

## Transmission mechanisms

of social learning in dolphins:  
underwater observations of free-ranging  
dolphins in the Bahamas

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*Abstract*

For most cetaceans the potential existence of culture is deduced from temporal or spatial patterns in the wild. Transmission mechanisms of information between conspecifics are usually observable only in close-proximity situations in captivity. In the clear waters of the Bahamas long-term underwater observations of two species, the Atlantic spotted dolphin (*Stenella frontalis*) and bottlenose dolphin (*Tursiops truncatus*), provide a unique opportunity to observe transmission mechanisms of social learning within and between these societies. Since 1985, 220 spotted and 200 bottlenose dolphins have been individually identified and regularly observed for five months every summer. Underwater video with hydrophone input was used to document individuals, sounds, and associated behavior. Many spotted dolphins are of known gender, relationships (mother/calf, siblings), and association patterns.

Spotted dolphin society has qualities conducive to socially oriented transmission mechanisms including (1) mixed age-class groups, (2) multi-generation family groups, and (3) long-lives and extended maturation periods. This suggests that there may be a variety of social mechanisms available for the transmission of information between dolphins. Vertical (mother/offspring), oblique (non-parental/juvenile), and horizontal (peer/peer) are potential directions of transmission. Transmission types of visual/kinesthetic behavior include (1) contagion, (2) observational learning, (3) matched dependent learning, (4) social exposure/enhancement and (5) goal emulation. Examples of foraging, courtship, play, and aggressive activity are given to explore potential mechanisms available to dolphins in the wild.

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Complex social systems and advanced cognitive abilities have been suggested as good predictors of animal culture (Roper, 1986). Studies of cetaceans that document biological aspects favoring social learning and social processes conducive towards cultural transmission of information include: long lives, extended parental care and childhood (Whithead et al., 2000; Connor et al., 1992), orcas (*Orcinus orca* – Ford, 1989), Atlantic bottlenose dolphins (*Tursiops truncatus* – Herzing, 1997), sperm whales (*Physeter macrocephalus* – Whitehead et al., 1980). Therefore, cetaceans are good candidates for looking at the evolution of culture in a social species. For most animals, advanced cognitive abilities in bottlenose dolphins (Herman et al., 1980).

Cetaceans are believed to be intelligent because they have the ability to learn from experience, to use tools, to solve problems, to communicate with each other, and to pass on knowledge through generations. These abilities are often attributed to complex social structures and behaviors, such as vocalizations, body language, and cooperation. However, it is also possible that some of these behaviors could be the result of instinctive responses to environmental stimuli. For example, when faced with a predator, a group of dolphins may work together to drive it away. This behavior is often interpreted as evidence of intelligence, but it could also be a simple instinctive response to a threat.

## Résumé (de F. Deljoue)

tions, we still lack the ability to observe the "process" or the "how" of social learning in wild cetaceans. This paper offers a beginning glimpse at a cetacean society underwater and a broad description of the likely mechanisms at work and the social conditions necessary for such transmissions.

To date, four species of cetacean, killer whales, bottlenose dolphin, humpback whales, and sperm whales have been analyzed for potential cultural traits (Rendell and Whitehead, 2001). In addition, culture variants found in these species, or between different species, are sympatric as animals with different variants often interact. This suggests that these groups maintain their own group-specific culture while being exposed to a wide range of cultural behavior from other groups.

Cultural patterns in cetaceans have been derived and deduced from spatial, temporal or social patterns of behavioral variations, which are not determined by genetic, ecological, or individual variation. Unfortunately, due to the lack of ability to observe animals underwater for extended periods of time, there has been little discussion on the transmission mechanisms, or type of learning processes available, that underlie these patterns. Such processes are normally derived from work with captive animals and in experimental settings. Definitions of culture and mechanisms of dissemination have been described by Whitehead and Rendell (2000).

In the Bahamas, a resident group of Atlantic spotted dolphins have been behaviorally observed underwater since 1985. Life history (Herzing, 1997), correlations with sound and behavior (Herzing, 1996), and association patterns (Herzing and Brunnick, 1997) and interspecific interactions (Herzing and Johnson, 1997) have been described. Because of the clarity of water and regular access to 220 resident individuals, this field site provides a unique opportunity to observe potential social learning mechanisms at work in the wild. Spotted dolphin society has qualities conducive to socially oriented transmission mechanisms including (1) mixed age-class groups, (2) multi-generation family groups, and (3) long lives and extended maturation periods. This suggests that there may be a variety of social mechanisms available for the transmission of information between dolphins.

#### THEORETICAL BACKGROUND AND FRAMEWORK

As discussed by Rendell and Whitehead (2000), social learning processes need to encompass other types of learning beyond teaching and imitation, which tend to be primate-centered requi-

of learning is viewed in figure 1. Transmission directions of information may include vertical (mother/offspring), horizontal (peer/peer), and oblique (non-parental/juvenile). A broader definition of non-mimetic social processes remains.

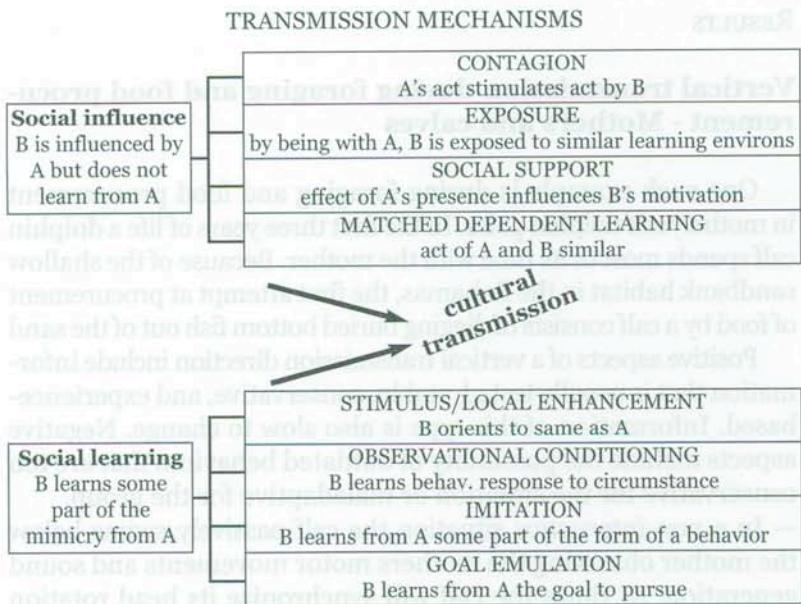
(1) in practice, mechanisms in dolphins may be complicated by the fact that: In addition, opportunities for observing potential transmission mechanisms in dolphins, creatures without appendages allowing tool manipulation, may be quite different than described for primates. The following scenario: a dolphin-eating shark may encounter another dolphin mother and calf. The mother shows fear and flees excitedly with her calf. In addition the mother enhances observational learning when she sees the shark. "Enhancement" by the action of the mother orienting to the shark, may lead to consistency of activity and learning over time by over-exposure, matched dependent learning, stimulus and local enhancement, observation, imitation, goal emulation, and cement, observational learning, imitation, and teaching. In recognition that non-human territorial and aquatic societies may have evolved differently, and may manifest in a variety of ways in different behavioral contexts, a broad description of mechanisms of potential social learning is projected.

This paper describes three sequences of social/sensory exposures by spotted dolphins to behavioral patterns that have functional significance in their society. What do dolphins really need to learn and what are the conditions of behavioral interaction by spotted dolphins that have functional significance in their society? Specific examples of potential transmission types and directions in various contexts are given. Examples are divided into two scenarios: (1) non-interactive situations and (2) more interactive situations between dolphins.

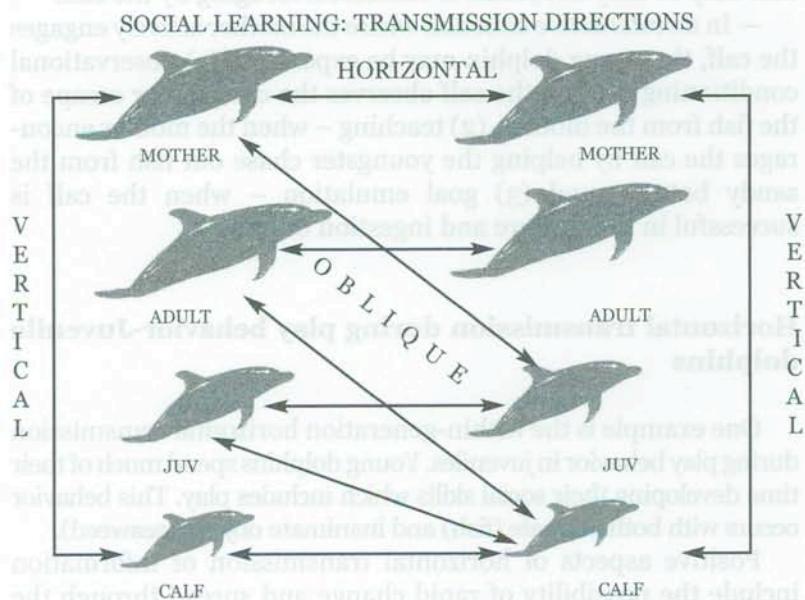
(2) transmission mechanisms and directions may not be mutually exclusive or unidirectional and therefore may interact with each other. For example, the real world of dolphins might include the following scenario: a dolphin-eating shark may encounter another dolphin mother and calf. The shark may experience "stimulus enhancement" by the action of the mother orienting to the shark. Secondarily, the shark may enhance observational learning when the mother shows fear and flees excitedly with her calf. In addition the mother enhances observational learning when she sees the shark. The following mechanism may enhance observational learning over time by over-exposure, matched dependent learning, stimulus and local enhancement, imitation, goal emulation, and cement, observational learning, imitation, and teaching. In recognition that non-human territorial and aquatic societies may have evolved differently, and may manifest in a variety of ways in different behavioral contexts, a broad description of mechanisms of potential social learning is projected.

(3) real-world scenarios of "practicing" sequences of activity may lead to consistency of activity and learning over time by over-exposure mechanisms and accumulating experience. Such practice may result in a variety of ways in different behavioral contexts, a broad description of mechanisms of potential social learning is projected.

The other entails potential auditory cues from the mother; the mother shows fear and flees excitedly with her calf. In addition the mother enhances observational learning when she sees the shark. "Enhancement" by the action of the mother orienting to the shark, may lead to consistency of activity and learning over time by over-exposure, matched dependent learning, stimulus and local enhancement, imitation, goal emulation, and cement, observational learning, imitation, and teaching. In recognition that non-human territorial and aquatic societies may have evolved differently, and may manifest in a variety of ways in different behavioral contexts, a broad description of mechanisms of potential social learning is projected.



**Figure 1—Definitions of transmission mechanisms can be divided into social influence factors and social learning factors, as reviewed by Whiten and Ham (1992)**



**Figure 2 – Transmission directions for social information are multidirectional, including vertical, horizontal, and oblique. Note that transmission directions can also be two-way, i.e. from calf to mother and vice versa**

### Vertical transmission during foraging and food procurement - Maternal - Mothers and calves

One such example is during foraging and food procurement. In mother/calf dolphin pairs, in the first three years of life a dolphin calf spends most of its time with the mother. Because of the shallow sandbank habitat in the Bahamas, the first attempt at procurement of food by a calf consists of digging buried bottom fish out of the sand

Positive aspects of a vertical transmission direction include informed

maternal transmission that is usually tested, stable, conservative, and experience-based. Information of this type is also slow to change. Negative aspects include the possibility of outdated behaviors that are too

conservative for the situation or maladaptive for the group.

In a non-interactive situation the calf passively swims below the mother observing the mothers' motor movements and sound generation. At times the calf will synchronize its head rotation with the mothers as if in practice. The calf potentially experiences (1) trial and error learning - if the calf explores on its own, (2) stimulus/local enhancement - when the mother is orienting and pointing to fish and (3) simple imitation - of motor movements that may or may not result in successful foraging by the calf.

- In an interactive situation where the mother actively engages the calf, the young dolphin may be exposed to (1) observational conditioning - when the calf observes the catching or escape of the fish from the mother, (2) teaching - when the mother encou-ages the calf by helping the youngestster chase out fish from the ripples the calf by helping the youngestster chase out fish from the sandy bottom, and (3) goal emulation - when the calf is successful in the capture and ingestion of prey.

One example is the within-generation horizontal transmission of play behavior-juvencile dolphins

During play behavior juveniles, young dolphins spend much of their time developing their social skills which includes play. This behavior occurs with both animate (fish) and inanimate objects (seaweed). Positive aspects of horizontal transmission of information include the possibility of rapid change and spread through the society with such a large pool of individuals. Negative aspects include some of the information may be transmitted by inexperienced young animals.

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- In a *non-interactive* situation a group of younger juvenile dolphins may be observing play behavior between an experienced juvenile dolphin and its target play item, a local fish. The non-interactive juveniles potentially experience (1) contagion – when the excitement of activity is transmitted in the group through movement and sound, (2) social support and motivation – when it is socially desirable to get in the game, and (3) stimulus enhancement – when the experienced juvenile dolphins target the object and receive the attention of the non-interactive dolphins.<sup>1a m</sup>
- In an *interactive* situation the experienced juvenile may expose the others to (1) observational conditioning – when the juvenile playing with the fish shows the others the contingencies necessary for successful play, (2) goal emulation – when the experienced juvenile incites the others to target a fish, and (3) simple imitation – when the other juveniles practice their motor or acoustic moves on the fish target.

### **Oblique transmission during courtship and mating – Presence of a calf**

One example is during courtship and mating behavior in the presence of a calf. Dolphin societies are considered very social/sexual. Into the second year of the calf's life, the mother is actively courted by male coalitions. At a young age before sexual maturity, juvenile dolphins also begin practicing the motor movements of courtship behavior and mating with their peers. Positive aspects of oblique transmission of information include the possibility that information is experience-based from a large pool of individuals in the society including adults. Rapid changes through the society are also possible. Negative aspects include the possibility that information is not stable and may be maladaptive to the group.

- In a *non-interactive* situation a calf that is present with its mother while she is being chased, courted, and mated with male dolphins, may be passively exposed to (1) exposure – when the calf hears and sees the behavior of the males towards its mother, (2) stimulus or local enhancement – when the male dolphins orient to and chase the mother, and (3) observational conditioning – when the inexperienced calf is able to see and hear successful mating and courtship motor movements, sounds, and reactions of its mother to these signals.
- In an *interactive* situation the calf may be exposed to juvenile mating behavior and begin to participate. In this case it is exposed to (1) social support – when there is high motivation to play and interact with the other juveniles, (2) simple imitation –

formation among male bottlenose dolphins (*Tursiops sp.*)», CONNOR R.C., SMOLKE, R.A., RICHARDS A.F., « Two levels of alliance Proceedings of the British Academy, n° 88, 1996, pp. 25-68, BOESCH C., « The emergence of cultures among wild chimpanzees », *Bibliography*

in different species evolved in unique sensory environments. Learning in primate species) by which information can be exchanged between (teaching and imitation thought to be the prime mechanisms (mission mechanisms we should remain open to all the mechanism except complex communication systems for such transmission may influence mate choices in social species, and may be faster than trial and error learning therefore utilizing the reported story of information available to the society. And although we may include rapid evolution (faster than genetic transfer), this may involve many advantages of social learning at work simultaneously and over time, to fully understand the process of social learning. Evolutionary advantages of social learning may influence multiple mechanisms and sensory systems or cumulative effects of multiple mechanisms and sensory systems and anatomical abilities. In addition we need to look at creature's sensory specific abilities for capacities appropriate to a creature's sensory and directions in non-primate species we need to look at species-specificities in the possibility of social learning mechanisms as described in experimental work (Xitco and Roitblat, 1996)?

point with sound or directionally point with its body orientation mark a critical factor or feature of a prey item. Would a dolphin mark a critical feature of a prey item, in the foraging example given above for or angle to, an object. In the foraging example given above for tenance, pointing, or marking critical feature such as position of, learning by chimpanzees as pushing, directing or direction movement by chimpanzees as species. Boesch (1996) describes encounter-learning in any social species. Food procurement is the most likely scenarios for recognition of learning, and one of the most common example given for chimpanzee learning, and when the call practices motor or acoustic moves during this scenario - courtship and copulation act. (3) goal emulation - when the call participates in the ratio, and (3) goal emulation - when the call participates in the

#### DISCUSSION AND CONCLUSION

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