancing when these cues are proximal (≤ 60 cm) to the correct container (Itakura & Tanaka, 1998). Two- and 3-y-old children can use informant-directed static gazing cues, direct pointing cues (i.e., pointing using the arm that is on the same side as the indicated object), and cross-body pointing cues (i.e., pointing using the arm on the opposite side from the indicated object) to more distally placed (ca ≥ 1.2 m) objects (Povinelli et al., 1997).

The classic approach in object-choice tasks uses containers, one of which is baited out-of-view of the subject (e.g., Anderson et al., 1995). Some recent studies have simply used arbitrary objects to which specified actions are performed (e.g., Herman et al., 1999). A principal question in evaluating performance in the object-choice task is "What does the subject understand about the gazing or pointing cue of an informant?" At a low level, the cue is simply understood as a learned discriminative stimulus that directs the subject to move in a specific direction until it encounters something of interest. At a higher level, the cue is understood as

a communicative tool that indicates the attention and terminal focus of the informant (Tomasello et al., 1999). Accuracy on initial trials with novel gazing or pointing problems allows for distinguishing between low- and high-level cue understanding inasmuch as initial trials (particularly first trials) preclude learning based on the association of a specific cue with a particular response. Below, we first examine the evidence for the dolphins' understanding of human-directed pointing cues. We then summarize evidence for the dolphins' understanding of human-directed gazing cues.

Object Choice in Response to Sustained Pointing to Objects Within a Receiver's Field of View

Despite their close evolutionary relationship to humans, nonhuman primates do not naturally point in the wild and also have difficulty in understanding pointing cues in the laboratory, unless the tip of the informant's pointing finger is positioned nearly touching the baited container (e.g., Povinelli et al., 1992, 1997; Call & Tomasello, 1994) or the task involves a competitive versus cooperative informant (Hare & Tomasello, 2004). Even under special testing conditions, such as a subject leaving the test area between each trial, performance remains poor with distal pointing cues, although these conditions may aid in the understanding of gazing cues (Barth et al., 2005).

Tschudin et al. (2001) examined the abilities of six relatively test-naïve dolphins (Kani, Kelpie, Jula, Khanya, Tombi, and Affrika) to use dynamic human-given pointing cues in an object-choice task with distal objects. The informant only used her right arm to give a pointing cue, implying that when the target object was on her right side, she would use a direct pointing cue, and when the target object was on her left side, she would use a cross-body pointing cue. On each trial, a red bucket and a white container lid were positioned 1.2 m to the left and right of a dolphin subject facing a human informant. The informant first signed a "fetch" gesture followed by a pointing cue that was held in place until the dolphin responded (the distance between the tip of the finger and the target object was not specified, but was likely greater than 0.2 m and less than 1.2 m inasmuch as the distance between the target and the dolphin was 1.2 m). The dolphin was reinforced for simply touching (not fetching) the indicated object. Each dolphin was tested in 12 trials, and those dolphins that performed well, but not significantly above chance, were given extended trials (Table 1). Three dolphins performed significantly above the 50% chance level for the first 12 trials, each committing only a single error, suggesting that they spontaneously understood the dynamic sustained pointing gesture as a cue to touch the indicated object. Additionally, these

three demonstrated an understanding of cross-body pointing as well as the dynamic sustained direct pointing. The remaining three failed to reach significance in the first 12 trials, although Affrika was significantly above chance after 18 trials.

Table 1. Dynamic direct points: two objects—one object was to dolphin's left and one was to its right; performance accuracy (total trials correct/total trials given) of individual dolphins tested in two-object-choice tasks using dynamic human direct pointing cues (data from Tschudin et al., 2001).

Dolphins	First trial accuracy
Kani	11/12**
Kelpie	11/12**
Jula	11/12**
Khanya	4/12
Tombi	14/25 ^a
Affrika	14/18**

^aSpecific data for the first 12 trials were not reported; authors then gave additional trials.

* = $p < .05$, ** = $p < .01$, cumulative binomial test

Object Choice in Response to Brief Points to Objects Behind the Dolphin

Herman et al. (1993, 1999) tested the dolphins Akeakamai (Ake) and Phoenix for their understanding of human points within more complex tasks than those employed by Tschudin et al. (2001). Specifically, human points were brief (ca < 3 s) rather than sustained, three objects (chosen from a set of four) were present on each trial instead of two, objects were positioned at greater distances from the human pointer than in the Tschudin study, and references were made not only to laterally placed objects but also to an object behind the dolphin. First, Phoenix was tested for her understanding of human-direct pointing using three different objects placed at the vertices of an equilateral triangle. The human informant was positioned in the pool on a surfboard at the center of the triangle, approximately 6.7 m from each object (Herman et al., 1993). The informant faced each of the vertices seven times across 21 trials. The dolphin faced the informant who pointed briefly (ca 2 to 3 s) to an object and signed one of several different actions to be performed to that object (e.g., go over the indicated object). Phoenix was rewarded for performing the correct action to the indicated object. Table 2 indicates that Phoenix performed well with this configuration, responding to the indicated object on 17 of 21 initial trials.

Both Phoenix and Ake were later tested on their responses to direct points followed by action instructions, with objects arranged in two novel configurations. In the first configuration, three objects

were arrayed along the perimeter of the pool. The informant stood immediately behind the pool wall so that his torso and head were exposed to the dolphin who "stood" on its tailfluke immediately on the other side of the wall facing the informant. Two of the objects were positioned approximately 8.7-m linear distance diagonally left and right of the dolphin. The third object was located nearly directly behind the dolphin at approximately 14.1-m distance. Trials consisted of "direct point + action gesture" sequences as in Herman et al. (1993). Points were now only approximately 1 s in duration. Ake and Phoenix responded well (80% and 95%, respectively) to direct points targeting the diagonally left and right objects (Table 2, 1st LRB column). However, only Phoenix performed above chance on initial trials to the object located behind her (60% correct responses with chance probability = 0.33).

Table 2. Dynamic direct points: three objects; performance accuracy (total trials correct/total trials given) of individual dolphins tested in three-object-choice tasks using dynamic human direct pointing cues (data from Herman et al. 1993, 1999). Distances between informant and object (in m) are indicated below the object locations.

Dolphins	Circumferential	L	R	B	L	R	B
Dolphins	6.7	8.7	8.7	14.1	3.1	3.1	2.7
Ake	--	32/40** ^a (8/20) ^b			32/36** ^a (11/23) ^b		
Phoenix	17/21**	18/19** ^a (12/20) ^{ab}			45/48** ^a (19/24)** ^{ab}		

L = object left of dolphin, R = object right of dolphin, B = object behind dolphin

^aCombined performance on left and right objects

^bPerformance on object behind dolphin

* = $p < .05$, ** = $p < .001$, cumulative binomial test

In the second novel configuration, left and right objects were moved closer and more laterally to the dolphin, each at approximately 3.1 m from the dolphin. The third object was also moved closer, to 2.7 m, and directly behind the dolphin. Ake and Phoenix performed much as they had with the previous configuration, both scoring well with left and right objects, but only Phoenix performed above chance on initial trials to the object behind her (Table 2, 2nd LRB column). Together, these findings demonstrated that dolphins can respond accurately to brief human-pointing gestures to laterally placed objects. Additionally, Phoenix showed an initial capability for responding reliably to the object behind. Ake eventually became proficient at responding to human-direct pointing to an object placed behind her after brief exposure to "exaggerated" pointing (informant leans slightly

in direction of object while pointing) (Herman et al., 1999). The dolphins' laterally placed eyes allow for a wide visual field that includes some of the area behind them. To what degree the objects placed behind the dolphins were perceived by them is unclear. Thus, object location and perception could be confounded, although the relative decline in performance for objects behind may suggest a perceptual difficulty.

Object Choice in Response to Dynamic Human-Gazing Cues

Given the strong aptitude of several primate species for head-gaze and eye-gaze following (as described earlier), as well as for chimpanzees and other apes to follow the gaze of another geometrically and around barriers (e.g., Brauer et al., 2005), it is surprising that these primates have general difficulties using head- or eye-gazing cues in object-choice tasks. For example, monkeys (*Cebus apella*, *Macaca mulatta*, and *Sanguinus Oedipus*) do not respond to dynamic head-gazing cues accurately in object-choice tasks unless these cues are presented concurrently with other cues such as proximal pointing or tapping, or gaze occurring next to the baited container (e.g., Anderson et al., 1995, 1996; Itakura & Anderson, 1996; Neiworth et al., 2002). Similarly, although some ape subjects may eventually learn to use the dynamic head-gazing cues of an informant to perform accurately in object-choice tasks, first trial accurate performance using dynamic head-gazing cues is rare (e.g., Call et al., 1998, 2000; Itakura et al., 1999). In contrast to non-human primates, domestic dogs have been shown to understand spontaneously the dynamic head-gaze of informants in object-choice tasks (Hare et al., 1998; Hare & Tomasello, 1999; Soproni et al., 2001).

Eight dolphins have been tested for their abilities to spontaneously understand human dynamic gazing cues. Tschudin et al. (2001) tested Kani, Kelpie, Jula, Khanya, Tombi, and Affrika for their responses to human-directed dynamic gazing cues using the same experimental set-up described earlier to test these dolphins for their comprehension of human dynamic pointing. The results are presented in Table 3. Two of the six dolphins, Kani and Jula, performed significantly above chance levels on a 12-trial test of dynamic gaze comprehension, and two other dolphins, Khanya and Affrika, performed above chance with extended trials.

The dolphins Ake and Phoenix were also tested for their understanding of human dynamic gaze (Pack & Herman, 2004). As with Tschudin et al.'s (2001) tests, two objects were placed to the left and right of the dolphin who faced a human informant; objects were further away from the informant (ca 3 m), however, and the dolphins were required to perform different actions to indicated

Table 3. Dynamic human head-gaze; performance accuracy (total trials correct/total trials given) of individual dolphins tested for the first time in two-object-choice tasks using dynamic human head-gaze cues with left and right objects only (data from Pack & Herman, 2004; Tschudin et al., 2001).

Dolphin	First trial accuracy
Kani	11/12**
Kelpie	10/18
Jula	10/12*
Khanya	13/18*
Tombi	11/17
Afrika	13/18*
Ake	23/24***
Phoenix	24/24***

Note: The type of cumulative binomial test employed here and throughout this paper uses one-sided probabilities (i.e., the probability of achieving that score or greater). Tschudin et al. (2001) evaluated dolphin performance using the cumulative binomial test with a two-sided probability—the probability of achieving a score greater than or equal to the difference of the expected value minus the observed value. This test did not show significance for Khanya or Afrika ($p = .096$).

* = $p < .05$, ** = $p < .01$, *** = $p < .001$, cumulative binomial test

objects instead of simply touching an object. On each trial, an action gesture was given followed by the informant turning his head (and eyes) to gaze at one of the objects. The dolphins were rewarded for performing the specified action to the indicated object. Ake and Phoenix performed at or near ceiling levels on their initial 24-trial test of dynamic gaze comprehension (Table 3). Furthermore, over the first 12 trials of this test, both dolphins were errorless. Both dolphins also responded without error to dynamic direct pointing trials run as controls and intermixed with gazing trials. There was no difference in performance between gazing and pointing conditions (Fisher's exact test, $n = 96$, $p = 1.0$). Overall then, half of the dolphins tested with human-given dynamic head-gazing cues were shown to understand spontaneously these cues to distal objects within the object-choice task.⁵

Object Choice in Response to Static Human-Pointing and Gazing Cues

In the dolphin experiments reviewed thus far, pointing cues and gazing cues were dynamic. For

⁵ Further experiments by Pack & Herman (2004) revealed that the eye direction component of human gaze was of itself ineffective. That is, head movement alone, with eyes covered by opaque goggles, was a sufficient cue, but eye movement alone, without head movement, was not.

pointing, the informant's arm moved into position before stopping and holding or before being withdrawn to a neutral position. For gaze cues, the informant's head moved from a neutral position to view one of two laterally placed objects and remained in that orientation. The extent to which the dolphins relied on arm movement to understand the pointing gesture or head movement to understand the gazing cue was unexplored. Both apes and dogs appear to rely heavily on movement in responding to indicative cues. For example, chimpanzees have not demonstrated first-trial understanding of either static head gazing (without any eye cues) or static pointing cues to distal objects (Povinelli et al., 1997), although there is evidence for eventual success in interpreting static head gaze (Povinelli et al., 1999). Dogs also fail to demonstrate first-trial understanding of static indicative cues, although, like apes, they may eventually comprehend these cues (Hare et al., 1998).

Pack & Herman (2004) tested the dolphins Ake and Phoenix for their understanding of human-given static direct pointing, static cross-body pointing, and static head-gazing cues, and compared each of these with their understanding of dynamic cues. For the static tests, two objects were placed approximately 3 m to the left and right of a dolphin who faced a human informant. The informant first signed one of several possible action instructions, such as "jump over" or "pectoral-fin touch," without indicating any object. Immediately thereafter, an opaque screen was raised, hiding the informant from the dolphin's view. The informant, while hidden, adopted either a direct pointing, a cross-body pointing, or a head-gazing posture (the head and eyes turned to the left or right). The screen was then lowered revealing the informant, unmoving, in one of the three postures. On control trials, the informant did not adopt a posture, but waited for the screen to drop and then presented dynamically either a brief direct point, a cross-body point, or a sustained head-gaze cue. On all trials, the informant wore opaque goggles. Table 4, derived from Pack & Herman (2004), shows that both Ake and Phoenix were errorless or nearly so under all six conditions. Thus, dolphins are able to spontaneously "read" a gazing or pointing cue from the "frozen" image of the informant without the benefit of any movement in the direction of the indicated object. Also, they appear to be the first nonhuman animals shown to interpret spontaneously both static head-gazing and static pointing cues.

All of the static data in Table 4 represent the first occasion that the dolphins experienced the three static conditions. The dynamic direct pointing and dynamic head-gazing conditions had been tested earlier, and as described previously, were largely met with success on first trials. Ake and Phoenix

Table 4. Dynamic versus static indicative cues; performance accuracy (total trials correct out of 12 given) of individual dolphins tested in two-object-choice tasks using dynamic versus static human direct point, cross-body point, and gaze cues (data from Pack & Herman, 2004).

Dolphins	Indicative cue	Dynamic (<i>n</i> = 12)	Static (<i>n</i> = 12)
Ake	Direct point	12***	12***
	Cross-body point	12***	10*
	Head-gaze	12***	12***
Phoenix	Direct point	12***	12***
	Cross-body point	12***	12***
	Head-gaze	12***	11**

Note: One object was to left of the dolphin and one was to its right, each at 3-m distance. There was no object behind. The static condition represents the dolphin's first exposure (i.e., its first 12 trials) to static direct points, cross-body points, and head gazes.

* = $p < .05$, ** = $p < .01$, *** = $p < .001$, cumulative binomial test

were also tested earlier with dynamic human-given cross-body pointing cues. Dynamic cross-body points were first given to Ake in the Herman et al. (1999) study during a test of her ability to use these cues. She was correct on 11 of the 13 trials given ($p < .001$, cumulative binomial test, chance = 0.33) with three objects positioned left, right, and behind her (the second condition listed in Table 2). Thus, Ake showed immediate comprehension of the cross-body point to left and right objects, even though the third object located behind her could also be responded to in theory. Phoenix was given her first test of understanding of cross-body points by Pack & Herman (2004). Only two objects, positioned to the right and left, were used. Phoenix responded without error to the 12 trials given her. Thus, both Ake and Phoenix demonstrated spontaneous understanding of both dynamic and static cross-body points to either right or left objects. Tschudin et al. (2001) did not distinguish between direct and cross-body points, but apparently used a direct point for the object to the right of the informant and a cross-body point for the object to the left, as previously described. From that, we can infer that, at the least, dolphins Kani, Kelpie, and Jula understood a cross-body point to the informant's left. It seems likely that they would have responded equally well to the right, had it been tested.

Understanding of the Geometry of Indicative Cues

We noted earlier that there is substantial evidence showing that ape species can follow the gaze direction of another geometrically to the terminal destination of an informant's line-of-sight around barriers and past distracting objects (e.g.,

Tomasello et al., 1999; Brauer et al., 2005). Both chimpanzees and dogs also understand that opaque barriers can occlude another's vision (Povinelli & Eddy, 1996; Hare et al., 2000; Brauer et al., 2004). In object-choice tasks, however, the ability to distinguish the geometry of an informant's gaze at an object versus at a distant point above that object was not found for juvenile chimpanzees (Povinelli et al., 1999), although it has been demonstrated in 3-y-old children (Povinelli et al., 1999) and in dogs (Soproni et al., 2001).

Pack & Herman (in press) examined a dolphin's understanding of the geometry of human-direct pointing and gazing by using a variation of the object-choice task. Two objects were positioned in the same plane, one near (proximal) and the other far (distal), one pair to the left and the second to the right of the dolphin (four objects total). The question asked was whether the dolphin would attend to the specific object of regard at the terminal destination of an informant's pointing or gazing cue. A positive answer would provide further evidence that pointing and gazing cues were referential in character, referring to an object at the indicated location, rather than merely indicating a direction.

For this test, two Frisbees floated on the water surface 0.8 m to the left and right of Ake and served as "near" or proximal objects. Two elevated garden hoses, streaming water slowly and located 3.7 m to the right and left of Ake, served as "far" or distal objects. On each side, the Frisbee and the water stream lay in line with each other; however, the angle subtended by the informant gazing or pointing at the top of the water hose versus at the floating Frisbee was 60°. Thus, the vertical angle of the informant's head or pointing gesture differed when indicating the two objects—downward for the near Frisbee and slightly upward for the far water stream.

Ake was errorless on the 12 trials using direct pointing to indicate either a near or far object. Thus, human-directed pointing was not understood by Ake as simply a cue to move in the direction of the point until encountering an object. If this were the case, Ake should have always responded to the closer of the two objects, regardless of whether the point was directed at the far object or the near object. Instead, when the informant pointed at a far object, Ake was able to ignore the "distractor" object lying along the same path as the distal point. These findings provide strong support that the dolphin understands human pointing geometrically.

The results for gaze trials, however, did not provide such support. Regardless of whether the object regarded by the informant was near or far, Ake always responded to the near object. Her performance here is at odds with her spontaneous,

correct responses to simple (nongeometric) gazing cues, reviewed earlier, as well as the spontaneous understanding of human-directed gazing cues in object-choice tasks by Tschudin et al.'s (2001) relatively test-naïve dolphins. Ake's difficulty on these geometric gaze trials is, however, similar to findings with human infants who were examined for their understanding of human pointing versus head-gazing cues to objects near and far (Butterworth, 1995). For both the human infant and dolphin, it appears that the larger lateral displacement traced by the long "lever" human arm compared with the human head is a more salient cue that can more easily be used to determine the terminal destination of an indicative cue. Indeed, in a study by Povinelli et al. (1997) that was similar in many aspects to that conducted with Ake (i.e., two objects were placed near and far from an informant and within the visual field of the subject), 2-y-old children had more difficulty selecting a far object gazed at by an informant than they did when the informant pointed at this object or used a combination of pointing and gazing cues.

Understanding of Sequences of Direct and/or Cross-Body Points

Both Ake and Phoenix were experienced in understanding instructions given within an artificial language-like symbolic communication system that required the processing of both the semantic and the syntactic features of the "language." The "words" of the language referred to agents, objects, actions, relationships, locations, and also included function words such as "yes," "no," or "erase" (Herman et al., 1984, 1993; Herman, 1986). For Ake, words were expressed by gestures of the human's arms and hands; and for Phoenix, they were expressed by computer-generated sounds. The key feature of the language was the ability to combine and recombine words into "sentences" of up to five words in length to convey unique instructions.

Herman et al. (1999) and Herman & Uyeyama (1999) tested the abilities of Ake and Phoenix to understand sentences when points were substituted for the gestural symbols (Ake) or the acoustic symbols (Phoenix). In the Herman et al. study, Ake spontaneously understood the incorporation of human-directed pointing cues within the grammatical structure of her familiar gestural language. Instructions were given to Ake to transport one referenced object to another, using the familiar inverse syntactic rule "destination object + transport object + fetch." This sequence instructed Ake to transport the second referenced object to the first. For example, the sequence of the three symbolic gestures "hoop + surfboard + fetch" instructed Ake to transport the surfboard to

the hoop (Herman et al., 1984). Note that in this sequence, the reference for the destination object, the hoop, must be represented and retained in memory while the dolphin processes and acts on the other sequence elements: surfboard and fetch. Also, the sequence of gestures can be rearranged as “surfboard + hoop + fetch,” in which case Ake is to transport the hoop to the surfboard. Ake’s high levels of performance on novel sequences of this reversible type demonstrated syntactic as well as semantic processing (Herman et al., 1984).

Herman et al. (1999) now substituted direct points and/or cross-body points for the object symbols within the noted inverse syntactic rule. For example, the purely symbolic sequence “hoop + surfboard + fetch” might now appear as “direct point at the hoop + cross-body point at the surfboard + fetch.” If the dolphin understands human points referentially, each sequence in which points are substituted for object gestures should result in the same transportation sequence as when the sequences are composed wholly of gestural symbols. For these substitution tests, three different objects were placed in the dolphin’s pool: one 3.1 m to Ake’s left, one 3.1 m to her right, and one 2.7 m behind her.

Table 5 shows Ake’s spontaneity of understanding novel relational sequences with direct points (noted as Pd) and cross-body points (noted as Px) substituted for one or both gestural symbol elements (noted as S). Thus, the first sequence, S + Pd + R, is interpreted as “refer to first object symbolically + refer to the second object using a direct point + give the relational symbol (R) for ‘fetch.’” The data show the results for the first trial on which the particular sequence was given. The location of the destination object and the transport object are indicated as is Ake’s response to each (1 or 0 meaning correct or incorrect, respectively). Ake was wholly correct (correctly responding to both the destination object [D] and the transport object [T]) on 28 of these 36 initial trials. With the probability of responding wholly correctly to a sequence by chance set at 0.17 (i.e., 1/3 chance of selecting the correct transport object multiplied by 1/2 chance of selecting the correct destination object), Ake’s overall performance on these 36 trials is well above chance ($p < .00001$, cumulative binomial test). Moreover, Ake was significantly above chance on seven of the eight sequence types ($p < .05$ on four types, $p < .001$ on three types, cumulative binomial test, chance = 0.17).

Herman & Uyeyama (1999) tested Phoenix’s ability to understand a sequence of indicative gestures. Unlike Ake, Phoenix had not been “schooled” to associate different symbolic hand and arm gestures with different objects. Nor did she understand the inverse grammar taught to Ake. However, Phoenix did understand gestural symbols for actions

(Herman et al., 1993). Also, more than 10 y earlier, Phoenix had been taught that different acoustic symbols could reference different objects and that sequences of these symbols in a linear framework of “object A sound + fetch sound + object B sound” instructed her to transport the object referenced first to the object referenced second (Herman et al., 1984). Thus, the sound sequence “hoop + fetch + surfboard” instructed Phoenix to transport the hoop to the surfboard; however, Phoenix had not experienced sound sequences of this type for at least 8 y. Nonetheless, using three different objects positioned to the left, right, and behind Phoenix, she readily interpreted sequences “direct point at an object + fetch + direct point at another object.” Each of 18 test trials involved a unique pairing of transport and destination objects (e.g., take the left object to the behind object) and a unique arrangement of the three objects (left, right, and behind). Phoenix was wholly correct on 9 of the 18 trials ($p < .002$, cumulative binomial test, chance = 0.16). Taken together, the findings of Herman et al. (1999) and Herman & Uyeyama (1999) strongly reinforce the idea that dolphins treat human pointing as referential communication. The results also showed that pointing may be understood as a reference to an object that must be responded to immediately, and also as a reference to an object that must be remembered and responded to subsequently. The latter ability requires the dolphin to form a mental representation of the indicated object.

Finding a Match for Objects Referenced Through Human-Directed Indicative Cues

The studies reviewed thus far have provided limited evidence for the precision of the geometry of gazing cues compared with pointing cues. To examine more specifically what dolphins may understand about the focus of an informant’s gazing or pointing cue, Pack & Herman (in press) tested the dolphin’s ability to report explicitly the identity of the particular object being gazed at or pointed to by a human informant. They created a matching-to-sample task in which two sample objects were presented simultaneously and an informant either gazed at or pointed to one of these samples. The observer dolphin was then required to select a match for the indicated sample by choosing between two alternative objects. The alternative objects were identical to the two samples and were located approximately 16 m from them at the opposite end of the pool.

A set of six objects was used to test Phoenix and Ake in this cue-directed matching task. Both dolphins were tested on 30 unique trials, each with human-direct points, cross-body points, or gaze cues used to indicate the sample object that was to be matched. To respond wholly correctly, the

Table 5. Understanding sequences of points; accuracy of the dolphin Ake in taking the transport object (T) to the destination object (D) on the first trial of each sequence type using the inverse grammatical rule D + T + R, which required the dolphin to execute its response in the inverse order T + R + D. An object is indicated either by a direct point (Pd), a cross-body point (Px), or through a symbolic gesture (S), with the location of objects relative to the dolphin as shown (data from Herman et al., 1999).

Object location		Sequence type					
		S + Pd + R		Pd + S + R		Pd1 + Pd2 + R	
D	T	D	T	D	T	D	T
Right	Behind	1	1	1	1	1	1
Right	Left	1	1	1	1	1	1
Behind	Right	1	1	1	1	1	1
Behind	Left	0	1	1	0	1	1
Left	Behind	0a	0a	1	1	0	1
Left	Right	1	1	1	1	1	1
No. entirely correct		4/6*		5/6**		5/6**	
Object location		Sequence type					
		S + Px + R		Px + S + R		Px1 + Px2 + R	
Right	Behind	-	-	1	1	-	-
Right	Left	1	1	1	1	1	1
Behind	Right	1	1	-	-	-	-
Behind	Left	0	1	-	-	-	-
Left	Behind	-	-	1	1	-	-
Left	Right	1	1	1	1	1	1
No. entirely correct		3/4*		4/4**		2/2*	
Object location		Sequence type					
		Pd + Px + R		Px + Pd + R			
Right	Behind	-	-	1	0		
Right	Left	1	1	1	1		
Behind	Right	1	1	-	-		
Behind	Left	0	1	-	-		
Left	Behind	-	-	0a	0a		
Left	Right	1	1	1	1		
No. entirely correct		3/4*		2/4			

Note: Dashes indicate that the sequence type was not valid because cross-body points could not refer to the object behind the dolphin; R = relational term (fetch); 1 = correct response, 0 = incorrect response

* The first and second elements were reversed.

* = $p < .05$, ** = $p < .001$, cumulative binomial test

dolphin must first correctly attend to the object being indicated by the informant, form a mental representation of this sample object and maintain it in memory, and finally select the alternative, matching the representation of the indicated sample. Chance probability of being wholly correct is thus 25% (i.e., one in two chances of selecting the correct sample multiplied by one in two chances of selecting the correct alternative).

The number of wholly correct responses for each dolphin on the first six trials with each cue and on each portion of the matching task is shown in Table 6. Phoenix was wholly correct on 29 of 30 trials with direct-pointing cues and also with cross-body pointing cues. She was also wholly correct on 26 of 30 gazing-cue trials. Phoenix was nearly flawless in approaching the indicated sample and also in finding a match to whichever

sample was approached. She responded wholly correctly (i.e., correctly to both portions of the task) on each of the first six trials with each different object as the indicated sample using human-direct points (6 of 6 correct), cross-body points (6 of 6 correct), and gaze cues (6 of 6 correct). Thus, by her strong matching performance, Phoenix indicated that she understood "what" the informant was attending to.

Ake did not perform as well as Phoenix, although her wholly correct responses in each condition were well above chance levels ($p \leq .003$, cumulative binomial test). Also, unlike Phoenix who performed accurately from the outset of testing, Ake performed relatively poorly on first trials. An examination of Table 6 indicates that Ake had little difficulty approaching the correct sample in response to the informant's cue, particularly the

Table 6. Matching indicated objects; the number of correct responses by Ake and Phoenix to each portion of a two-sample indicative matching task (data from Pack & Herman, in press).

Dolphins	Cue	Correct responses first trials (<i>n</i> = 6)	Correct responses all trials (<i>n</i> = 30)	No. approaches to indicated sample (<i>n</i> = 30)	No. matches to approached sample ^a (<i>n</i> = 30)
Ake	Direct-point	1	19***	30***	19
	Cross-body point	3	18***	30***	19
	Head-gaze	4*	15**	21*	16
Phoenix	Direct-point	6***	29***	30***	29***
	Cross-body point	6***	29***	30***	29***
	Head-gaze	6***	26***	28***	27***

Note: “Correct responses first trials” and “Correct responses all trials” are the number 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.

^aNumber of matches to the sample approached, regardless of whether it was the indicated sample or not

* = $p < .05$, ** = $p < .01$, *** = $p < .001$, cumulative binomial test

pointing cues; however, she performed poorly on the second portion of the task (i.e., finding a match to the approached sample). This implies that her difficulty was not in attending to the indicated object, but, rather, it was in encoding the identity of the cued sample, or in maintaining her representation of the cued sample, or in choosing the matching alternative, or some combination of these variables. Regardless of Ake’s difficulties in this task, the findings with Phoenix indicate that dolphins can understand “what” is being indicated as well as “where.”

Spontaneous Production of Pointing Cues and Understanding of the Importance of Audience Attention

There appears to be a fundamental asymmetry in the comprehension and production of animal communication systems, greatly favoring comprehension (Herman & Morrel-Samuels, 1990). The studies reviewed thus far have focused on the dolphin’s ability to comprehend human-directed pointing and gazing cues. Here, we ask whether dolphins can produce referential indicative cues for others. For all ape species, there is a lack of evidence for referential productive pointing in the wild (e.g., Goodall, 1986; Savage-Rumbaugh, 1986; Povinelli & Davis, 1994; Povinelli & Preuss, 1995). Pointing in conjunction with alternation of gaze between an object of interest and a receiver (i.e., monitoring) may develop in chimpanzees and orangutans (e.g., Greenfield & Savage-Rumbaugh, 1990; Miles, 1990; Leavens et al., 1996; Krause & Fouts, 1997), however, as well as in dogs (Hare et al., 1998; Miklosi et al., 2000, 2005) in contexts in which the subjects have extensive contact with humans.

Xitco et al. (2001) investigated capabilities for productive pointing by two dolphins (Bob and Toby) exposed to human divers wearing SCUBA

gear within the dolphins’ expansive underwater habitat. The divers used a large underwater visual/sonic keyboard to “name” goal objects (e.g., foods, toys, tools) or locations within the habitat. Goal objects were typically placed within transparent containers that prevented a dolphin from gaining access to the object without the assistance of a human diving companion (who could open the container) or a tool (that could be used to gain access). In addition to retrieving goal objects from containers, divers generally engaged the dolphins in various activities.

After approximately 6 mo of this type of association with divers, each dolphin, in the presence of a diver, began spontaneously “pointing” at goal objects (within containers) by remaining stationary in front of a container and aligning its rostrum and the longitudinal axis of its body with the goal object. While pointing, the dolphin often engaged in monitoring of a human diving companion by turning its head sideways (within the limits allowed by the partially fused cervical vertebrae of dolphins) towards the diver while maintaining its body alignment with the goal object. The diver responded by opening the container and giving the goal object to the pointing dolphin. The divers apparently did not shape pointing and monitoring, however. Instead, the initial pointing event observed for each dolphin included monitoring.

Xitco et al. (2001) reported that pointing dolphins were more likely to engage in monitoring when pointing to relatively distant objects (> 2 m) and when divers were far from the dolphin (ca > 2 m). They were more likely to refrain from monitoring when divers were near the dolphin (ca 1 to 2 m). Also, the dolphins only pointed when diving companions were present, providing support for the idea that a dolphin was intending to direct a diver’s attention to the indicated object—that is, the

dolphins were engaged in referential pointing. If goal object containers were supplemented with ring handles, and no divers were present, pointing did not occur. Instead, the dolphins transported the containers to humans who were outside of the habitat and out-of-view of the goal objects under water.

For pointing behavior to be considered referential, it should be coordinated closely with the receiver's attentional state (Tomasello, 1995), which in many instances may be inferred from the receiver's face or body orientation (e.g., eyes open and head facing the target object of the informant). Call & Tomasello (1994) tested whether orangutans that had been explicitly taught to point would take into account a human receiver's attentional state when trying to communicate to the human, through pointing, which of two glasses of juice it desired when both glasses were out of its reach. The orangutans pointed more often when the receiver was face forward than when the receiver's back was turned or when the receiver had left the testing room.

Using a similar procedure to Call & Tomasello (1994), Xitco et al. (2004) reported that the dolphins appeared to monitor the attentiveness of the receiver as well as their presence or absence. Xitco et al. created a task in which a dolphin, located on one side of a clear divider, was shown two water-filled clear jars located on the other side. A human receiver was also located on the opposite side of the divider and was stationed behind and between the jars. On each trial, the human receiver placed the two jars in the center of the apparatus, baited one of the jars with fish in view of the dolphin, and then placed one jar at each end of the apparatus. The dolphins, Bob and Toby, engaged in pointing and monitoring significantly more often when the diver was face forward (i.e., so they could see the dolphin's points) than when the diver had his back turned or swam away and hid. Together, the Xitco et al. (2001, 2004) studies appeared to indicate spontaneous imperative pointing (Liszowski et al., 2004) behavior that is referential in character. It is unknown whether dolphins may also engage in declarative pointing.

Understanding the Belief State of Another Through Joint Attention

Does the dolphin understand that an informant observing an object has knowledge or beliefs about that object? One method used to answer this question, especially when language is not available, is to employ the nonverbal "belief task." In the usual form of this task, a subject observes a "witness" watching a desired object or treat being hidden in one of two side-by-side boxes (i.e., the subject observes others engaged in a joint attention task). The subject, however, cannot see which box has

received the object and, thus, must rely on the witness to inform it. Before this can occur, however, the witness leaves the area, and during his or her absence, the locations of the two boxes are either switched (in which case the witness has a "false" belief about the object's location) or not (in which case the witness has a "true" belief). When the witness returns, he or she taps on or points to the box in the location that was seen being "baited" (i.e., the one the witness believes contains the object, not knowing that the boxes may have been switched). The key is that the subject never sees the original hiding process, but does observe the witness watching the process and sees the boxes either being switched or not. Consequently, the subject's task is to infer the type of belief of the witness and act accordingly. Historically, success in the false belief task has provided evidence that the subject has at least the rudiments of a "theory of mind" (Call & Tomasello, 1999).

Call & Tomasello (1999) used a nonverbal false belief task to examine if chimpanzees, orangutans, and 4- and 5-y-old children could make appropriate decisions based on their correct perception of the belief state of a human witness who marked the box he or she believed to have been baited but who had not seen whether the boxes were switched. Call & Tomasello found that most 5-y-old children succeeded in the false belief task, whereas few 4-y-old children performed accurately. No apes succeeded, even though they had demonstrated competence in pretest tasks in which they had to use the marker to locate the baited container, locate the reward in both visible and invisible displacements, and ignore the marker when they knew it was incorrect (i.e., they had observed the hider switch the bait from one container to the other before the witness returned).

Tschudin (2006) tested dolphin understanding of the attention and belief state of a human through use of a series of tasks modeled after the procedures of Call & Tomasello (1999). Tschudin first tested the four dolphins, Jula, Affrika, Khanya, and Kani, in a false belief task. The initial experiment was carried out in several training phases (akin to the pretest tasks given children and apes by Call & Tomasello, 1999) that culminated in the false belief test. In the first test, the location of the boxes was switched on every trial. Thus, the beliefs of the witness were always false. After the witness returned and tapped on a box, the boxes were slid forward toward the dolphin who indicated its choice by pointing its rostrum or moving towards a box.

Each dolphin received four false belief trials. Affrika, Khanya, and Kani were errorless on all four trials. Jula committed one error following a malfunction of the apparatus and was given another

four trials on which she was errorless. Collapsing the data across subjects yields performance accuracy significantly above chance levels, regardless of whether one uses Jula's initial four-trial performance or her performance on all eight trials.

These findings are impressive. Unlike the apes that passed the pretest tasks but failed the false belief tests, most of the dolphins passed all pretest tasks, and all of the dolphins passed the false belief tests. Despite these results, Tschudin (2006) cautioned that the dolphins might have learned a conditional discrimination rule based in part on the behavior of the witness and the state of the boxes (switched or not switched) during the earlier training phases of the experiment and then applied this rule in the false belief test. This would implicate a theory of behavior rather than a theory of mind. Additionally, there was a possibility of inadvertent cueing by the experimenter because this individual who had full knowledge of the correct location of the bait acted as both baiter and box presenter.

A second experiment conducted by Tschudin (2006) attempted to control these potential confounds by contrasting true belief with false belief trials. Three of the dolphins tested earlier were tested again. The false belief trial procedures were identical to those described earlier, with the exception that a naïve assistant presented the boxes to the dolphin for a choice to preclude possible experimenter bias. On true belief trials, the experimenter switched the boxes only after the witness returned and in full view of this individual (and the dolphin). Because the witness observed the switch, she had a true belief and tapped the originally baited box in its new location.

Each dolphin was tested on at least six belief trials, the first four of which were composed of two false belief trials and two true belief trials in different orders. Affrika was tested on six false belief trials and six true belief trials. She responded correctly on nine of these trials, including the first four. Kani was only tested in seven trials, but was correct on six of these, including the first four. Khanya was correct on only four of the six trials, with errors being committed on a true belief test (Trial 2) and a false belief test (Trial 4). Although Tschudin found evidence of a significant interaction between the belief state and the dolphin's response to the signal provided by the witness, no individual dolphin's performance on different test conditions attained significance (i.e., $p < .05$). An examination of the location of errors committed by Affrika and Kani (as reported in Tschudin, 2006) showed that all occurred during the second half of their tests, possibly indicating a buildup of proactive interference (i.e., memory for the events of prior trials affecting the current

trial) (see Herman, 1975). This trend did not hold for Khanya, however. Her errors fell in both the first and second halves of her test. Nonetheless, if these data from the first four trials with each dolphin are pooled for a total of six true belief and six false belief trials, the response accuracy of 10 out of 12 correct responses is significantly above chance ($p < .05$, cumulative binomial test). These results are suggestive, but, clearly, more tests with other dolphins are required.

Discussion

We began this review with six questions that reflect principal issues in studies of joint attention. To the extent that these questions have been addressed through empirical studies with dolphins (as reviewed here), the following answers may be synthesized. First, to the question of whether the receiver follows the informant's cue to locations within and outside of the receiver's visual field, if one accepts that gaze-following or point-following is the initial obligatory requirement of responding in object-choice tasks, then the answer is "yes" for dolphins attending to gazing cues and pointing cues directed at objects within their visual field (e.g., Herman et al., 1999; Tschudin et al., 2001; Pack & Herman, 2004). For objects out of the dolphins' visual field, pointing cues tested with objects behind the dolphins yielded positive results in later tests (Herman et al., 1993, 1999), although the dolphins had some initial difficulty relative to laterally placed objects. As we noted earlier, given the dolphins' laterally placed eyes and consequent broad field of vision, it is unclear whether the objects behind them were within or outside their field of view.

For the second question—the ability of a receiver to select the indicated object in an object-choice task with distally placed objects—again the evidence is positive for dolphins with direct-pointing cues cross-body pointing cues, and gazing cues (Herman et al., 1999; Tschudin et al., 2001; Pack & Herman, 2004).

For the third question—the key structural components of human-given pointing or gazing cues—Pack & Herman (2004) demonstrated that like many other species—for example, dogs (Hare et al., 1998; Soproni et al., 2001), chimpanzees (Povinelli et al., 1999), gorillas (Peignot & Anderson, 1999), capuchin monkeys (Vick & Anderson, 1999), and fur seals (Scheumann & Call, 2004)—eye-gazing cues for the dolphin are not as salient in object-choice tasks as head-gazing cues. Also, movement is not a necessary cue for dolphins to understand pointing or head-gazing cues. The spontaneity with which the static postures of the informant are "read" by the

dolphins is in contrast to responses of apes and dogs that may respond appropriately to these cues only after extended exposure and training.

One of the key questions in studies of joint attention (our fourth question) is the degree to which a subject understands the referential character of the informant's indicative cue, and also the precision with which the cue may be associated with specific objects (i.e., extracting the geometry of the cue). The reviewed studies of object-choice tasks performed by dolphins provide substantial evidence that dolphins understand that human-directed pointing cues and head-gazing cues refer to specific objects. Furthermore, the studies of Herman et al. (1999) and Pack & Herman (in press) indicated that dolphins may attend to and form a mental representation of the referent of an informant's pointing cue or head-gazing cue without taking any specific action to that object. Thus, dolphins appear to respond to declarative pointing (Liszkowski et al., 2004). Regarding the geometry of pointing cues, the three-object arrays used by Herman et al. (1993, 1999) indicated that the focus of the pointing cue is understood with indicative references to objects differing in angular extent by 90°, or in some cases less than that. Pack & Herman (in press) showed that dolphins can easily distinguish between pointing cues to near vs far objects in the same linear plane, but like human infants, they have some difficulty making this distinction based on gazing cues alone (Butterworth, 1995; Povinelli et al., 1997; cf. Soproni et al., 2001).

Our fifth question addressed the issue of production of indicative cues. Data provided by Xitco and colleagues showed not only that dolphins can develop spontaneously imperative pointing skills (using their rostrums and body alignment) to communicate the object of their attention to human companions, but importantly, they apparently take into account the presence, as well as the attentiveness, of the receiver. The ability of dolphins to point declaratively (i.e., point in an attempt to simply share attention and interest in an object or event—Liszkowski et al., 2004) remains unexplored, although, as shown earlier, dolphins appear to understand the declarative pointing of another.

Question six remains largely unanswered at this point. Clearly, dolphins can act as both informant and receiver in joint attention tasks. Even so, no studies have investigated the extent to which the dolphin informant “knows” about its common mental state with the human receiver towards the item of joint attention, although the dolphin appears aware of the requirement of the human receiver's attention for communication to be effective.

With the dolphin acting as a receiver, Tschudin's (2006) study is the only one thus far that touches upon the dolphin's understanding of the

knowledge state of a human informant. Using a false belief test, Tschudin provided some intriguing evidence in support of the idea that the dolphin receiver may understand the informant's belief state. Clearly, however, more subjects need to be examined on both true and false belief tests to determine with confidence the extent to which dolphins understand that an observer looking at something has knowledge and a belief about what they have witnessed.

When the studies reviewed in this paper are considered collectively, they reveal that dolphins' responses in tests of joint attention were largely accurate and robust, especially when considering the diversity of tests that have been applied. Further, the responses appear to be roughly symmetric across tests of comprehension and production.

The superiority of dogs over apes in comprehension of gazing and pointing cues within object-choice tasks has been attributed to the selective advantage of attending to human social cues during the long history of domestication of dogs (Hare et al., 2002). This hypothesis was supported by findings of Hare et al. (2002) that human-reared wolves, a species that has not been domesticated but is an ancestor of dogs, show little evidence for comprehension of gazing cues in object-choice tasks. Other domesticated species also show some skill in correctly interpreting distal indicative cues in object-choice tasks. For example, domestic goats (Kaminski et al., 2005) can accurately interpret sustained human-pointing cues combined with gaze alternation between the subject and the baited container, although less accurately than with alternating-gaze cues alone. Domesticated cats respond successfully to brief distal points (ca 1 s) in object-choice tasks.

Dolphins provide an example that a history of domestication is not a necessary condition for skill in responding accurately to human-directed indicative cues. Other evidence that domestication is not a requisite for skill in indicative-cued object-choice tasks comes from two other species of marine mammal. Schuemann & Call (2004) showed that four fur seals (*Arctocephalus pusillus*) between 4.5 and 5 y of age responded accurately to sustained distal pointing cues and that three of the seals responded accurately to sustained head-gazing cues. Shapiro et al. (2003) demonstrated that a wild-caught gray seal (*Halichoerus grypus*) between 4 and 6 mo old with very little training experience nonetheless understood a variety of different pointing cues, including brief pointing to distal objects. The dolphin and pinniped findings together illustrate that the understanding of indicative cues within object-choice tasks is not simply a “side effect” of domestication (cf. Kaminski et al., 2005).

Does enculturation explain the dolphin's understanding of pointing- and head-gazing cues? The most telling data on this question come from those studies in which dolphins with different enculturation histories were tested on similar joint attention tasks. The dolphins Akeakamai, Phoenix, Kani, Kelpie, Jula, Khanya, Tombi, and Affrika were all tested for their responses to direct-pointing cues and head-gazing cues. Despite large differences in degree of enculturation—Ake and Phoenix had many more years of human social contact and much more experience with various cognitive tasks than did Kani, Kelpie, Jula, Khanya, Tombi, and Affrika—dolphins from these different laboratories nonetheless demonstrated similar high levels of comprehension of human indicative cues. Thus, the degree of enculturation did not appear to influence the extent to which the dolphins understood pointing or gazing cues. Inasmuch as none of the dolphins received formal training with pointing or gazing cues, the results indicate that comprehension of these cues apparently occurred through inference as a consequence of informal exposure to human indication in facilities or conditions in which dolphins were in close contact with humans. Further evidence that enculturation is not the determining factor in attention to human-given cues comes from Shapiro et al. (2003) who, as noted earlier, demonstrated understanding of human-directed pointing cues in a young gray seal that had been in captivity for approximately 5 mo and had received only minimal training and human social interaction.

As shown by Xitco et al. (2001), dolphins that are obviously without arms and hands with which to point nevertheless appear to be prepared to spontaneously use their rostrums and body alignment to “point” at desired objects. This behavior may be a derivative of dolphin echolocation behavior, as suggested by Herman et al. (1999). Echolocation can provide a dolphin with object-related information, including the identity and spatial structure of complexly shaped objects (e.g., Pack & Herman, 1995). Echoic emissions are narrow in beam width (ca 10°) and directed forward and slightly upward from the melon (Au, 1993). Herman et al. (1999) hypothesized that attending to another's distal interrogation of an object through echolocation is a natural behavior that may generalize to other types of functionally similar distal referencing. Thus, a dolphin echolocating on an object may in effect “point” with its echoic emission and correlated body orientation to that object, although not necessarily with the intention of informing another. Nonetheless, if a dolphin receiver identifies an object being interrogated echoically by a nearby dolphin informant, the animals may be engaging in an act of joint

attention. In support of this idea, Xitco & Roitblat (1996) showed that a silent dolphin located near another echolocating dolphin that is targeting on an object could listen in (i.e., “eavesdrop”) on the echoes returning from the object and faithfully report the object's identity. Consequently, joint attention to the reflections from an ensonified object whose originating ensonifier can be identified may provide the basis from which the dolphin's spontaneous understanding of human-directed pointing and gazing emerges.

For the dolphin producing pointing behavior, an additional element is necessary for joint attention and communication to be effective and referential—the understanding by the pointer that the receiver's attention must be engaged. This characteristic may derive naturally from the complex societies of dolphins. Within the structure of dolphin society, individual identification is crucial; long-term associations are common; and individuals form coalitions and coordinate behaviors related to feeding, socialization, and mating (e.g., Connor et al., 2000). For coordinated behaviors to be effective, individuals must ensure that their collaborators are attentive.

Finally, regarding future efforts to study joint attention in dolphins, we suggest a few additional questions that will build on our current understanding of this skill and its development:

- Do dolphins take into account barriers that completely obstruct or occlude their vision (or echolocation) of what an informant sees?
- Will a dolphin take into account another dolphin's attentional state in tasks that require cooperation between two or more dolphins?
- Given the hypothesis that dolphins' abilities for joint attention may have derived from social activities involving echolocation, do other cetacean species that echolocate and engage in coordination of social behaviors also show abilities for understanding the referential character of human-given indicative cues?

Finally, what are the broader implications of the exceptional facility of dolphins for joint attention? Joint attention, as a social phenomenon, reinforces theories of the social basis of intellect in dolphins, including the evolution of exceptionally large brains (see Herman, 1980; Connor & Mann, 2006). Connor & Mann described the complexities and intricacies of social life in bottlenose dolphins at Shark Bay, Australia, including multilevel male alliances that collaborate or compete to control females, apparent female-female affiliative behaviors, and closely coordinated synchronous behaviors among pairs or trios of dolphins. These authors have also remarked on peer-group competition that can give an

advantage to those who can “outwit” others by enlisting cooperation or by “cleverly deceiving” others—the Machiavellian Intelligence hypothesis (see chapters in Byrne & Whiten, 1988; Whiten & Byrne, 1997). To those types of social acumen, we might add attending to others and manipulating the attention of others as social skills that can greatly benefit the informant, the receiver, or both. 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. Thus, in the findings from the cognitive laboratory and in observations of wild dolphin societies, there is an emerging understanding of how advanced cognitive skills manifest themselves in the real social world of the dolphin.

Acknowledgments

The preparation of this review was supported by financial contributions from The Dolphin Institute and its members; by equipment donations from Apple Computer Inc.; and by grants to The Dolphin Institute from West Honolulu Attractions, the Arthur M. Blank Foundation, and LeBurta Atherton. Michelle Schneider, Jeanette Thomas, and two reviewers provided helpful editorial comments. This review is dedicated to the memory of Akeakamai and Phoenix who together provided a wealth of information on our current understanding of dolphin cognition.

Literature Cited

- Anderson, J. R., & Mitchell, R. W. (1999). Macaques but not lemurs co-orient visually with humans. *Folia Primatologica*, 70, 17-22.
- 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.
- Au, W. W. L. (1993). *The sonar of dolphins*. New York: Springer-Verlag.
- Barth, J., Reaux, J. E., & Povinelli, D. J. (2005). Chimpanzees’ (*Pan troglodytes*) use of gaze cues in object-choice tasks: Different methods yield different results. *Animal Cognition*, 8, 84-92.
- Bates, E., Camaioni, L., & Volterra, V. (1975). The acquisition of performatives prior to speech. *Merrill-Palmer Quarterly*, 21, 205-224.
- Brauer, J., Call, J., & Tomasello, M. (2004). Visual perspective taking in dogs (*Canis familiaris*) in the presence of barriers. *Applied Animal Behaviour Science*, 88, 299-317.
- Brauer, J., Call, J., & Tomasello, M. (2005). All great ape species follow gaze to distant locations around barriers. *Journal of Comparative Psychology*, 119, 145-154.
- Butterworth, G. (1991). The ontogeny and phylogeny of joint visual attention. In A. Whiten (Ed.), *Natural theories of mind: Evolution, development and simulation of everyday mind reading* (pp. 223-232). Oxford, UK: Basil Blackwell.
- 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 space: Spatial mechanisms serving joint visual attention in infancy. *British Journal of Developmental Psychology*, 6, 255-262.
- Byrne R. W., & Whiten, A. (1988). *Machiavellian intelligence: Social expertise and the evolution of intellect in monkeys, apes and humans*. Oxford, UK: Clarendon Press.
- Call, J., & Tomasello, M. (1994). Production and comprehension of referential pointing by orangutans (*Pongo pygmaeus*). *Journal of Comparative Psychology*, 108, 307-317.
- Call, J., & Tomasello, M. (1999). A nonverbal false belief task: The performance of children and great apes. *Child Development*, 70, 381-395.
- Call, J., Agnetta, B., & Tomasello, M. (2000). Social cues that chimpanzees do and do not use to find hidden objects. *Animal Cognition*, 1, 89-100.
- Call, J., Hare, B., & Tomasello, M. (1998). Chimpanzee gaze following in an object choice task. *Animal Cognition*, 1, 89-100.
- Connor, R. C., & Mann, J. (2006). Social cognition in the wild: Machiavellian dolphins? In S. Hurlley & M. Nudds (Eds.), *Rational animals?* (pp. 329-367). Oxford, UK: Oxford University Press.
- 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.
- Eilan, N., Hoerl, C., McCormack, T., & Roessler, J. (2005). *Joint attention: Communication and other minds*. Oxford, UK: Clarendon Press.
- 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 abilities to follow eye gaze and its emergence during

- development in macaque monkeys. *Proceedings of the National Academy of Sciences, USA*, 97, 13997-14002.
- Goodall, J. (1986). *The chimpanzees of Gombe: Patterns of behavior*. Cambridge, MA: Belknap Press.
- Greenfield, P. M., & Savage-Rumbaugh, E. S. (1990). Grammatical combination in *Pan paniscus*: Processes of learning and invention in the evolution and development of language. In S. T. Parker & K. R. Gibson (Eds.), *"Language" and intelligence in monkeys and apes* (pp. 540-578). New York: Cambridge University Press.
- 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.
- Hare, B., & Tomasello, M. (2004). Chimpanzees are more skillful in competitive than in cooperative cognitive tasks. *Animal Behaviour*, 68, 571-581.
- 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., 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.
- Herman, L. M. (1975). Interference and auditory short-term memory in the bottlenose dolphin. *Animal Learning and Behavior*, 3, 43-48.
- Herman, L. M. (1980). Cognitive characteristics of dolphins. In L. M. Herman (Ed.), *Cetacean behavior: Mechanisms and functions* (pp. 363-421). New York: Wiley-Interscience.
- Herman, L. M. (1986). Cognition and language competencies of bottlenose dolphins. In R. J. Schusterman, J. A. Thomas, & F. G. Wood (Eds.), *Dolphin cognition and behavior: A comparative approach* (pp. 221-251). Hillsdale, NJ: Erlbaum.
- Herman, L. M. (2002). Vocal, social, and self-imitation by bottlenose dolphins. In C. Nehaniv & K. Dautenhahn (Eds.), *Imitation in animals and artifacts* (pp. 63-108). Cambridge: MIT Press.
- Herman, L. M. (2006). Intelligence and rational behaviour in the bottlenose dolphin. In S. Hurley & M. Nudds (Eds.), *Rational animals?* (pp. 439-467). Oxford, UK: Oxford University Press.
- Herman, L. M., & Morrel-Samuels, P. (1990). Knowledge acquisition and asymmetries between language comprehension and production: Dolphins and apes as a general model for animals. In M. Bekoff & D. Jamieson (Eds.), *Interpretation and explanation in the study of behavior: Vol. 1: Interpretation, intentionality, and communication* (pp. 283-312). Boulder, CO: Westview Press.
- Herman, L. M., & Ueyama, R. K. (1999). The dolphin's grammatical competency: Comments on Kako (1999). *Animal Learning and Behavior*, 27, 18-23.
- 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 bottlenose dolphins. *Cognition*, 16, 129-219.
- Herman, L. M., Abichandani, S. L., Elhajj, 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.
- 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.
- 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.
- Kaminski, J., Riedel, J., Call, J., & Tomasello, M. (2005). Domestic goats (*Capra hircus*) follow gaze direction and use some social cues in an object choice task. *Animal Behaviour*, 69, 11-18.
- Kaplan, G., & Rogers, L. J. (2002). Patterns of gazing in orangutans (*Pongo pygmaeus*). *International Journal of Primatology*, 23, 501-526.
- Krause, M. A., & Fouts, R. S. (1997). Chimpanzee (*Pan troglodytes*) pointing: Hand shapes, accuracy, and the role of eye gaze. *Journal of Comparative Psychology*, 111, 330-336.
- Leavens, D. A., Hopkins, W. D., & Bard, K. A. (1996). Indexical and referential pointing in chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology*, 110, 346-353.
- Lempers, J. D. (1979). Young children's production and comprehension of nonverbal deictic behaviors. *Journal of Genetic Psychology*, 135, 93-102.
- Liszowski, U., Carpenter, M., Henning, A., Striano, T., & Tomasello, M. (2004). Twelve-month-olds point to share attention and interest. *Developmental Science*, 7, 297-307.
- Miklosi, A., & Soproni, K. (2006). A comparative analysis of the animals' understanding of the human pointing gesture. *Animal Cognition*, 9, 81-93.
- Miklosi, A., Polgardi, R., Topal, J., & Csanyi, V. (2000). Intentional behaviour in dog-human communication: An experimental analysis of "showing" behaviour in the dog. *Animal Cognition*, 3, 159-166.
- Miklosi, A., Pongracz, P., Lakatos, G., Topal, J., & Csanyi, V. (2005). A comparative study of the use of visual communicative signals in interactions between dogs (*Canis familiaris*) and humans and cats (*Felis catus*) and humans. *Journal of Comparative Psychology*, 119, 179-186.

- Miles, H. L. W. (1990). The cognitive foundations for reference in a signing orangutan. In S. T. Parker & K. R. Gibson (Eds.), *"Language" and intelligence in monkeys and apes* (pp. 511-539). New York: Cambridge University Press.
- Moll, H., & Tomasello, M. (2004). 12- and 18-month-old infants follow gaze to spaces behind barriers. *Developmental Science*, 7, F1-F9.
- Moore, C., & Dunham, P. J. (1995). *Joint attention: Its origins and role in development*. Hillsdale, NJ: Erlbaum.
- Morissette, P., Ricard, M., & Decarie, T. G. (1995). Joint visual attention and pointing in infancy: A longitudinal study of comprehension. *British Journal of Developmental Psychology*, 13, 163-175.
- Neiwirth, 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. (2004). Dolphins (*Tursiops truncatus*) comprehend the referent of both static and dynamic human gazing and pointing in an object choice task. *Journal of Comparative Psychology*, 118, 160-171.
- Pack, A. A., & Herman, L. M. (in press). The dolphin's (*Tursiops truncatus*) understanding of human gaze and pointing: Knowing *what* and *where*. *Journal of Comparative Psychology*.
- 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.
- Povinelli, D. J., & Davis, D. R. (1994). Differences between chimpanzees (*Pan troglodytes*) and humans (*Homo sapiens*) in the resting state of the index finger: Implications for pointing. *Journal of Comparative Psychology*, 108, 134-139.
- Povinelli, D. J., & Eddy, T. J. (1996). Chimpanzees: Joint visual attention. *Psychological Science*, 7, 129-135.
- Povinelli, D. J., & Preuss, T. M. (1995). Theory of mind: Evolutionary history of cognitive specialization. *Trends in Neurosciences*, 18, 418-424.
- 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., Nelson, K. E., & Boysen, S. T. (1992). Comprehension of role reversal by chimpanzee: Evidence of empathy? *Animal Behaviour*, 43, 633-640.
- 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.
- Savage-Rumbaugh, E. S. (1986). *Ape language: From conditioned response to symbol*. New York: Columbia University Press.
- Scaife, M., & Bruner, J. S. (1975, January 24). The capacity for joint visual attention in the infant. *Nature*, 253, 265-266.
- Scheumann, M., & Call, J. (2004). The use of experimenter-given cues by South African fur seals (*Arctocephalus pusillus*). *Animal Cognition*, 7, 224-230.
- Shapiro, A. D., Janik, V. M., & Slater, P. J. B. (2003). Gray seal (*Halichoerus grypus*) pup responses to experimenter-given pointing and directional cues. *Journal of Comparative Psychology*, 117, 355-362.
- 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. (1995). Joint attention as social cognition. In C. Moore & P. J. Dunham (Eds.), *Joint attention: Its origin and role in development* (pp. 103-130). Hillsdale, NJ: Erlbaum.
- Tomasello, M., & Call, J. (1997). *Primate cognition*. Oxford, UK: 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. (2006). Belief attribution tasks with dolphins: What social minds can reveal about animal rationality. In S. Hurley & M. Nudds (Eds.), *Rational animals?* (pp. 413-436). Oxford, UK: Oxford University Press.
- 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.
- Whiten, A., & Byrne, R. W. (1997). *Machiavellian intelligence II: Extensions and evaluations*. Cambridge, UK: Cambridge University Press.
- Xitco, M. J., Jr., & Roitblat, H. L. (1996). Object recognition through eavesdropping: Passive echolocation in bottlenose dolphins. *Animal Learning and Behavior*, 24, 355-365.
- Xitco, M. J., Jr., Gory, J. D., & Kuczaj II, S. A. (2001). Spontaneous pointing by bottlenose dolphins (*Tursiops truncatus*). *Animal Cognition*, 4, 115-123.
- Xitco, M. J., Jr., Gory, J. D., & Kuczaj II, S. A. (2004). Dolphin pointing is linked to the attentional behavior of a receiver. *Animal Cognition*, 7, 231-238.