

A Cognitive Scientist's Perspective on Knowledge and Reasoning

I am struck by a beautiful section in Steven Pinker's *How the Mind Works* (W.W. Norton & Co., New York and London, 1997: 186-190). Apart from eloquently making the "survivalist" case for the origin of human intelligence, it puts planning and reasoning (together with language) at center stage:

THE COGNITIVE NICHE

Ambrose Bierce's *Devil's Dictionary* defines our species as follows:

Man, n. An animal so lost in rapturous contemplation of what he thinks he is as to overlook what he indubitably ought to be. His chief occupation is extermination of other animals and his own species, which, however, multiplies with such insistent rapidity as to infest the whole habitable earth and Canada.

Homo sapiens sapiens is indeed an unprecedented animal, with many zoologically unique or extreme traits. Humans achieve their goals by complex chains of behavior, assembled on the spot and tailored to the situation. They plan the behavior using cognitive models of the causal structure of the world. They learn these models in their lifetimes and communicate them through language, which allows the knowledge to accumulate within a group and over generations. They manufacture and depend upon many kinds of tools. They exchange goods and favors over long periods of time. Food is transported long distances, processed extensively, stored, and shared. Labor is divided between the sexes. Humans form large, structured coalitions, especially among males, and coalitions wage wars against each other. Humans use fire. Kinship systems are complex and vary with other aspects of their lifestyles. Mating relations are negotiated by kin, often by groups exchanging daughters. Ovulation is concealed, and females may choose to have sex at any time rather than at certain points in the reproductive cycle.

A few of these traits are found among some of the great apes, but to a much lesser degree, and most are not found at all. And humans have rediscovered traits that are rare among primates but found in other animals. They are bipedal. They live longer than other apes, and bear helpless offspring who stay children (that is, sexually immature) for a substantial part of their lives. Hunting is important, and meat a large part of the diet. Males invest in their offspring: they tote children around, protect them against animals and other humans, and give them food. And as *The Devil's Dictionary* points out, humans occupy every ecozone on earth.

Aside from the retooling of the skeleton that gives us upright posture and precision manipulation, what makes us unusual is not our body but our behavior and the mental programs that organize it. In the comic strip *Calvin and Hobbes*, Calvin asks his tiger companion why people are never content with what they have. Hobbes replies, "Are you kidding? Your fingernails are a joke, you've got no fangs, you can't see at night, your pink hides are ridiculous, your reflexes are nil, and you don't even have tails! Of course people aren't content!" But despite these handicaps, humans control the fate of tigers, rather than vice versa. Human evolution is the original revenge of the nerds.

Perhaps recoiling from the image of the pasty-faced, pocket-protected, polyester-clad misfits, theorists on human evolution have looked far and wide for alternative theories. Human ingenuity has been explained away as the by-product of blood vessels in the skull that radiate heat, as a run-away courtship device like the peacock's tail, as a stretching of chimpanzee childhood, and as an escape hatch that saved the species

from the evolutionary dead end of bearing fewer and fewer offspring. Even in theories that acknowledge that intelligence itself was selected for, the causes are badly underpowered in comparison with the effects. In various stories the full human mind sprang into existence to solve narrow problems like chipping tools out of stone, cracking open nuts and bones, throwing rocks at animals, keeping track of toddlers, following herds to scavenge their dead, and maintaining social bonds in a large group.

There are grains of truth in these accounts, but they lack the leverage of good reverse-engineering. Natural selection for success in solving a particular problem tends to fashion an idiot savant like the dead-reckoning ants and stargazing birds [a reference to the discussion a few pages earlier of the Tunesian desert ants that perform path integration, and nestlings of migratory birds that learn the position of the stationary North Star, relative to nearby constellations, by lengthy star-gazing]. We need to know what the more general kinds of intelligence found in our species are good for. This requires a good description of the improbable feats the human mind accomplishes, not just one-word compliments like "flexibility" or "intelligence". That description must come from the study of the modern mind, cognitive science. And because selection is driven by the fate of the whole individual, it is not enough to explain the evolution of a brain in a vat. A good theory has to connect all the parts of the human lifestyle -- all ages, both sexes, anatomy, diet, habitat, and social life. That is, it has to characterize the ecological niche that humans entered.

The only theory that has risen to this challenge comes from John Tooby and the anthropologist Irven DeVore. Tooby and DeVore begin by noting that species evolve at one another's expense. We fantasize about the land of milk and honey, the big rock candy mountain, and tangerine trees with marmelade skies, but real ecosystems are different. Except for fruits (which trick hungry animals into dispersing seeds), virtually every food is the body part of some other organism, which would just as soon keep that part for itself. Organisms evolve defenses against being eaten, and would-be diners evolve weapons to overcome these defenses, prodding the would-be meals to evolve better defenses, and so on, in an evolutionary arms race. These weapons and defenses are genetically based and relatively fixed within the lifetime of the individual; therefore, they change slowly. The balance between eater and eaten develops only over evolutionary time.

Humans, Tooby and DeVore suggest, entered the "cognitive niche". Remember the definition of intelligence from Chapter 2: using knowledge of how things work to attain goals in the face of obstacles. By learning which manipulations achieve which goals, humans have mastered the art of the surprise attack. They use novel, goal-oriented courses of action to overcome the Maginot Line defenses of other organisms, which can respond only over evolutionary time. The manipulations can be novel because human knowledge is not just couched in concrete instructions like "how to catch a rabbit". Humans analyze the world using intuitive theories of objects, forces, paths, places, manners, states, substances, hidden biochemical essences, and, for other animals and people, beliefs and desires. (These intuitive theories are the topic of Chapter 5.) People compose new knowledge and plans by mentally playing out combinatorial interactions among these laws in their mind's eye.

Many theorists have wondered what illiterate foragers do with their capacity for abstract intelligence. The foragers would have better grounds for asking the question about modern couch potatoes. Life for foragers (including our ancestors) is a camping trip that never ends, but without the space blankets, Swiss Army knives, and freeze-dried pasta al pesto. Living by their wits, human groups develop sophisticated technologies and bodies of folk science. All human cultures ever documented have words for the elements of space,

time, motion, speed, mental states, tools, flora, fauna, and weather, and logical connectives (not, and, same, opposite, part-whole, and general-particular). They combine the words into grammatical sentences and use the underlying propositions to reason about invisible entities like diseases, meteorological forces, and absent animals. Mental maps represent the locations of thousands of noteworthy sites, and mental calendars represent nested cycles of weather, animal migrations, and the histories of plants. The anthropologist Louis Liebenberg recounts a typical experience with the !X\~{o} of the central Kalahari Desert:

While tracking down a solitary wildebeest spoor [tracks] of the previous evening !X\~{o} trackers pointed out evidence of trampling which indicated that the animal had slept at that spot. They explained consequently that the spoor leaving the sleeping place had been made early that morning and was therefore relatively fresh. The spoor then followed a straight course, indicating that the animal was on its way to a specific destination. After a while, one tracker started to investigate several sets of footprints in a particular area. He pointed out that these footprints all belonged to the same animal, but were made during the previous days. He explained that the particular area was the feeding ground of that particular wildebeest. Since it was, by that time, about mid-day, it could be expected that the wildebeest may be resting in the shade in the near vicinity.

All foraging peoples manufacture cutters, pounders, containers, cordage, nets, baskets, levers, and spears and other weapons. They use fire, shelters, and medicinal drugs. Their engineering is often ingenious, exploiting poisons, smokeouts, glue traps, gill nets, baited lines, snares, corrals, weirs, camouflaged pits and cliff tops, blowguns, bows and arrows, and kites trailing sticky fishing lines made out of spider silk.

The reward is the ability to crack the safes of many other living things: burrowing animals, plants' underground storage organs, nuts, seeds, bone marrow, tough-skinned animals and plants, birds, fish, shellfish, turtles, poisonous plants (detoxified by peeling, cooking, soaking, parboiling, fermenting, leaching, and other tricks of the kitchen magician), quick animals (which can be ambushed), and large animals (which cooperating groups can drive, exhaust, surround, and dispatch with weapons). Ogden Nash wrote:

The hunter crouches in his blind
'Neath camouflage of every kind,
And conjures up a quacking noise
To lend allure to his decoys,
This grown-up man, with pluck and luck
Is hoping to outwit a duck.

And outwit he does. Humans have the unfair advantage of attacking in this lifetime organisms that can beef up their defenses only in subsequent ones. Many species cannot evolve defenses rapidly enough, even over evolutionary time, to defend themselves against humans. That is why species drop like flies whenever humans first enter an ecosystem. And it's not just the snail darters and snowy owls recently threatened by dams and loggers. The reason you have never seen a living mastodon, saber-tooth, giant woolly rhinoceros, or other fantastic Ice Age animal is that humans apparently extinguished them thousands of years ago.

The cognitive niche embraces many of the zoologically unusual features of our species. Tool manufacture and use is the application of knowledge about causes and effects among objects in the effort to bring about goals. Language is a means of exchanging knowledge. It multiplies the benefit of knowledge, which can not only be used but exchanged for other resources, and lowers its cost, because knowledge can be acquired from the hard-won wisdom, strokes of genius, and trial and error of others rather than only

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from risky exploration and experimentation. Information can be shared at a negligible cost: if I give you a fish, I no longer possess the fish, but if I give you information on how to fish, I still possess the information myself. So an information-exploiting lifestyle goes well with living in groups and pooling expertise -- that is, with culture. Cultures differ from one another because they pool bodies of expertise fashioned in different times and places. A prolonged childhood is an apprenticeship for knowledge and skills. That shifts the balance of payoffs for males towards investing time and resources in their offspring and away from competing over sexual access to females (see Chapter 7). And that in turn makes kinship a concern of both sexes and all ages. Human lives are long to repay the investment of a long apprenticeship. New habitats can be colonized because even if their local conditions differ, they obey the laws of physics and biology that are already within humans' ken, and can be exploited and outsmarted in their turn.