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# CAN DOLPHINS UNDERSTAND LANGUAGE?

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THE ISSUE OF LINGUISTIC COMPETENCIES OF ANIMALS<sup>1</sup> has implications not only for the understanding of human language and its evolution (see e.g., different and competing views in Hauser, Chomsky & Fitch 2002, Jackendoff & Pinker 2005, Lieberman 2006), but also for its relevance to the larger issue of the uniqueness of the human mind relative to that of nonhuman animals. The latter issue subsumes language as just one facet of a human mind that, unlike that of the nonhuman animal, is seen by some as uniquely capable of reasoning systematically and productively about higher-order relations (e.g., Penn, Holyoak & Povinelli, in press).

It is within the context of these diverse views and challenges that the study of cognitive processes in animals and animal competencies for learning forms of communication that have language-like properties take on special meaning and value. As Philip Lieberman has stated, “the nature and evolution of the biological basis of language can ultimately be ascertained only by actually studying the cognitive, linguistic, and communicative behavior of human beings and the other animals to whom we are all related (Lieberman 1984: 333).” The developing body of work on animal cognition indeed testifies to the depth and breadth of cognitive skills that may be demonstrated in many large-brained mammals, not only the close relatives of humans, the great apes, but also in the evolutionarily divergent but large brained bottlenose dolphin (*Tursiops truncatus*) and several other cetacean species. Within this work, the ability of animals to learn some defining properties of language has been a subject of intense study.

The early work on teaching language-like systems to apes (Gardner & Gardner 1969, Premack 1971, Rumbaugh 1977) seemed to provide a genuine link between human and ape in fundamental language competency (see reviews in Herman 1987, Ristau & Robbins 1979). This early work reported that common chimpanzees (*Pan troglodytes*) were able to learn to understand and use not only individual words but also words strung together into sentences. This claim was largely dismissed by additional studies or criticisms of others arguing that the putative “sentences” produced by the apes were largely an artifact of context, imitation, or social cueing, or were explainable more parsimoniously by simpler mechanisms (e.g., Terrace *et al.* 1979, Ristau & Robbins 1979). Further, although sequences

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<sup>1</sup> I thank the scores of students, interns, and volunteers who assisted in these studies over the years, and particularly those four dolphins, Akeakamai, Phoenix, Hiapo, and Elele, now deceased, whose contributions to our understanding and appreciation of their species’ cognitive characteristics will remain their legacy. Portions of this work were supported by grants from the National Science Foundation, the Office of Naval Research, the Earthwatch Foundation, and the Dolphin Institute.

of symbols were indeed produced by the apes, the sequences often had no syntactic structure that enhanced, explained, or modified meaning.

Historically, this work with apes was focused primarily on language production and paid scant attention to language comprehension. Investigators attempted to teach the apes to produce requests or to make statements through learned gestures, or by the pressing of keyboard symbols or other types of artificial symbols, assuming that if the ape produced a gesture or other learned symbol, or a sequence of such productions, that it understood what it was communicating—that it understood what the word or sequence meant or represented. A further assumption was that the ape would understand those same words or sequences when produced by the human partner. These assumptions, when later tested, proved largely false. It was found, instead, that comprehension did not flow automatically from production. The preeminence of language comprehension over language production, only relatively recently appreciated by ape language researchers (see e.g., Herman & Morrel-Samuels 1990), has long been appreciated among those studying child language (e.g., Bloom 1974).

More recent language work with bonobo chimpanzees (*Pan paniscus*), pioneered by Sue Savage-Rumbaugh (e.g., Savage-Rumbaugh *et al.* 1993), emphasized language comprehension and has progressed well beyond the findings from the earlier ape language studies. The bonobos have shown an ability to learn to understand instructions given in spoken English sentences, with at least a rudimentary appreciation that sentence structure affects meaning. Further, Savage-Rumbaugh has shown that both common and bonobo chimpanzees can learn to appreciate that symbols (words) of the language can function as linguistic references to objects and actions. This understanding that words *refer* is one of the key characteristics of human language.

In the remainder of this paper, I summarize our findings on linguistic skills in bottlenosed dolphins and on some related cognitive abilities.

1. SHORT PRIMER ON DOLPHIN BIOLOGY AND NATURAL HISTORY. Inasmuch as the readers in this journal may have had only limited exposure to the biology and natural history of bottlenose dolphins, a short primer may prove useful.

The bottlenose dolphin is a *cetacean* belonging to the suborder of toothed whales, comprised of six or more families depending on the particular taxonomist. The largest family is the Delphinidae (dolphins) numbering about 32 species. Besides the bottlenose dolphin, examples of some other dolphin species are the killer whale (the largest member of the dolphin family), the pilot whale, spinner dolphin, and common dolphin. Modern dolphins emerged only about ~5–12 million years ago.

Bottlenose dolphins are a cosmopolitan species, widely distributed throughout the temperate and tropical seas worldwide. They are exquisitely adapted to the marine world, anatomically, physiologically, behaviorally, and socially. Their adaptations include extensive sensory specializations and vocal flexibility. Their eyes are laterally placed, giving them a panoramic field of view, without sacrificing depth perception. They can see laterally, forward, and rearward, and they have good visual acuity in both water and in air (Herman *et al.* 1975). Their echolocation sense enables them to inspect their environment even in

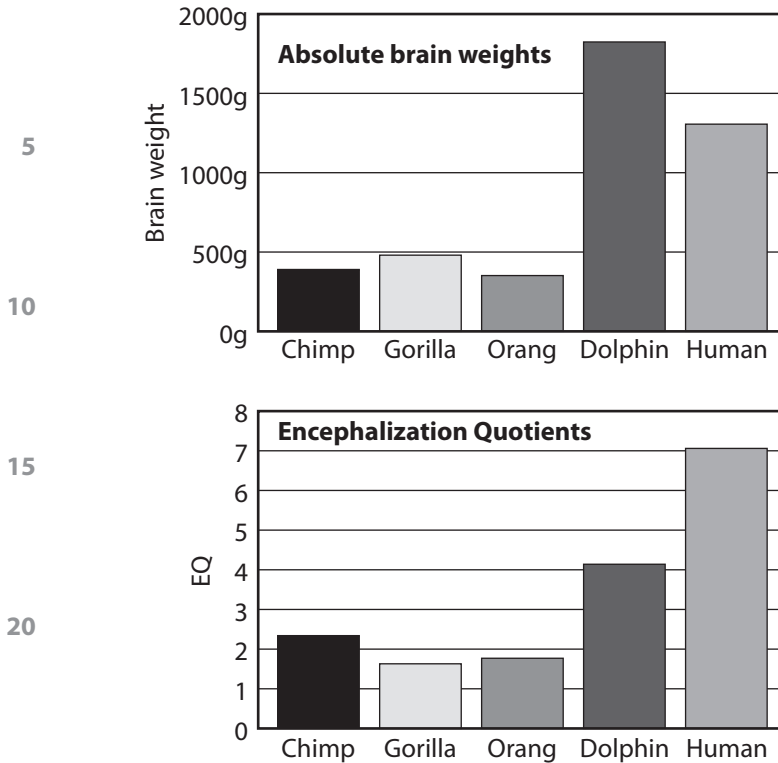
the darkness of the deep waters or at night, through listening to and analyzing the echoes returning from their emitted clicks (Au 1993). In addition to these broadband, very short duration echolocation clicks, dolphins also produce broadband burst pulse sounds that convey their emotional state, such as slow “pleasure” clicks and strident “annoyance” sounds (Herman & Tavolga 1980). Finally, narrow band frequency varying whistles are apparently used in inter-animal communication, to identify individual animals by the unique pattern of their most common whistle and to maintain contact though dispersed. 5

Bottlenose dolphins live in intricate “fission-fusion” societies (Connor *et al.* 2000). They associate in small groups within this larger society, but group membership is often fluid, yet preferential. Females associate primarily with other females and their young and juveniles, while males leave their natal group as subadults. Pairs of males may form close collaborative and enduring alliances. In one of the most well studied areas, Shark Bay in Western Australia, male alliances may be used to capture and control lone females (Connor, Smolker & Bejder 2006). At times, two alliances may join temporarily to take away a female being guarded by a pair of males. Furthermore, there seems to be some form of memory of who helped whom, with possible reciprocity occurring later. 10 15

Developmentally, bottlenose young nurse up to ages 3–5, and enjoy a protracted period of development, care, and socialization, during which there is much opportunity to learn about the intricacies of their society, the habitat, the predators, the prey, and more. Although there is a high degree of infant and juvenile mortality, individuals who survive may live into their 40s or even 50s. 20

Dolphins exhibit great flexibility of behavior, illustrated, for example, by their diverse and inventive feeding strategies (Connor *et al.* 2000). In Shark Bay, for example, there is a small subgroup that uses tools to forage—they carry sponges on their beaks to aid in their foraging along the rocky bottom, protecting their beaks from becoming abraded. Along the shores of South Carolina, four or more dolphins may collaborate in herding fish, driving them onto a sloping muddy bank, and then sliding out in unison to capture the prey flopping about on the bank. In the sandy bottom of Bahamian waters, dolphins, using their echolocation, detect fish buried in the sand and then root them out, corkscrewing into the sand, driving them out, and then quickly capturing them. 25 30

2. MOTIVATIONS FOR STUDYING DOLPHIN INTELLECT. The intense interest in bottlenose dolphin intelligence over the years has been largely driven by the exceptionally large size and complexity of their brain (Hof, Chanis & Marino 2005). In absolute size, the bottlenose dolphin brain is larger and heavier than the human adult brain, about 1500–1700 grams compared with about 1200–1400 grams for the human (**Figure 1**, top, overleaf). In addition, the cortex of the dolphin brain has more convolutions than the human brain, giving it a greater surface area relative to the whole brain than occurs in the human. However, the dolphin cortex is thinner than the human cortex, so that the volume of the cortex relative to the whole brain is greater in the human. Moreover, inasmuch as larger animals tend to have larger brains, in part to account for the increased somatic tissue to control, a more satisfactory measure of brain size is its weight relative to the weight of the body. The measure of relative brain size most often used is the encephalization quotient (*EQ*), developed 35 40



25 **Figure 1.** Absolute brain weights (top) and encephalization quotients (bottom) of chimpanzees, gorilla, orangutans, dolphins, and humans.

30 by Harry Jerison (1973), and defined as the degree to which brain weight departs from that expected for a given body weight, based on the regression of brain weight on body weight for a wide range of mammals. The regression equation is given as:

$$\text{EQ} = \text{brain wt} / 0.12(\text{body wt})^{0.67}$$

35 Values lying on the regression line have an EQ of 1.0; those lying above have an EQ greater than 1.0 and those lying below have an EQ less than 1.0. Applying this metric, humans have an EQ of about 7.0; that is, humans are about seven times more encephalized (seven times more excess brain tissue) than would be expected given our average body weight (**Figure 1**, bottom). Bottlenose dolphins, and several other dolphin species similarly sized to the  
 40 bottlenose, have an EQ of about four, second only to the human and well the above the EQs of about 2.0 for the great apes (chimpanzees, gorillas, and orangutans) (Marino 1998). Relative brain size may suggest intelligence, but in the final analysis it is behavior and not structure that must ultimately measure the intellectual breadth and depth of the species.

Thus, the relative size of the dolphin brain, coupled with the complexity of their society, motivates formal study of their intellect—and their potential for any linguistic competency. Although there is no evidence that dolphins in the wild have anything approaching a human natural language, it is still of interest to ask whether they may be capable of acquiring, through tutoring, some of the fundamental defining attributes of a human language—particularly the semantic and syntactic components. More broadly, beyond language—dolphin intellect is of fundamental and comparative interest and importance because of the numerous similarities noted in cognitive abilities and traits of dolphin and ape—and this despite the immense divergences of these two groups in their evolution, general biology, brain architecture, and ecology. This drives the question of whether there may be some pressures in common to these divergent groups that might select for intellect, and if so, what this might inform about the emergence of human intellect.

3. KEWALO BASIN STUDIES OF DOLPHIN LINGUISTIC AND COGNITIVE SKILLS. Our dolphin studies were carried out at the Kewalo Basin Marin Mammal Laboratory in Honolulu with the dolphins Akeakamai (“Ake”), Phoenix, Hiapo and Elele. All were wild born Atlantic bottlenose dolphins from the Gulf of Mexico, and all arrived at our laboratory at about the age of two or three. Ake and Phoenix, both females, arrived together in 1978 and Hiapo, a male, and Elele, a female, arrived together in 1987.

The philosophy that guided our work on cognitive and linguistic skills of these dolphins was that the full flower of intellect is best revealed through immersion in a program of long-term intensive education within a culture that values education. Inasmuch as this seems to be the conditions under which the full flower of human intellect emerges, why should that not be the case as well for other long-lived large-brained animals? To this end, we used an educational progression with our dolphins in which they began their education at about 2–3 years of age, starting with simple tasks and then progressing gradually to tasks and challenges of increased complexity. Through this process, the dolphins accrued knowledge, and learned rules, concepts and strategies. They learned how their laboratory world worked and were then able to demonstrate cognitive skills that might not have been realized otherwise.

3.1. SENTENCE UNDERSTANDING. Our initial work began with Ake and Phoenix shortly after their arrival and asked, “Can a dolphin *understand* a sentence? This was an obvious reference to the work of Terrace *et al.* (1979) that asked, “Can an ape *create* a sentence?” Thus, unlike the chimp work, including that of Terrace *et al.*, we chose to focus on language comprehension, rather than language production. The emphasis of the ape work on production introduced a great deal of subjectivity into the studies, as the researchers attempted to interpret the productions of the apes. In contrast, our emphasis on comprehension allowed for objectivity in analysis and interpretation. The dolphins were given instructions through the language systems to take an indicated action to an indicated object or to construct one or another relationship between two objects. We measured comprehension by the accuracy with which the instructions were carried out, particularly new or novel instructions. The dolphins’ responses were described in real time by an observer blind and deaf to what

Non-relational		
1.	Object + Action	<i>Surfboard Over</i>
2.	Modifier + Object + Action	<i>Left Hoop Through</i> <i>Right Water Tail-Touch</i>
5 Relational		
3.	Object1 + Object2 + Relational Term (R)	<i>Person Ball Fetch</i> <i>Ball Person Fetch</i>
4.	Modifier + Object1 + Object2 + R	<i>Right Pipe Frisbee Fetch</i>
5.	Object1 + Modifier + Object2 + R	<i>Phoenix Left Net Fetch</i>
6.	Modifier + Object1 + Modifier + Object2 + R	<i>Left Basket Right Ball In</i> <i>Right Basket Left Ball In</i> <i>Right Basket Right Ball In</i> <i>etc.</i>

15 **Table 1.** Ake's sentence frames and examples of instructions.

instruction was given. If the observer's labeling of the response completely matched the instruction given, the dolphin was scored as correct and was rewarded with fish and social praise. A complete description of the languages, the various tests given, the controls used, and the responses of the dolphins are available elsewhere (Herman 1986, 1987; Herman, Pack & Morrel-Samuels 1993; Herman, Richards & Wolz 1984). Here, I summarize some of the key points.

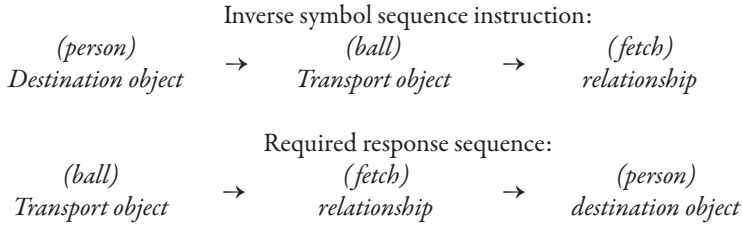
We developed two different language formats: an acoustic language for Phoenix and a gestural language for Ake. Inasmuch as the bulk of our work was done with the gestural language, I will focus on that. Description of the work with Phoenix in the acoustic language can be found within the references just cited.

As shown in **Table 1**, there were two general sentence forms: nonrelational and relational, expressed within the five sentence frames shown in the table. The two- and three-word nonrelational sentences required that the dolphin take a specified action to a specified object. An optional locative modifier (*left* or *right*) was used before the object name in the three-word frame. For example, the gestural instruction *Surfboard Over* directed Ake to jump over the surfboard, while *Left Surfboard Over* directed her to jump over the surfboard to her left (and not the one to her right). Multiple named objects were always present in the tank during formal testing, with one or two of the objects positioned as left and right pairs (relative to the dolphin's location).

We used an inverse grammar for the relational sentences. As shown in the following example, in the inverse grammar the symbol sequence does not flow in the same order as the required response sequence. For example, consider the instruction *person ball fetch* asking Ake to take a ball (floating in the water) to a person (also in the water, or standing at tankside). The instruction and the required response are expressed as shown in **Figure 2**.

The inverse grammar does not allow for word-by-word processing—that is, taking an action to each word as it occurs—but requires *sentence* processing, our prime interest. Ake cannot interpret the instruction (the required actions) until the entire sequence





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**Figure 2.** Instruction and required response for person fetch ball.

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has occurred. Thus, the first word alone, *person*, does not inform as to its function, which might be as a direct object, as in the sentence *person under*, or as an indirect object, as in the relational illustration above. Similarly, the second word, *ball*, does not predict the exact instruction inasmuch as there are alternate endings (third words) including in, *fetch*, and *erase* (*erase* means ‘cancel’ or ‘disregard the preceding’). Therefore, all words must be processed and interpreted before Ake can organize the correct response. The relational sequence allows for some semantic contrasts, in which a reversal of object names requires a reversal of action. Thus, *person ball fetch* requires Ake to take the ball to the person, while *ball person fetch* requires the opposite.

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Ake’s language allowed for four- and five-word-long sentences, as shown in **Table 1**, Frames 4–6), by incorporating locatives before one or both object names. These longer sentences were a concatenation of the two three-word forms shown in **Table 1**, Frames 2 and 3), and were not explicitly taught. Instead, Ake correctly inferred their interpretation the *first* time she was given four- and five-word sequences. These longer sequences also allowed for semantic contrasts, by reversing object order as illustrated earlier, or by changing locative order, or both. For example, the sentence *Right Basket Left Frisbee In* instructs Ake to put the Frisbee on her left in the basket on her right, while *Left Basket Right Frisbee In* requires the opposite. Ake understood these differences well, taking account of both gesture meaning (the semantic component) and sequences of gestures (the syntactic component) to interpret her instructions correctly. Of 75 2- and 3-word novel *nonrelational* sentences given, Ake responded wholly correctly to 53 (71%), and of 139 3-, 4-, and 5-word novel relational sentences given, Ake responded wholly correctly to 86 (62%). Each sentence was a novel instruction, that is, she had never received that instruction previously. A strict scoring criterion was used: the instruction must be performed entirely correctly in order for Ake’s response to be scored as correct. For example, if she put the left ball in the left basket instead of the right basket, that would be scored as an error, even though, overall, the instruction was understood semantically and syntactically.

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3.2. GRAMMATICAL UNDERSTANDING: INTERPRETING ANOMALOUS SEQUENCES. Ake had a deep understanding of the grammar of her language, as illustrated by her *rational* responses to anomalous sequences (Herman, Kuczaj & Holder 1993; Holder, Herman & Kuczaj 1993; also see Herman & Uyeyama 1999). We tested her responses to both semantic and syntactic anomalies. A *semantic anomaly* violated a semantic rule or relationship.

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Anomaly	N	Reject	Substitute	Extract	Reverse	Non sequitur
Semantic	18	13	4	0	0	1
Syntactic	37	6	7	24	0	0

5 **Table 2.** Responses to anomalous semantic and syntactic sequences.

Examples are the two- item sequence *Surfboard Through*, an obvious impossibility, and the three-item sequence *Hoop Phoenix Fetch*, a request to transport the dolphin Phoenix to the floating hoop, but Phoenix cannot or will not be transported. Possible responses to semantic anomalies are to reject the instruction, or reverse it where possible (i.e., bring the hoop to Phoenix) or create a substitution response (e.g., *Hoop Pipe Fetch*). **Table 2** shows Ake's responses to 18 semantic anomalies. She rejected 13 (72%) outright, briefly beginning a slight orienting movement on seeing the first gesture, but then immediately facing the trainer again, and taking no further action. On four (22%) occasions she created a substitution response by transporting a movable object instead of the immovable object signified, and on one occasion responded in a way that had no bearing on the original instruction (non sequitur). She never reversed the sequence, however, illustrating the strong control of word order on her interpretation of instructions.

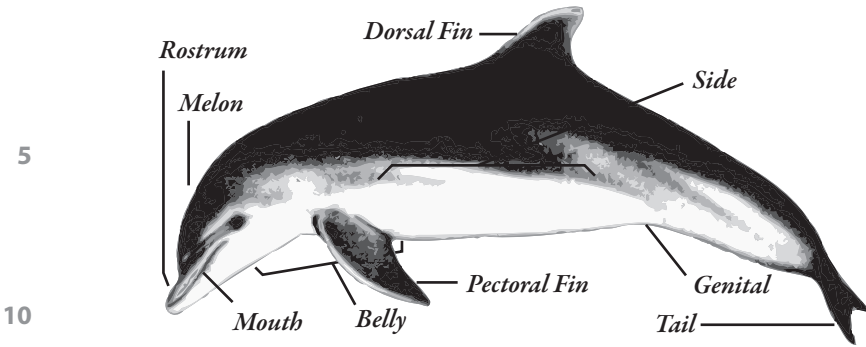
*Syntactic anomalies* violated a syntactic rule or relationship. Examples are *Speaker Surfboard Basket Fetch* and *Water Phoenix Ball On* (note that *Speaker*, attached to the tank wall, *Water*, streaming from a suspended hose, and *Phoenix* are nontransportable objects, while *Surfboard*, *Basket*, and *Ball* are transportable). As a whole, each sequence is syntactically anomalous in that there is no syntactic rule allowing for three object names in a row. However, embedded in each sequence are subsets of three items that together could form legitimate semantic and syntactic relations. For example, in the first case above all of the following are legitimate three-item subsets (grammatically correct and capable of being carried out): *Speaker Surfboard Fetch*, *Speaker Basket Fetch*, and *Surfboard Basket Fetch*. **Table 2** shows that in 24 (65%) of 37 syntactic anomalies given Ake, she extracted a grammatical subset and responded to that, for example transporting the basket to the speaker in the first sequence illustrated, and in doing so, conjoining nonadjacent items to complete the extracted subset. On six occasions, she rejected the entire anomaly, and on seven occasions created a substitute response. As a whole then, Ake's response to the anomalies reveals a deep understanding of the grammar of the tutored language. Importantly, no reinforcement or tutoring was given for Ake's responses to anomalies. Instead, anomalies were inserted at a very low density within a larger set of grammatical sequences given to her (e.g., two anomalous sequences occurred at random locations within a larger set of 17 normal sequences of various types, no more than once per day, over a six week period). After Ake had responded to the sequence, the trainer simply waited for her to return on her own to the testing station.

3.3. UNDERSTANDING REPRESENTATIONS OF REALITY. Television can represent the real world, yet in general animals have difficulty in interpreting these scenes representationally. Savage-Rumbaugh (1986) reported, for example, that even her language trained chim-

panzees, Sherman and Austin, had difficulty interpreting television scenes; and did not respond as if they understood what was happening on the television screen. Extensive periods of social facilitation, covering many months, with trainers responding enthusiastically to the scenes while watching television together with the chimps, finally resulted in the chimps exhibiting behaviors indicating they recognized what was occurring on the screen. In sharp contrast, Ake, on the *first* occasion she was exposed to television of any sort, immediately responded to an image of a trainer gesturing to her in her familiar language format, and carried out the instructions being conveyed as accurately as she did in the real world. The small 13-inch television screen we used in our first studies was viewed by Ake through an underwater window. Later, we were able to show that Ake not only understood literal representations of humans, but also “disembodied” humans whose torso and head were blocked out so that only their arms and hands were visible on the screen. These results are fully described in Herman, Morrel-Samuels and Pack (1990) and attest to the dolphin’s ability for inferring relations between the represented world and the real world.

3.4. UNDERSTANDING THAT SYMBOLS HAVE REFERENCE. Were the gestural signs we used for objects in Ake’s tutored language understood by her as references to those objects? A strong indicant that a symbol refers, i.e., elicits the concept or the properties of an object is an understanding of a symbolic reference to the *absent* object. To test for this indicant, we developed a procedure in which we “seeded” the tank with several objects, each shown to the dolphin and then thrown into the tank. Then, using a newly taught gesture we glossed as *Question*, we created a new sentence frame *Object + Question*. For example, *Pipe Question*, asked, “Is there a pipe in your tank?” Ake could answer *Yes* by pressing a paddle to her right, or *No* by pressing a paddle to her left (Herman & Forestell 1985). Generally, two or three objects would be thrown into her tank and then a series of questions were asked, some answerable *Yes* and some answerable *No*. Overall, Ake was approximately as accurate (~90%) at reporting absence of an object as she was at reporting presence. This gave evidence that the gestural symbols we used for objects represented those objects to Ake. In further tests, we probed her responses to 3-word relational instructions,  $O_1 + O_2 + R$ , where either both objects were present, or one of the other was absent. Our first probe was a case where  $O_1$ , the destination object was missing. We expected that Ake would simply press the *No* paddle to indicate that the relationship could not be constructed. To our surprise and initial puzzlement, she swam to  $O_2$ , the transport object that was present, and carried it to the *No* paddle, in effect reporting that  $O_2$  was present but  $O_1$  was absent. In contrast, if  $O_2$  were absent and  $O_1$  present, she simply pressed the *No* paddle directly, indicating that there was no object to transport. Finally, if both objects were present, then Ake completed the relation, taking  $O_2$  to  $O_1$ , or occasionally taking  $O_2$  to the *Yes* paddle (see Herman, Pack & Morrel-Samuels 1993 for a more complete description of these studies).

3.5. UNDERSTANDING INDICATIVE GESTURES. Human pointing refers another to an object or event of interest (“referential pointing”) and typically seeks to share that attention with another. Few animals are capable of understanding the human pointing gesture. Dogs, which have co-evolved with humans, have undoubtedly been selected over the eons



**Figure 3.** The body parts of the bottlenose dolphin having gestural names.

for their attention to humans and are excellent at interpreting human pointing gestures as references to distal objects. Chimpanzees, on the other hand, are notoriously poor at that task. During informal activities with the dolphins, we routinely used pointing gestures to refer a dolphin to some object we wished it to bring to us, and the dolphins readily complied. We asked therefore to what extent dolphins might be capable of understanding referential pointing. Using Ake again as our subject we constructed an experiment in which three named objects from her language paradigm were arrayed about her, one 10 ft to her left, a second 10 ft to her right, and a third 10 ft behind her (Herman *et al.* 1999). We could then point at an object and follow that with a symbolic action gesture from her language, asking her to take the indicated action to the object pointed to. Note that this sequence, Point + Action, or  $P + A$ , follows the same syntax as the previously described  $O + A$  nonrelational term. Ake had no problem with this form. We then tested her responses to a sequence of relational points,  $P_1 + P_2 + R$ , again following syntactically the previous familiar relational form  $O_1 + O_2 + R$ , embedding the pointing sequences at low density within sequences of the simpler nonrelational forms. Ake responded by spontaneously incorporating the inverse grammar used with the wholly symbolic forms into the indicative form, by taking the object pointed to *second* to the object pointed to *first*. We speculated that the ability of the dolphin to follow the human pointing gesture might be a derivative of the structure of their echolocation behavior in which both the dolphin's body and the echolocation beam are "pointed" toward the target being inspected. Moreover, nearby dolphins "eavesdropping" on the echolocating dolphin can identify the target being inspected, seemingly jointly attending to where and to what the echolocator is "pointing" (Xitco & Roitblat 1996).

3.6. UNDERSTANDING SENTENCE FRAMES INVOLVING BODY PARTS: EXAMINING SELF-AWARENESS. We asked whether the dolphin Elele might understand symbolic gestural references to her own body parts, as shown in **Figure 3**, and how to use those parts in novel ways, as directed by other symbols. Elele was already familiar with the gestural names for *rostrum* and *tail*, but the remaining gestural names were specially taught for this new study (Herman *et al.* 2001). We then constructed four new sentence frames, as shown in **Table 3**. Elele, like

<i>Body-part + display</i> <i>Body-part + shake</i> <i>Object + body-part + touch</i> <i>Object + body-part + toss</i>
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**Table 3.** Sentence frames using body part names.

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Ake, was familiar with the gestural names for the actions listed. We then carried out a formal study of her ability to understand instructions given within those sentence frames.

For example, *Frisbee, dorsal fin, touch* asked Elele to swim to the floating Frisbee and lay her dorsal fin on it, an action that required her to turn part way on her side and target the Frisbee with her dorsal fin while looking behind her with her wide field of vision. She executed that response perfectly, as well as many other requests that asked her to use a body part in a novel way. Her responses were scored by an observer having no knowledge of what instruction she had been given. Like Ake's protocols, the response had to be entirely correct for Elele to be scored as correct. Under these conditions, Elele's responses to the two-word requests averaged 76% correct and her responses to the three-word forms averaged 73% correct, both highly significant levels of performance. Thus, we can conclude that Elele displayed conscious awareness and conscious control of her body parts. The results suggest that the dolphin has a well-developed body image that revealed itself not only in this study, but also in other studies of dolphin behavioral mimicry (Herman 2002). These results also bear on the issue of *self-awareness*. Self-awareness has many dimensions and is exhibited here through the dolphin's conscious awareness of its own body parts. That body-part awareness is controlled by specific brain areas is shown by deficits in such awareness in patients suffering damage to the left parietal area (Sirigu *et al.* 1991). Such patients, diagnosed with *autotopagnosia*, cannot locate their own body parts. If asked, "Where is your knee?" or "Point to your nose," they do not know where those parts are. They thus have a deficiency in body image. They do not lack semantic knowledge of those body parts, however. If the examiner points to the patient's knee and asks what that is, the patient can accurately reply that it is a knee. What they lack is topographical knowledge.

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3.7. AWARENESS OF ONE'S OWN BEHAVIORS. Another form of self-awareness we investigated involves conscious memory for behaviors just performed and the use of that memory to self-select a subsequent behavior. To study this process, we created two new gestures, *repeat* and *any*. The first gesture asks the dolphin to do once again the behavior it just did, while the second asks for a behavior different from the one just performed. As described in Herman (2002, see also Mercado *et al.* 1998), we created a paradigm in which we directed the dolphin Phoenix to carry out the specific action we designated, either *over*, *under*, *tail-touch*, *pectoral-fin touch*, or *mouth* (= *bite*), to a single object floating nearby in the tank. After completing the behavior and returning to the trainer, Phoenix was given either the *repeat* gesture or the *any* gesture. This was repeated three times, as in the following sequence: *Directed Behavior (Over, Under, Tail-touch, Pec-touch, or Mouth), Any or Repeat, Any or Repeat, Any or Repeat*. Phoenix understood that *Any* required her to perform any of

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		Four-item sequences						
Sequence	<i>BAAA</i>	<i>BAAR</i>	<i>BARR</i>	<i>BARA</i>	<i>BRAA</i>	<i>BRAR</i>	<i>BRRR</i>	<i>BRRA</i>
% correct	80	85	80	85	70	65	95	100

5 **Table 4.** Percent of correct responses to each sequence ( $n = 20$ ) of the dolphin Phoenix ( $B =$  directed first behavior;  $R =$  repeat behavior;  $A =$  any behavior of the five except the one just completed.)

10 the five behaviors other than the one she just performed. An example of an actual recorded four-item sequence given and Phoenix's responses to each (in parentheses) was: *Directed behavior* (*Pectoral-fin touch*), *Any* (*Over*), *Repeat* (*Over*), *Any* (*Tail-touch*). Since the entire sequence was performed correctly, Phoenix was scored as correct on that trial. We examined all possible three-item permutations of *Repeat* and *Any*, with the results shown in **Table 4** for the first 20 instances of each particular permutation. Permutations were given

15 in a balanced, quasi-random order.

To perform at the levels shown in **Table 4**, Phoenix had to retain in memory a representation of the last behavior performed and, depending on the particular gesture given, *repeat* or *any*, self-select the next behavior from among the remaining set of four, and then update her immediate memory for that new "last" behavior. Her ability to do this so well illustrates

20 her awareness of her own recent behaviors, one of the many dimensions of self-awareness. Importantly, inasmuch as the gestures *repeat* and *Any* were not associated with any one particular behavior, Phoenix had to rely on her memory for what she just did, rather than on a specific action direction from a trainer, as in the more familiar  $O + A$  sequence.

25 3.8. CREATIVE SYNCHRONY. We developed a gestural sign we called *create* that instructed a dolphin to perform any behavior of its choice. The behavior could be a learned behavior or one of the dolphin's own creation. If a second *create* gesture were given after the dolphin had responded to the preceding one, the rule was that the second behavior had to be different from the first. All four dolphins, but especially Elele, were adept at creating a range

30 of different behaviors. In one formal test (described in Herman 2006), Elele created 72 different behaviors in 144 requests to *create*. We also taught the dolphins a gestural sign that we called *tandem*. If an action sign followed the tandem sign, such as *tandem back-dive*, it instructed a pair of dolphins to perform that action together in tight synchrony, both in timing and in location. Later, we tested the dolphin's responses to the novel and challeng-

35 ing two-element sequence *tandem create*. Here, a pair of dolphins is being asked to create their own behavior—it must be the same behavior and it must be executed together in close synchrony. Typically, in response, the pair will swim off together underwater, apparently organizing or coordinating some response. Responses may range, for example, from a simultaneous headstand with tail exposed and wiggling, to a dramatic high leap, both dolphins spinning counterclockwise on their long axis and squirting water from their mouth.

40 In one test pairing the dolphins Elele and Hiapo, 79 different behaviors were documented in response to *tandem create* (reported in Herman 2002). We were unable to determine with certainty how such behaviors were selected and organized. The most parsimoni-

ous explanation was that it was done though behavioral mimicry, one dolphin selecting a behavior and the other following extremely closely. Videotape analyses revealed that in many cases the dolphins appeared to be in virtual synchrony, but in 44 cases one or the other dolphin could be detected performing the act slightly ahead of the other.

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3.9. MIMICRY. Imitation is a key mechanism for social learning and the spread of culture. Surprisingly, therefore, a capability for behavioral mimicry is not widespread among non-human animals. The old saw “monkey-see, monkey-do” simply does not hold up to empirical testing (Visalberghi & Fragaszy 1990). In contrast to the norm, bottlenosed dolphins are generalized mimics, capable of faithfully copying both arbitrary sounds and arbitrary motor behaviors. We demonstrated flexible *vocal* mimicry in Ake, who could copy a variety of electronically generated sounds that were broadcast into her tank through an underwater speaker (Richards, Wolz & Herman 1984). *Behavioral* mimicry was demonstrated with all four dolphins in a variety of ways and a variety of contexts (see review in Herman 2002). These included imitation of the behaviors of another dolphin, imitation of the behaviors of a human demonstrated both in-water or at tankside, and imitation of either dolphin or human behaviors viewed on a television screen behind an underwater window. The dolphins also understood the concept of *mimic*. In a formal testing of in-water mimicry of either a dolphin model or a human model, the observer dolphin only imitated if given the *mimic* gesture after observing the model’s behavior. If given some other gesture, such as one meaning *spiral swim*, it would do that instead. Dolphins thus appear to be the only nonhuman animal capable of both varied vocal and behavioral mimicry, capabilities that likely derive from the adaptive function of these abilities in the wild. Thus, dolphins can imitate the signature whistles” of another. Signature whistles are so termed because they typically are individual-specific, apparently serving as an individual identifier useful for maintaining social cohesion in a group. Motor mimicry abilities may be an extension of the natural synchrony seen among pairs or groups of dolphins in the wild, leaping together in unison, for example. The *tandem* behaviors we have demonstrated in the lab are also a likely extension of this naturally synchronous capability.

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4. SUMMARY AND CONCLUSIONS. The various studies reviewed have shown a wide array of domain-general linguistic and cognitive capabilities of bottlenose dolphins, as expressed though laboratory investigations.

4.1. LANGUAGE UNDERSTANDING. With respect to language-learning skills, emphasizing an understanding of instructions conveyed through an artificial gestural language system, the dolphin Ake demonstrated all of the following:

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- a. Processed whole sentences (not just word-by-word processing), as demanded by the inverse grammar of the symbolic gestural artificial language system,
- b. Accounted for both the semantic and syntactic components of the grammar when interpreting the instruction given her,
- c. Carried out most novel instructions correctly on the first occasion they occurred,

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- 5 d. Correctly inferred the meaning of new four- and five-word syntactic structures on the first occasion they occurred,
- e. Understood object symbols referentially,
- 5 f. Revealed a deep understanding of the grammar of the language system by rejecting most semantic anomalies and by extracting the grammatically correct subsets embedded within longer syntactically anomalous sequences, including conjoining nonadjacent terms when necessary or desired,
- 10 g. Understood representations of the real world, responding correctly to gestural instructions given by trainers appearing live on a television screen the first time she viewed a television image; she could also understand immediately the gestural instructions given through decomposed images of trainers, whose head and torso were blocked out revealing only the movement of the arms and hands alone,
- 15 h. Spontaneously applied the inverse grammar to sequences of deictic gestures that were substituted for gestural object symbols, by taking the object pointed to second to the object pointed to first.

4.2. SOCIAL COGNITION. In the social domain, the dolphins demonstrated the following:

- 20 a. An ability to share attention with a human pointing to objects, by swimming to those objects and carrying out the accompanying gestural action instruction given by the trainer,
- 25 b. A profound ability for social imitation of the behaviors of others. Although the vocal imitation we demonstrated in the laboratory was not in a social context, in the wild dolphins do imitate the vocalizations of each other, particularly the signature whistles; the generality of behavioral imitation was shown through the ability to copy behaviors of other dolphins and humans, and to recognize and copy behaviors displayed on a television screen,
- 30 c. An ability to carry out highly coordinated and synchronized behaviors in tandem—two dolphins acting in the same way at the same time and place, if so instructed; tandem behavior extended even to creative acts, a pair of dolphins executing together behaviors of their own joint choice, the same behavior carried out together in space and timing in response to the instruction, *tandem create*.

35 4.3. SELF-KNOWLEDGE. In the domain of self-awareness or self-knowledge, the dolphins demonstrated the following:

- a. Conscious awareness of their own behaviors, repeating or not repeating behaviors on command and maintaining and updating a mental inventory of the last behavior performed in order to choose the next behavior,
- 40 b. Conscious awareness and conscious control of their own body parts, by an understanding of gestural symbolic references to their own body parts and how to use them in novel ways as directed by further gestural instructions.



4.4. COGNITIVE CONVERGENCE AND EVOLUTION OF INTELLECT. The diversity, depth, and breadth of the linguistic and cognitive skills demonstrated by these dolphins revealed rich behavioral flexibility in these different intellectual domains. In many cases this included apparent logical inferences and innovative responding. Some of the behaviors demonstrated by the dolphins are similar to behaviors demonstrated in laboratory studies of chimpanzees. These include, but are not limited to *language comprehension*, *referential understanding of symbols*, and *motor mimicry*. Several of the dolphin capabilities illustrated were not within the capabilities of chimpanzees or have not yet been tested in that species. These include *vocal mimicry*, *the immediate interpretation of TV scenes*, *comprehension of object-directed points and point sequences*, and *an understanding of the concepts of tandem and innovate*.

Despite these differences, many of the similarities are striking, and suggest a convergence of cognitive abilities in these two distinct groups, separated otherwise by wide gulfs in their biology, ecology, and evolution. Yet the convergent cognitive characteristics suggest some underlying commonality in pressures selecting for intellect. Dolphins and chimpanzees in fact share some interesting societal similarities. Both are long-lived, have a protracted period of development and caregiving, and live in a fission-fusion society in which relationships among individuals are important, and dependence on integrating into the societal norms is crucial for individual benefit and survival. This suggests that

The major link that cognitively connects the otherwise evolutionary divergent dolphins and primates may be social pressure—the requirement for integration into a social order having an extensive communication matrix for promoting the well-being and survival of individuals. (Herman 1980:421)

Finally, it seems reasonable to conclude that social forces were also a likely driving force behind the evolution of intellect in humans.

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