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The Cognitive Ecology of Dolphin Social Engagement

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Investigating social cognition in dolphins is a complex, demanding task. Alien in senses, form, and habitat, dolphins are challenging to comprehend and difficult to study. As the previous chapters in this book have made clear, they are also sophisticated, innovative creatures whose cognition we have only just begun to understand. "Cognitive Ecology" (Hutchins, 2010a, 2014) is a transformative new approach that is making exciting inroads in the study of human cognition (Enfield & Levinson, 2006; Goodwin, 2000, 2013; Hutchins, 1995, 2001, 2010a, 2010b; 2014; Malafouris & Renfrew, 2010) Because it provides a way to study social cognition based on observations of naturally-occurring behavior, some researchers working with nonhumans have adopted it as well (e.g. Byrne & Bates, 2014; Forster, 2002; Hirata & Matsuzawa, 2001; Johnson, 2001, 2010; King, 2004; Russon & Andrews, 2011). By outlining how this approach might be applied to the study of social interaction in dolphins, this chapter aims to present a new set of conceptual and methodological tools for studying dolphin communication and cognition (see also Herzing, 2006; Johnson, 2010).

This chapter will begin with an overview of the basic tenets of Cognitive Ecology, describing the models and methods involved. It will then illustrate how this approach can be used to investigate social cognition in four types of complex social engagements in dolphins. Note that while the focus here will be on social discourse in adults, this approach also offers many advantages for the study of development (e.g. Rogoff, 1990; Russon, 2006; Hutchins & Johnson, 2009; de Barbaro, Johnson & Deak, 2013). Its emphasis on system dynamics is a particularly good fit for addressing the unfolding of events. It allows us to study how individuals engage in real-world cognition - problem solving, learning, communicating - by providing a way for us to make sense of the complexity and diversity of everyday behavior.

Cognitive Ecology

Traditional approaches in cognitive science take cognition as the set of abilities, possessed by an individual, which it brings to bear to solve the problems it encounters. The use of these abilities is presumed to involve the manipulation of mental representations, and to correspond to specific neurological activity. While much has been, and will continue to be, learned from this perspective, it has its limitations, especially for the study of nonhumans. Since mental activity is not directly observable, these 'individual ability' approaches to animal cognition often start with postulations based on humans' experience of their own mental lives. This can prove problematic (Barrett & Würsig, 2014; Harley, 2013; Johnson, 2002). Particularly so, one would think, when studying animals like dolphins whose ways of perceiving and acting in the world are so different from our own. This chapter will focus on an alternative view that suffers less from these difficulties, by enabling us to do a cognitive analyses of behavior itself.

From the perspective of *Cognitive Ecology*, cognition is not something you have, it's something you do. When animals (including humans) actively engage with the world - navigating around obstacles, searching for and obtaining food, negotiating with conspecifics, etc. - their behavior continually adapts to the constraints of their physical and social environments. Constrained as well by their own senses and range of responses, each species has its own way of "coming into coordination" with its world (Hutchins, 1995a, 1995b; Johnson, 2001). A hunting dolphin, for instance, using echolocation and pursuit, adaptively "comes into coordination" with its prey. Similarly, when dolphins mate, they must coordinate the trajectory, proximity, and orientation of their bodies to accomplish copulation. In cognitive ecology, such changes in coordination are documented and analyzed as visible incidents of cognitive activity. This approach provides a significant advantage for those studying nonhuman cognition, since it frees us from having to postulate unobserved mental events, and allows us instead to employ systematic observations of engagement as the basis for understanding and comparing animal cognition.

Shifting to a view in which cognition is defined as "adaptive engagement with the world" brings along a host of theoretical and methodological consequences. Probably the principal of these is that it demands that we treat the object of study *as a system* (Hutchins 1995a, 2001, 2010ab). That is, this approach is called Cognitive Ecology because it recognizes that animals operate within a complex web of relationships, in a multi-faceted setting. As a result, the cognitive ecologist must maintain a focus on the system as a whole. Just as a biologist studying a natural eco-system will investigate how various system factors (like population density, predator-prey ratios, resource availability, etc.) co-constrain one another, and track transformations in these relationships over time, so too will the cognitive ecologist emphasize interaction and transformation. When the system of interest is social cognition - as it will be in this chapter - the resources that are transformed are those that enable animals to come into adaptive coordination with each other.

Information Flow

These social resources - the calls and gestures the animals produce, the attention they show to one another, the extent to which one animal's actions "fit" with another's, etc. - are all familiar aspects of what we typically think of as animal communication. In fact, from the view of cognitive ecology, communication and social cognition are virtually synonymous (Bateson, 1978). Both involve the coordination of what Goodwin (2013) calls the "semiotic resources" that mediate meaningful engagement. But, rather than characterizing these in terms of an exchange of signals between a sender and a receiver, requiring mental encoding and decoding, cognitive ecology directly observes transformations of the "media of information flow" within such a system.

Suppose, for example that the cognitive system of interest was the brain. Researchers could track information flow as changes in the electro-chemical media that constitute the circuitry of that system, identifying the many factors that constrain its trajectory. In cognitive ecology, information flow is not tracked along neurological pathways, but across changes in observable, embodied media, both within and between individuals. For instance, when an animal hears the call of another, it may turn to look at the source of that call. In this case, the cognitive ecologist would say that, within the animal-in-its-world system, information has been transformed across sensory-motor media, from audition to vision. Seen as a social system, when one animal calls and the other responds, the flow of information can be tracked in behavior from one to the next. As a result, the cognitive ecologist is primarily engaged in tracking how configurations of relevant media transform, within and across participants.

It is tracking such transformations that provides insights into which media matter - i.e. which are salient and consequential, in a particular setting, for those animals. For example, a wandering infant, startled by the world, will repeatedly re-orient its sensory modalities, and possibly vocalize, until it targets, and then rapidly approaches and contacts, its mother. The information flow in this adaptive event can be readily tracked in the infant's orientations and trajectories relative to the mom, as well as in the timing and types of her responses. This pattern would be species-specific in the particular modalities engaged, the nature of the calls, the roles played by other family members, etc. When an account of information flow also involves longer-term factors like rank or friendship, and especially when multiple individuals are involved, the configurations of relevant media can become quite complex. But, by adhering to some basic principles, interesting patterns can be revealed. In this way, this approach not only allows us to study complex social cognition, but provides us with a basis for comparing even quite disparate systems.

Embodied Media

By treating the study of cognition as a life science (Bateson, 1972, 1978; Rosch, Varela & Thompson, 1991), cognitive ecology takes the notion of "embodied" cognition literally, using the attention, action, and arousal shown by interacting animals as its raw data (see also Barrett, 2011). When we see animals interacting with their surroundings - orienting, discriminating, engaging - we are directly observing cognition in action. Clearly, knowing something of the sensory systems and behavioral repertoire of a species is essential. For example, recognizing that dolphins can both vocalize and hear in what to humans are ultrasonic frequencies (Au, 1993), while elephants do so at infrasonic frequencies (Payne, Langbauer & Thomas, 1986) would be critical to the species-appropriate study of information flow in those two systems. In contrast, other aspects of embodied cognition may cross such species boundaries. In most social animals, for instance, high arousal tends to involve increases in the pace and extent of the body movements observed, with related changes in vocal amplitude and other sound-making activities.

When one such sensory-motor-arousal system comes into coordination with another, *social* cognition occurs. During social engagement, relevant behaviors include the relative body positions, orientations, affective displays, gestures, vocalizations, and so on, that have long been the focus of ethological research. In fact, the methods of cognitive ecology have much in common with those of traditional ethology. Ethology is generally concerned with documenting a species' behavioral repertoire and understanding the ways in which factors like age, gender, rank, reproductive state, etc. affect behavior. While such issues also come into play in cognitive ecology, the latter is more concerned with how adaptations are accomplished. For example, while ethology may be concerned with whether related animals are more likely to collaborate than nonrelated ones, cognitive ecology would further investigate which behaviors and senses mediate collaboration, and how the effectiveness of this coordination develops over time. As a result, one key difference between these approaches is that cognitive ecology includes the detailed micro-analysis of engagement. A glance, a gesture, a turn to or from, are brief but often key components of social discourse. During social cognition, it is at this millisecond time scale that many critical adaptations occur.

Attentional behavior is a good case in point. Social attention consists of a shift in an animal's sensors such that it gains perceptual access to one or more conspecifics. Each overt act of attention - whether sniffing, turning to look, or echolocating - provides us with an observable cognitive event, critical to specifying information flow in that species. Social attention is often a joint activity, in which multiple animals concurrently moinitor one another, or direct their attention to a common target. Gaze following, for instance, is a widespread behavior among primates (Tomasello, Call & Hare, 1998) and plays a major role in their social negotiations (Emery, 2000; Johnson & D'Arcy, 2006). Plus, since acts of attention are often a preamble to interaction, they can become ritualized into displays that predict or deny engagement. Baboons, for example, can solicit affiliative engagement with a nonthreatening look, or avoid responding to a solicitation, or even to a threat, by directing their visual attention elsewhere - a tactic called "gaze aversion" (Chance & Jolly, 1970; Kummer, 1971).

In addition, attentional behavior can also be used as a general measure of "salience". Salience - the likelihood that a target will be attended - is a particularly useful cognitive metric here. Consider, for example, the case when one individual attends a target, thereby drawing the attention of others to it. In the mimicry literature, this is called "stimulus enhancement", and is a common means by which animals come to converge in their behavior toward a particular target, such as food or other resource (Whiten & Ham, 1992). By recording micro-level changes in attention, the cognitive ecologist can track how the salience of a particular target moves through a group, and identify other actions that help to direct or deflect it. We can also see changes in salience over time within a given individual. For example, food is salient when one is hungry, less so when one is sated. Similarly, a female, previously ignored, may become salient to a male when a third party begins to court her. In general, changes of consequence - the appearance of a predator, the challenge of a competitor, the threat to an offspring - are more likely to be attended than less important events would be. As a result, tracking salience can tell us a great deal about what matters to the participants in a given cognitive system.

Valences and Social Markets

Understanding "what matters" in a social group is necessary to an account of its cognitive ecology. If cognition is to be defined as "adaptive engagement with the world", there must be a rubric for what counts as adaptive. Note that in this setting, "adaptive" is not synonymous with "optimal", only with "advantageous in context". But identifying even the latter can be no small feat in socially complex animals. This is particularly true when multiple animals with differing interests are involved. Fortunately, there are a variety of behavioral patterns that we can use to get a handle on these slippery issues.

Long traditions, in both ethology and psychology, argue that an animal will tend to move toward stimulus with a positive valence, and away from one with a negative valence (e.g. Garcia 1966; Boyd, Robinson & Fetterman, 2011). As a result, measures like the proportion of moves *to* versus *from* a particular resource, especially relative to the propensities of other participants, can inform us about the relevance and changing value of that resource for that animal (e.g. Johnson & Oswald, 2001). Similarly, the more effort an animal invests toward a particular end, or the stronger its reaction to a diversion from that end, the greater the valence we can assign to it (see Zahavi, 1977). Thus, if an animal persists in its pursuit of a potential mate, despite many obstacles, we can assume that that partner has a high positive valence for that animal. And, if it invests considerable effort in avoiding another individual, that individual can be taken has having a high negative valence. Behaviors can be considered "adaptive", then, when they are consistent with maximizing positive and minimizing negative valence.

Furthermore, we know that if a particular turn of events has a positive valence for a given individual, that animal will tend to act in ways that perpetuate that state (Thorndike, 1898). In contrast, if the valence is negative, the individual is likely to do something to destabilize that system. For example, if having a partner in a particular enterprise (such as grooming or cooperative foraging) has a positive valence, then, other things being equal, animals with partners should tend to remain with them, while animals without should be expected to put effort into altering their solitary state, either by joining or displacing others. In this way, we can learn what is important to the groups that we study. For example, data on reconciliation after aggression suggests that dolphins (Samuels & Flaherty, 2000; Weaver, 2003), like primates (Aureli & de Waal, 2000), value the re-establishment of peaceful relations within their groups.

In some cases, assigning valence can be fairly straightforward. Prey, for example are undoubtedly a valuable commodity, and activity that generally results in their capture can be considered adaptive. High arousal often arises in critical survival contexts, where behaviors related to attack and defense are performed. In dolphins, high arousal actions associated with biting and “hitting with sound” - such as head jerks, jaw claps, and open mouths - are typical of negatively-valenced interactions, while gentle contact or synchrony can be assigned more positive valences (McBride & Hebb, 1948; Tavolga, 1966; Caldwell & Caldwell, 1972; Samuels & Gifford, 1997; see Herzing, this volume). Shifting arousal - such as in the escalation or de-escalation of an engagement, often involving ritualized behaviors that mark the gradations - can also be informative. In primates, for example, an animal can display a relatively low-level yawn threat, or escalate to bristling pilo-erection, or move all the way to outright attack. When a dolphin escalates from a head bob to an “S posture” (Caldwell & Caldwell, 1972; Pryor, 1990) it alters the sensory access its adversary has, by filling more of its visual field (see also Norris & Dohl, 1980). Such changes in behavior and access can thus reveal how much is at stake for the participants in a given engagement.

But, especially in complex social creatures like dolphins, valence is often highly context-dependent (see Smith, 1977; Johnson, 1993), and can accrue to virtually any aspect of a negotiation. That is, social engagement is always situated within a particular “economy”, and what operates as currency within that economy depends on the history of the group as well as its current state. Barrett & Henzi (2006) have outlined, in their discussion of “biological markets”, how the costs of such social commodities can vary with supply and demand (see also Noe & Hammerstein, 1994). In a baboon troop, for example, where animals pay the cost of grooming a mother to gain access to her infant, this cost increases when there are fewer infants in the troop (Henzi & Barrett, 2002). That is, an interested party must groom a lone mother for longer than she would if multiple mother-infant pairs were available. Note that while valences differ for different individuals, it is not necessary to attribute them as invisible “mental states”. Instead, they are observable states of a behavioral system, that can be tracked and analyzed within a given ecology.

Socio-Cognitive Complexity

Social cognition occurs, of course, among all animals that interact. But the way that dolphins are social is different from the way that, for example, fish are social. Certainly, information does flow through a fish school, as they dodge and veer together, rapidly and jointly maintaining coordination. But dolphins organize into more variable sub-groupings, and show greater flexibility in how they interact (e.g. Connor, 2007; Lusseau & Newman, 2004; Norris & Dohl, 1980; Wells, 2003). It is understanding the multiple factors that shape these complex interactions that is the real challenge in dolphin cognitive research (see Johnson, 2010).

De Waal (1986) offers a definition of social complexity that may prove useful here. In it he suggests that a complex society is one in which power is not equal to rank. In many animal societies, rank is synonymous with power - that is, with one’s capacity to acquire or control contested resources. But in de Waal’s “complex” society, lower-ranking animals can band together to out-compete a higher-ranking one. In this sort of system, not only does each individual need to be concerned about its own relationships, - e.g. who it can dominate and who can dominate it - but also about the relationships between others. For example, a high ranking animal needs to be on the alert for coalition-building between subordinates, and low-ranking animals have new interests in courting coalitional support (see Harcourt & de Waal, 1992) Thus, the occurrence of polyadic interactions - such as those involving coalitions or other functional sub-groupings - are hallmarks of complex socio-cognitive systems. Such a polyadic system is more cognitively demanding because it compounds the media that are relevant to monitor and manipulate - both for the animals, and for the researcher (Johnson, 2001, 2010).

In what follows, we will examine social engagements that have been observed, or may be expected, in dolphins, each of which show this polyadic complexity. By working our way through four types of engagement - collaboration, the use of social tools, social attention, and information brokering - we will see how cognitive ecology can be applied to learn more about the social cognition involved. In each case, we will review the embodied media and type of information flow displayed, situate these accounts within their social markets, and discuss the types of complexity that can arise.

Applying Cognitive Ecology to Complex Dolphin Engagements

Tracking Information Flow

Information flow, of the sort described above, can be tracked in a number of ways (see Table 1.). Since information can be defined as “a difference that makes a difference” (Bateson, 1972), our unit of analysis in such a study is always an interaction. That is, when one animal makes a change in its behavior, only if that difference makes a difference in the behavior of the second animal can we observe information flow. These forms of information flow are not specific to dolphins, but should be applicable to most social animals, as long as they are tracked in species-relevant media.

Information Flow Through Social Interaction

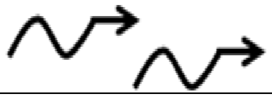
INTERACTION	RELATIONSHIP BETWEEN BEHAVIORS	
Contiguous		Proximal and/or Immediate
Congruent		Synchronous and/or Mimetic
Complementary		“Fit”, Affordance
Ritualized		Next Move in Conventional Sequence

Table 1: Information flow can be tracked through any series of behavioral interactions of these four types or combinations thereof. See text for examples.

Contiguous Interactions

As in many other disciplines, cognitive ecologists rely heavily on the temporal or spatial contiguity of events. Behaviors that co-occur, or immediately follow, are often pertinent to one another. The antiphony of animal calling, the flight of the prey the moment the predator charges, the look toward a conspecific who quickly looks away, are all commonplace examples of this sort of information flow.

Congruent Interactions

In a congruent engagement, an animal witnesses the action of another and repeats it. Thus, if one animal synchronizes with another, or notices another’s behavior and later imitates it, information flow can be assumed between the model and the mimic. Whether tracking pragmatic actions like obtaining food, attentional behavior like head turns, or signal exchanges like call matching, the cognitive ecologist observes the form of the action passing from one body to the next.

*Complementary Interaction*s

Complementary activity (see Hutchins & Johnson, 2009) concerns the notion of “fit” (e.g. Hinde & Simpson, 1975) in which the activity of the second animal can, in some sense, be seen to “fit” with the first. For example, to accomplish mating, one party will tend to assume a certain posture that will make it easier for the other to assume the complementary posture. This evokes the Gibsonian notion of an “affordance” (Gibson, 1979) since, in a complementary interaction, the first action can be seen as affording - i.e. making it easier or more obvious to perform - the second. Complementarity can be simultaneous or sequential, and can be used as a measure of confluent interest and of shared expertise.

*Ritualized Interaction*s

Information flow can also depend on the normative routines within a particular species or group. As ethologists have often described (Tinbergen, 1952; see Smith, 1977; Alcock, 1998), many social engagements, such as courtship, dominance, or play, can be ritualized, either phylogenetically or ontogenetically (e.g. Tomasello, Gust & Frost, 1989). Once socialized within a community, participants can be assumed to be familiar with such routines, and so the performance of the "next move" in a familiar sequence also provides evidence of information flow. Not surprisingly, ritualized behaviors often take advantage of affordances that promote the coupling of action, of the sort described for congruent and complementary interactions, above (see Hutchins & Johnson, 2009).

In fact, it may often be the case that several of the above types of information flow are observable in a given engagement. Plus, especially when multiple parties are involved, relevant events can be separated in time, and links must be carefully substantiated. Collecting large quantities of data helps to both establish regularities, and to recognize violations. Disruptions of information flow, for example, like hesitancy, incongruity, and obstruction, can still be interpretable as "adaptive", as long as one knows enough about habitual behavior, and the valences of the relevant social economy.

Let us now consider how these forms of information flow may operate in complex polyadic engagements in dolphins.

Example 1: Collaboration

Dolphins have been observed to engage in multiple forms of collaboration. By working together to control schools of fish, individuals can feed more successfully than they might if foraging alone (e.g. Gazda, Connor, Edgar & Cox, 2005; Würsig, 1986). Multiple dolphins can circle the prey, causing them to bunch tightly in defense, and then pin that school against the surface or drive it out onto a beach. This limits the prey's escape options and makes it easier for dolphins to consume them. The emergence of this activity is an example of a cognitive adaptation arising through joint participation. Another form of collaboration occurs in coalitions of bottlenose dolphins, in which pairs or trios of adult males compete for, herd, and mate with select females (Connor, 2007). This collaboration can become particularly complex when coalitions band together, forming "super-alliances", to compete with other such alliances (Connor, Heithaus & Barre, 1999).

One important type of information flow that we might expect to see in such engagements is congruency. Synchronous displays, for example, are well-documented between coalitional males (Connor, Smolker & Richards, 1992) and there is some indication that synchronous calls may also be used during coalitional competitions (Herzing, 2015?). Synchrony is a fundamental dolphin achievement, practiced from birth, that likely serves as a frequent medium of information flow (Fellner, Bauer & Harley, 2006; Cusick & Herzing, 2014). While we know, from the lab, that dolphins are also excellent mimics (Taylor & Saayman, 1973; Herman, 2002; Kuczaj & Yeater, 2006), we have little data on how this functions for them in their daily social lives. With cognitive ecology's focus on unfolding processes, it would move beyond questions such whether or how much imitation occurs, to asking how it is used.

One hypothesis might be that imitation can serve as a solicitation - an invitation to join - as during the development of a social alliance (Johnson & Norris, 1994). Research with nonhuman primates reveals that, like humans, they recognize when they are being imitated (Paukner et al., 2005). Furthermore, humans become increasingly prosocial, as a result of being imitated (van Baaren et al., 2004; Carpenter, Uebel & Tomasello, 2013). If this is also the case for dolphins, we should be able to find changes in partner valence based on who duplicates whose behavior.

To investigate the role of congruence in collaboration, one might compare interactions between well-established allies and ones that are not as stable or long-lasting. Might the long-term allies be more prone to coordinate their own actions first (e.g. synchronize their behavior), before taking on a joint effort like facing-off another coalition? Might the more novice collaborators invest more of their off time, outside of inter-alliance conflicts, into imitation? As this would align their attention to one another's bodies, it could provide relevant training for collaborative activities. Cantor & Whitehead (2013) suggest that similarity of behavior - what they call "conformism" - might be more likely within established social clusters than between them, further differentiating those subgroups. Thus, understanding how, when, and with whom imitation is used can also provide insights into the role that social cognition plays in structuring the social context.

If congruency impacts not only on feeding efficiency but also on subgroup stability, then it seems likely that a social market for it could arise. As a result, we might ask if imitative effort is reciprocated. That is, we might predict that inequalities in such reciprocation could provoke shifts in arousal, aggression, or other indicators of partner valence between potential collaborators (see Schino & Aureli, 2009). Game theoretical models have argued that for reciprocity to become a stable strategy, “cheaters” must be identified and sanctioned (Trivers, 1971; Maynard Smith 1982; see also Connor & Norris, 1982). This could be put to an empirical test by doing micro-analyses of solicitations for collaboration, comparing successful and unsuccessful trajectories, as well as any retaliation against errant participants.

Another pertinent aspect of collaboration is the division of labor and the emergence of tactical roles. In bottlenose dolphins off Cedar Key Florida, one animal serves as the “driver”, herding a fish school toward a tight-knit line of collaborators, who serve as a “barrier” against which the fish can be pinned (Gazda et al., 2005). Such collaboration provides an excellent example of how apropos - and in fact necessary - a systems perspective is; the cognitive accomplishment here could not be captured by the behavior of any one participant alone. It is only so long as the barrier dolphins are doing their part that the driver’s actions are meaningful and effective, and vice versa. Clearly, a relevant type of information flow here is complementarity, as the two types of behavior “fit” together, and only together create a functional system.

The two collaborative groups studied by Gadza et al. (2005) also showed distinct differences in the nature and effectiveness of their routines. The more successful group had a long history of being sighted together, suggesting they had had ample opportunity to practice working as a team (see Anderson & Franks, 2001). We could examine how the micro-level behavior of these two groups differs. Are the practices of the more successful cadre more energetically efficient? Expert performance in many domains is characterized by a “smoothness” of execution. In this case, that smoothness could be a function of a particularly tight contiguity between the actions of the participants, as well as a sustained complementarity by the “driver”, and congruency between the “barrier” dolphins.

Similarly, might the less effective group be more prone to ‘bobbling’ their discourse - generating false starts, missed cues, vacillations, etc? Breaks in information flow - violations like hesitancy and incongruency - offer a direct measure of the relative stability and proficiency of a cognitive adaptation. How susceptible a discourse is to disruption is another measure of the robustness of the cognition that accomplishes it (Hutchins, 2006, 2010b). Such disruptions can include errors by participants, and so how experts versus novices recover from such errors is also of interest (Hayashi, Raymond & Sidnell, 2013). Plus, longitudinally, one could explore the development of such expertise, and thus what behaviors, specifically,the animals are learning to do, and the role their co-constrained situation plays in that process.

One way to think about complexity during collaboration is in terms of multi-tasking. Consider participation in a “super-alliance” engagement (Connor, Heithaus & Barre, 1999). Each animal in such an event is simultaneously participating in a coalitional undertaking, an inter-coalitional collaboration, a cross-coalitional competition, and courtship. Plus, inasmuch as these animals live in a fission/fusion society (Connor, et al., 2000) but still need to maintain such relationships, they must also spend time tending to different relationships intermittently, and shifting between roles depending on current subgroup membership, requiring a more protracted form of multi-tasking. A society with a myriad of social roles - each with its distinctive behavioral patterns - is necessarily complex. The number of roles with which an individual shows facility provides one measure of its cognitive flexibility - a hallmark of “intelligent” behavior.

Example 2: Social Tool Use

Another form of role-based, polyadic engagement has been called “social tool” use (Chance & Jolly, 1970; Byrne 1995). In this triadic interaction, one animal, the “user”, engages another as a “tool”, to influence its relationship with a third, the “target”. For example, a user may position a tool between it and an aggressive target, as a “buffer” against the threat. Alternatively, the user may groom a “passport” - a close associate of an attractive target - in order to get closer to the target itself. In the above-described case of adolescent female baboons grooming mothers to gain access to their infants, the mother would be the adolescent user’s “passport” to the target infant. In some schemes, even the recruitment of an ally against a common adversary can be considered a case of social tool use. More typically, however, the term “social tool” implies that the user is, in some way, exploiting the tool, serving primarily its own, rather than their joint, interests.

Because this sort of exploitation is connoted as “insincere” and “Machiavellian”, it has engendered discussions on topics like whether engagement with the tool involves premeditation, or whether the target is necessarily represented as being duped (Byrne & Whiten, 1988) But these are not the key questions facing the cognitive ecologist. Because of its focus on cognitive activity, this approach is more concerned with the complexity of the social configurations that are established in these engagements, and the cognitive demands this puts on participation.

Social tool use arises when the current interaction between the user and the target has a negative valence for the user. If an aggressive target threatens a user, or an attractive target ignores the user, the user will act to destabilize this interaction, to either end or change it. What makes this a polyadic (and thus complex) engagement is that the user accomplishes this by initiating a routine with a third party, the tool. Furthermore, this routine must be incompatible with the current user-target trajectory. Thus, in a "buffer" engagement, in response to a threat from the target, the user initiates an affiliative interaction with a receptive tool, especially one toward which the target is unlikely to aggress. As a result, if the target were to carry through on its threat, this would also impact on the valence of his relationship with the tool. If this poses too high a cost for him, the threat is deescalated, and the cumulative information flow is diverted from an aggressive to an affiliative routine. In the case of a "passport", the initial negative valence for the user of being prevented from approaching a desirable target is mitigated through its friendly interaction with the target. In the above baboon example (Barett & Henzi, 2006), as the mother becomes increasingly relaxed by being groomed, she likewise relaxes her constraints on the user's access to her infant.

While bottlenose dolphins have been proposed as likely candidates in which to find social tool use (Connor & Mann, 2006) - in part, from their embedded, coalitional behavior - there is no study to date that directly investigates exploitative engagements in these animals. The communicative repertoire of dolphins is, of course, quite different from that in primates, but some of the same measures could be used. Certainly the complementarity involved in the solicitation of a partner, the violation of complementarity that constitutes a rejection, along with ritualized behaviors such as petting or threat, should be readily observable. In addition, as discussed above, characterizing an engagement as a social tool also requires evidence of a "conflict of interest" between the user and target.

As discussed in the introduction, "to/from" patterns can be used to identify both shared and conflicting interests . For example, in a study of social tool use in bonobos, researchers compared triadic social tool interactions with interactions between a dyad with a third party nearby (Johnson & Oswald, 2001). In their micro-analysis of these engagements, every time one of the three animals turned its head or body to or from another was recorded. In the dyads, the to/from patterns tended to be identical. That is, if one turned to the other, the other would also turn to it, and if one turned from, the other also turned from. Plus, there was no such contingency between the dyad and the third party. This was interpreted as only the pair having converging interests in their current engagement.

This was in stark contrast to the user and target in the social tool engagements; the user and target had consistently opposite patterns. In a buffer, for example, when the target turned to the user, the user predictably turned away, while if the user turned to the target, the target also turned to the user. This was taken as evidence of conflicting interests. In fact, each type of social tool use studied had its own distinctive conflicting pattern between the user and target. Furthermore, the "insincerity" often attributed to the user regarding its engagement with the tool was reflected in a much less tight contingency between their turns than was seen in the normal dyads. It would be most interesting to conduct such analyses of dolphin interactions to see if similar patterns emerge.

Example 3: Social Attention

The emergence of sophisticated social attention, it is argued, is most likely in species with embedded social networks, who must therefore track and coordinate multiple levels of social engagement (Grove, Pearce & Dunbar, 2012) Many dolphins, such as bottlenose (Wells, Irvine & Scott, 1980; Connor, 2007), spinner (Norris & Dohl 1980) dusky (Würsig, Würsig & Cipriano, 1989) and spotted dolphins (Herzing, 2011) show complex, embedded sociality (see Würsig & Pearson, this volume). Laboratory research reveals that they can make use of human attentional behavior, such as pointing or head turns (Pack & Herman, 2006; although see Tomonaga, Uwano, Ogura & Saito, 2010), and may even direct the attention of others (Xitco, Gory & Kuczaj, 2001, 2004). As such, these dolphins provide a promising model by which to test hypotheses concerning the competitive control, and cooperative sharing, of information through social attention.

The media of information flow in social attention are the behaviors that achieve a change in access to others. In dolphins, this will mostly involve visual and acoustic access. Dolphins' eyes are laterally placed, each having a panoramic view of its own visual hemisphere (e.g. Madsen & Herman, 1980; see Hanke & Erdsack, this volume). Recent research suggests that bottlenose dolphins may show lateralization in their use of one eye over another for certain types of targets (e.g. Yaman et al., 2003; Thieltges et al., 2011), although little is yet known about the role this may play during social engagement. While dolphins have omni-directional hearing, their optimal listening position is with head directed at the target (See Cranford et al., this volume). Their narrow echolocation beam likewise points directly forward, and there is evidence that they can adjust the depth and direction of their "acoustic gaze" (Wisniewska, et al., 2012). They also have a limited binocular visual field directly ahead and below, which is probably involved when approaching prey or conspecifics. As a result, a shift in head orientation toward another animal, especially in conjunction with echolocation, can be a telling act of social attention in these animals (see Gregg, Dudzinski & Smith, 2008).

Information flow might also involve congruency, such as when one animal notices another attending a target and shifts its own attention to that target as well. Such "gaze following" has been observed in a wide variety of nonhuman primates (Tomasello, Call & Hare, 1998), as well as in human-dog interactions (Kaminski, Brauer, Call & Tomasello, 2009). Developmentally, it provides a means of learning about 'what matters' in a shared environment, especially in association with displays of arousal and affect. Dolphins can engage in such shared attention not only by looking at and/or ensonifying the same target, but also by passively "listening in" to the returning echoes of another's echolocation (Xitco & Roitblat, 1996). While this practice affords less information about the target than if they had ensonified it themselves, such "eavesdropping" may provide important social information about the nature and extent of an echolocator's involvement (see Gotz, Verfuss & Schnitzler, 2006).

Situating observations of attention within a social market can help identify the factors that impact on salience in that system. Long ago, Chance (1967) suggested that rank within a monkey troop is, in part, expressed through patterns of social monitoring. He suggested, and later data support, that subordinates would be more likely to monitor dominants than vice versa (e.g. McNelis and Boatright-Horowitz, 1998; see Johnson, 2001 for a review). Presumably, the potential consequences of the dominant's actions are of greater valence to the subordinate, than vice versa, making it more wary and watchful. In many cases however, the distribution of social attention in a group is more complicated than Chance's rank-based model would predict. As discussed above, if two subordinates engage in bonding behavior, which might lead to their coalitional activity against a third dominant animal, that dominant is likely to find such an event highly salient. This would be observable in how he monitors and potentially intervenes in such an engagement (Kummer, 1971; de Waal, 1982; Ferreira, Izar & Lee, 2006). Only by situating this event within the current social economy can such salience be understood.

As ever, the cognition involved here becomes increasingly complex when social attention occurs during polyadic engagement. For example, displays of attention can offer additional options for social tool use. In an "alibi", for instance, the user can direct its own attention to a tool, as a way of avoiding engagement with an unwelcome target (Byrne, 1995; Johnson, 2010). Similarly, when performing what has been called a "distraction display" (Whiten & Byrne, 1988), the user can redirect the attention of the target, through attention-following, to the tool, thus distracting the target from the user or its resources. For example, a subordinate chimpanzee who has discovered a treat that a dominant may be liable to take from him, can make a big display of attending a third party (the tool). Following his gaze, the dominant may then become engaged with the tool, freeing the user to enjoy its treat unmolested (e.g. Goodall, 1986; Hirata & Matsuzawa, 2001). In fact, the sort of to/from analysis, discussed in the above section on social tools, often includes attentional moves to or from another.

Under polyadic conditions, social attention might also become embedded - as when A attends B attending C attending D, etc. It would be interesting to see how many such embeddings are observable in dolphins. To what extent do they modify their behavior based on who is, or is not, present to observe them? Do they suppress behavior that might provoke negative consequences from a particular audience? Might they even display surprise or heightened interest about a phenomenon already known to them, as a means of maintaining the appearance of ignorance? By tracking social attention through a polyadic marketplace, we may begin to find answers to such intriguing questions.

Example 4: Information Brokering

An individual who provides information about third party, or about other events that it witnessed but that its audience did not, is an "information broker". One form of information brokering found in a number of species is alarm calling. The individual making the alarm presumably has access to information about a predator that its audience does not - until they hear the call. Various avian and primate species, for example, have distinct calls associated with particular predators and particular evasive responses (Seyfath, Cheney & Marler, 1980; Evans, Evans & Marler, 1993). But alarm calls are "broadcast behaviors" and, as such, are directed to the group at large, making them more like dyadic interactions, rather than truly polyadic ones. Given the subgroup structure of polyadic engagement, information brokering is liable to become more complex (Lusseau, 2007). This should be particularly true in "fission/fusion" societies, such as those seen in many dolphin groups (see Wursig & Pearson, this volume), where, as individuals alter their subgroup structure, they have differential access to important social information.

One focus of research on information brokering has been in the study of apprenticeship (Vygotsky, 1978; Rogoff, 1990; Russon, 2006). The information brokering between teacher and learner is foundational to human cognition. Unlike in nonhuman primates, there is some evidence that Odontocetes may also engage in teaching. In particular, killer whales (Guinet & Bouvier, 1995) and Atlantic spotted dolphins (Bender, Herzing & Bjorklund, 2009) have been observed to modify their foraging behavior, in the presence of an attentive less-experienced conspecific, in a way that decreases their own foraging efficiency, but makes the relevant moves more salient to the observing animal (see Caro & Hauser, 1992). Presumably, this increase in salience would lead to better reproductions of the behavior by the novice. Thus, through the tutor's congruent demonstration, information on its group's foraging practices flows through this system, helping the novice's performance become more adaptive.

Information brokering also arises in network analyses of dolphin social structure. In these analyses, clusters of association within a dolphin community can be identified, and animals at the intersection of such clusters - i.e. that are relatively common associates of both groups - can be seen as likely "brokers" of information (Lusseau & Newman, 2004; See also Coussi-Korbel & Frageszy, 1995). Such a broker might learn an activity in one group, and then perform it in another group that does not yet practice it. In this setting, we could observe the information flow from one group to the next, as the members of the second group produce either congruent imitations of the broker's activity, or the complementary actions afforded by the broker playing his part. In this way, the two groups and the broker together accomplish the "cultural transmission" of that activity. Evidence continues to accumulate on the occurrence of culturally distinctive practices in cetaceans (e.g. Rendell & Whitehead, 2001; Mann & Sargeant, 2003; Allen, Bejder & Krutzen, 2011) but little is as yet known about how such practices emerge (see Kuczaj & Winship, this volume).

One important way that humans broker information is through practices that "make reference" - that is, that direct the attention of others to current, absent, or even imaginary events. Probably the most species-specific of these practices organizes vocalizations into syntactical combinations of arbitrary symbols. The arbitrariness of human words (there is nothing dog-like about "dog") opens up a huge range of vocal activities to a species like ourselves, who can master a large vocabulary, and rules for producing novel but still informative combinations. But using symbols is not the only way to provide others with access to events displaced in space or time.

Humans also broker information by making "iconic reference". In iconic reference, the relation between a communitative act and its referent is not arbitrary; instead, the act is congruent with its referent. Consider how much a human in a foreign land can communicate, even if she does not speak the language. Using pantomime and vocal mimicry, a human can request and gain information, and even tell a story, effectively recounting events that its audience does not know. Humans also incorporate these skills during normal language use - including mimicking the words, gestures, and facial expressions of others - as a way of passing on information about them. Thus, iconic reference plays a vital role in information brokering in humans.

In experimental work, attempts have been made to determine if dolphins can communicate "arbitrary information" to one another (Bastian, 1968; Zanin, Markov & Sidorva, 1990). In these inconclusive studies, visual or auditory information - such as a flashing light - was provided by the experimenter to one dolphin, who was then required to somehow vocally pass on this information to the other. Due to issues involving training protocols, it was never clear if the dolphins could accomplish this, but their performance was suggestive enough to make further pursuing the question worthwhile.

A more tractable way to address the question of whether dolphins engage in referential communication may be to track a group's use of their "signature whistles". We have long known that many dolphin species produce signatures - individual-specific whistles which they may use to identify themselves to others (Caldwell & Caldwell, 1965; Harley, 2008; Sayigh, Esch, Wells & Janik, 2007; see Lammers & Oswald, this volume). But, while a signature whistle is defined as that contour most often produced by a particular animal - let's call it the "signatore" - a fair number of times this call is also made by others in its group. At times, this appears to be in answer to the signatore producing its own whistle - a practice known as "call matching" (Caldwell & Caldwell, 1968; Janik, 2000; Nakahara & Miyazaki, 2011; Watwood, Tyack & Wells, 2004). But, at other times, signatures are produced in the absence of the signatore (e.g. Watwood, Owen, Tyack & Wells, 2005; *Pers. obsv*.).

While we still know very little about how dolphins use and respond to each other's signatures, research in the lab shows that dolphins can differentiate between familiar vs. unfamiliar signatures (Bruck, 2013; Caldwell & Caldwell, 1972; see Harley, 2008). Surely, in a long-term social group, it is reasonable to assume that the animals have had sufficient exposure to the regularities of signature use, such that the correlations between signatores and their whistles are well established. Consider, too, that these animals are documented to be vocal mimics (Richards, Wolz & Herman, 1984; Reiss & Mc Gowan, 1993). A mimic could make reference to an absent animal by reproducing a portion of the group's common experience of that animal - i.e. its signature. The congruence between the whistle made by the signatore itself, and that made by the non-signatore, would allow information about the signatore to flow in this system. This, then, would also be a case of "iconic reference".

Furthermore, with an interest in discourse, we would also want to track how the audience embodies transformations of such information. Might the call pass from animal to animal to animal? Might the use of its call alter the salience of the signatore, or the readiness of the audience to respond to it, should it re-appear? Perhaps hearing an absent animal's whistle would prompt others to seek it out? And what if the signatore itself heard the call - would that change its likelihood of approaching the caller? In addition, if the animal using the signature alters it in ways that connote it, or that add information besides the signatore's identity - such as who it was with, what mood it was in, what it was doing, etc - would audience members act in ways consistent with having witnessed such events? Non-signatore whistle use could also tell us something about the cognitive accomplishments of the informant, such as tracking who witnessed what, and making strategic use of privileged information. However the dolphins' complicated communication system may operate, using cognitive ecology may give us the best hope for understanding it.

Conclusion

As intriguing as such speculations may be, it is clear that there is much work to be done if we are to gain answers to the sorts of questions posed in this chapter. Fortunately, the technology for making multi-modal recordings of dolphin engagement is more accessible and advanced than ever. It would be low-impact and relatively inexpensive, for example, to equip any of the many facilities currently housing dolphins, with multiple hydrophones and underwater video-cameras. In the wild, habituated groups tolerate audio-video recording by humans swimming with the animals (Herzing, 2011), and new developments in aerial cameras can capture interactions even in non-habituted animals, or in less clear or hospitable seas (Nowacek, 2002). As long as the data that are collected are multi-modal and multi-party, and are analyzed at multiple time scales, from frame-by-frame micro-analysis to long-term history, we can situate events in their social economy. In this way, we can investigate their cognitive ecology, and track information flow through these socio-cognitive systems. Imagine what we might discover!

References

Allen, S. J., Bejder, L., & Krutzen, M. (2011). Why do Indo-Pacific bottlenose dolphins carry conch shells (*Turbinella* sp.) in Shark Bay, Western Australia? *Marine Mammal Science, 27,* 449-454.

Anderson, C., & Franks, N. R. (2001). Teams in animal societies. *Behavioral Ecology, 12*, 534-540.

Au, W. W. L. (1993).*The sonar of dolphins*. New York: Springer-Verlag.
Aureli, F., & de Waal, F. B. M. (2000). *Natural conflict resolution*. Berkeley: University of California Press.

Barrett, L. (2011). *Beyond the brain: How body and environment shape animal and human minds.* Princeton, NJ: Princeton University Press.

Barrett, L., & Henzi, S. P. (2006). Monkeys, markets and minds: Biological markets and primate sociality. In P. M. Kappeler & C. P. van Schaik (Eds.), *Cooperation in primates and humans: Mechanisms and evolution* (pp. 209-232). New York: Springer.

Barrett, L., & Würsig, B. (2014). Why dolphins are not aquatic apes. *Animal Behavior and Cognition 1*(1), 1-18.

Bastian, J. (1968). The transmission of arbitrary environmental information between bottlenose dolphins. In R. G. Busnel (Ed.), *Animal sonar systems* (pp. 803-874). Jouy-en-Josas, France: Laboratoire de Physiologie Acoustique.

Bateson, G. (1972). *Steps to an ecology of mind*. New York: Ballantine.

Bateson, G. (1979). *Mind and nature: A necessary unity*. New York: Dutton.

Bender, C. E., Herzing, D. L., & Bjorklund, D. F. (2009). Evidence of teaching in Atlantic spotted dolphins (*Stennela frontalis*) by mother dolphins foraging in the presence of their calves. *Animal Cognition, 12*: 43-53.

Boyd, R.L., Robinson, M. D., & Fetterman, A. K. (2011). Miller (1944) revisited: Movement times in relation to approach and avoidance conflicts. *Journal of Experimental Social Psychology, 47*, 1192-1197.

Bruck, J. N. (2013). Decades-long social memory in bottlenose dolphins. *Proceedings of the Royal Society, B, 280,* 1-6.

Byrne, R. W. (1995). *The Thinking Ape: Evolutionary origins of intelligence.* Oxford: Oxford University Press.

Byrne, R. W., & Whiten, A. (1988). *Machiavellian intelligence*. Oxford: Oxford University Press.

Byrne, R. W., & Bates, L. A. (2014). Cognition in the wild: Exploring animal minds with observational evidence. *Biological letters, 7,* 619-622.

Caldwell, M. C., & Caldwell D. K. (1965). Individualized whistle contours in bottlenose dolphins (*Tursiops truncatus*). *Nature, 207*, 434-435.

Caldwell, D.K., & Caldwell, M.C. (1972). *The world of the bottlenose dolphin*. Philadelphia, PA: Lippencott.

Cantor, M., & Whitehead, H. (2013).The interplay between social networks and culture. *Philosophical Transactions of the Royal Society, B, 368*, 1-10.

Caro, T. M., & Hauser, M. D. (1992). Is there teaching in nonhuman animals? *Quarterly Review of Biology, 67,* 151-174.
Carpenter, M., Uebel, J., & M. Tomasello, M. (2013). Being mimicked increases prosocial behavior in 18-month-old infants. *Child Development, 84*, 1511-1518.

Chance, M. R. A., & Jolly, C. (1970). *Social groups of monkeys, apes, and men.* New York: Dutton.

Chance, M. R. A. (1967). Attention structure as the basis of primate rank orders. *Man, 2*, 503-518.

Connor, R. C., & Mann, J. (2006). Social cognition in the wild: Machiavellian dolphins? In S. Hurley and M. Nudd (Eds.), *Rational Animals* (pp. 329-367). Cambridge: Oxford University Press.

Connor, R. C., Heithaus, R. M., & Barre, L. M. (1999). Super-alliance of bottlenose dolphins. *Nature, 371*, 571-572.

Connor, R. C., Smolker, R. A., & Richards, A. F. (1992). Two levels of alliance formation among male bottlenose dolphins (*Tursiops* sp.). *Proceedings of the National Academy of Sciences USA, 89*, 987-990.

Connor, R.C. (2007). Complex alliance relationships in bottlenose dolphins and a consideration of selective environments for extreme brain size evolution in mammals. *Phiosophical Transactions of the Royal Society, B, 362,* 587-602.

Connor, R. C., & Norris, K. S. (1982). Are dolphins reciprocal altruists? *The American Naturalist, 119*, 358-374.

Coussi-Korbel, S., & Fragaszy, D. (1995). On the relation between social dynamics and social learning. *Animal Behavior, 50*, 1441–1453.

Cusick, J. A., & Herzing, D. L. (2014). The dynamics of aggression: How individual and group factors affect the long-term interspecific aggression between two sympatric species of dolphin. *Ethology, 120,* 287-303.

de Barbaro, K., Johnson, C. M., & Deak, G. O. (2013). Twelve-month “social revolution” emerges from mother-infant sensorimotor coordination: A longitudinal investigation. *Human Development, 56,* 223-248.

de Waal, F. B. M. (1982). *Chimpanzee politics*. New York: Harper and Row.

de Waal, F. B. M. (1986). Dynamics of social relationships. In B. B. Smuts, et al. (Eds.) *Primate societies* (pp. 421-430), Chicago: University of Chicago Press.

Emery, N. J. (2000). The eyes have it: The neuro-ethology, function and evolution of social gaze. *Neuroscience and Biobehavioral Reviews, 24,* 581-604.

Enfield, N. J., & Levinson, S. C. (2006). *Roots of human sociality: Culture, cognition and interaction*. New York: Berg.

Evans, C. S., Evans, L., & Marler, P. (1993). On the meaning of alarm calls: Functional reference in an avian vocal system. *Animal Behaviour, 46,* 23-38.

Fellner, W., Bauer, G. B., & Harley, H. E. (2006). Cognitive implications of synchrony in dolphins: A review. *Aquatic Mammals, 32*(4), 511-516.

Ferreira, R. G., Izar, P., & Lee, P. C. (2006). Exchange, affiliation and protective interventions in semifree-ranging brown Capuchin monkeys (*Cebus paella*), *American Journal of Primatology, 68,* 765-776.

Forster, D. (2002). Consort turnovers as distributed cognition in Olive baboons: A distributed approach to mind. In M. Bekoff, C. Allen, & G. M. Burghardt (Eds.), *The cognitive animal* (pp. 163-171). Cambridge, MA: The MIT Press.

Garcia, J. (1996). Relation of cue to consequence in avoidance learning. *Foundations of animal behavior: Classic papers with commentaries (pp. 374-375)*. New York: Scientific American.

Gazda, S. K., Connor, R. C., Edgar, R. K., & Cox, F. (2005). Division of labor with role specialization in group hunting bottlenose dolphins (*Tursiops truncatus*) off Cedar key Florida. *Proeedings of the Royal Society of London, B, 227*, 135-140.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflan.

Goodall, J. (1986). *The chimpanzees of Gombe*. Cambridge, MA: Harvard University Press.

Goodwin, C. (2000). Action and embodiment within situated human interaction. *Journal of Pragmatics, 32*, 1489-1522.

Goodwin, C. (2013). The cooperative, transformative organization of human action and knowledge. *Journal of Pragmatics, 46*, 8-23.

Gotz, T., Verfuss, U. K., & Schnitzler, H. U. (2006). Eavesdropping in wild rough-toothed dolphins (*Steno bedanensis*)? *Biology Letters, 2*(1), 5-7.

Gregg, J. D., Dudzinski, K. M., & Smith, H. V. (2008). 3D MASC: A method for estimating relative head angle and spatial distance of dolphins from underwater video footage. *Animal Behaviour, 75,* 1181-1186.

Guinet, C., & Bouvier, J. (1995). Development of intentional stranding techniques in killer whale (*Orcinus orca*) calves at Crozet Archipelago. *Canadian Journal of Zoology, 73*, 27-33.

Harcourt, A. & de Waal, F. B. M. (1992) *Coalitions and alliances in humans and other animals*. New York: Oxford University Press.

Harley, H. E. (2008). Whistle discrimination and categorization by the Atlantic bottlenose dolphin (*Tursiops truncatus*): A review of the signature whistle framework and a perceptual test. *Behavioral Processes*, 77, 243–268.

Harley, H. E. (2013). Consciousness in dolphins? A review of recent evidence. *Journal of Comparative Physiology, 199,* 565-582.

Hayashi, M., Raymond, G., & Sidnell, J. (2013). *Conversational repair and human understanding*. Cambridge, Cambridge University Press.

Henzi, S. P., & Barrett, L. (2002). Infants as a commodity in a baboon market. *Animal Behaviour, 63,* 915-921.

Herzing, D. L. (2011). *Dolphin diaries*. New York: St Martin Press.

Herzing, D. L. (2006). The currency of cognition: Assessing tools, techniques and media for complex behavioral analyses. *Aquatic Mammals, 32*(4), 544-553.

Hinde, R. A., & Simpson, M. J. A. (1975). Qualities of mother-infant relationships in monkeys. CIBA Foundation Symposium. *Parent-infant interaction* (pp. 39-67). Amsterdam: Elsevier.

Hirata, S., & Matsuzawa, T. (2001). Tactics to obtain a hidden food item in chimpanzee pairs (*Pan troglodytes*). *Animal Cognition, 4*, 285-295.

Hutchins, E., & Johnson, C.M. (2009). Modeling the emergence of language as an embodied collective cognitive activity. *Topics in Cognitive Science, 1*: 523-546.

Hutchins, E. (1995a). *Cognition in the wild*. Cambridge, MA: MIT Press.

Hutchins, E. (1995b). How a cockpit remembers its speed. *Cognitive Science, 19*, 265-288.

Hutchins, E. (2001). Distributed cognition. *International Encyclopedia of the Social and Behavioral Sciences*. (pp. 2068-2072). New York: Elsevier Science Ltd.

Hutchins, E. (2006). The distributed cognition perspective on human interaction. In N. J. Enfield & S. C. Levinson (Eds.), *Roots of human sociality: Culture, cognition and interaction* (pp. 375–398). Oxford: Berg Publishers.

Hutchins, E. (2010a). Cognitive Ecology. *Topics in Cognitive Science, 2*(4), 705 - 715.

Hutchins, E. (2010b). Enaction, imagination and insight. In J. Stewart, O. Gapenne & E. A. Di Paolo (Eds.), *Enaction: Toward a new paradigm for cognitive science* (pp: 425-450). Cambridge, MA: MIT Press.

Hutchins, E. (2014). The cultural ecosystem of human cognition. *Philosophical Psychology, 27* (1), 34-50.

Janik, V. M. (2000). Whistle matching in wild bottlenose dolphins (*Tursiops truncatus*). *Science, 289*, 1355–1357.

Johnson, C. M., & Karin-D'Arcy, M. R. (2006). Social attention in primates: A behavioral review. *Aquatic Mammals, 32,* 423-442.

Johnson, C. M., & Norris, K. S. (1994). Social behavior. In K. S. Norris, B. Würsig, R. S. Wells & M. Würsig (Eds.), *The Hawaiian spinner dolphin* (pp. 243-286). Berkeley, CA: University of California Press.

Johnson, C. M. & Oswald T. M. (2001). Distributed cognition in apes. In J.D. Moore & K. Stenning (Eds.), *Proceedings of the Twenty-Third Annual Conference of the Cognitive Science Society* (pp 453-458). University of Edinburgh, Scotland: Human Communication Research Centre.

Johnson, C. M. (1993). Animal communication via coordinated cognitive systems. In P. P. G. Bateson, N. Thompson & P. Klopfer (Eds.), *Perspectives in Ethology, Volume X: Variability in Behavior* (pp. 187-207). New York: Plenum.

Johnson, C. M. (2001). Distributed primate cognition: A review. *Animal Cognition, 3*(4), 167-183.

Johnson, C. M. (2002). The Vygotskian advantage in cognitive modeling: Participation precedes and thus prefigures understanding. *Behavioral and Brain Sciences, 25*, 628-629.

Johnson, C. M. (2010). Observing cognitive complexity in primates and cetaceans. *International Journal of Comparative Psychology, 23*, 587-624.

Kaminski, J., Brauer, J., Call, J., & Tomasello, M. (2009). Domestic dogs are sensitive to a human's perspective. *Behaviour, 146*, 979-998.

King, B. J. (2004). *The dynamic dance: Nonvocal communication in African great apes*. Cambridge, MA: Harvard University Press.

Kuczaj, S. A., & Yeater, D. B. (2006). Dolphin imitation: Who, what, when and why? *Aquatic Mammals, 32(4)*, 413-422.

Kummer, H. (1971). *Primate societies.* Arlington Heights, IL: Harlan Davidson.

Lusseau, D. (2007). Evidence for social role in a dolphin social network. *Evolutionary Ecology, 21,* 357-366.

Lusseau, D., & Newman, M. E. J. (2004). Identifying the role that animals play in their social networks. *Proceedings of the Royal Society, B, 271*, S477-S481.

Madsen, C. J., & Herman, L. M. (1980). Social and ecological correlates of cetacean vision and visual appearance. In L. M. Herman (Ed.), *Cetacean behavior: Mechanisms and functions* (pp. 101-147). New York: Wiley.

Malafouris, L., & Renfrew, C. (2010). *The cognitive life of things: Recasting the boundaries of the mind.* Cambridge: McDonald Institute Monographs.

Mann, J., & Sargeant, B. (2003). Like mother, like calf: the ontogeny of foraging traditions in wild Indian Ocean bottlenose dolphins (*Tursiops* spp.). In D. M. Fragaszy & S. Perry (Eds.), *The biology of traditions: Models and evidence* (pp. 236-266). Cambridge, UK: Cambridge University Press.

Maynard-Smith, J. (1982). *Evolution and the theory of games*. Cambridge, Cambridge University Press.

McBride, A. F., & Hebb, D. O. (1948). Behavior of the captive bottlenose dolphins, *Tursiops truncatus. Journal of Comparative and Physiological Psychology, 41*, 111-123.

McNelis, N. L., & Boatright-Horowitz, S. L. (1998).Social monitoring in a primate group: The relationship between visual attention and hierarchical ranks. *Animal Cognition, 1*(1), 65-69.

Nakahara, F., & Miyazaki, N. (2011). Vocal exchanges of signature whistles in bottlenose dolphins (*Tursiops truncatus*). *Journal of Ethology, 29,* 309-320.

Noe, R., & Hammerstein, P. (1994). Biological markets: Supply and demand determine the effect of partner choice in cooperation, mutualism and mating. *Behavioral Ecology and Sociobiology, 35*, 1-11.

Norris, K. S., & Dohl, T. (1980). The structure and function of cetacean schools. In L. M. Herman (Ed.), *Cetacean behavior: Mechanisms and functions* (pp. 211-262). New York: John Wiley & Sons.

Nowacek, D. (2002). Sequential foraging behaviour of bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, FL. *Behaviour, 139*(9), 1125–1145.

Pack, A. A., & Herman, L. M. (2006). Dolphin social cognition and social attention: Our current understanding. *Aquatic Mammals, 32*, 443-460.

Paukner, A., Anderson, J.R., Borelli, E., Visalberghi, E., & Ferrari, P.F. (2005). Macaques (*Macaca nemestrina*) recognize when they are being imitated. *Biological Letters, 1*(2), 219-222.

Payne, K., Langbauer, Jr., W.R., & Thomas, E. (1986). Infrasonic calls of the Asian elephant (*Elephas maximus*). *Behavioral Ecology and Sociobiology, 18*, 297-301.

Pryor, K. (1990). Non-acoustic communication in small cetaceans: Glance, touch, position, gesture, and bubbles. *NATO ASI Series, 196*, 537-544.

Reiss, D., & Mc Cowan, B. (1993). Spontaneous vocal mimicry and production by bottlenosed dolphins (*Tursiops truncatus*): Evidence for vocal learning. *Journal of Comparative Psychology, 107*, 301-312.

Rendell, L., & Whitehead, H. (2001). Culture in whales and dolphins. *Behavioral and Brain Sciences, 24*, 309-382.

Richards, D. G., Wolz, J. P., & Herman, L. M. (1984). Vocal mimicry of computer-generated sounds and vocal labeling of objects by a bottlenosed dolphin, *Tursiops truncatus*. *Journal of Comparative Psychology, 98*, 10-28.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. Oxford: Oxford University Press.

Rosch, E., Varela, F., & Thompson, E. F. (1991). *The embodied mind.* Cambridge, MA: MIT Press.

Russon, A. E. (2006). Acquisition of complex foraging skills in juvenile and adolescent organutans (*Pongo pygmaeus*): Developmental influences. *Aquatic Mammals, 32*, 500-510.

Russon, A., & Andrews, K. (2011). Orangutan pantomime: Elaborating the message. *Biological Letters, 7, 627-630.*

Samuels, A., & Gifford, T. (1997). A quantitative assessment of dominance relations among bottlenose dolphins. *Marine Mammal Science, 13*, 70–99.

Samuels, A., & Flaherty, C. (2000). Peaceful conflict resolution in the sea? In F. Aureli, & F. B. M. de Waal, (Eds.), *Natural Conflict Resolution* (pp. 229-231). Berkeley, CA: University of California Press.

Sayigh, L. S., Esch, H. C., Wells, R. S., & Janik, V. M. (2007). Facts about signature whistles of bottlenose dolphins (*Tursiops truncatus*). *Animal Behaviour, 74*, 1631–1642.

Schino, G., & Aureli, F. (2009). Reciprocal altruism in primates: Partner choice, cognition and emotions. *Advances in the Study of Behavior, 39*, 45–69.

Seyfarth, R. M., Cheney, D. L., & Marler, P. (1980). Vervet monkey alarm calls: Semantic communication in a free-ranging primate. *Animal Behaviour, 28* (4), 1070–1094.

Smith, W. J. (1977). *The behavior of communicating: An ethological approach*. Cambridge, MA: Harvard University Press.

Tavolga, M.C (1966). Behavior of the bottlenose dolphin (*Tursiops truncatus*): Social interactions in a captive colony. In K. S. Norris (Ed.) *Whales, dolphins and porpoises* (pp. 718-730). Berkeley: University of California Press.

Tayler, C.K., & Saayman G.S. (1973). Imitative behaviour by Indian Ocean bottlenose dolphins (*Tursiops aduncus*) in captivity. *Behaviour, XLVI*: 286-298.

Thieltges, H., Lemasson, A., Kuczaj, S., Boeye, M., & Blois-Heulin, C. (2011). Visual laterality in dolphins when looking at (un)familiar humans. *Animal Cognition, 14*(2), 303-308.

Thorndike, E. L. (1998). Animal intelligence: A study of the associative processes in animals. *Psychological Monographs, 2,* 1-8.

Tinbergen, N. (1952). “Derived” activities: Their causation, biological significance, origin, and emancipation during evolution. *Quarterly Review of Biology, 27*, 1-32.

Tomasello, M., Gust, D., & Frost, G.T. (1989). The development of gestural communication in young chimpanzees: A follow-up. *Primates, 30*, 35–50.

Tomasello, M., Call, J., & Hare, B. (1998). Five primate species follow the visual gaze of conspecifics. *Animal Behaviour, 55*, 1063-1069.

Tomonoga, M., Uwano, Y., Ogura, S. & Saito, T. (2010). Bottlenose dolphins’ (*Turiops truncatus*) theory of mind as demonstrated by responses to their trainers’ attentional state. *International Journal of Comparative Psychology, 23*, 386-400.

Trivers, R. L. (1971). The evolution of reciprocal altruism. *Quarterly Review of Biology, 46,* 35-57.

van Baaren, R. B., Holland, R. W., Kawakami, K., & van Knippenberg, A. (2004). Mimcry and prosocial behavior. *Psychological Science, 15,* 71-74.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Watwood, S. L., Owen, E. C. G., Tyack, P.L., & Wells, R. S. (2005). Signature whistle use by temporarily restrained and free-swimming bottlenose dolphins, *Tursiops truncatus*. *Animal Behaviour, 69*, 1373–1386.

Watwood, S. L., Tyack, P. L., & Wells, R. S. (2004). Whistle sharing in paired male bottlenose dolphins, *Tursiops truncatus*. *Behavioral Ecology and Sociobiology, 55*, 531–543.

Weaver, A. (2003). Conflict and reconciliation in captive bottlenose dolphins, *Tursiops truncatus. Marine Mammal Science, 19*(4), 836-846.

Wells, R. S., Irvine, A. B., & Scott, M. D. (1980). The social ecology of inshore Odontocetes. In L. M. Herman. (Ed.), *Cetacean Behavior* (pp. 263-318). New York: John Wiley & Sons.

Wells, R. S. (2003). Dolphin social complexity: lessons from long-term study and life history. In F. B. M. de Waal, & P.L. Tyack (Eds.), *Animal social complexity: Intelligence, culture, and individualized societies* (pp. 32-56). Cambridge: Harvard University Press.

Whiten, A., & Ham, R. (1992). On the nature and evolution of imitation in the animal kingdom. In P. J. B. Slater, J. S. Rosenblatt, C. Beer & M. Milkinski (Eds.), *Advances in the study of behavior, Vol. 21* (pp. 239-283). New York, Academic Press.

Whiten, A., & Byrne, R. W. (1988). Tactical deception in primates. *Behavioral & Brain Sciences, 11*, 233–273.

Wisniewska, D. M., Johnson, M., Beedholm, K., Wahlberg, M., & Madsen, P. T. (2012). Acoustic gaze adjustments during active target selection in echolocating porpoises. *Journal of Experimental Biology, 215,* 4258-4373.

Würsig, B. (1986). Delphinid foraging strategies. In R. J. Schusterman, J. A. Thomas, & F. G. Wood (Eds.), *Dolphin cognition and behavior* (pp. 347-359). Hillsdale, NJ: Erlbaum Associates.

Xitco, M. J., & Roitblat, H. L. (1996). Object recognition through eavesdropping: Passive echolocation in bottlenose dolphins. *Animal Learning and Behavior, 24*, 355–365.

Xitco, M. J., Jr., Gory, J. D., & Kuczaj II, S. A. (2004). Dolphin pointing is linked to the attentional behavior of a receiver. *Animal Cognition, 7*, 231-238.

Xitco, M. J., Gory, J. D. & Kucjaz, S. A. (2001). Spontaneous pointing by bottlenose dolphins (*Tursiops truncatus). Animal Cognition, 4*: 115-123.

Yaman, S., von Fersen, L., Dehnhardt, G., & Güntürkün, O. (2003). Visual lateralization in the bottlenose dolphin (*Tursiops truncatus*): Evidence for a population asymmetry? *Behavioural Brain Research*, *142*, 109–114.

Zahavai, A. (1977). The testing of a bond. *Animal Behaviour, 25*, 246-247.

Zanin, A. V., Markov, V. I., & Sidorva, I. E. (1990). The ability of bottlenose dolphins, *Tursiops truncatus*, to report arbitrary information. In J. Thomas & R. Katelein (Eds.), *Sensory abilities in cetaceans* (pp. 685-696). New York, Plenum Press.