

Cummins, D.D. (2002) Adaptive Cognitive Mechanisms: Reasoning about Social Norms and Other Minds. In R.Elio (ed.), *Common Sense, Reasoning and Rationality, Vancouver Studies in Cognitive Science*, vol. 11. Oxford: Oxford University Press.

Chapter 7

Introduction

Consider the fundamental question: *What is reasoning for?*

Decades of research in disciplines as diverse as psychology, artificial intelligence, robotics, and philosophy seem to converge on the following answer:

The function of reasoning is to ensure that there is a non-arbitrary relation between the inputs a system receives on the one hand, and its thoughts (inferences) and actions on the other.

This non-arbitrary relation requires reasoning be *constrained* in some way. Without constraints, the reasoning process can take on the unproductive characteristics of a run-away freight train, yielding an explosion of inferences, most of which are irrelevant to the problem at hand. A common solution to this problem is to *allow the reasoner's goals or interests to constrain the inference process by focusing attention on some inputs and some inference paths at the expense of others*. Binding action sequences too tightly to goals, however, can produce a brittleness in the reasoning process that once again leads to unproductive action, as this example of the *Sphex* wasp's nest-building shows:

For example, the Wasp's routine is to bring the paralyzed cricket to the burrow, leave it on the threshold, go inside to see that all is well, emerge, and then drag the cricket in. If the cricket is moved a few inches away while the wasp is inside making her preliminary inspection, the wasp, on emerging from the burrow, will bring the cricket back to the threshold, but not inside, and will then repeat the preparatory procedure of entering the burrow to see that everything is right...The wasp never thinks of pulling the cricket straight in. On one occasion, this procedure

was repeated forty times, always with the same result. (Wooldridge, 1963, p. 82,
as cited in Dennett, 1984, p.11)

Intelligent reasoning must be *flexible*, that is, *capable of opportunistically exploiting variable environmental constraints*, as in this example of orangutan behavior from Byrne & Russon (1998):

Supinah's goal appeared to be using the soap and laundry possessed by camp staff...While she could directly take the goods from the staff by intimidating them (they were afraid of her), they were protected by a guard stationed on the dock to block her access. Her overall strategy to get the soap and laundry required foiling the humans and this entailed two different tactics--bypassing the guard, then taking the goods from the staff. Bypassing the guard meant detouring around him, which meant travelling through water because the end part of the dock where Supinah lurked stood knee-deep in water. Below this part of the dock was a dugout canoe. These orangutans are well-known for cruising down the river in pilfered canoes, but this one was moored and half full of water. Supinah dealt with this situation with two more subroutines--preparing the canoe for use, then riding it past the guard to the raft. Preparing the canoe had two subroutines - freeing it and baling it out...Riding the canoe required re-orienting it relative to the dock and raft, then propelling it alongside the dock towards the raft. Taking soap and laundry from the staff was then easy; Supinah merely hopped onto the raft, staff obligingly shrieked and jumped into the water, abandoning soap and laundry. Supinah immediately set to work washing the clothes...

As this example dramatically illustrates, walking the tightrope between goal-constrained action and opportunistic planning requires the capacity to do deep embedding, that is, *the capacity to form hierarchically embedded goal structures*.

To be intelligent, then, an agent must be capable of opportunistic planning, which typically necessitates the capacity to construct and negotiate hierarchically embedded goals. Further, if one is interested in reasoning as instantiated in biological organisms (as opposed to artificial or normative systems), then one must seriously confront the fact that the mind is a product of evolution.

Cognition and evolution

If you are a materialist, then you are committed (at least implicitly) to the view that

The mind (collection of cognitive functions) is what the brain does.

That is, our cognitive processes are instantiated as neurological processes. And unless you are a creationist, you are also committed to the view that

The brain was shaped by natural selection.

If you accept these two premises, you are also committed to accepting their logical conclusion, namely, that

The mind (collection of cognitive functions) was shaped by natural selection.

If you accept this conclusion (which is clearly entailed by the premises), then reasoning is readily seen as a cognitive adaptation, that is, as a function that was shaped by pressures exerted by the environment. In this paper, I argue that several important cognitive functions were shaped (through natural selection) by the exigencies of the *social* environment. These functions include (a) a *biological predisposition* to rapidly and effectively acquire implicit rules that specify what we are *permitted, obligated, or forbidden* to do within our social groups and (b) a domain-specific embedding function that enables us to effortlessly form hierarchically structured representations of what is socially crucial but essentially hidden from view, namely, *the minds of others*. The implication is that our capacity to form deeply embedded mental representations (and hence deeply embedded goal structures) emerged as an adaptation to the social environment. The pressure to compete and cooperate successfully with conspecifics constituted a crucible that necessitated and

forged this crucial cognitive function.

How natural selection works. Let me begin by providing a brief summary of how natural selection works: Variation exists in the traits of the members of most species, and some of this variation is heritable. Because of their particular heritable attributes, some individuals will be better able to cope with survival pressures than others within the same environmental niche. These individuals will survive better or longer and hence leave more living offspring than others in their species. The differential reproductive success of individuals based on their genetic differences is called *natural selection*. The outcome of this process is that organisms will evolve behavioral or other traits that promote individual reproductive success within a particular environmental niche, which is referred to as *reproductive success* (or fitness), and is defined in terms of *the number of one's offspring that live to reproduce themselves*.

From an evolutionary standpoint, therefore, the fundamental problem that an organism must solve is *maximizing reproductive success*. This problem reduces in turn to solving the problems of acquiring mates, accessing sufficient food to feed oneself and one's progeny, and avoiding or reducing the risk of death due to predation. Many of these problems can be greatly reduced by living in social groups. Social living yields a reduction in predator pressure by improved detection or repulsion of enemies, improved foraging and hunting efficiency, improved defense of limited resources against conspecific intruders, and improved care of offspring through communal feeding and protection.

But there are also costs associated with sociality, including increased competition within the group for food, mates, nest sites, and other limited resources. In most mammalian and avian species, competition and cooperation among conspecifics produces a complex social structure called the *dominance hierarchy*. In functional terms, this means that

Certain individuals have priority of access to resources in competitive situations

(Clutton-Brock & Harvey, 1976).

These individuals are referred to as dominant or higher-ranking, while those who have lower priority of access are called subordinate or lower-ranking. In its most developed form, the dominance hierarchy is transitive, meaning that if A has priority over B, and B has priority over C, then A has priority over C, and so on. The role of dominance is most pronounced in situations characterized by high levels of competition for resources, such as high population density or the onset of breeding season (Clutton-Brock & Harvey, 1976).

In most species, there is a direct relationship between rank and reproductive success, with higher ranking members being less likely to die of predation or starvation (Cheney & Seyfarth, 1990, pp. 33-34), and more likely to leave living offspring (e.g., Bertram, 1976; Bygott, Bertram, & Hanby, 1979; Dewsbury, 1982; Clutton-Brock, 1988; Ellis, 1995; Fedigan, 1983; Hausfater, 1975; McCann, 1981; Nishida, 1983; Robinson, 1982; Silk, 1987; Tutin, 1979; de Waal, 1982; Watts & Stokes, 1971). Among primates, the relationship is even more striking because dominance status is unstable; for this reason, the level of reproductive success achieved by any individual is directly related to the length of time during which the individual is high-ranking (Altmann et al., 1996).

From a cognitive standpoint, a dominance hierarchy is a set of *implicit social norms*. These social norms are reflected in virtually every activity, including who is allowed to sit next to, play with, share food with, groom, or mate with whom (Hall, 1964; Aruguete, 1994). Dominant individuals not only have priority of access to resources, they also typically take on the role of protecting "the social contract", aggressing against those who violate social norms and breaking up disputes between lower-ranking individuals (see, e.g., Boehm, 1992). Indeed, Hall (1964) designated perceived violations of the social code as the single most common cause of aggression in primate groups.

To summarize, living with conspecifics produces a variety of survival pressures that have a direct impact on reproductive success. High-ranking individuals have priority of access to available resources, particularly reproductive opportunities. Maximizing reproductive success, therefore, is intimately connected to maximizing one's rank. Which brings us to the obvious question: Which factors determine dominance rank?

Dominance hierarchies and intelligent reasoning functions. Common wisdom has it that dominance is merely a matter of brawn--biggest wins all. But in point of fact, this is not the case in many species. Among primates, and most notably chimpanzees, *dominance rank does not correlate with size*. Instead, attaining and maintaining a high-ranking position depends on a collection of *cognitive* traits.

First and foremost, one must be capable of *violation detection*; otherwise, one cannot maintain priority of access to resources nor control the behavior of subordinates. One must have the cognitive wherewithall to recognize when a subordinate is violating a social norm. For example, high-ranking individuals often punish violations of social norms as benign as grooming or sharing food with forbidden individuals (de Waal, 1992, pp. 246-249). And for good reason: In order to secure and maintain a high-ranking position, individuals must *form and maintain alliances through reciprocal obligations* (Chapais, 1988 and 1992; Datta, 1983a-b; Goodall, 1986; Harcourt, 1988; Harcourt & Stewart, 1987; Harcourt & de Waal, 1992; Riss & Goodall, 1977; Seyfarth & Cheney, 1984; Smuts, 1985; Uehara, Hiraiwa-Hasegawa, Hosaka, & Hamai, 1994; de Waal, 1989 and 1992). During contests of rank, individuals typically call for help, and *non-kin allies are most likely to supply that help if the individual in question has groomed them, shared food with them, or assisted them in agonistic encounters in the past* (Chapais, 1992; Cheney & Seyfarth, 1990, pp. 67-69; Prud'Homme & Chapais, 1993; Seyfarth, 1976; Seyfarth & Cheney, 1984). These are reciprocal relationships in that the rate of intervention by individual A on behalf of B is

proportional to the rate of intervention of B on behalf of A (de Waal, 1989 and 1992).

Furthermore, there is a preference for forming alliances with high-ranking individuals (Chapais, 1992; Prud'Homme & Chapais, 1993).

All of this would be impossible if one did not have at least an implicit capacity to recognize individuals, to monitor one's dyadic relationships, and to update one's knowledge of them as they shift. But there are even more "hidden" cognitive traits at work here. The most important of these are recognizing (a) what is permitted and what is forbidden given one's rank, (b) what is obligated given one's history with particular individuals, and c) violations of social norms (i.e., cheating). Without a cognitive function that allows one to quickly learn what is *forbidden* and what is *permitted* given one's rank, subordinates risk incurring the wrath of their higher-ranking conspecifics, a situation that can (and does) result in ostracism and even death. Without a cognitive function that allows one to grasp the structure of an *obligation*, fruitful alliances cannot be formed and maintained. Without a *violation detection* function, high-ranking individuals cannot monopolize resources, nor can fruitful alliances be maintained. These, I argue, constitute basic and early emerging cognitive functions in social mammals, including humans.

Social norms and violation detection in human primates. Psychological and philosophical treatments of human reasoning distinguish between deontic (or practical) reasoning and theoretical reasoning. Whenever one reasons about what one is *permitted*, *obligated*, or *forbidden* to do, one is reasoning deontically (Hilpinen, 1971 and 1981; Manktelow & Over, 1991). This type of reasoning is distinct from discursive or theoretical reasoning in which the reasoner is required to determine the epistemic status (truth) of a rule or other description of a state of affairs. When reasoning deontically, one is less concerned with what is true than in choosing a correct or prudent course of action.

When reasoning about deontic rules (social norms), people spontaneously adopt a violation

detection strategy, that is, *they look for cheaters* (Cheng & Holyoak, 1985 and 1989, Cosmides, 1989; Cosmides & Tooby, 1992; Cummins, 1996a-d, 1997a-b, 1998a-b; Manktelow & Over, 1991 and 1995). This extremely cogent and crucial reasoning strategy seems to be triggered almost exclusively by problems with deontic content, particularly permissions, obligations, prohibitions, promises, and warnings.

As a simple example, imagine someone tells you something odd about mutual friend of yours, namely:

If Joan goes to the movies, she cleans her room first (If <p>, then <q>)

Information regarding Joan's recent activities is recorded on cards. One side of the card indicates whether or not she went to the movies, and the other side indicates whether or not she cleaned her room. You are shown four cards with the following information face up:

Movies No Movies Cleaned Room Didn't Clean Room

Which card(s) must be turned over to find out whether or not the statement is true?

The typical answer on truth-testing problems like this is p and q ("Movies" and "Cleaned Room").

Now imagine that Joan is your teenaged daughter, and you expect her to obey the rule mentioned above. *Which card(s) must be turned over to find out whether or not Joan is obeying the rule?*

The typical answer on *deontic* problems like this is p and not-q ("Movies" and "Didn't Clean Room"). In other words, when reasoning about the *truth* of a conditional statement (hypothesis), people spontaneously seek to discover whether the antecedent (p) and the consequent (q) did in fact occur together. When reasoning about obedience to prescriptive rules (*social norms*), they instead spontaneously look for possible cheating. But consider this: In the hypothesis-testing case, had the "Didn't Clean Room" card been turned over and "Movies" appeared on the other side, this would have provided incontrovertible proof that the statement was false. Yet it does not occur to us

to look for potential violations of the statement in the hypothesis-testing case. The need only seems apparent in the deontic case.

The *deontic effect* does not just appear in the reasoning of adults. It has been observed in children as young as three years of age, making it one of the earliest emerging reasoning functions (Cummins, 1996a). Children spontaneously adopt a violation detection strategy when attempting to determine whether or not a social rule is being followed, but not when attempting to determine whether a conditional utterance is true or false. The magnitude of this effect is equivalent to the magnitude found in the adult literature. Furthermore, children also find it easier to recognize instances of cheating than instances that prove a rule false (Harris & Nuñez, 1996).

Even more crucial to my argument is the observation that consideration of relative social rank strongly influences the likelihood that a cheater detection strategy will be evoked. Reasoners are far more likely to look for cheaters *when checking on individuals who are lower ranking than themselves* (65%) than when checking on individuals of equally high (20%), equally low (18%) or higher rank (20%) than themselves (Cummins, 1997b). Social rank had no effect on the likelihood of adopting a violation detection strategy in a lie detection condition. (The percentage "p and not-q" responses ranged from 15% to 18% across the rank manipulations in the lie detection task). Similarly, Mealey and her colleagues found that subjects were far better at remembering low-status cheaters than high-status cheaters or non-cheaters of any rank (Mealey, Daood, & Krage, 1996). Other studies have found that increases in blood pressure associated with anger or frustration in social situations can be eliminated if the individual is given an opportunity to aggress against the person who caused their distress (target), *but only if the target is of lower status than the retaliator*; if the target is of higher status, blood pressure remains at the frustration-induced elevated level (Hokanson, 1961; Hokanson & Shetler; 1961).

These results can be readily understood from the perspective offered here: Violation detection

is a basic cognitive function that facilitates social regulation. It is a crucial function for ensuring that implicit (or explicit) social norms are honored, and, more particularly, that higher-ranking individuals can protect the status quo by regulating the behavior of those over whom they have power or authority.

The selective pressure for thwarting social norms through guile

Conforming to social norms ensures social harmony. But in a social dominance hierarchy, social norms can take on a more insidious purpose--that of preserving high-ranking individuals' privileged access to resources. Low-ranking individuals must choose between conforming to the norms and resigning themselves to a much smaller (and perhaps, entirely inadequate) share of resources, or *thwarting the norms by use of guile*. Violating norms in social dominance hierarchies means acquiring a larger share of resources than one is entitled to by virtue of one's rank, a situation which would immediately provoke cheater detection and punishment among those of higher rank--unless one were clever enough to avoid detection. Such a situation produces enormous pressure to develop--or evolve--a capacity for deception, and this is exactly what the ethology literature shows.

Nature is replete with instances of deception, much of it aimed at avoiding predation (as in the piping plover's broken wing display which lures a would-be predator away from the nest) or *thwarting dominance in order to garner a larger share of resources*.

The following excerpt from Menzel (1974) illustrates the latter point quite dramatically. In this excerpt, Belle, a young female chimpanzee, is the only one shown the location of hidden food on successive trials. Although willing to share the food, Rock (to whom she is subordinate) repeatedly thwarted her by taking all of the food himself as soon as she uncovered it. Belle's subsequent actions were as follows:

Belle, accordingly stopped uncovering the food if Rock was close. She sat on it

until Rock left. Rock, however, soon learned this, and when she sat in one place for more than a few seconds, he came over, shoved her aside, searched her sitting place, and got the food. Belle next stopped going all the way <to the food>. Rock, however, countered by steadily expanding the area of his search through the grass near where Belle had sat. Eventually, Belle sat farther and farther away, waiting until Rock looked in the opposite direction before she moved toward the food at all, and Rock in turn seemed to look away until Belle started to move somewhere. On some occasions Rock started to wander off, only to wheel around suddenly precisely as Belle was about to uncover some food...on a few trials, she actually started off a trial by leading the group in the opposite direction from the food, and then, while Rock was engaged in his search, she doubled back rapidly and got some food.

It is clear that Belle is using whatever cognitive capacity she has at her disposal to elude detection by Rock, and that Rock counters by using whatever cognitive capacity he has at his disposal to thwart her attempts to hide her illicit plans and actions.

But more importantly, *deception can be used more directly to enhance the reproductive success of subordinate individuals*. Recall that high-ranking individuals typically monopolize reproductive opportunities. Often, only the alpha male mates with estrus females, and subordinates who are caught consorting (i.e., cheating) face severe punishment. This doesn't mean, however, that such matings don't occur. They do occur, but surreptitiously. For example, females will suppress their copulation cries when mating with subordinate males, thereby avoiding attracting the attention of dominant individuals, and both parties will attempt to move their clandestine trysts out of line of sight of dominant individuals (Kummer, 1988; de Waal, 1988). Gagneux, Woodruff, & Boesch (1997) report that over 50% of the offspring born to female chimpanzees in their study

group were fathered by males from *other troops*. The females in question had surreptitiously disappeared around the times of their estrus and reappeared a few days later. During these times, they had apparently engaged in clandestine matings.

Deception is used not only to engage in clandestine matings, but to form illicit alliances that enable individuals to move up in rank. Recall that during contests of rank, each contestant calls for support from allies, and contestants are more likely to receive aid from non-kin if they have groomed or shared food with them (see Whiten & Byrne, 1988b for numerous examples.) It is through these illicit exchange of “goods” and services, therefore, that alliances are formed that allow low-ranking individuals to move up in rank.

Deception and the evolution of mental representation. Deceptions are important to researchers interested in the evolution of mind not just because of their impact on reproductive success but because they can be analyzed in terms of the complexity of the *mental representation* they require (Byrne, 1995; Dennett, 1988; Whiten & Byrne, 1988).

Consider, for example, the hawk moth, which flicks open its hind wings in response to looming objects (Byrne, 1995). The spots on its hind wings look strikingly similar to the eyes of a large hawk. The deception is strategic in that it is used only when something is looming at (threatening) the moth. But this sort of “deception” requires no capacity for mental representation.

In contrast, consider a cognitive system that is capable of intentional states such as

"I *believe* (that the berries are ripe)"

or

"I *want* (the ripe berries)"

Such a system is capable of first-order intentional mental states, but cannot reflect on its own mental states nor represent the mental states of others. Most higher-order mammals (e.g., at the

very least, those with a fully developed limbic system and a modicum of neocortex) surely are capable of such states. They behave purposively, display gustatory and other types of preferences, seek mates, defend territory, and so on. Lesioning the nervous system above the midbrain abolishes such purposive behavior, yielding an animal that behaves reflexively toward environmental stimulation. Without the basic motivations provided by these higher neural structures, the animal essentially behaves "reflexively" to environmental stimuli, eating only when food is there rather than seeking it, climbing when placed on a climbable object rather than exploring the environment, etc (xx).

The question becomes more thorny when it comes to higher-orders of intentionality that are reflected in hierarchically embedded mental representations such as

"I *know* (that you *want* (my food cache))".

or

"I *want* (you to *believe* (that I *believe* (the food is in location A)))"

and so on.

Notice that as the *capacity for hierarchical embeddings of mental representations increases, so does the capacity to represent the mental states of others, and concomitantly, so does one's capacity for deception*. An organism that is capable of forming second- or third-order embedded mental representations is also capable of engaging in stunning acts of deception--and of forming complex plans that involve deeply embedded goal structures. Dominating (or controlling) such an organism would constitute a daunting feat, as the interaction between Belle and Rock and the anecdote about Supinah amply illustrate.

Does this mean that other higher-order mammals are capable of hierarchically embedded mental representation? This is a hotly debated topic in animal cognition (see, e.g., Byrne, 1995; Whiten & Byrne, 1988; Bekoff, 1998; Ristau, 1998). As is apparent from AI work on robotics,

the negotiating the physical environment is not without its challenges. But if that environment is also imbued with agents who move of their own volition, are motivated by invisible internal states, and whose behavior must be successfully forecasted if one is to secure opportunities to leave progeny, these pressures enormously favor an adaptation for forming embedded mental representations. For this reason, many researchers have concluded that it was the exigencies of the social environment that forged the evolution of the mind (Cheney & Seyfarth, 1990; Byrne, 1995; Byrne & Whiten, 1988; Cummins, 1998a-c; Tomasello, in press).

The development of mental state attribution skills in childhood. When it comes to forming hierarchically embedded mental representations, humans clearly excel. It is apparent in our language, in our tool making, and in our capacity to represent the mental states of others. But more informative is the development of this capacity over the course of early childhood. In contrast to the early emergence of cheater detection, the capacity for mental state attribution exhibits a more gradual developmental pace, with separate subskills developing at different rates. For this reason, the development of *theory of mind reasoning*, as this type of reasoning is called, is a case where “ontogeny recapitulates phylogeny” is perhaps more than metaphor.

By age 3, children can clearly identify acts of cheating, but identifying lies is another story. Typically, children in this age group fail to take into account a speaker’s knowledge when evaluating utterances, and simply label inaccurate statements as lies. For example, if puppet A watches an event, then lies about it to puppet B, who then innocently passes the inaccurate information on to puppet C, children in this age group will call both A and B liars (Wimmer, Gruber, & Perner, 1984; Strichartz & Burton, 1990). It is not until about the 7th or 8th year life that consideration of what a speaker believed or knew reliably appears in their judgments. (See Haugaard & Reppucci, 1992 and Bussey, 1992 for reviews of this literature.)

Prior to about age 4, children also perform inconsistently on tasks that require attributing

false beliefs to others. In the standard false belief task, children watch while a puppet hides a toy in location A and then leaves. A second puppet then appears, finds the toy, and hides it in location B. The child is then asked where the first puppet left the toy, where the toy is now, and where the first puppet thinks the toy is. Prior to about age 4, children answer the first two questions correctly, yet believe the first puppet thinks the toy is in the current location (location B). Their behavior is typically explained as a failure or inability to attribute false beliefs to others (see Gopnik & Wellman, 1994 and Leslie, 1994 for reviews of this literature.)

What deception and false belief tasks have in common is that they require appreciating the knowledge/belief states of others. In the deception task, puppet A knew one thing, but falsely reported another, but puppet B reported accurately what it knew. In the false belief task, the first puppet can't know that the toy was moved because it didn't see the toy get moved. But on both types of tasks, young children seem to focus almost exclusively on accuracy or current reality. They seemingly failing to take into account what others saw, knew, or believe, particularly if that knowledge or belief may be contrary to fact. Clearly, there is something about creating and/or manipulating representations of the mental states of others that very young children find difficult. That something is probably the ability to construct hierarchically embedded mental representations, representations that allow one to distinguish between what one believes to be true and what others (perhaps falsely) believe to be true.

This pattern of results would suggest that forming hierarchically embedded representations of the mental states of others--a skill at which humans excel compared to other species--emerges later during ontogeny than does cheater detection--a skill we seem to have in common with other mammals. Consistent with this interpretation is the fact that it is not until about ages 5 to 7 that children can reliably perform tasks that require understanding statements that express second-order intentionality such as "John wants his mother to think that..." (Perner & Wimmer, 1985).

Was it the social environment that produced the types of pressure that favored the evolution of this capacity? The direct relationship between dominance, deception, and reproductive success strongly suggests that it was. So is the fact that theory of mind reasoning emerges earlier in later borns than first borns, suggesting that the capacity to mentally represent the mental states of others can serve the very useful purpose of thwarting dominance through guile (Jenkins & Astington, 1996; Lewis, Freeman, Kyriakidou, Maridaki-Kassotaki, & Berridge, 1996; Perner, Ruffman, & Leekam, 1994; Ruffman, Perner, Naito, Parkin, & Clements, 1998).

Summary

Like all social animals, humans live in social environments that exert extraordinary cognitive and socio-emotional pressures. Extracting the social norms that implicitly (or explicitly) regulate our behavior and allow continued group membership is crucially important, as is developing the capacity to read the intentions, desires, and beliefs of others. I propose that our basic cognitive architecture contains functions that enable fast-track learning of the social norms crucial to our survival, facilitate detecting violations of such norms, and a latent capacity for forming hierarchically-embedded mental representations that is triggered through adequate interactions with animate beings, particularly conspecifics. In short, our reasoning architecture is replete with domain-specificity, and the domains in which we as reasoners excel are also those that have a very deep evolutionary history.

References

- Altmann, J., S.C. Alberts, S.A. Haines, J. Dubach, P. Muruth, T. Coote, E., Geffen, D.J. Cheesman, R.A. Mututua, S.N. Saiyalel, R.K. Wayne, R.C. Lacy, & M.W. Bruford (1996). "Behavior Predicts Genetic Structure in a Wild Primate Group", *Proceedings of the National Academy of Sciences*, 93: 5795-5801.
- Arugete, M. (1994). Cognition, tradition, and the explanation of social behavior in non-human primates, [Review of *Social Processes and Mental Abilities in Non-Human Primates*]. *American Journal of Primatology* 33: 71-74.
- Bekoff, M. (1998) Playing with play: What can we learn about cognition, negotiation, and evolution? In D. Dellarosa Cummins and C.A. Allen (eds.) *The Evolution of Mind*, 162-182. New York: Oxford University Press.
- Bertram, B.C.R. (1976). Kin selection in lions and evolution. In P.P.G. Bateson and R.A.Hinde (eds.) *Growing Points in Ethology*, 281-302. Cambridge: Cambridge University Press.
- Boehm, C. (1992). Segmentary "warfare" and the management of conflict: Comparison of East African chimpanzees and patrilineal-patrilocal humans. In F.B.M. de Waal and A.H. Harcourt (eds.) *Coalitions and Alliances in Humans and Non-Human Animals*, 137-174. Oxford: Oxford University Press.
- Bygott, J.D., B.C.R. Bertram, & J.P. Hanby (1979). Male lions in large coalitions gain reproductive advantage. *Nature* 282: 839-841.
- Byrne, R. (1995). *The Thinking Ape: Evolutionary Origins Of Intelligence*. Oxford: Oxford University Press.
- Byrne, R., & A.E. Russon (1998). Learning by imitation: a hierarchical approach. *Behavioral and Brain Sciences*.

- Byrne, Richard, & Andrew Whiten (1988). (eds.) *Machiavellian Intelligence*. Oxford: Oxford University Press.
- Bussey, K. (1992). Children's Lying and Truthfulness: Implications for Children's Testimony. In S.J. Ceci, M.De Simone Leichtman, and M. Putnick (eds.) *Cognitive and Social Factors in Early Deception*, 89-110. Hillsdale, NJ: Erlbaum.
- Chapais, B. (1988). Rank maintenance in female japanese macaques: experimental evidence for social dependency. *Behavior* 104. 41-59.
- Chapais, B. (1992). Role of alliances in the social inheritance of rank among female primates. In A. Harcourt and F.B.M De Waal (eds.) *Cooperation in Contests in Animals and Humans*, 29-60. Oxford: Oxford University Press.
- Cheng, P., & K. Holyoak (1985). Pragmatic reasoning schemas. *Cognitive Psychology* 17:391-416.
- Cheng, P., & K. Holyoak. (1989). On the natural selection of reasoning theories. *Cognition* 33:285-313.
- Cheney, D.L., & R.M. Seyfarth. (1990). *How Monkeys See the World*. Chicago: University of Chicago Press.
- Clutton-Brock, T.H. (1988). Reproductive success. In T.H. Clutton-Brock (ed.) *Reproductive Success*. Chicago: University of Chicago Press.
- Clutton-Brock, T.H., & P.H. Harvey (1976). Evolutionary rules and primate societies. In P.P.G. Bateson & R.A. Hinde (eds.) *Growing Points in Ethology*, 195-238. Cambridge: Cambridge University Press.
- Cosmides, L. (1989). The logic of social exchange: Has natural selection shaped how humans reason? studies with the Wason selection task. *Cognition*, 31: 187-276.
- Cosmides, L., & J. Tooby (1992). Cognitive adaptations for social exchange. In J. Barkow,

- L. Cosmides, and J. Tooby, (eds.) *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*. New York: Oxford University Press.
- Cummins, D. D. (1996a). Evidence of deontic reasoning in 3- and 4-year-olds. *Memory & Cognition* 24: 823-829.
- Cummins, D. D. (1996b). Evidence for the innateness of deontic reasoning. *Mind & Language* 11:160-190.
- Cummins, D.D. (1996c). Dominance hierarchies and the evolution of human reasoning. *Minds & Machines* 6: 463-480.
- Cummins, D. D. (1996d). Human reasoning from an evolutionary perspective. *Proceedings of 18th Annual Meeting of the Cognitive Science Society*, 18: 50-51.
- Cummins, D. D. (1997a). Rationality: biological, psychological, and normative theories. *Cahiers de Psychologie Cognitive (Current Psychology of Cognition)* 16: 78-86.
- Cummins, D. D. (1997b). Cheater detection is modified by social rank. Paper presented at the meetings of the Human Behavior and Evolution Society, University of Arizona, Tucson, June 1997.
- Cummins, D. D. (1998a). Social norms and other minds: the evolutionary roots of higher cognition. In D.D. Cummins & C.A. Allen (eds.) *The Evolution Of Mind*, 30-50. New York: Oxford University Press.
- Cummins, D. D. (1998b) Can humans form hierarchically embedded mental representations? Commentary on R.W. Byrne & A.E. Russon, Learning by imitation: A hierarchical approach. *Behavioral and Brain Sciences*.
- Datta, S.B. (1983a). Relative power and the acquisition of rank. In R.A. Hinde (ed.) *Primate Social Relationships*. Oxford: Blackwell.
- Datta, S.B. (1983b). Relative power and the maintenance of rank. In R.A. Hinde (ed.) *Primate*

- Social Relationships*. Oxford: Blackwell.
- Dennett, Daniel (1984). *Elbow Room*. Cambridge, MA: Bradford/MIT Press.
- Dennett, Daniel (1988). The Intentional Stance in Theory and Practice. In R.W. Byrne & A. White (eds.) *Machiavellian Intelligence*, 180-202. Oxford: Oxford University Press.
- Dewsbury, D.A. (1982). Dominance rank, copulatory behavior and differential reproduction. *Quarterly Review of Biology* 57: 135-159.
- Ellis, L. (1995). Dominance and Reproductive Success Among Nonhuman Animals: A Cross-Species Comparison. *Ethology & Sociobiology* 16: 257-333.
- Fedigan, L. (1983). Dominance and Reproductive Success in Primates. *Yearbook of physical Anthropology* 26: 91-129.
- Gagneux, P., D. S. Woodruff, & C. Boesch (1997). Furtive Mating in Female Chimpanzees. *Nature* 387: 358-369.
- Goodall, Jane (1986). *The Chimpanzees of Gombe*. Cambridge: Belknap Press.
- Gopnik, A., & H.M. Wellman (1994). The Theory Theory. In L.A. Hirshfeld and S.A. Gelman (eds.) *Mapping the Mind: Domain Specificity in Cognition and Culture*. Cambridge: Cambridge University Press.
- Hall, K.R.L. (1964). Aggression in Monkey and Ape Societies. In J. Carthy and F. Ebling (eds.) *The Natural History of Aggression*, 51- 64. London: Academic Press.
- Harcourt, A. H. (1988). Alliances in Contests and Social Intelligence, In R.W. Byrne & A. Whiten (eds.) *Machiavellian Intelligence* 131-152. Oxford: Oxford University Press.
- Harcourt, A.H., & K.J. Stewart (1987). The influence of help in contests on dominance rank in primates: hints from gorillas. *Animal Behaviour* 35: 182-190.
- Harcourt, Andrew H., & Frans B.M. De Waal (eds.) (1992). *Coalitions and Alliances in Humans and Other Animals*. Oxford: Oxford University Press.

- Harris, P., & M. Nuñez (1996). Understanding of Permission Rules by Preschool Children. *Child Development* 67: 1572-1591.
- Haugaard, J., & N.D. Reppucci (1992). Children and the Truth. In S.J. Ceci, M. De Simone Leichtman, and M. Putnick (eds.), *Cognitive and Social Factors in Early Deception*, 29-46. Hillsdale, NJ: Erlbaum.
- Hausfater, G. (1975). Dominance and reproduction in baboons (*Papio Cynocephalus*): A quantitative analysis. *Contributions in Primatology* 7: 1-150.
- Hilpinen, Risto (1971). *Deontic Logic: Introductory and Systematic Readings*. Boston: Reidel/Kluwer.
- Hilpinen, Risto (1981). *New Studies in Deontic Logic*. Boston: Reidel/Kluwer.
- Hokanson, J.E. (1961). The effect of frustration and anxiety on overt aggression. *Journal of Abnormal and Social Psychology* 62: 346- 351.
- Hokanson, J.E., & S. Shetler (1961). The effect of overt aggression on physiological arousal. *Journal of Abnormal and Social Psychology* 63: 446-448.
- Jenkins, J., & J. W. Astington (1996). Cognitive factors and family structure associated with theory of mind development in young children. *Developmental Psychology* 32: 70-78.
- Klem, W.R. (1990). Historical and introductory perspectives on brainstem-mediated behaviors. In W.R. Klemm and R.P. Vertes (eds.) *Brainstem mechanisms of behavior*. New York: Wiley.
- Kummer, H. (1988). Tripartite relations in hamadryas baboons. In R.W. Byrne & A. Whiten (eds.), *Machiavellian Intelligence*, 113-121. Oxford: Oxford University Press.
- Leslie, A. (1994). ToMM, ToBY, and agency: core architecture and domain specificity. In L.A. Hirshfeld and S.A. Gelman (eds.), *Mapping the Mind: Domain Specificity in Cognition and Culture*, 119-148. Cambridge: Cambridge University Press.

- Lewis, C., N. Freeman, C. Kyriakidou, K. Maridaki-Kassotaki, & D. Berridge (1996). Social influences on false belief access: specific contagion or general apprenticeship? *Child Development* 67: 2930-2947.
- Manktelow, K.I., & David Over (1991). Social roles and utilities in reasoning with deontic conditionals. *Cognition* 39: 85-105.
- Manktelow, K.I., & David Over (1995). Deontic Reasoning. In S.E. Newstead & J. St. B. Evans (eds.), *Perspectives On Thinking and Reasoning*. Englewood Cliffs, NJ: Erlbaum.
- McCann, T.S. (1981). Aggression and sexual activity of male southern elephant seals (*Mirounga Leonina*). *Journal of Zoology* 19: 295-310.
- Mealey, L., C. Daood, & M. Krage (1996). Enhanced memory for faces of cheaters. *Ethology and Sociobiology* 17: 119-128.
- Menzel, E.W. (1974). A group of chimpanzees in a 1-acre field: leadership and communication. In A.M. Schrier & F. Stollnitz (eds.), *Behavior of nonhuman primates*, 83-153. New York: Academic Press.
- Nishida, T. (1983). Alpha status and agonistic alliance in wild chimpanzees (*Pan Troglodytes Schweinfurthii*). *Primates* 24:318-336.
- Perner, J., T. Ruthman, & S. R. Leekam (1994). Theory of mind is contagious: you catch it from your sibs. *Child Development* 65: 1228-1238.
- Perner, J., & H. Wimmer (1985). John thinks that Mary thinks that...: Attribution of second-order beliefs by 5-10-year-old children. *Journal of Experimental Child Psychology*. 38: 437-471.
- Prud'homme, J., & B. Chapais (1993). Aggressive interventions and matrilineal dominance relations in semifree-ranging barbary macaques. *Primates*, 34: 271-283.
- Riss, D.C., & Jane Goodall (1977). The recent rise to the alpha-rank in a population of free-

- living chimpanzees. *Folia Primatologica* 27: 134-151.
- Ristau, C. A. (1998) Cognitive ethology: The minds of children and animals. In D. Dellarosa Cummins and C. Allen (eds.) *The Evolution of Mind*, 127-161. New York: Oxford University Press.
- Robinson, J.G. (1982). Intrasexual competition and mate choice in primates. *American Journal of Primatology* 1 (Supplement): 131-144.
- Ruffman, T., J. Perner, M. Naito, L. Parkin, & W.C. Clements (1998). Older (but not younger) siblings facilitate false belief understanding. *Developmental Psychology* 34: 161-174.
- Schmidt, R.F. (1986). Motor systems. In R.F. Schmidt (ed.) *Fundamentals of neurophysiology* (3rd edition). New York: Springer-Verlag.
- Seyfarth, R.M. (1976). Social relationships among adult female monkeys. *Animal Behavior*. 24: 917-938.
- Seyfarth, R.M., & D.L. Cheney (1984). Grooming, alliances, and reciprocal altruism in vervet monkeys. *Nature* 308: 541-543.
- Silk, J.B. (1987). Social behavior in evolutionary perspective. In B.B. Smuts, D.L. Cheney, R.M. Seyfarth, R.W. Wrangham, and T.T. Struhsaker (eds.), *Primate Societies*, 318-329. Chicago: University of Chicago Press.
- Smuts, Barbara (1985). *Sex and Friendship in Baboons*. Hawthorne: Aldine Press.
- Strichartz, A.F., & R. Burton (1990) Lies and the truth: a study of the development of the concept. *Child Development*, 61: 211-220.
- Tomasello, M. (in press). Uniquely primate, uniquely human. *Developmental Science*.
- Tutin, C.E.G. (1979). Mating patterns and reproductive strategies in a community of wild chimpanzees (*Pan Troglodytes Schweinfurtii*). *Behavioral Ecology and Sociobiology* 6: 29-38.

- Uehara, S., M. Hiraiwa-Hasegawa, K. Hosaka, & M. Hamai (1994). The fate of defeated alpha male chimpanzees in relation to their social networks. *Primates* 35: 49-55.
- de Waal, Frans B. M. (1982). *Chimpanzee Politics*. Baltimore: Johns-Hopkins University Press.
- de Waal, F. B. M. (1988). Chimpanzee politics. In R.W. Byrne, & A. Whiten (eds.), *Machiavellian Intelligence*, 122-131. Oxford: Oxford University Press.
- de Waal, F. B. M. (1989). Food sharing and reciprocal obligations among chimpanzees. *Journal of Human Evolution* 18: 433-459.
- de Waal, F. B. M. (1992). Coalitions as part of reciprocal relations in the Arnhem chimpanzee colony. In A.H. Harcourt and F. B. M. de Waal (eds.), *Coalitions and Alliances in Humans and Other Animals*, 233-258. Oxford: Oxford University.
- Watts, C.R., & A.W. Stokes (1971). The social order of turkeys. *Scientific American* 224: 112-118.
- Whiten, A., & R.W. Byrne (1988). The manipulation of attention in primate tactical deception. In R.W. Byrne, & A. Whiten (eds.), *Machiavellian Intelligence*, 211-224. Oxford: Oxford University Press.
- Wimmer, H., S. Gruber, & J. Perner (1984). Young children's conception of lying: Lexical realism--moral subjectivism. *Journal of Experimental Child Psychology*, 37: 1-30.
- Wooldridge, D. (1963). *The Machinery of The Brain..* New York: McGraw-Hill.