Primates, a cog in cognitive science

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Cognitive science is a human science. Our interest in explaining cognition stems from our own thinking and is directed at explaining this thinking. In the process human cognition often strikes us as one of a kind, perhaps even odd, compared to the rest of nature. But this is only because there are human minds that ask the questions and choose what to compare. The question of what it means to be a thinking human is namely only partly answered by the question "what is *uniquely* human". Most of our functions, and perhaps also experiences, are consequences of the fact that we are primates, mammals, vertebrates, and so on. For this reason the study of human minds is only partly a study of humans. What is needed to understand the human mind is to understand what it is for, i.e. its adaptive context. In order to understand this context, in turn, a comparative and contrastive approach is needed where other minds in other contexts are also observed. Such comparisons can take two forms which can be called "*phylogenetic*" and "*adaptive*".

Cognition is part of an organism and hence follows evolutionary principles. One of these is that evolution is largely a conservative process. As long as adaptations do their job of creating, or at least not hindering reproductive opportunities, little change will occur. This means that the human organism is destined to share most of its features with ancestral forms, and hence with its sister species. In many of its facets human cognition can therefore be expected to be identical to animal, and most of all primate, cognition (Tomasello, 2000). This *phylogenetic* approach can take an evolutionary reconstructive form by contrasting closely related species with species more distantly related. If e.g. chimpanzees and humans share a trait that is absent in the more distantly related gorilla, one can assume that this trait evolved after gorillas and chimpanzees/humans went separate ways in their respective branches, or *clades*, in the tree of adaptations. One can thus roughly pinpoint when a specific trait appeared. When pertaining to cognitive traits this method can be termed *cognitive cladistics*. By taking the respective ecologies of the compared species into consideration one can even infer the reasons for a trait to appear.

But there are also general principles at play which make traits appear over and over again irrespective of ancestral relations. Human thinking has largely evolved as *adaptations* to certain problems that we have in common with other species, even when these are evolutionary distant. Comparison directed at general principles, say the way social structures affect neocortex size in a species (e.g. Dunbar, 1993), often take the form of looking at *convergent* development in species that have similar living conditions. Primate cognition is for example believed to be a response to extractive foraging of resources that are widely distributed in space and time while living in a complex physical and social milieu. This is an ecological heritage that still affects humans and that we share with many other species.

For the above reasons cognitive science should not ignore animal research but embrace it as a valuable tool. The human form is not independent of its adaptive history, and the study of this history is central for understanding the human organism, including its cognitive processes. Animal research, in turn, has often ignored the mental life of animals, especially in behaviourist and ethological paradigms. It was not until the 1980s that cognition was incorporated into ethological research in, for example, de Waal's (1998) studies of "chimpanzee politics", or Seyfarth, Cheney, and Marler's (e.g. 1980) studies of vervet monkey alarm calls (Tomasello, 2000). However, nowadays animal cognition is a buzzword, and new substantial discoveries are made on a monthly basis, stemming both from experiments in captivity and from naturalistic observations. That said, in the typical textbook on animal behaviour a chapter on animal cognition is typically still placed at the very end, as if cognition were the icing on a cake. Using a broad definition of cognition,

this is naturally inappropriate. Most of the processes that we call cognitive, such as perception, learning, and memory, are involved in the most fundamental of behaviours.

When it comes to a narrower definition of cognition, of special interest for cognitive science is the study of mental mediation in animals. This is an area of investigation that long preceded the "cognitive revolution" (see Gärdenfors, chapter 1, this book) in human psychology. Today such mediation would perhaps be called *representation*. In early days it was often called *symbolic* thinking. We can now say with some certainty that primates actively utilize some form of mental representations when making sense of "space, tools, object categories, quantities, causality, and the behavior and perhaps mental lives of conspecifics in interactions involving cooperation, competition, communication, and social learning" (Tomasello, 2000, p. 353). In the remainder of this chapter I will suggest that primate research has spearheaded this newfound, or rather rediscovered (see Mitchell, 1999), interest in animal minds. But it has also contributed to the study of human minds, and in particular the minds of children.

1. Gradualism

When looking at the rest of the animal kingdom for clues about human heritage, one group has attracted a heightened interest. These are the non-human great apes (orangutans, gorillas, bonobos, and chimpanzees). But the reflection in these hairy mirrors has been far from clear or certain. Before Charles Darwin and the 1860s there was little consensus regarding man's place in nature, and after Darwin the order of man's evolutionary relatives was hotly debated. For some time the gorilla, for example, was considered man's closest relative. However, the correct ordering with chimpanzees and bonobos closest to humans was later corroborated with molecular studies (see Kaessmann & Pääbo, 2002). That the great apes group with humans differently depending on what features one investigates is an important point that extends also to the cognitive domain. As long as individuals are seen as conglomerates of competences and features there is not *one* relationship to other species. Sometimes humans are like orangutans, sometimes they are like chimpanzees, and sometimes like dolphins or hyenas. Most of the time, of course, individual humans group with other humans, but even this is dependent on the features that one target and the individuals or groups that one compares.

In addition to anatomical comparisons, primates and their cognition received an early interest due to a Darwinian debate regarding the role of language for thinking (Radick, 2007). Was it at all possible to reason without language, without symbols? Could therefore animals, and notably humans' closest relatives the great apes, think? Were they intelligent and rational? The influential Sanskrit scholar Friedrich Max Müller concluded that the qualitative difference between humans and other apes was language. The reason, he believed, that animals did not have language was that they did not need thought. But others, notably Darwin himself, did not believe in a heavy dependence of thought on language. The amateur primatologist Richard Lynch Garner, in turn, preferred to believe that primates *do* reason, but not because it is possible without language, but because non-human primates have a *kind* of language. Non-human primates live simple lives and therefore have simple thoughts, which are expressed in simple codes (languages). This is gradualism in its essence and was inspired by the way primate brains seem to increment in complexity when going from *prosimians* (e.g. lemurs), to *monkeys* (e.g. macaques), to *apes* (e.g. gibbon), to *great apes* (e.g. orangutans), and to humans. This view also highlights the important idea of how ways of life influence mind complexity. Human brains are large because human ancestors have lived lives that have required as well as allowed such brains. Garner was a true Darwinist and a true cognitivist already in the 1880s.

The gradualist language model still very much exists in a light version in

contemporary cognitive science in the search for symbolic, or representational, processes in animal minds. Note, however, that there at present are a myriad of symbolic and non-symbolic notions of "representation" (Ludvigson, 1998) as well as various meanings of the word "symbolic". Nevertheless, it is expected that animals have *some* forms of inner life (see Gärdenfors, chapter 5, this book). It is also often assumed, perhaps prematurely, that this is limited in respect to that of humans.

2. Pioneers

It has always been clear that animals can be quite clever, and observers of non-human primates saw this extra clearly. In fact, mentalistic interpretations of primate abilities are as old as are human interactions with these animals (Mitchell, 1999). Julien Offray de La Mettrie wrote in 1748: "such is the likeness of the structure and functions of the ape to ours that I have very little doubt that if this animal were properly trained he might at last be taught to pronounce, and consequently to know, a language" (La Mettrie, 1912). The ease by which humans can reflect in primates has also entailed that primatologists are often accused of *anthropomorphism*, which means reading human qualities into animal behaviour only because it appears the same in animals and humans. This critique is often well founded but can also border on "*anthropodenial*", which is to refuse animal achievements apparently for the sake of it.

Besides Garner, and a handful of forays into the mental world of great apes by others (see Mitchell, 1999), Wolfgang Köhler and Robert Yerkes, both in the 1910s, are generally considered the fathers of the cognitive study of primates (Tomasello & Call, 1997). That is, the study of some sort of inner life in animals that goes beyond "mere" stimulus-response associations as it was framed in notably Edward Thorndike's learning theory at the time (Köhler, 1957; see Balkenius & Morén, chapter 2, this book).

Köhler, a German gestalt psychologist, conducted extensive experiments and observations on chimpanzees at the Anthropoid Station in Tenerife. His studies focused on spatial problem-solving, perception, and tool-use. He claimed that the chimpanzees were capable of solving tasks by *insight*, which at the time was believed to be a hallmark of human intelligence. By this he meant that the animals mentally manipulated the solution to a problem before they tried it out, rather than applying hands-on trial and error. The focus on tool-use and problem-solving has had a central place in cognitive primatology ever since. This is not surprising since such research has for the most part been synonymous with intelligence research, and intelligence is often defined as flexible problem-solving abilities.

Yerkes (1916), independently of Köhler, came to similar conclusions regarding the presence of "ideas" in ape minds in his studies of an orangutan. He would later create a leading centre for the study of great ape behaviour and cognition. Even during times of heavy behaviourist influences in America the Yerkes facilities continued their cognitive research. For example, Otto Tinklepaugh (a student of Tolman, see below) developed the *delayed reaction* experiments for macaque monkeys and chimpanzees in the 1930s. These experiments were based on the research of Walter Hunter on rats and dogs two decades earlier. The setup was a simple test of whether an animal could keep a correct hiding place in memory before being allowed to make its choice among a set of containers. That is, they needed to mentally represent the position of the unseen objects in order to succeed. Although both primate species tested by Tinklepaugh performed well, chimpanzees outperformed macaques. These tests were made years before Jean Piaget presented his notion of *object permanence* in children (Vauclair, 1996).

In similar experiments Yerkes and colleagues later investigated whether specific features, such as a colour, could be abstracted irrespectively of spatial cues and held in mind by chimpanzees. They called such selective memory a symbolic process,

corresponding to something like a word. Today we would perhaps call it a *concept*. The "non-spatial delayed response" experiments did indeed show that chimpanzees could make correct choices based on colour concepts (Yerkes, 1945). However, it was far from easy to bring about this competence since the subjects preferred other strategies in their problem solving, mainly spatial ones. It is thus important to remember that the question whether a non-human mind can contain ideas is very different from questions addressing the content of these ideas. Add to this the artificial and contrived situations that most psychological experiments pose which can affect the nature of those ideas in unexpected ways. Yerkes (1945) concluded this, his most cognitivist research, with the following musings: "If symbolic processes occur in chimpanzees, do they exhibit also language, racial tradition, culture? Whatever our reply, we shall contradict respected authorities. This, instead of inhibiting, emboldens me to say 'yes.' But, I hasten to add, all these functional expressions are exceedingly rudimentary, simple, and of limited usefulness by comparison with what we know in ourselves" (p. 189). Even when honouring ape cognitive achievements the comparison to humans is never far away, and the animal is seldom allowed to be a complete and fully equipped organism in its own right.

Despite Yerkes' and others' experimental successes the study of mental complexity suffered during times of behaviourist influence, when instead minimal principles of learning were sought. Interest in comparisons diminished because learning mechanisms were believed to be general and species-independent. When it came to learning there was thus no need to look for gradualism in complexity across related species. Behaviourism is also often accused of banning mentalistic reasoning, but in retrospect it is not possible to draw a sharp line between behaviourist and cognitivist approaches, especially in experimental primatology. In fact, findings from learning theory fuelled a shift to again consider the mental worlds of animals. This was notably due to the works by Edward Tolman (1948; Balkenius & Morén, chapter 2, this book) on *cognitive maps* in animals (and humans) and to Harry Harlow's discovery of the *learning set* phenomenon in macaque monkeys. Learning set formation can be described as "learning how to learn a kind of problem" (Harlow, 1949, p. 53). In a simple *discrimination task* one of several choice items is rewarded, and the subject eventually learns which item it should chose in order to obtain food. Many primates, and non-primates (see Tomasello & Call, 1997), get better at solving discrimination problems the more problems they are subjected to, even when they do not get enough trials per individual problem to learn by trial and error. It seems as if they retain some form of hypothesis from earlier problems that they evaluate on subsequent ones. They can thereby discover the "rules" of the task. With time the feedback from a single trial can be enough to inform the subject about the correct response on following ones. A learning set has been formed. That primates learn across problems how to solve a particular type of problem was by no means a new discovery, but it was described in a paradigm that convinced the behavioural psychologists at the time. It was again clear that non-human minds can contain hypotheses, ideas, plans for action, etc., that could not easily be reduced to stimulus–response associations. The debate, however, is by no means settled and it seems difficult to agree on a proper way of describing animal thought (see e.g. Hurley & Nudds, 2006).

3. Cognitive comeback

It was not until the "cognitive revolution" in psychology that the study of the primate mind, as opposed to behaviour, really became fashionable again in the western scientific world. It surfaced, after a slow start, in the 1970s with names such as Emil Menzel, David and Ann Premack, Allen and Beatrix Gardner, and Duane Rumbaugh among others (Tomasello & Call, 1997). The "rediscovery" of cognition was also coupled with a renewed interest in an evolutionary perspective, but this time a shift occurred in the

purpose of comparing species. In Darwinian times the focus had been on finding continuities between human and animal intelligence. Gradualism itself, and not discrete end products, was the very point of Darwin's theory. But the question of human *uniqueness* received a boost with a renewed interest in cognition, because human minds again seemed very different. This was especially true if one construed cognition as being the mental manipulation of "symbols" as in the early information processing models of cognition (Ludvigson, 1998). At the same time evolutionary theory was too influential to be ignored. Studies of primates as ecological models for prehistoric humans were in the process of transforming anthropology, and the timely advent of sociobiology in the 1970s further promoted evolutionary reasoning. But rather than using evolutionary theory to look for gradualism, cognitive scientists started to construct evolutionary scenarios that would explain the unique path of the human species, highlighting differences rather than similarities. Now the non-human primate, especially the chimpanzee, got a new role, which was that of being "the other": a contrast to highlight what had changed, rather than a model on which to study the factors shaping great ape cognition in general.

This view is perhaps most evident in comparisons between apes and human children. Whether child and ape development are related is today continuously being investigated in *Piagetian* (after Jean Piaget) approaches to primate studies, where questions of e.g. object permanence, spatial and causal relations, object manipulation, inferential reasoning, numerical competence, and analogical reasoning are being studied. Here the question is how much of child development recapitulates ape development, and even species development, and the important points where they diverge. However, there is a problematic idea in these kinds of comparisons, which is that human adult competence is a set ladder which the child climbs. And furthermore, this climb is in the same order as the species has developed. The amount that e.g. a chimpanzee, in turn, can climb indicates the abilities of the last human–chimpanzee common ancestor. *Recapitulationism* of this sort stems from Ernst Haeckel, a naturalist and Darwin contemporary. But unfortunately the idea is grossly simplified. Individual development does not follow predefined ladders (see Björne, chapter 3, this book), and species are likewise not ordered according to competence ladders. Some of the very top positions in Piaget's ladder, for example the ability to count, are found in a variety of animals, close and distant to humans (Vauclair, 1996), which lack "lower levels" of the ladder. Defining competences in the first place is tricky, and relating them to each other in hierarchies is naturally even more so. Abilities tend to criss-cross in ways atypical for ladders. On these grounds the child developmentalist Lev Vygotsky (1999) in 1930 opposed Köhler's claims that chimpanzees are human-like. Instead Vygotsky claimed that human children are chimpanzee-like, but that this is only for a limited period at the end of the first year of life, and furthermore only a surface appearance. While for example chimpanzee problem-solving is independent of language, human problem-solving, even in the first year of life, seems to be intertwined with language according to Vygotsky.

It is not surprising that great apes are the animals that best compare to humans in a Piagetian framework, but this does not necessarily lend credit to the validity of this specific framework. It can rather be an effect of the overall similarities between human and ape cognition, independently of how the ladders are defined. The conglomerate of functions that we call cognition is naturally more similar in similar brains and bodies than in dissimilar brains and bodies. In addition, similar organisms interact with the environment in similar ways, and if experiences affect cognition convergences are expected. Hence the appearance of climbing the *same* ladder. But the "ladders" can already be different from the start, as Vygotsky pointed out, and only appear similar if you look at them in a certain way. Although humans are great apes they are not chimpanzees, bonobos, gorillas, or orangutans.

4. Hunt for competencies

In cognitive science we have ended up with a comparative approach that is often contrastive. As a consequence of focusing on human uniqueness, questions are often limited to what non-humans can or cannot do. That is, research on a purely descriptive level. The questions of what non-humans do instead when they "cannot do", how they do what they do, and how different things that they do affect each other, receives less attention. A focus on *processes* is rare, which is unfortunate if one is aiming for a detailed understanding of cognition. Nevertheless, looking for "human" traits in great apes has boosted primatological research, which in turn has fed back into the study of human cognitive development. This is likely a side effect of the experimental inventiveness needed when studying non-linguistic subjects. Examples of such areas are the *Gallup mirror mark test*, which is a test for self-recognition/awareness (Gallup, 1970), and the notion of *theory of mind* (TOM) (Premack & Woodruff, 1978). The latter is an enormously expansive field and has become a household name in all forms of psychological research. TOM has many definitions but can, in general terms, be said to be the ability to imagine the content of another individual's experiences and knowledge.

A further area with much cross-fertilization between the fields, which is much spurred by the TOM debate, is the study of *imitation* in children and apes. Only recently, after thorough empirical approaches spanning over a decade, has the ape been experimentally confirmed as a true aper (see Whiten et al., 2004). Imitation has proven difficult for motivational reasons, that is, the identity of the model to imitate has been a crucial factor. Also, in apes, causal analysis of a problem seems to have a privileged place before blind, or unreflected, copying. Human children on the other hand seem to trust that a model's actions are important even when these actions do not make any sense. These two approaches set the stage for social learning very differently. But that chimpanzees are indeed sensitive to social learning is clear from their cultural variation in the wild (Whiten et al., 2001). This gives Yerkes right in his bold "yes" above regarding his hunch that, given their representational abilities, chimpanzees should have culture.

A popular method of psychological investigation, mainly in developmental research, is the *matching-to-sample* (MTS) paradigm, which also has its roots in chimpanzee research, namely the classical studies of Nadezhda Ladygina-Kohts (2002). In MTS a subject is required to choose among an array of choice items the one that matches a sample item on a predefined dimension such as colour, or on overall categorical identity. MTS is thus a useful method for studying *categorization* in non-linguistic subjects. What things do they group together at the expense of other things? An important version that had a large and early impact is the *cross-modal MTS* where the sample and matches/non-matches are presented in different sense modalities. To solve such matching it is argued that one needs a multimodal representation of the object that is matched, or "symbolic mediation" between the modalities. An example would be to match the physical feel of an object to a picture of the same object. This was considered a uniquely human attribute before Davenport and Rogers (1970) demonstrated cross-modal matching in chimpanzees and an orangutan.

The types of research that have been mentioned in this chapter are common in the practice of comparing species. However, a fact regarding most cognitive abilities is that there is individual variation, and this variation furthermore often transcends species boundaries. If one needs to relate abilities to species one is therefore forced to talk about the typical. But the typical is descriptive and does not tell us much about the processes behind a competence, "what it really is". An alternative to study the species level is therefore to study cognition as part of an individual, not detached from her in the form of a species average. This approach entails a focus on development, learning, and the potential of the non-human mind.

Raising apes in human environments is a classic way of studying the ape potential to

develop typically "human" abilities. But contrary to researchers' original expectations, the apes that have travelled the human path the furthest, i.e. acquired humanized competencies such as language, are *not* the individuals that have been raised as closely as possible to human children. Early failures due to forcing the apes into the wrong moulds were, for example, attempts to teach chimpanzees a vocal language. Their anatomy does not allow the formation of human words. Supplying the ape with a gestural or printed system has been a necessity. Also, it is not possible to "teach" an ape to become a child. It has to be an integral part of everyday life. The only working approach has thus been to expose apes to everyday human problem situations, but with means to solve these problems that take their ape nature into consideration. The language competent bonobo Kanzi, apt in using visual printed symbols, is a good example in this regard (e.g. Savage-Rumbaugh & Lewin, 1994). Given an early start there is perhaps no limits to the convergences that can occur between apes and children faced with the same environment, given that they are allowed to take different developmental routes.

5. A science of relations

The examples of studies given in this chapter have one thing in common which makes them proper stuff for cognitive science. They are all concerned with *stimulus relations.* Symbolization, mirror self-recognition, imitation, TOM, MTS, etc., are names for acting on relations between experiences. Relations emerge in the cognizing organism as forces that can affect behaviour. The ability to "fill in" relations where they are not apparent, as the relation between a tool and the solution to a problem, is the "insight" of Köhler, or the "ideation" of Yerkes. But some relations seem more difficult than others to invoke. Among these are relations that require an explanation that addresses the question *why* a relation exists. *Why* are A and B related? Some forms of *causality* in the physical domain and *intentions* in the social domain are such relations that are argued to be difficult for apes (Tomasello & Call, 1997). Dynamic relations like these cannot be directly observed but need to be formed as theories about chains of events.

Also with a focus on relations we cannot escape the notion of representation. It has been found that when relations are signified with e.g. a visual symbol, they can be made more explicit. (A symbolic relationship is in itself a relation.) A label on a relation, such as "same", seems to tune attention to relevant aspects of the entities to be compared. Learning an MTS procedure, for example, can be a painstaking endeavour or directly intuitive depending on how the concept of "same" is made salient in the task. Here an explicit symbol seems to help. When relations are represented by e.g. a visual symbol, animals (i.e. chimpanzees) are even able to judge relations between relations, such as in analogical reasoning (e.g. Premack & Premack, 1983) – that is, the judgement that a half-filled glass of milk is to half an apple what a full glass is to a whole apple. It is thus clear why ape-language studies can enlighten theories about language evolution, which is a favourite topic in evolutionary cognitive science.

Cognition is a vast field and as human cognitive science is redefined, away from language-like symbolic processes, the more interest seems also to be invested in the cognitive study of other primates (Tomasello, 2000) and animals. The area of distributed cognition, for example, with its focus on cognition as residing in interaction between an organism and its environment, has been useful for analysing e.g. great ape imitation and communication (for a review, see Johnson, 2001). However, such a focus must not entail shying away, in the manner of traditional ethology and behaviourism, from the hard questions regarding animal inner worlds (see Gärdenfors, chapter 5, this book), subjective experience, etc. These are the issues where cognitive science may probably contribute most to animal sciences. Cognitive science thus has a duty to continue to map the cognition of primates, but with an open mind and with ambition to describe more than

surface similarities and differences. The aim should be not only to understand cognition, but also the individuals whose minds are picked. In this way the living conditions of, for example, primates in captivity can be greatly enriched while we muse over development, variation, and general principles of cognition.

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