Spring 5-2017

Pragmatic Understanding of Bottlenose Dolphins (*Tursiops truncatus*) Use of a Two-Way Communication System

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PRAGMATIC UNDERSTANDING OF BOTTLENOSE DOLPHINS' (*TURSIOPS TRUNCATUS*) USE OF A TWO-WAY COMMUNICATION SYSTEM

by

Pepper Reid Hanna

A Dissertation
Submitted to the Graduate School
and the Department of Psychology
at The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

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May 2017

Published by the Graduate School

ABSTRACT

PRAGMATIC UNDERSTANDING OF BOTTLENOSE DOLPHINS' (*TURSIOPS TRUNCATUS*) USE OF A TWO-WAY COMMUNICATION SYSTEM

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Pragmatics focuses on how a communication system is used to achieve a communicative goal, the social context of the communication, and the organizational structure of communications (Horn & Ward, 2004; McLaughlin, 1998). There is evidence of pragmatics within animal communication systems. For example, context appears to be an important component in both signal production and a receiver's response in vervet monkeys (Seyfarth, Cheney, & Marler. 1980).

The current study used an underwater keyboard to establish a two-way communication system between humans and dolphins. The purpose of this study was to determine if, under these conditions, dolphins displayed pragmatic abilities within communicative interactions with humans.

The dolphins did show evidence of pragmatic understanding based on evidence of turn-taking both at the keyboard and using behavioral gestures. Dolphins engaged in multi-turn conversations and showed a decline in interruptions over time. Dolphins appeared to pay attention to the attentional state of the human listener and predominately used the keyboard when the human was facing toward them.

Future studies that examine the specific keys activated by dolphins and humans can provide important information regarding the type of information that is exchanged during these interactions. Further studies are needed to examine any differences in

human responding based on his or her location and orientation when the dolphin uses the keyboard.

ACKNOWLEDGMENTS

I would like to thank Dr. Mark Xitco for all of his assistance, guidance, and encouragement throughout my work on this project. He stepped in as my advisor at a critical point, something for which I will always be grateful. I would like to thank Dr. Alen Hajnal for serving as my committee chair and providing important support contributing to the completion of my project. I appreciate the assistance of Dr. Richard Mohn and Dr. Donald Sacco serving on my committee and providing their insight that assisted in my completion of this study.

I would like to thank all the graduate students, interns, and volunteers in the Marine Mammal Behavior and Cognition Lab at The University of Southern Mississippi who assisted with this study, especially Ali Taylor who assisted with reliability coding and Lisa Lauderdale who provided important insight throughout my work on this project. I am appreciative of Disney for allowing the use of the data for my project.

Finally, I would like to thank my family for providing their understanding and encouragement throughout my work on this project.

DEDICATION

This dissertation is dedicated to Dr. Stan Kuczaj. Stan was one of the most intelligent people I have ever known. He also had a curiosity that made him a great scientist. He was never afraid to try something new to answer a question. One of the most important things I learned from Stan was how to critically analyze research. These methods I have incorporated into my research, my teaching, and my own life. These are the characteristics he taught his students and I am truly thankful to Stan for making me a better scientist, teacher, and person.

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NAP	Nonoverlap of All Pairs

CHAPTER I – INTRODUCTION

Defining Pragmatics

Semantics, syntax, and pragmatics are three important concepts used to describe communication and language systems. Semantics is the meaning of signals, syntax the grammar or structure of the system, and pragmatics the way in which the system is used. Pragmatics focuses on how the system is used to achieve the communicative goal, the social context of the communication, and the organizational structure of communications (Horn & Ward, 2004; McLaughlin, 1998).

Within a pragmatic framework signals or utterances may be described by their function. (Scott-Phillips, 2010). For example, while the "leopard" alarm call in vervet monkeys might mean "leopard" in the semantic sense, from a pragmatic understanding this call would functionally signal "run up a tree," since that is the ultimate response produced (Seyfarth et al., 1980).

Pragmatics provides a description of the ways in which the environment and context can shape both the production and meaning of utterances. In many animal communication systems, context plays an important role in whether and which type of vocalizations are produced (Scarantino & Clay, 2015). Grice (1975) recognized the role of context in a conversation by describing particularized implicatures, where a conversational implication can only be made in a specific context. For example, person A states "What happened to the roast beef?" Person B responds with "the dog looks very happy." Person A's implicature that "the dog ate the roast beef" is only possible if both A and B are responding to relevant information in a specific context. The context dependent nature of many signals also raises the problem of linguistic underdeterminancy, in which the precise meaning of an utterance is perhaps different than the meaning intended by the signaler. The context must provide the necessary information to understand the phrase “he’s here.” Otherwise, the listener would not know who the “he” is or where “here” is (Carston, 2002).

Pragmatics also focuses on the specific interactions involved in communicative exchanges. Many social exchanges require the participants to smoothly alternate roles from signaler to receiver. Each act as signaler or speaker can be vocal/verbal or nonverbal. This turn taking is a fundamental characteristic of communicative interactions. To understand pragmatics in conversation, however, goes beyond simply alternating who the speaker is. For example, statements within a linguistic exchange must be presented in the correct form within the specific social context. These exchanges require cooperation between the parties involved (Grice, 1975). This structure is governed by several general principles, which Grice defined as the cooperative principle. In order for a conversation to be beneficial, each member must follow this agreed upon structure within the exchange or conversation.

The pragmatic characteristics of a communication system have implications within every level of that system, from the broad (e.g., whether an utterance or gesture is used) to specific (e.g., how exchanges are structured). It is apparent that aspects of pragmatics are useful in describing animal communication systems, and may have important implications for the evolution of language.

Pragmatics in Animal Communication Systems

In understanding animal communication systems, there has been an emphasis on the semantics (meaning) of the signals within the communication system, often discussed as functional reference or the extent to which the signals identify features or stimuli in the external environment (Scarantino & Clay, 2015). In their seminal paper on vervet monkey (*Cercopithecus aethiops*) alarm calls, Seyfarth et al. (1980) provided evidence for semantically meaningful signals in an animal communication system. Seyfarth et al. (1980) observed that vervet monkeys used three distinct alarm calls each associated with a specific type of predator (eagle, leopard, snake). Predator alarm calls have been described in a number of other bird (see Gill & Bierema, 2013 for review) and monkey species (see Townsend & Manser, 2013 for review). Such signals have often been considered examples of functional reference in non-human species.

However, more recent research has indicated that context can play an important role in how alarm calls are used. Scarantino and Clay (2015) found that vervet monkeys at times emit their alarm calls in the absence of the corresponding predator, and that context appears to be an important component in signal production and a receiver's response in these instances. For example, in some cases upon hearing a predator alarm call vervet monkeys will sometimes look for more information in the environment, and will even ignore the alarm call in situations in which there are no supporting contextual cues (Price & Fisher, 2013; Seyfarth et al., 1980).

In several other species of monkeys, the alarm call given most often for terrestrial predators may be emitted in the presence of other stimuli such as falling trees, or during social encounters (Arnold & Zuberbuhler, 2013; Fichtel & Kappeler, 2002; Wheeler, 2010). The response of animals (including other species) to alarm calls also varies based on information in the environment. Diana monkeys (*Cercopithecus diana*) respond in distinct ways to human and leopard predators (Zuberbuhler, Jenny, & Bshary, 1999;

Zuberbuhler, Noe, & Seyfarth, 1997). Diana monkeys also respond to a single alarm call produced by crested guinea fowl (*Guttera pucherani*) to both leopards and humans. Without context cues associated with playback of crested guinea alarm calls, Diana monkeys respond as if a leopard were present (Zuberbuhler, 2000). When primed for either humans or leopards by playing audio of either human speech or leopard growls 5 min prior to playbacks of crested guinea fowl alarm calls, Diana monkeys responded in distinct ways. The leopard-primed group did not give any more leopard alarm calls but increased the rate of alert calls. The human-primed group gave no leopard alarm calls and significantly lower alert calls (Zuberbuhler, 2000). This is consistent with the different responses of Diana monkeys to human and leopards (Zuberbuhler et al., 1997, 1999). Observations like these indicate that the signal alone is not sufficient, but that the context in which it is emitted is important in many animal communication systems.

Social-Pragmatic Theory of Language Acquisition

It has been suggested that language acquisition (semantic, syntactic, and pragmatic development) occurs through the social context of communicative interactions (Tomasello, 1992). Tomasello argues that early language acquisition occurs within specific routines or contexts (e.g., bath time, reading a book, diaper changes). These specific contexts create a scaffold the child uses to learn the referential characteristics of new words within these contexts. Formal linguistic theorists have argued that there exist certain innate constraints that allow for the acquisition of new words. One such example is the whole object constraint proposed by Markman (1989). Markman suggests that upon hearing a new word a child will associate the word with the whole object rather than specific attributes of the object (e.g., color, speed, size). The social-pragmatic theory suggests that because language learning occurs in a specific context (e.g., naming colors), this context provides the information to overcome the whole object constraint and associate a new word with just the correct attribute of the object (Tomasello, 1992). Because this social context is critical to language acquisition, a child must have the ability to coordinate attention with the adult and construct a shared environment (Tomasello, 1992), referred to as joint attention and secondary intersubjectivity. Support for the importance of joint attention comes from evidence that autistic children who lack gestural joint attention also exhibit language difficulties. In children with autism, it has been shown that there is a correlation between their joint attention ability and their ability to learn new words (Mundy, Sigman, & Kasari, 1990). Once the infant establishes joint attention, it can further its understanding of others by observing and interacting in the shared environment. The infant observes not only the object itself but how the object is used. Support for the importance of joint attention and secondary intersubjectivity comes from the fact that early words are learned more quickly when the parent capitalizes on the current focus of the infant's attention to teach new words, rather than attempting to direct attention elsewhere (Tomasello & Farrar, 1986; Schaffer & Liddell, 1984). Similarly, children learn verbs later than nouns, since the actions adults often refer to could have taken place in either the recent past or the near future, making it less frequent for the child to engage in joint attention with the adult at the precise moment of the referenced action (Tomasello & Kruger, 1992).

Several studies on the protoconversations of young infants highlight that the structure established by the parent in these interactions likely plays a role in the development of communicative competency (Bateson, 1975; Ninio & Bruner, 1978;

Oller, 2000), and the development of pragmatic skills like turn taking. For example, Gros-Louis West and King (2009) argued that the early incorporation of vocal behavior, nonverbal gestures, and attentional states of the infant are important contributing factors to pragmatic development in the infant. Stern, Beebe, Jaffe, and Bennett (1977) suggested that it is not the production of verbal utterances that is critical to develop, but the pattern and timing of utterances. In the protoconversations they observed, the mother provided the model for a conversational structure by responding to unintentional vocalizations of the infant. For example, the infant utters an exclamation “aaaahhh” after excitement and the mother responds, acknowledging a shared experience (Stern et al., 1977). As the child developed joint attention and the use of nonverbal gestures for intentional communication, these three aspects of language were incorporated, and together appeared to provide the foundation the child needed to engage in appropriately structured interactions.

Tomasello (1992) highlighted the importance of a specific type of interaction on pragmatic or conversational competence. These are situations in which the parent and child were engaged in an interaction and the child made an utterance that was not understood by the parent. These instances required the child to modify the original utterance. When the child was invested in the interaction and recognized the importance of the parent understanding his or her utterance, the child tended to amend the original utterance to compensate for the misunderstanding or lack of understanding. Even very young infants may desire to remain in sync with caregivers and will alter their behavior to reestablish an interaction when a breakdown has occurred (Murray & Trevarthen, 1985). As children’s linguistic abilities develop, they begin to seek clarification from adults when they themselves do not understand the adult's utterance (Wilcox & Webster, 1980).

In communicative interactions, an infant as young as 4 months old may differentiate between the mother and a stranger partner (Jaffe, Beebe, Feldstein, Crown, & Jasnow, 2001). Jaffe et al. (2001) examined four-month-old infants' vocal interactions in face-to-face play with adults. They analyzed two partnerships (mother-infant and stranger-infant) in two settings (home and laboratory) and found that, based on average infant durations in interactions with the mother or a stranger, infants displayed different patterns of vocalizations when interacting with each (Jaffe et al., 2001). This trend was even more pronounced when comparing these pairs in the home to their interaction in the lab. These infants engaged in longer vocal turns and spent a greater percentage time vocalizing with their mothers at home whereas the shortest infant turns occurred with strangers in the lab. At home, coordination between mothers and infants was well-practiced and brief compared to that between infants and strangers in the infant's home. As the novelty of the setting increased in the lab, bidirectional coordination increased for both types of pairs, however, mother – infant conversations remained more flexible than interactions with a stranger. The authors suggested that this shift to greater coordination in novel situations is a means of accommodation and differentiating interactions with the mother from interactions with others (Jaffe et al., 2001).

Further support for the social basis of language development comes from the demonstration of a link between early conversational capacity and other areas of social development. Jaffe et al. (2001) observed that regulation based on monitoring of a partner within an interaction exists on a continuum (from inhibited to excessive monitoring) with a defined set point that most interactions tended toward, but which also contains extremely high and low degrees of regulation. Four-month-olds whose interactions were close to this set point were more likely to be classified as having a secure attachment at 12 months. Four-month-olds who showed either high or low regulation were more likely to be classified as insecurely attached at 12 months.

Pragmatic Development

A central theme in the pragmatics of language is a focus on performatives or how a speaker intends to a use a sentence (e.g. request for object) (Bates, 1976). These performatives are the speech acts described by Austin (1962) in which using language is an action. Austin categorized these speech acts as perlocutionary, illocutionary, locutionary. Perlocutionary acts, whether intentional or unintentional, cause a response or behavior in the listener (e.g., utterance causes individual to pass the scissors) (Austin, 1962; Bates, 1976). Understanding the development of pragmatics in children focuses primarily on the development of the intentions of the speaker to communicate or the pragmatics of the individual utterance (performatives). A second focus has been the conversational capacity of the individual (pragmatics of conversation) (Klecan-Aker & Swank, 1988; Snow, Pan, Imbens-Bailey, & Herman, 1996). The development of communicative intent can be followed through the progression of the speech acts defined by Austin (1962). Bates (1976) states that early forms of perlocution (i.e., causing response in listener) can be observed in the hunger cries of infants. Perlocutionary acts do not necessarily require the speaker to have the intent to produce the effect observed. Soon the infant develops the earliest form of functional or intentional communication, those nonverbal gestures that occur before the onset of spoken language. The ability to exhibit illocutionary acts is demonstrated by the intent or meaning of these gestures (e.g. requesting a toy). Illocutionary acts refer to the meaning or the intent of the utterance. This can include commanding, urging, promising, asserting, or suggesting (e.g., “please pass me the scissors.”) This protolanguage has been described by several researchers (e.g., Bateson, 1975; Halliday, 1979; Snow et al., 1996). This use of gestures continues to be important during the one-word utterance phase (Snow et al., 1996). Locutionary acts are then observed when the child begins to produce verbal utterances (Bates, 1976). Locutionary speech acts refer to the specific utterance and the behaviors required to make such an utterance. (e.g., asking “do you have the scissors?”). These first locutionary acts are produced as the child begins using spoken language connected to illocutionary and perlocutionary acts related to the utterance.

The cries of a young infant initiate a brisk and immediate response in the listener. These earliest cries are likely not intentional communications by the infant. Coincident with these early events, infants are also beginning to develop a rudimentary understanding of the relationship between the self and other. Trevarthen and Aitken (2001) coined the term intersubjectivity to describe the understanding of this relationship. They use the development of joint attention, specifically person – object – person interactions to describe the development of intersubjectivity in the infant. It is argued that there is an innate capacity for intersubjectivity, and infants as young as 2 months old have been shown to be receptive to the rhythms of the mother’s expressions (Trevarthen & Aitken, 2001). Kaye and Fogel (1980) found that although overall time looking at the mother declined from 6 to 26 weeks of age, there was not a change in time spent looking when the mother was actively engaged in interactions with the infant. This provides support for the conclusion that even very young infants are attuned to the communicative state of the mother and are aware of expressive behavior of the mother. During this time, infants begin producing coo vocalizations, which adults treat as intentional communications (Beaumont & Bloom, 1993; Bloom & Lo, 1990). This leads to what Bateson (1975) described as protoconversations. The mother vocalizes in response to the infant's vocalizations and establishes a rhythm, with each vocalization followed by a pause. The vocalizations produced by the mother during these interactions are adjusted to closely resemble the infant's vocalizations, encouraging the infant to continue to produce vocalizations (Gratier & Devouche, 2011). This pattern closely mimics the turn-taking within adult conversations (Gratier et al., 2015). However, the vocalizations of the infants within these are not considered intentional communications. As such, the pattern of turn-taking within these protoconversations is established by the adult. It is not generally accepted that the infant plays an active role in the turn-taking pattern in these exchanges (Gratier et al., 2015). For example, Rochat, Querido, and Striano (1999) compared smiling and cooing of 2, 4, and 6-month-old infants within both organized and disorganized games of peekaboo. The peekaboo games were designed to consist of vocalizations and gestures within three units (approach phase, peak phase, and release phase). Organized games went through each unit in the specified order (approach phase: "look, look, look," peak phase: "peekaboo" (hands up, hands down), and release phase "yes" (lean back, nod). The disorganized games presented vocalizations and gestures representing each unit of the game in a randomized order. The primary distinction between the organized and disorganized game was the temporal organization. Gazing responses included any look at the experimenter that lasted longer than 1 s and looked away for longer than 1 s. Smiling behaviors were defined when there was a co-occurrence of eye (slight crinkles) and mouth movement (mouths turned upward). Gazing and smiling behaviors were coded independently--smiling events did not have to occur with gazing and vice versa. The 2-month-old infants smiled and gazed with equal frequency in the organized and disorganized game. However, 4 and 6-month-old infants smiled significantly more and gazed significantly less in the organized game. This suggests that there is a development in the attunement to the organization of a social interaction. Two-month-olds did not discriminate between an organized and disorganized interaction, whereas 4 and 6-month-old infants were able to distinguish between these interactions and engaged in less gazing and more socially appropriate smiles when the interaction was organized. This suggests that while 2-month-olds are attuned to the adult within an interaction, they do not yet process the specific structure of the interaction.

Before they learn verbal language, infants can also engage in illocutionary acts (Bates, 1976). Piaget (1952) described the period of development between 4 – 8 months as involving secondary circular reactions when the child begins to act on objects outside of the body. At approximately 6 months, infants begin spending less time in face to face interactions with mothers or caregivers and more time interacting with objects (Adamson, 1995; Trevarthen & Hubley, 1978). When a child uses a culturally recognized symbol (such as a pointing or gazing gesture) to request an object, these actions can be considered illocutionary acts. Such gestures are interpreted as requests for the object that is the subject of the gesture.

Piaget (1952) described the next phase, which emerges at approximately 8 - 9 months, as characterized by the child's ability to coordinate secondary schemes into a single act (e.g., move one object out of the way of the other to play with the desired object). Piaget argues that it is this coordination that allows one to call these actions intentional, with a specific goal for the action. In studying the development of intentional communicative gestures, researchers have focused on the instances highlighted by Piaget in which these acts involve the infant acting on an adult to achieve a goal (Adamson, 1995).

During this same period of development, the child begins to coordinate attention between the object of interest and an adult. This begins as a shift in gaze (back and forth) between object and person at around 6 months (Newson & Newson, 1975). This coordinated engagement continues to develop until 13 months when the infant begins to maintain long periods of joint attention (Bakeman & Adamson, 1984). Secondary intersubjectivity (Trevarthen, 1979) is reached when the infant begins to coordinate its own communicative actions with those of adults. Secondary intersubjectivity emerges at around 9 months of age when the infant begins participating in joint attention as an equal partner and directs the attention of adults to objects. Secondary intersubjectivity supports the co-regulation required to establish true turn-taking within a conversation and indicates an understanding of the association between the infant's actions and a response in another individual (Gratier et al., 2015). Interactions between mothers and 9-month infants revealed adult-like temporal associations, including turn taking with few interruptions (Jasnow & Feldstein, 1986). Before they are 12 months old, infants are already engaging in adult-like gaze following during interactions and the amount of time spent gazing at the mother during her vocalizations has plateaued at adult levels (Rutter & Durkin, 1987). 18-month-olds were also found to begin using the “terminal look”, something common in adult speakers at the end of their vocalizations (Rutter & Durkin, 1987, p. 60). By 24 months, Rutter and Durkin (1987) found that toddlers began using even more adult-like turn taking in their interactions. The rate of interruptions decreased, and, most importantly, the child began regulating and coordinating their vocalizations with those of the mother (e.g., appearance of the terminal look in which the speaker looks up at the end of a vocalization to indicate they are done vocalizing). This study finds there is an increase in the active use of communicative regulation. Similar results have been found by Schaffer, Collis, and Parsons (1977).

Chimpanzee Studies

There have been many attempts to teach chimpanzees language. Techniques have included sign language (Terrace, 1985), as well as simplified token (Premack, 1971), and lexigram systems (Savage-Rumbaugh, McDonald, Sevcik, Hopkins, & Rubert, 1986).

The majority of the studies on chimpanzees (*Pan troglodytes*) have involved attempting to specifically train the association between a candidate symbol and its referent via conditioning procedures that reward the animal when a symbol and corresponding object were paired (Fouts, 1972; Gardner & Gardner, 1971; Premack, 1976; Savage-Rumbaugh et al., 1986). There has been limited evidence of spontaneous symbol comprehension or production within these systems. Fouts, Hirsch, and Fouts (1982) reported that one chimpanzee began spontaneously producing symbols, however, it was not clear that this chimpanzee fully understood the referents corresponding to these symbols. Chimpanzees have been observed producing nonreferential gestures (McGrew

& Tutin, 1978). Producing gestures does not provide evidence of the understanding of the gestures' referential properties. The responses of the chimpanzees taught these language systems appeared to be limited to an associative nature. Other chimpanzees trained to use symbols to request information experienced difficulty switching to paradigms in which they were asked to use the same symbols to label or name the same objects (Savage-Rumbaugh, 1984, 1986; Savage-Rumbaugh et al., 1983). Savage-Rumbaugh (1986) had to utilize explicit training procedures in order to achieve this transfer between naming and requesting situations. This suggested that these animals did not understand that the symbol referred to or took the place of the corresponding object, or that the symbol could be used in any situation to refer to the object.

In contrast, Kanzi, a bonobo chimpanzee (*Pan paniscus*) appeared to spontaneously learn a lexigram language system and fully understood the referential properties of the symbols within this system (Savage-Rumbaugh et al., 1986). Kanzi's experience with the lexigrams differed from the specific training programs used in the previous studies of common chimpanzees. Kanzi used a keyboard system that was highly portable and could be moved between the indoor and outdoor environment (Savage-Rumbaugh et al., 1986). He was first exposed to the lexigrams at 6 months of age while being cared for by his mother (Savage-Rumbaugh et al., 1986). She was being trained informally on using the lexigram keyboard, with humans modeling the use of the keyboard and allowing her to use the symbols in any way. Specific drills were used when she also showed difficulty learning the referential characteristics of the symbols (Savage-Rumbaugh et al., 1986). During this period, Kanzi was not engaged in any direct training with the keyboard but was instead an observer. When Kanzi was separated from his mother at 2.5 years old, he was already demonstrating an interest in the lexigram keyboard (Savage-Rumbaugh et al., 1986). Human caregivers, in their interaction with Kanzi, modeled keyboard use by commenting on daily activities in which they were engaged (e.g., playing, eating, walking outdoors, etc.). Kanzi did show evidence of an understanding of the referential properties of the symbols on the keyboard and began using symbols spontaneously. In addition, Kanzi did not demonstrate difficulties in switching between requesting and naming interactions like other chimpanzees that received explicit, structured training (Savage-Rumbaugh et al., 1986).

Benson et al. (2002) reported that in addition to understanding the referential properties of the lexigram symbols, Kanzi also displayed an understanding of pragmatics. Kanzi demonstrated turn-taking within interactions with human caregivers. He was able to engage in back-and-forth interactions, and give and respond to requests, although Benson cautioned that it was difficult to determine how much of the conversation structure was directed by the humans (Benson et al., 2002).

The results obtained with Kanzi provide important support for the social-pragmatic theory of language development, which suggests that language acquisition occurs during communicative interactions within specific daily activities, providing important context for the referential characteristics of words. The type of interaction used with Kanzi was similar to interactions with mothers and human infants that are focused around specific daily activities. By modeling keyboard use to Kanzi within these structured activities, Kanzi was able to achieve a greater understanding and use of the lexigram keyboard when compared to chimpanzees that received explicit training with the symbols.

Following the success of this approach with Kanzi, it was repeated with a second bonobo (Panbanisha) and a common chimpanzee (Panpanzee). Both subjects were able to successfully learn to use the lexigram keyboard and often used gestures to indicate their communicative intent (Brakke & Savage-Rumbaugh, 1996). This replication was important because it provided further support for the role of the social pragmatic environment in language acquisition. It also refuted the notion that the limitations in previous studies with common chimpanzees were due to species differences between bonobo and common chimpanzees. Using the social pragmatic approach, more than one non-human species has learned to communicate via referential symbols.

Current Study

Study Species

The developing ability of infants for intersubjectivity may play an important role in language acquisition (Trevarthen, 2001). Studies on dolphin social cognition suggest that this species does have this understanding of the relationship between the self and others. Evidence of joint attention has been found in bottlenose dolphins (Xitco, Gory, & Kuczaj, 2001, 2004), as well as the ability to use this triadic interaction for communicative purposes (Pack & Herman, 2007).

Xitco et al. (2001) described spontaneous, communicative pointing in the bottlenose dolphin. Pointing in dolphins was identified when dolphins would align the anteroposterior axis of their body with rostrum directed towards an object. These dolphins only pointed when a human was available and were more likely to include a monitoring behavior (moving the head toward human with body remaining in alignment over object) when the human was greater than 2 m away. It was also found that there were more pointing and monitoring events when the human was facing towards the dolphin compared to when the human was swimming away (Xitco et al., 2004). This indicated that dolphins were more likely to use pointing behaviors when the human was attending to them (Xitco et al., 2004). Human children as they develop joint attention also begin using pointing gestures in order to establish the person-person-object attentional state necessary for joint attention (Mundy & Gomes, 1998).

Pack and Herman (2007) demonstrated that dolphins were able to use the points and gazes of humans to identify the objects indicated by these points. Paired with the dolphins' own pointing, the evidence suggests that dolphins may be capable of understanding the attentional states of other dolphins as well as humans, and may be capable of using this information for communicative purposes as well as directing the attention of others to achieve a goal. If dolphins possess intersubjectivity capabilities similar to young children, they may demonstrate pragmatics in their use of a communication system.

Purpose

The current study used an underwater keyboard to establish a two-way communication system between humans and dolphins. The humans modeled the use of the keyboard and the dolphins received no explicit training on the keyboard. The purpose of this study was to determine if, under these conditions, dolphins displayed pragmatic abilities within communicative interactions with humans. Turn taking (gestural and key activation) and changes in behavior and key activation based on the attentional state of the human were assessed. There were some limitations with this study that are important to note. The study subjects were adult animals, and a critical learning period is thought to be important for language development in young humans (e.g., Grimshaw, Adelstein, Bryden, & Mackinnon, 1998). In addition, and unlike the lexigrams used successfully with Kanzi, Panbanisha, and Panzee, the dolphin keyboard was very large and was not mobile within a session. This limited the way the keyboard could be used as animals and humans moved through the environment and could have affected the pragmatics of human – dolphin interactions.

CHAPTER II – METHOD

Subjects

Two adult male bottlenose dolphins (Bob and Toby) housed at Disney's The Living Seas in Orlando, Florida were the subjects for this study. At the time of study, the dolphins were approximately 15 years old and had participated in research studies for 8 years. The dolphins received a portion of their daily food ration during sessions but received all of their ration regardless of their participation in the sessions. The dolphins consumed approximately 9.5kg of food per day, with a diet consisting of herring, mackerel, capelin, sardine, night smelt, and silver smelt. Their participation in this study was approved by Disney's Animal Care and Use Committee.

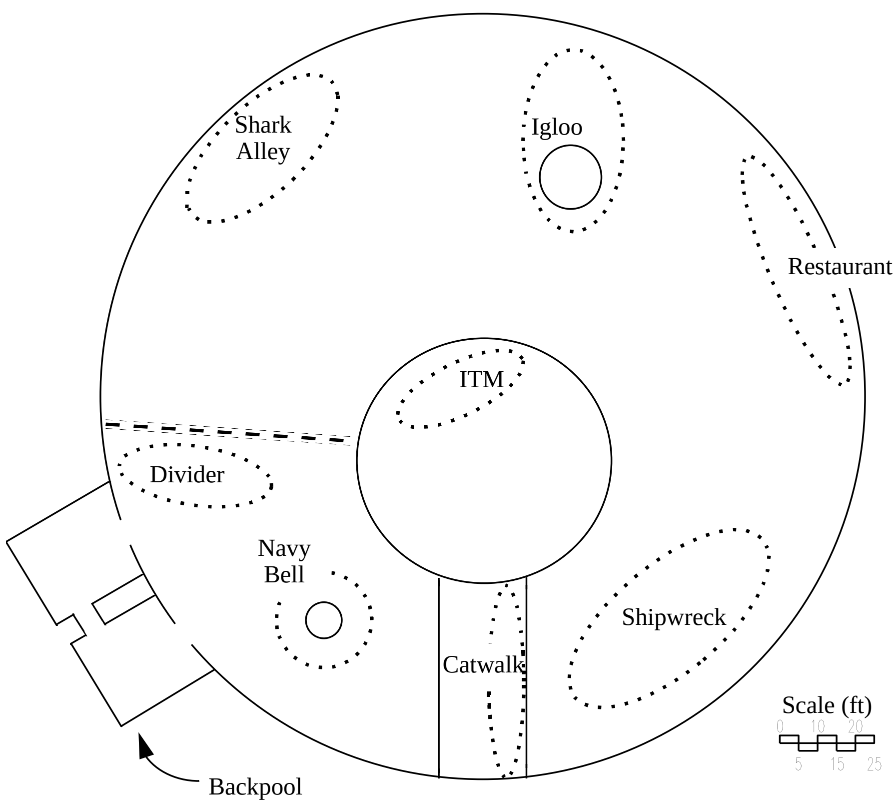

Figure 1. Diagram of Disney's The Living Seas

Study Environment

A layout of the enclosure in which sessions were conducted, and depicting the nine named locations within the exhibit, can be found in Figure 1. Keyboard sessions were performed in the main aquarium. This was a circular aquarium (61 m in diameter and 8 m deep) capable of holding 22 million liters. The aquarium was designed to resemble a Caribbean reef, containing artificial corals and housing approximately 1,000 other animals including sharks, rays, sea turtles, and many species of fish. In addition, there was a central underwater viewing window for guests.

Apparatus

The communication keyboard consisted of four panels, each with a unique set of keys. There were up to 15 individual keys located on each panel. Each key consisted of a hollow tube containing a three-dimensional object unique in form, size, and/or material. An infrared beam was focused across the opening to each key tube. Key activation occurred when this beam was broken and was accompanied by an auditory component in which the English word for that key was played over an underwater speaker mounted to the interior of the keyboard. The keyboard apparatus is displayed in Figure 2. Table 1 provides a list of the individual keys on the keyboard and how each was classified for the present study.

Figure 2. Keyboard apparatus with dolphin and human present

Table 1

Individual keys on the dolphin keyboard

Key Classification	Keys
Actions	chase, find, give, get, go, have, open, place, play, search, touch, watch
Agents	bob, toby, person, speaker, nina, noriko, we
Foods	food, herring, mackerel, sardine, smelt, whitebait
Grammatical	and, or, at, past, no, yes, question, same, which, what, with, who, where
Locations	back-pool, catwalk, divider, igloo, itm, navybell, restaurant, shark-alley, shipwreck
Modifiers	big, small, near, far
Objects	ball, bumper, buoy, cone, hoop, snake, cannon, container, surprise
Tools	float, stick, weight
Tool Sites	float catcher, stick plunger, weight receptacle

Procedure

Humans, wearing scuba gear, and dolphins interacted at the keyboard during sessions that lasted between 10 – 40 min. The dolphins did not receive any specific training with the keyboard or the specific keys. Sessions were conducted such that an individual human in SCUBA typically interacted with one of the dolphins and modeled the use of the keyboard. The study took place between July 28, 1992, and September 5, 2000. This included 2,174 individual sessions. Video recordings were obtained using a Sony V801 Hi8 mm camcorder that was placed within a handheld Amphibico underwater housing apparatus. The first 33 sessions and a random selection of subsequent sessions were video recorded. Video recordings were obtained through July 16, 1998. Table 2 provides a description of the video data obtained in this study.

Table 2

Summary of data

Year	**Number of Sessions with Video**	**Minutes of Video**	**Total Number of Keyboard Sessions**
1992	32	814	39
1993	53	1367	190
1994	69	1371	355
1995	15	351	342
1996	14	258	332
1997	14	234	281
1998	18	169	241
1999	N/A	N/A	309
2000	N/A	N/A	85

In addition to video, a log of all keypresses that occurred during all sessions was kept. Each keypress was recorded and time coded in real time by the computer that controlled the acoustic feedback for the keys. For each key press or string of key presses, the identity of the individual that activated the key(s), i.e., the speaker, and the identity of the individuals to whom this utterance was directed, i.e., the listener(s), was recorded by a human observer in dive or snorkel gear positioned in a shelter directly above the keyboard. Contextual information and notes provided by the human observer were also recorded in the log.

Analyses

This study analyzed the keypress data for all 2,174 sessions as well as the video data for the sessions recorded. This data was examined to determine the extent to which dolphins engaged, in turn, taking in their interactions with humans. A determination was made as to how the location of the human affected the behavior of dolphins and their use of the keyboard.

Turn-Taking

Key activation. Utterances were defined as single key activations or a series of key activations produced by an individual. Multi-key utterances required that a single individual used a series of keys, and each key activation occurred within 30 s of the previous activation. Conversational turns were counted when a different speaker used a key within 30 s of the end of the previous individual's utterance, and the same individuals were identified as listener of each other's key activations. Descriptive measures were used to determine how many human-dolphin interactions featured a key activation turn by a dolphin, whether via a response to human key activation or when a human responded to a dolphin initiated conversation. In those interactions featuring a key activation turn by the dolphin, frequencies of multi-turn conversations were obtained for each dolphin. The maximum number of turns by a dolphin within a single conversation was noted. Analyses were calculated for the entire study period as well as by year to examine any changes over time. The 30 s criterion was based on inter-key intervals for all key activations made throughout study (Figure 3).

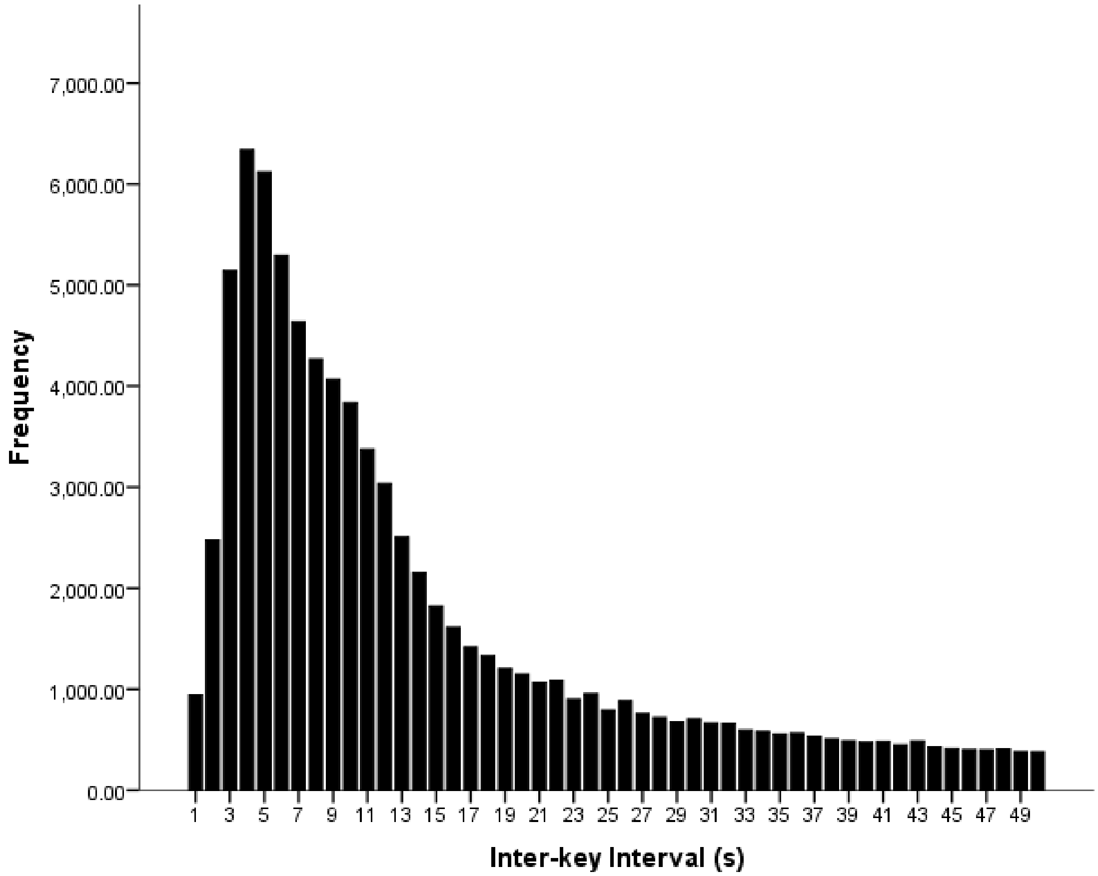

Figure 3. Inter-key intervals for all key activations across study

Interruptions. Interruptions were classified according to the following categories: concordant interruptions, grammatical interruptions, repetitions, and ungrammatical interruptions. Concordant interruptions were coded when the dolphin interrupted or completed a human utterance in a way that followed the keyboard grammar and was accepted by the human by either continuing the utterance or ending the conversation. Grammatical interruptions were coded when the dolphin interrupted the human utterance in a way that followed the grammar of the keyboard but was followed by a correction by the human. Repetitions were coded when the dolphin repeated the previous key activation produced by a human in the context of a human multi-key utterance. Ungrammatical interruptions were coded when the dolphin produced a key activation not consistent with the grammar of the keyboard within a human multi-key utterance. The number of each category of interruptions by each dolphin was calculated for the entire data set as well as by year.

Conversations Featuring Human Gesture. Dolphin keyboard activations were periodically followed by one of the three human gestures (shrug, negative head shake (“no”), or positive head nod (“yes”). Key activations following each type of human gesture by each dolphin was examined for each year of the study.

Behavioral. Any pointing behavior consistent with that described by Xitco et al. (2001, 2004) that occurred immediately after a key activation by a human was considered a behavioral turn. In order to be considered a turn in conversation, the dolphin must have been observed swimming directly to the point of interest indicated in the keypress.

Contingent Use of Keyboard

For each keypress by a dolphin recorded on video, the location of the human listener was determined to be either within 2 m of the dolphin or greater than 2 m from the dolphin. In addition, the human listener’s body orientation was coded as either facing towards the dolphin or facing away. Descriptive measures were used to determine the conditions in which the dolphin engaged in the most key activations. The presence of any monitoring behaviors described previously in Xitco et al. (2001, 2004) in association with dolphin pointing were recorded if they occurred in association with key activation.

Descriptive measures were used to determine how location and orientation of the human listener affected the frequency of these monitoring behaviors before or after key activations.

Reliability

Inter-coder reliability was calculated to test the accuracy of the speaker and listener identity information recorded in the keypress log. A rater naïve to the study design and purpose coded a random sample representing 10% of videoed sessions, with the provision that each year of the study was included. This rater identified the signaler and the listener for each key activation present on video. A Cohen's kappa was used to measure agreement between the rater and the data recorded by the observers in the log. In addition, reliability was similarly measured for all pointing behavioral turns by dolphins, and for the position and orientation of humans after dolphin keypresses by comparing coding made by the author and a second rater.

CHAPTER III - RESULTS

Intercoder Reliability

For dolphin key activations based on orientation and location of the human listener, the agreement between coders was found to be 97.5%, and this corresponds to a kappa of 0.65 and is considered "good" agreement. Reliability was calculated for human and dolphin gestures including human shrugs, "no", and "yes," and dolphin pointing events. Agreement was found to be 98.6%. This corresponds to a kappa of 0.72 and is considered to be "good" agreement. Reliability was also calculated between a video coding of key activations and the key activation log. The agreement was found to be 98.9%, corresponding to a kappa of 0.921. This agreement is considered to be "very good."

Analysis of Turn-Taking

Keyboard Conversations

The frequency of food and location keypresses are shown in Figure 4 and 5. 1992 was excluded from analysis due to low frequencies of key activations. This year was eliminated from all analyses performed.

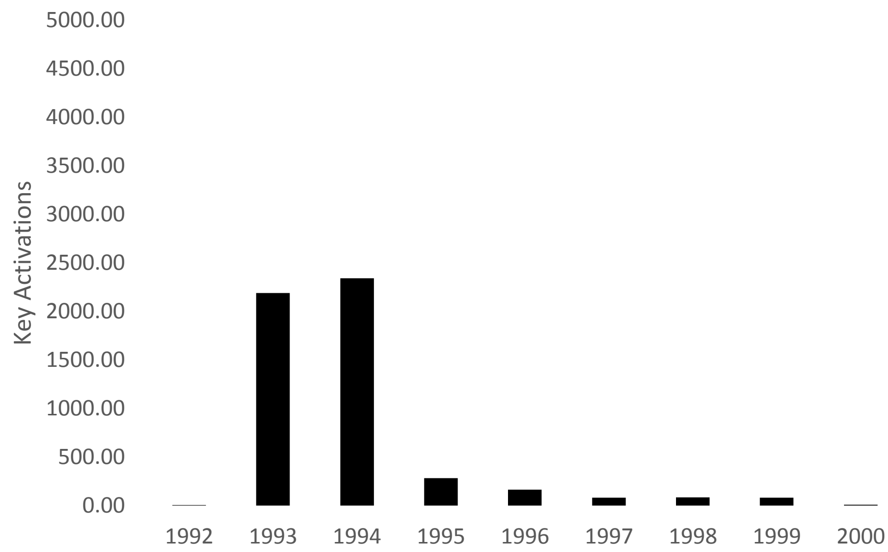

Figure 4. Frequency of dolphin food key activations

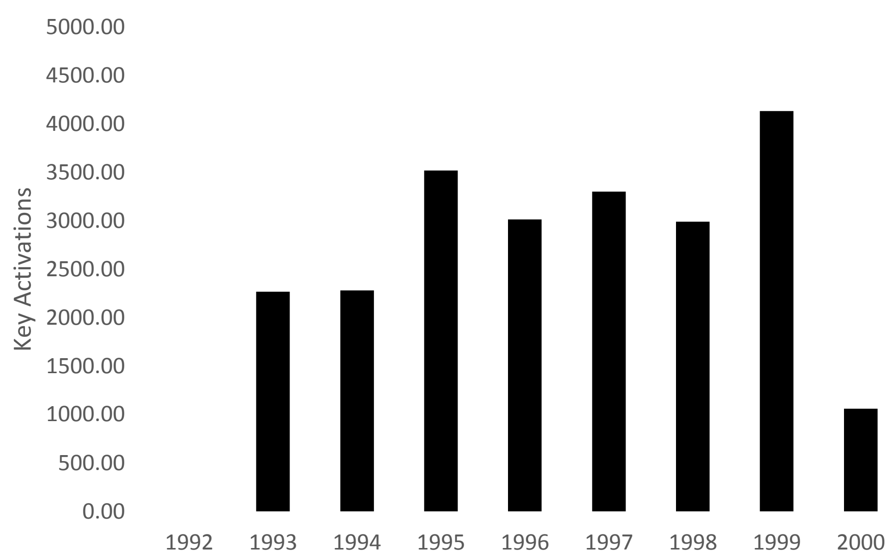

Figure 5. Frequency of dolphin location key activations

Frequencies of dolphin initiated conversations, dolphin continued conversations, multi-turn conversations, and the maximum number of turns by a dolphin in a single conversation for each year of study are presented in Table 3. Nonoverlap of All Pairs (NAPs) (Parker & Vannest, 2009) were conducted to measure the effect size of changes in rates of initiated and continued conversations per session for each dolphin between study years. The proportion of conversations initiated and continued by each dolphin to their total key activations is displayed in Table 4. These frequencies were converted to a rate using the number of keyboard sessions each year. NAPs were also performed to measure the effect size of changes in the proportion of dolphin continued to initiated conversations by study year. To conduct these measures data was collapsed across months within each year.

Table 3

Description of conversations based on keypress log

	Dolphin Initiations	**Dolphin Continuations**	**Proportion (Initiations: continuation)**	**Multi-Turn Conversations**	**Most Turns in Single Conversation**
1992					
Bob	3 (0.08)	1 (0.03)	0.33	0 (0)	1
Toby	1 (0.03)	0 (0)	0	0 (0)	1
1993					
Bob	1047 (5.51)	100 (0.52)	0.10	215 (1.13)	4
Toby	614 (3.23)	65 (0.34)	0.11	34 (0.18)	3
1994					
Bob	909 (2.56)	141 (0.40)	0.16	128 (0.36)	3
Toby	719 (2.02)	43 (0.12)	0.06	44 (0.12)	4
1995					
Bob	795 (2.32)	101 (0.30)	0.13	115 (0.34)	4
Toby	336 (2.32)	36 (0.11)	0.11	24 (0.070)	2
1996					
Bob	387 (1.17)	93 (0.28)	0.24	54 (0.16)	4
Toby	270 (0.81)	37 (0.11)	0.14	30 (0.09)	3
1997					
Bob	430 (1.53)	90 (0.32)	0.21	89 (0.32)	4
Toby	213 (0.76)	17 (0.06)	0.08	14 (0.05)	3

Table 3 (continued).

1998					
Bob	312 (1.29)	86 (0.36)	0.28	54 (0.22)	3
Toby	23 (0.10)	42 (0.17)	1.83	26 (0.11)	3
1999					
Bob	146 (0.47)	64 (0.21)	0.44	42 (0.14)	5
Toby	90 (0.29)	32 (0.10)	0.36	13 (0.04)	4
2000					
Bob	80 (0.95)	43 (0.51)	0.54	20 (0.24)	4
Toby	48 (0.57)	20 (0.24)	0.417	14 (0.17)	2

Note. Parentheses represent the rate of the behavior based on frequency per total number of keyboard sessions each year.

Table 4

Proportion of initiated and continued conversations to total keypresses

		Dolphin Initiation Rate	**Dolphin Continuation Rate**
1992			
	Bob	0.25	0.09
	Toby	0.14	0
1993			
	Bob	0.28	0.03
	Toby	0.27	0.03
1994			
	Bob	0.32	0.05
	Toby	0.31	0.02
1995			
	Bob	0.29	0.04
	Toby	0.26	0.0
1996			
	Bob	0.18	0.04
	Toby	0.24	0.03
1997			
	Bob	0.19	0.04
	Toby	0.19	0.02
1998			
	Bob	0.16	0.04
	Toby	0.02	0.04
1999			
	Bob	0.12	0.05
	Toby	0.13	0.05

Table 4 (continued).

2000			
	Bob	0.12	0.06
	Toby	0.12	0.05

There was an overall decline in the number of conversations (both from initiations and continuations) each dolphin engaged in over time. This is consistent with the data on the overall number of keypresses per year of study. This was most likely due to the decline in food key activations (Figure 4). The activation of location keys by dolphins remained consistent throughout the course of the study (Figure 5).

There was a significant decrease in Toby's rate of initiated conversations between 1994 and 1995 (NAP = 0.95, $p < 0.001$) and between 1998 and 1999 (NAP = 0.82, $p = 0.01$). There was a significant decrease in Toby's rate of continued conversations between 1993 and 1994 (NAP = 0.74, $p < 0.049$) and between 1996 and 1997 (NAP = 0.75, $p = 0.04$).

There was a gradual, steady increase in the proportion of Bob's continued to initiated conversations over the study years. Based on NAPs, there was a significant increase in the proportions of continued to initiated between 1993 and 1994 (NAP = 0.82, $p = 0.01$), as well as 1995 and 1996 (NAP = 0.80, $p = 0.01$). There was also an increase in the proportion of Toby's continuations to initiations. There was a significant increase in this proportion between 1994 and 1995 (NAP = 0.82, $p = 0.009$). However, the decrease in this proportion between 1996 and 1997 was significant (NAP = 0.74, $p = 0.046$). In 1998, Toby engaged in almost twice as many continuations to human initiated conversations as conversations he initiated compared to only 10% early in the study (See Figure 6). This coincided with a decrease in the proportion of conversations Toby initiated to total key activations in 1998. There was not a change in the proportion of continuations to total key activations for Toby in 1998 (Table 4).

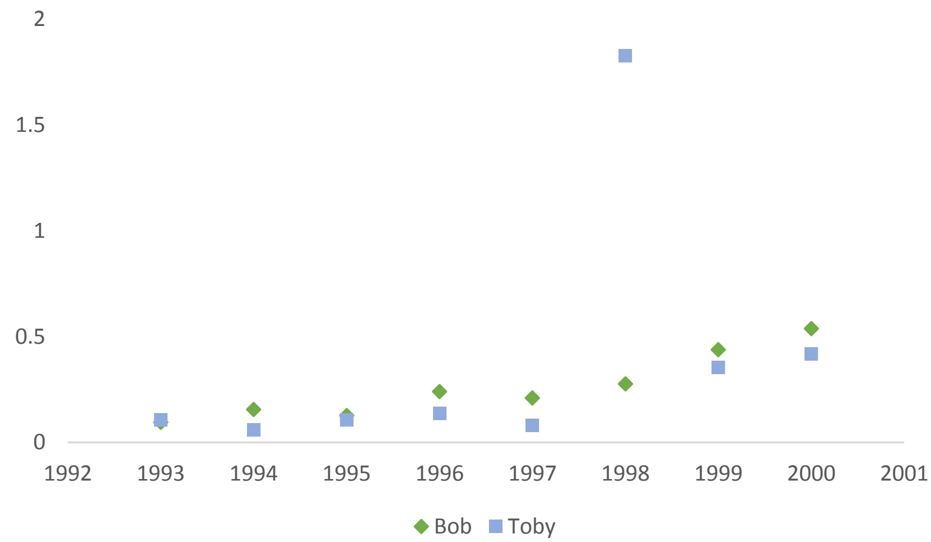

Figure 6. Proportions of conversations initiated by human to conversations initiated by dolphin

The frequency of multi-turn conversations Bob and Toby engaged in is presented in Table 3. There was a significant decrease in Bob's rate of multi-turn conversations per session between 1993 and 1994 (NAP = 0.79, $p = 0.02$) and 1995 and 1996 (NAP = 0.93, $p < 0.001$). However, there was significant increase in his rate of multi-turn conversations between 1996 and 1997 (NAP = 0.78, $p = 0.02$). Toby used significantly more multi-turn conversations per session between 1994 and 1995 (NAP = 0.77, $p = 0.03$).

Figure 7 shows the change in the proportion of multi-turn conversations to all single-turn conversations (including both dolphin and human initiated conversations) overall study years. Bob maintained a steady proportion of multi-turn conversations to single-turn conversations. There were no significant changes in Bob's proportion of multi-turn conversations to all conversations between years based on NAPs.

Toby engaged in more multi-turn conversations compared to single-turn conversations in 1998 compared to other years of study. In 1999, this proportion decreased to just above the proportion in 1997. There was a slight increase in Toby's proportion of multi-turn conversations between 1999 – 2000. Based on NAP measures, there were no significant changes in Toby's proportion of multi-turn conversation to all conversations between study years.

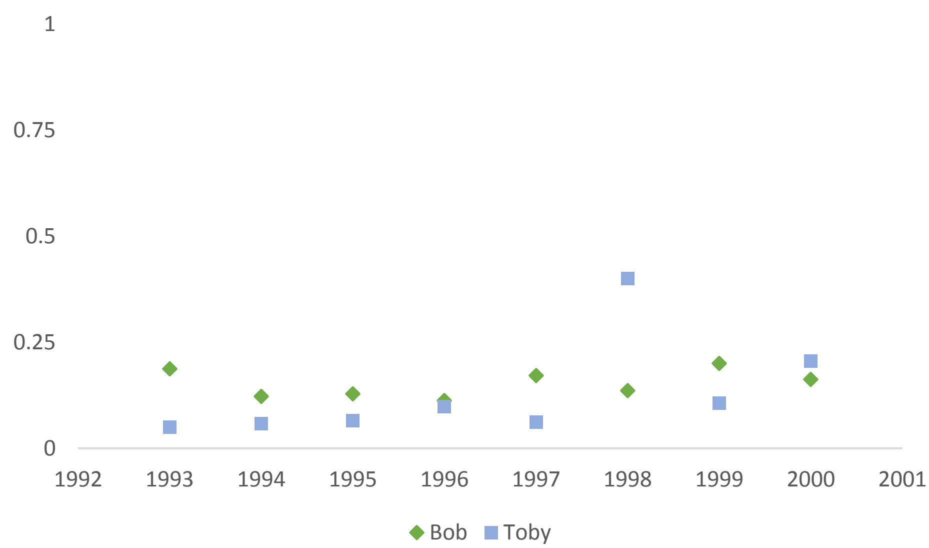

Figure 7. Proportion of multi-turn conversations to all single-turn conversations.

Interruptions Based on Keypress Log

The frequency of each type of interruption is summarized in Table 5. Both Bob and Toby showed a decline in the frequency of interruptions throughout the study (Figures 8 and 9). There was a significant decrease in Bob's rate of interruptions per session between 1993 and 1994 (NAP = 0.81, p = 0.01) and between 1998 and 1999

(NAP = 0.79, p = 0.02). There was a significant decrease in the rate of Toby's interruptions per session between 1993 and 1994 (NAP = 0.75, p = 0.04).

In addition, there were changes in the types of interruptions over time. Initially, both dolphins' interruptions were predominately ungrammatical interruptions. Over the course of the study, the rates of concordant and grammatical interruptions increased to be equivalent to ungrammatical and eventually became the more common types of interruptions. This trend was observed for both Bob and Toby.

Table 5

Frequency of interruptions for each year of study

	Repetitions	**Concordant Interruptions**	**Grammatical Interruptions**	**Ungrammatical Interruptions**
1993				
Bob	0 (0)	16 (0.41)	24 (0.62)	124 (3.18)
Toby	1 (0.03)	6 (0.15)	4 (0.10)	21 (0.54)
1994				
Bob	1 (0.01)	9 (0.05)	10 (0.05)	20 (0.11)
Toby	0 (0)	3 (0.02)	4 (0.02)	3 (0.02)
1995				
Bob	1 (0.003)	14 (0.04)	27 (0.08)	22 ((0.06)
Toby	0 (0)	1 (0.003)	1 (0.003)	3 (0.01)
1996				
Bob	0 (0)	12 (0.04)	15 (0.05)	15 (0.05)
Toby	0 (0)	4 (0.01)	7 (0.02)	4 (0.01)
1997				
Bob	0 (0)	13 (0.05)	2 (0.01)	13 (0.05)
Toby	0 (0)	0 (0)	0 (0)	0 (0)
1998				
Bob	0 (0)	5 (0.02)	15 (0.06)	6 (0.02)
Toby	0 (0)	3 (0.01)	2 (0.01)	0 (0)
1999				
Bob	0 (0)	3 (0.01)	1 (0.003)	0 (0)
Toby	1 (0.003)	2 (0.01)	1 (0.003)	1 (0.003)
2000				
Bob	0 (0)	0 (0)	2 (0.02)	0 (0)
Toby	0 (0)	0 (0)	0 (0)	0 (0)

Note. Values in parentheses represent the rate of interruptions based on frequency per number of keyboard sessions each year.

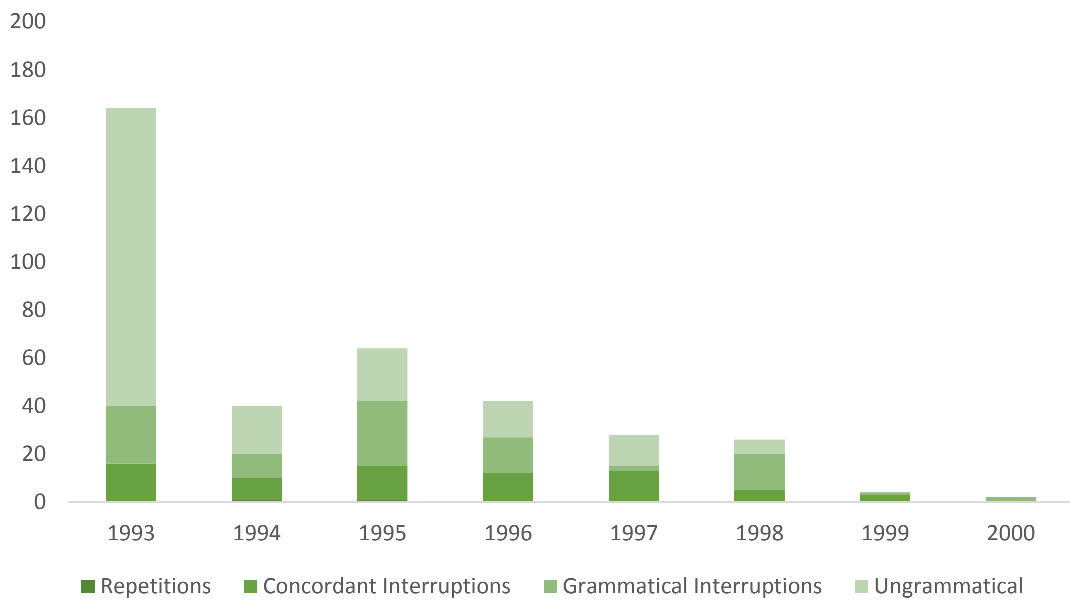

Figure 8. Categorization of Bob's interruptions over time

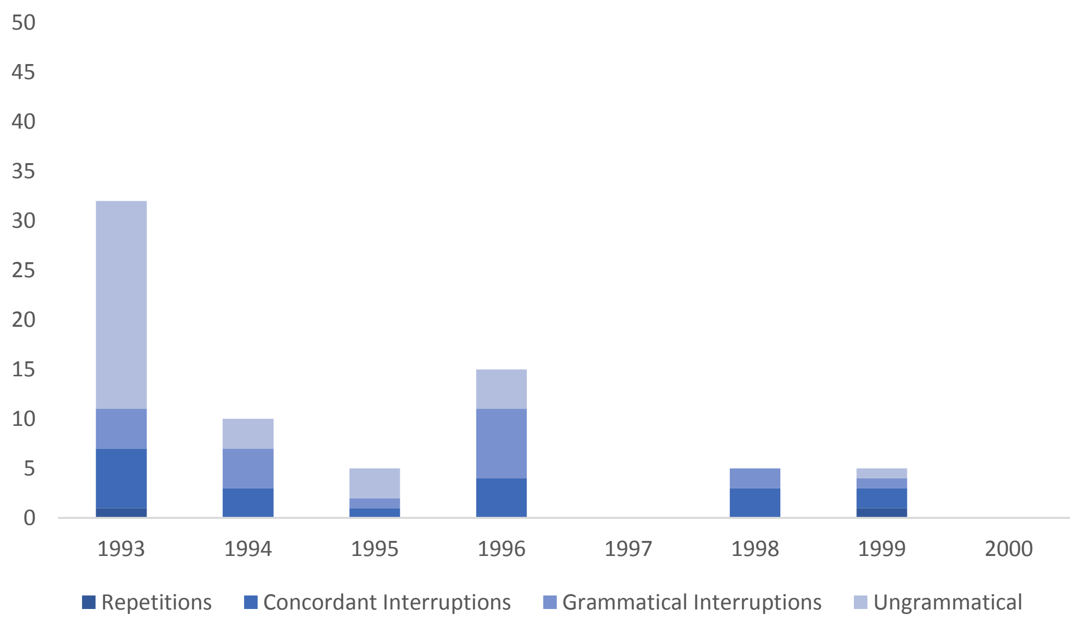

Figure 9. Categorization of Toby's interruptions over time

Conversations Including Human Gestures

The frequencies with which each dolphin responded to each type of human gesture with a subsequent key activation are presented in Table 6. Bob and Toby produced very few utterances that resulted in shrugs after 1994. In 1993, Bob was more likely to respond to a shrug with a key activation. This difference disappeared in 1994. There was a significant decrease in the rate at which Bob responded to a human shrug per video coded between 1993 and 1994 (NAP = 0.74, $p = 0.02$). There were no significant changes in the rate at which Bob did not respond to a shrug with a key activation throughout the study. There were no significant changes in responses to "no" and "yes" gestures between years. There was also no change in frequency with which Bob did not respond to a "no" gesture with a key activation. Between 1995 and 1996, there was a significant increase in the frequency of "yes" gestures not followed by a key activation by Bob (NAP = 0.84, $p = 0.048$). Between 1997 and 1998, there was a significant increase in the "yes" gestures not followed by a key activation by Bob (NAP = 1.0, $p = 0.02$).

Toby, on the other hand, was equally likely to activate a key or not in response to a shrug in 1993 and slightly more likely to activate a key in response to a shrug in 1994. In 1993, Bob was more likely to activate a key in response to a "no" gesture given by a human, however, this pattern was reversed in 1994. The subsequent years have low rates of "no" gestures given by humans. Toby was equally likely to activate a key or not in response to a human "no" gesture in 1993 but was more likely to not activate a key in response to this gesture in 1994. Again, in subsequent years there were only a small number of key activations that resulted in a human "no" gesture. Bob and Toby were both consistently less likely to activate a key in response to "yes" gestures produced by a human throughout the years of study. There were no significant changes in Toby key activations following a human shrug, "no" gesture, or "yes" gesture across study years. Toby decreased the frequency with which human shrugs were not followed by a key activation between 1993 and 1994 (NAP = 0.76, *p* = 0.01). There were no changes in "no" gestures not followed by a key activation by Toby. There was a significant increase in the frequency of "yes" gestures not followed by a key activation by Toby between 1993 and 1994 (NAP = 0.76, *p* = 0.01).

Table 6

Description of keyboard activations to human gestures

		Shrug		**"No"**		**"Yes"**	
		No	*Yes*	*No*	*Yes*	*No*	*Yes*
1993							
	Bob	2	15	7	38	29	13
	Toby	12	13	5	5	14	4
1994							
	Bob	2	2	25	10	41	16
	Toby	3	7	25	9	52	13
1995							
	Bob	0	0	7	0	21	6
	Toby	0	0	1	0	10	0
1996							
	Bob	0	0	0	0	4	1
	Toby	0	1	1	0	5	1
1997							
	Bob	0	0	5	2	13	7
	Toby	0	0	2	4	9	2
1998							
	Bob	0	2	1	2	12	0
	Toby	0	0	2	1	3	1

Conversations Including Dolphin Gesture

A dolphin was considered to have used a behavioral turn within a conversation if a pointing event took place after a key activation made by a human. The frequencies of conversations featuring a behavioral turn by the dolphins is described in Table 7. The frequencies were converted to a rate of frequency per minute of video (See Figure 10).

Table 7

Frequencies of dolphin behavioral turns

Year	**Bob**	**Toby**
1993	54 (0.04)	21 (0.02)
1994	53 (0.04)	46 (0.03)
1995	17 (0.05)	14 (0.04)
1996	14 (0.05)	12 (0.05)
1997	13 (0.06)	8 (0.03)
1998	19 (0.11)	0 (0)

Note. Values in parentheses represent rate of pointing events based on frequency per minute of video each year

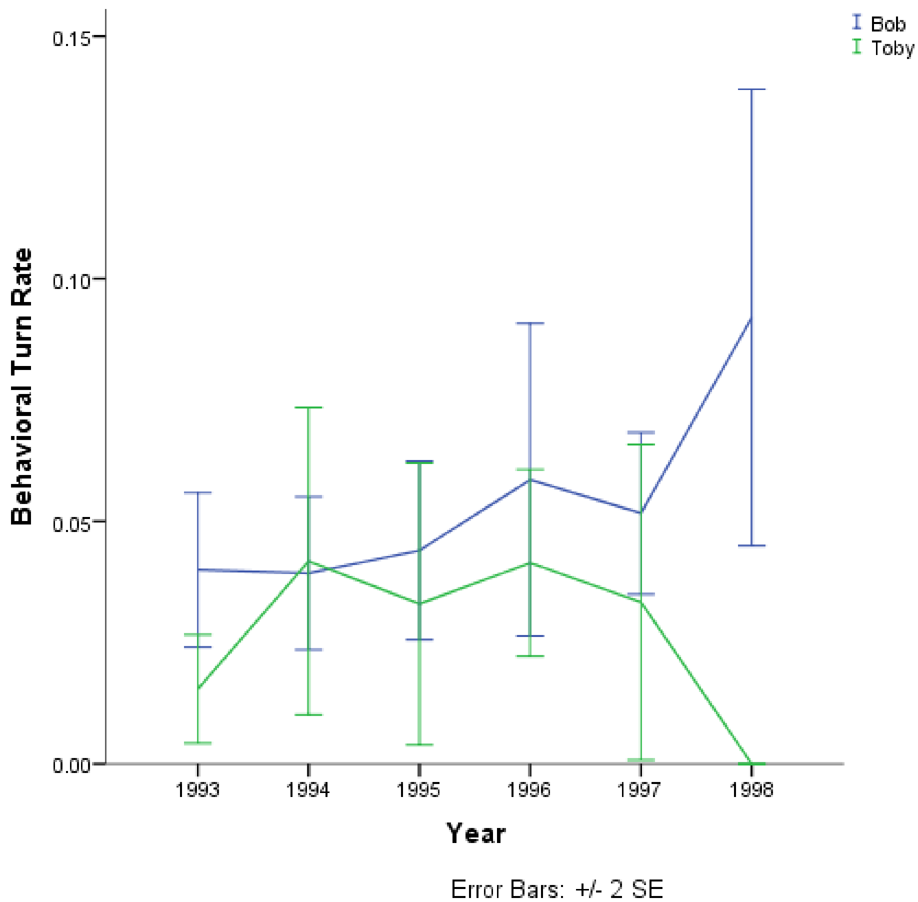

Figure 10. Rate of behavioral turns per minute of video

Bob and Toby both increased the rates of behavioral turns from 1993 through 1996. Bob continued to increase his use of pointing in response the human key activations. Toby, on the other hand, decreased the rate at which he pointed in response to a human key activation with a behavioral turn. There were no significant changes in the frequency of behavioral turns for Bob or Toby between study years.

Contingent Use of Keyboard

The frequencies of dolphin key activations based on location and orientation of human listener are presented in Table 8. The dolphins were most likely to use the keyboard when the listener was facing towards them. There were more keypresses by dolphins when the human was greater than 2 m and facing away than when located in close proximity and facing away. Due to differences in the number of videotaped sessions by year, frequencies were converted to rates based on the minutes of recorded sessions for that year.

Table 8

Keypress frequency based on location and orientation of human listener

	Human Within 2m Facing Towards	**Human Within 2m Facing Away**	**Human Greater than 2m Facing Towards**	**Human Greater than 2m Facing Away**
1993				
Bob	257 (0.19)	31 (0.02)	160 (0.12)	177 (0.13)
Toby	102 (0.07)	7 (0.01)	180 (0.13)	80 (0.06)
1994				
Bob	76 (0.06)	14 (0.01)	133 (0.10)	71 (0.05)
Toby	41(0.03)	7 (0.01)	127 (0.09)	41 (0.03)
1995				
Bob	29 (0.08)	6 (0.02)	38 (0.11)	4 (0.01)
Toby	10 (0.03)	0 (0)	14 (0.04)	5 (0.01)
1996				
Bob	13 (0.05)	1 (0.004)	18 (0.07)	5 (0.02)
Toby	11 (0.04)	0 (0)	10 (0.04)	3 (0.01)
1997				
Bob	21 (0.09)	1 (0.004)	27 (0.11)	15 (0.06)
Toby	9 (0.04)	1 (0.004)	18 (0.08)	12 (0.05)
1998				
Bob	16 (0.09)	2 (0.01)	20 (0.12)	10 (0.06)
Toby	3 (0.02)	0 (0)	8 (0.05)	2 (0.01)

Note. Frequency counts are based on recorded sessions. Each year had a different number of recorded sessions. Values in parentheses represent key activation per minute of video.

Figures 11 and 12 display changes in rates of keypresses based on location and orientation of human listener for Bob and Toby respectively. Bob was more likely to activate a key when the human was facing towards him. Although initially, Bob used the keyboard more often when the human was within 2 m, this rapidly declined and became similar to the keypress rate when the human was at a greater distance. There were no significant changes between study years in Bob keyboard activations when the human listener was within 2m and facing towards, within 2m and facing away, or greater than 2m facing towards. Between 1993 and 1994, there was a significant decrease in Bob key activations when the human listener was greater than 2m and facing away (NAP = 0.22, $p < 0.001$).

Throughout the study, Toby activated keys most often when the human was greater than 2 m away but facing towards him. There were no significant changes between study years in Toby keyboard activations when the human listener was within 2m and facing towards and within 2m and facing away. There was a significant increase in Toby key activations with human greater than 2m and facing towards between 1993 and 1994 (NAP = 0.69, $p = 0.01$). There was a significant decrease in Toby Key activations when the human listener was greater than 2m and facing towards between 1994 and 1995 (NAP = 0.73, $p = 0.04$). There were no significant changes in Toby key activations when the human was greater than 2m and facing away between study years.

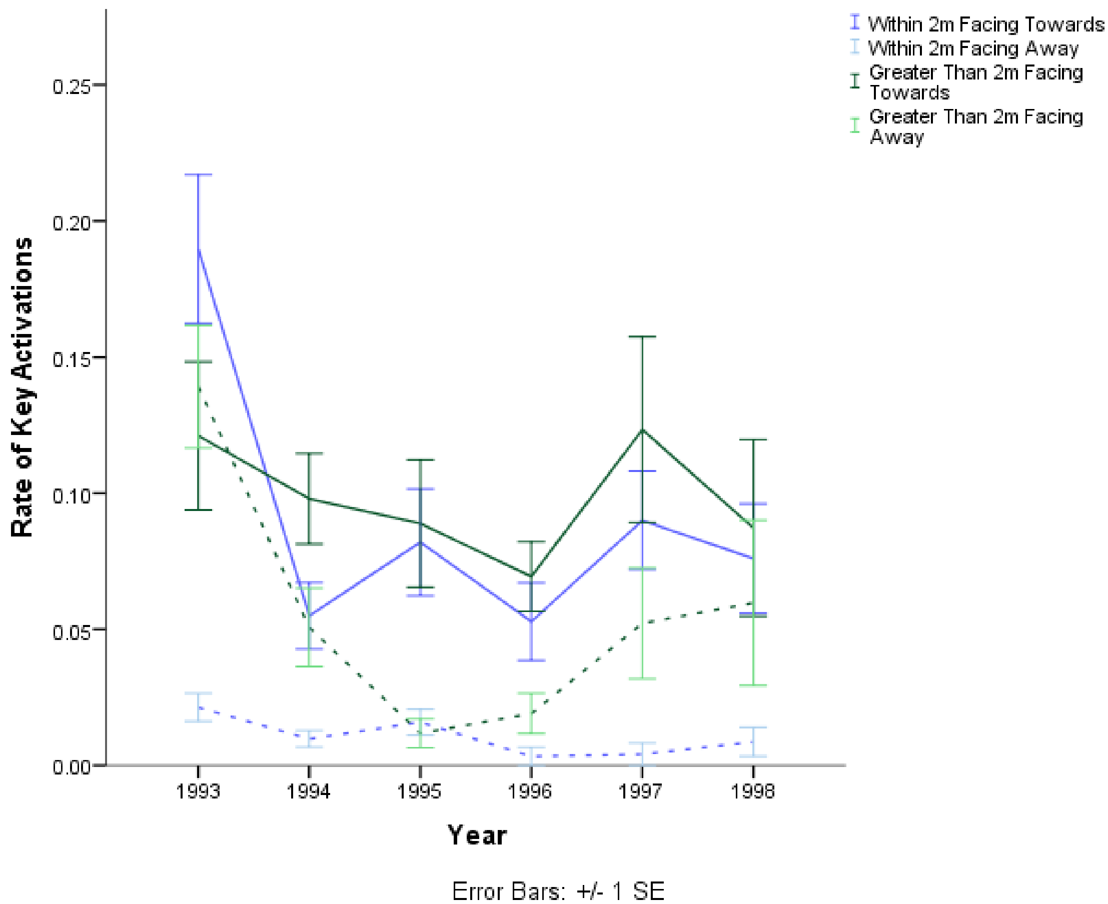

Figure 11. Bob's rate of keypresses per minute of video based on location and orientation of human listener

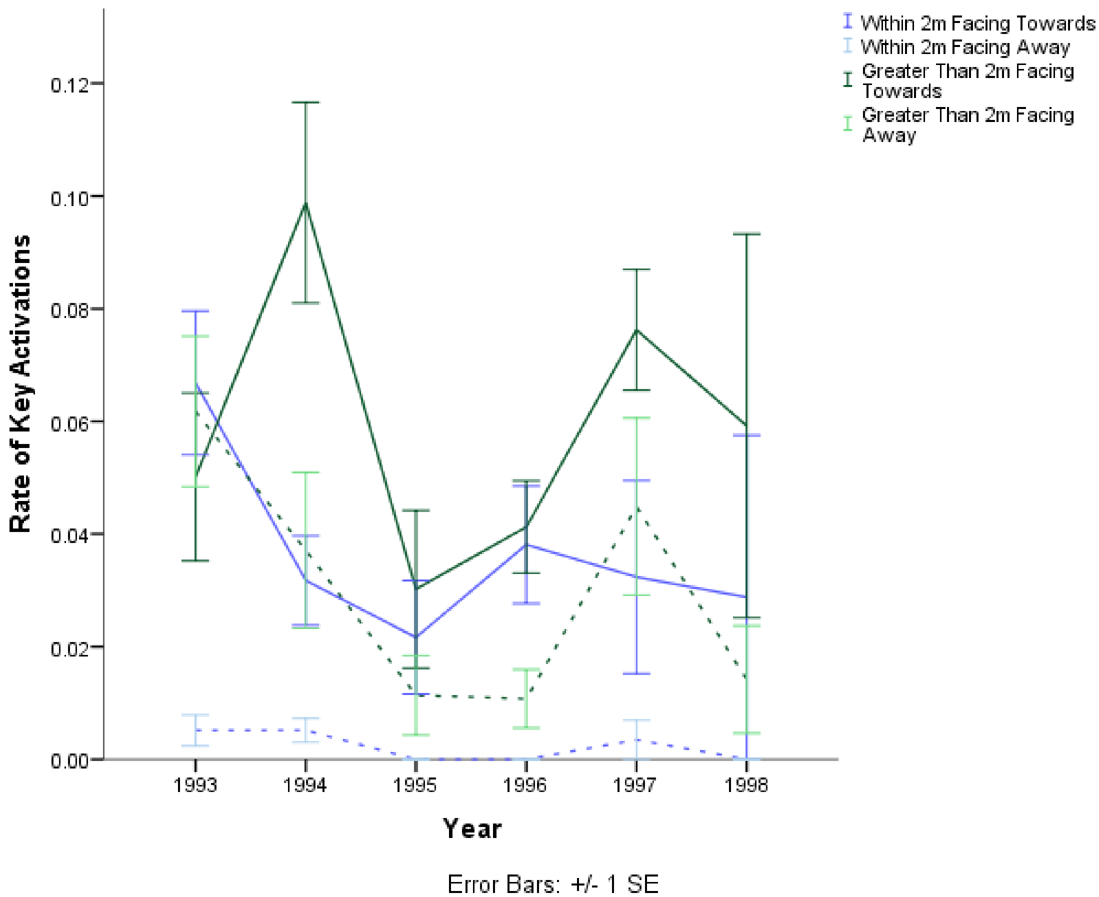

Figure 12. Toby's rate of keypresses per minute of video based on location and orientation of human listener

CHAPTER IV – DISCUSSION

This study represents an exploratory analysis of a very rich dataset. The purpose was to determine if there is evidence of pragmatic understanding in dolphins' use of a symbolic communication keyboard. The results indicate that there was a change in how the dolphins used the keyboard during the course of the study. There was evidence for turn-taking in dolphin – human interaction using both key activations and gestures provided by dolphins and humans. There was a decline in interruptions over time suggesting a greater understanding of the structure of a conversation. Dolphins appeared to pay attention to the orientation of a human listener when using the keyboard. Dolphins used the keyboard more often when the human was facing the dolphin. In addition, this study identifies areas of future analysis that would provide additional detail regarding the specifics of these changes.

Turn-Taking

Keyboard Conversations

There was a decline in the frequency of dolphin initiated conversations for both Bob and Toby (See Table 3). This coincides with an overall decrease in key activation frequency for both dolphins due to a decline in the use of food keys (See Figure 4). While there was also a decrease in the absolute frequency of human initiated (dolphin responses) conversations, there was an actual increase in the proportion of these responses compared to initiations. This is important when considering how the dolphin is using the keyboard to converse with a human. In dolphin initiated conversations, the human either continues the conversation, responds with a gesture, or swims to an identified location or object. Human-initiated conversations feature a dolphin response that establishes the conversation. It is these human initiated conversations that are particularly meaningful in determining a dolphin's understanding of the communicative nature of the keyboard. Humans did not wait for the dolphin to activate a key at the keyboard before taking appropriate action based on their own key activation. This was a design feature of the study to avoid reducing subsequent dolphin key activation after a human key activation to a simple operant. The interaction would continue whether the dolphin chose to activate a key or not. Dolphin key activation was never required. In fact, at times, dolphin continuation of the conversation at the keyboard delayed the human's action. The increase in the proportion of human initiated to dolphin initiated conversations suggests that dolphins became more responsive with the keyboard, perhaps indicating a possible understanding of the two-way communication function of the keyboard.

Interruptions

The analysis of interruptions suggests that dolphins did learn information about how a conversation is structured. Again, there is an overall decline in frequency of interruptions due to the decreased frequency of key activations. However, there was a shift in the predominant type of interruption over the years of study. Initially, the dolphins were more likely to interrupt with the ungrammatical type. This can be explained by a more random use of the keyboard keys. The increase in grammatical and concordant interruptions in which the dolphin is paying attention and following the grammar of the keyboard suggests a more meaningful use of the keyboard. Since interruptions were counted as conversations, this also indicates that the conversations later in the study were more meaningful and not due to random use of the keyboard by the dolphins. Future studies designed to look at the specific keys involved in these conversations and interruptions will be able to elucidate this aspect of the dolphins' keyboard communications more clearly. To fully understand the nature of the conversations between the dolphin and the human at the keyboard, an analysis that includes the specific keys used by each participant is necessary. This can be used to determine whether any transfer of information occurred within a conversation.

Multi-turn Conversations

Multi-turn conversations provide evidence for a greater pragmatic understanding of the structure of keyboard conversations. Bob did not show an increase in his use of multi-turn conversations. In 1998, Toby showed an increase in multi-turn conversations, however, these declined in the subsequent year. A longer study period would be necessary to determine the long-term changes in the use of multi-turn conversations. The low rate of multi-turn conversations can possibly be explained by the general use of the keyboard by the dolphins. Specifically, the dolphins developed a systematic use of the keyboard that involved primarily location keys. If the goal of the dolphin was to go to a certain location and possibly obtain an object or food item available there, then a multi-turn conversation may not have been necessary.

Conversations with Dolphin Activation Response to Human Gesture

Dolphins also showed aspects of turn-taking by using the keyboard to respond to various human gestures (See Table 6). While there was not a consistent trend in the dolphins' responses to shrugs or "no" gestures, they were consistently more likely to not respond than to respond to the "yes" gesture. Rather than activate a key, the dolphins swam to the location and object and pointed. Xitco (1996) observed the pointing behavior of dolphins during keyboard sessions. The results indicated that this pointing behavior was also affected by the gestures provided by humans in response to each pointing event. Points that elicited an affirmative response ("yes") were more likely to be followed by additional points. Points that elicited a negative response (shrug or "no") were less likely to be followed by points. Similar to their behavioral responses, it appears that dolphins do regulate their use of the keyboard based on human behavioral gestures.

If a dolphin understands a "yes" gesture as a confirmatory response, then the dolphin should not respond with an additional key activation. These results are consistent with this interpretation. However, it is possible that the human and dolphin behavior during keyboard interactions could make it more or less likely for a key activation by a dolphin to occur. A "yes" gesture typically was followed by the human diver and dolphin swimming towards the desired object, food, or location. This movement away from the keyboard makes subsequent key activations less likely. If a dolphin correctly interprets a "no" gesture as a negative response and a shrug as an unclear response, the dolphin should respond by activating other keys. The results did not show such a tendency in the dolphins. However, shrugs and "no" gestures could be followed by a key activation by the human. For example, a dolphin might activate the "shipwreck" key. A human might gesture "no" and then activate the following keys: "no" "herring" at "shipwreck." The human clarifies the negative gesture, and it is not necessary for the dolphin to respond. An analysis of conversations featuring human gestures that includes information about the specific keys activated in response to the human gesture is needed to fully interpret a dolphin's understanding of these gestures. Examining whether a dolphin produced the same key activation after a negative gesture or whether the dolphin altered the key used would provide important information.

Conversations Including Dolphin Gestures

Bob and Toby initially increased the rate at which they produced pointing behaviors as behavioral turns within a conversation. It is difficult to interpret the subsequent decline in Toby's rate of behavioral turns since in 1998 he was the subject of only one focal follow video. Therefore there is limited data from which to calculate the rate of this behavior. Xitco et al. (2001) was the first to describe this pointing behavior in these two dolphins. It was found that after the behavior appeared the dolphins engaged in a constant rate of behavior. Xitco et al. coded all occurrences of pointing events, whereas the current study specifically examined the pointing events that occurred after a human key activation. In addition, to be considered a behavioral turn, the pointing must have indicated the object or an object placed at the location referenced by the human. The proportion of points that count as behavioral turns should increase as the animal learns the association between the key and the object or location to which it refers. As the animal learns what the keys mean the number of correct points increases and therefore more of these points are scored as behavioral turns. This offers an explanation as to why there was an increase in the rate of the behavioral turns as opposed to the relatively constant rate observed by Xitco et al. (2001).

The dolphins' interactions at the keyboard, both via key activations and behavioral turns follow the principles of turn-taking described by Sacks, Schegloff, and Jefferson (1974) in which each participant talks at a time with limited simultaneity. This is indicated by the increase in proportion of dolphin responses to initiations, the use of multi-turn conversations, the decrease in interruptions (particularly the nongrammatical type) over time, as well as responses to human gestures and production of pointing gestures in response to human key activation. It is important that dolphins responded to human gestures and provided their own gestures using the same principles of turn-taking utilized when interacting at the keyboard. This parallels findings in human infants that highlight the importance of timing and the use of nonverbal gestures in establishing the sequence within a conversation (Oller, 2000; Stern et al., 1997).

Contingent Use of Keyboard

The use of the keyboard by the dolphins was dependent upon the orientation of the human listener. Both Bob and Toby used the keyboard often when the human was facing towards the dolphin regardless of whether the human was within 2 m. This is similar to the observations described by Xitco et al. (2004). In this study, dolphins were required to point to one of two clear plastic tubes that contained a goal object (identifiable to the dolphin by both vision and echolocation). A human recipient to the point was available in three conditions. (1) Face-Forward in which the human was located directly in front of the apparatus containing the jars and was facing the dolphin and receptive to any pointing behaviors, although the human did not respond to points during testing, (2) Face-Backward in which the human recipient was located in the same place as in the face-forward condition, but was positioned with the back toward the dolphin, making this person unavailable to receive a pointing gesture, and (3) Swim-Away in which the human recipients trainer turned away after placing the jars and swam 4.9 m away from the dolphin to a low-lying reef and was unavailable to receive a pointing gesture. The dolphins were more likely to point the object when the human was facing towards the dolphin and apparently receptive to the behavior. The dolphins used a pointing gesture more often when the human's back was turned than when the human was swimming away. Additionally, studies on apes have found that if the human recipient is close in proximity, even when unavailable to receive a behavior the animal is more likely to engage in behaviors directed at the human (Call & Tomasello, 1994; Kaminski, Call, & Tomasello, 1994). Kaminski et al. (2004) studied the spontaneous behavior of chimpanzees, bonobos, and orangutans when presented with a choice between two glasses of juice. Four conditions differing in human orientation toward the subject were used. (1) Human facing subject with eyes fully opened, (2) human facing subject with eyes closed, (3) human located in same position but with back turned to subject, and (4) human exited room after experimental setup. Results indicated that all subjects engaged in more behaviors during the conditions in which the human was facing the animal with eyes open or eyes closed. Fewer behaviors were produced during conditions in which the human back was turned or the human was out of the room (Kaminski et al., 2004). Future studies can examine the proportion of responses and reinforcement offered by the human in response to a dolphin key activation based on the location and orientation of the human listener. If the response by the human to the dolphin is the same regardless of his or her location and orientation, then the differences observed in frequency of dolphin key activations based on location and orientation of the human cannot be explained by differential reinforcement but rather by a communicative function.

It is important to note that in the current study, there was no systematic manipulation of the orientation of the human diver. The humans were instructed to pay attention to the dolphin throughout the course of a session. The greater swim speed capacities of dolphins compared to humans provided opportunities for the dolphin to initiate a conversation by activating a key when the human was still a substantial distance away.

Conclusion

The purpose of the current study was to determine what evidence of pragmatics existed in dolphin – human interactions at an underwater communication keyboard. The dolphins did show evidence of pragmatic understanding based on evidence of turn-taking both at the keyboard and using behavioral gestures. Dolphins engaged in multi-turn conversations and showed a decline in interruptions over time. The physical structure of the keyboard may have limited the amount of turn-taking observed since the keyboard was large and immobile within a session. This developed an organized structure to keyboard communications which consisted of brief interactions at the keyboard and then travel to locations to get food or objects referenced in the keyboard conversation. This may contribute to the observed trend in which dolphins engaged in less key activations over time and use of locations predominated. The ultimate goal was to go to a specific location, and multi-key utterances in particular and multi-turn conversations at the keyboard were not needed. Future studies that examine the specific keys activated by dolphins and humans can provide important information regarding the type of information that is exchanged during these interactions.

Dolphins appeared to pay attention to the attentional state of the human listener and predominately used the keyboard when the human was facing toward them. It is possible that the human was more likely to be facing the dolphin during keyboard sessions. Further studies are needed to examine any differences in human responding based on his or her location and orientation when the dolphin uses the keyboard.

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