Monkeys – a great asset to reveal human cognitive functions

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There is agreement between biologists, psychologists, behavioural scientists, anthropologists as well as philosophers, about the superior performance of the human brain in cognitive and behavioural tasks over that of the brain of any other animal species. The questions that still remain fully open are about the degree of kinship between animals’ and human minds.

Basically, two contrasting positions characterize the contemporary debate [1]. The Darwinian stream of reasoning puts emphasis on the continuity between animals and humans, and, consequently, on the continuity between animal intelligence and human intelligence. The mental capacities of humans are considered to be present also in animals—in less well-developed forms. In contrast, the Cartesian stream of reasoning emphasises the unique and unparalleled capacities of the human mind and behaviour, not found in animal species. In other words, the human brain has novel qualities not present in the animal world.

Tool-making and advanced tool-use are among those behavioural capacities that are extensively explored in animal species and provide key data for this debate. It is generally accepted that apes have excellent abilities to create and use tools [2–6]: in several respects their use of tools can be regarded as a model of human tool use, especially with reference to the pre-hominid and hominid stages of the development of Homo sapiens sapiens [7]. But are apes the only animal species capable of making and using tools?

Recent studies yield new evidence for a negative answer to this question: No, also some non-primate species possess the ability of creating and using artificial tools in their everyday activities. Interestingly, these species are not entirely “clustered” around certain taxa and advanced tool use has been demonstrated, for instance, in birds [8–10] as well as in monkeys. There seems to be here an intriguing parallel with language: protolanguage in the sense of Bickerton [11] (put simply: words but no syntax) appears (at least in latent form) in phylogenetically distantly related species, such as apes, bottle-nosed dolphins, and grey parrots.

Sub-primate monkeys are interesting because it is possible to combine behavioural observations with functional neuroimaging investigations. These techniques will help to reveal the neuronal machinery behind the sensory (visual, visuo-spatial), motor (sequence planning and execution) and cognitive (ideation, planning, motivation, etc.) components of advanced tool use in brains which are often used as a model for human brain studies.

Earlier studies using positron emission tomography in macaques [12–13] have shown that the cortical neuronal populations engaged in simple tool use are, in many respects analogous with those involved in similar tasks in humans [14–15]. These findings lent support to the notion that sub-primate monkeys can be adept in tool use, and showed elegantly the usefulness of a functional neuroimaging technique in the study of the neuronal processes underlying tool use in behaving monkeys. A paper in this issue of NeuroReport [16] opens a new vista into this field. Obayashi et al. document how the brain of a macaque monkey activated during a complex tool-combination task, and clearly show that the activation pattern is in many respects similar to that found in the human brain in similar tasks.

These studies can, therefore, provide a basis for the analysis of the neuronal machinery underlying complex and intelligent behaviours that are highly developed in humans but can also be studied in non-primate model animals such as macaques. These early studies have so far revealed that there are no fundamental differences between the macaque, the ape and the human brain in many respects: at first sight, similar neuronal macro-networks are engaged in the brain of these species during complex and innovative tool use.

What should come now, is the fine analysis of visualised neuronal operations and their behavioural correlates, in order to understand what mental strategies are used by monkeys, apes and humans, and to what extent are these mental strategies in different species analogous to, or homologous with, each other. Let us exemplify this issue with a crucial point, which would contribute to a better understanding of the evolution of human intelligence.

In order to use tools in goal-directed ways, actions have to be carried out in serial order, either involving hierarchies or not. The capacity of different species to learn and perform sequences sheds further light on the problem [17]. Learning of fixed sequences can be studied by the serial ordering of visual stimuli, for example [18]. The task is to learn the sequence of circles of different size. These stimuli can be presented either as ‘monotonic’ or as ‘non-monotonic’ lists, the former term referring to a monotonously ascending or descending sequence in size. Japanese monkeys, chimpanzees and humans can all master the task, but apparently they use different strategies. Humans always plan ahead: they perform a ‘collective search’ on the task, and then execute the plan whether the list is monotonic or not. Chimpanzees use the collective search on the monotonic
task only, and monkeys rely always on a serial search without planning. Thus, here, monkeys seem limited in their capacity to handle sequences (although this is not so in different tasks). They, like primates, seem to be able to represent the ordinal position of items in different lists [19]. Some sequences result from the linear encoding of hierarchies and here humans appear to have a strong advantage. Observations on the African mountain gorilla indicate that although they can observationally learn a strategy to remove indigestible material from the plant, and that this strategy seems to have a hierarchical structure, the complexity of the hierarchy is nonetheless limited [20]. When apes (common chimpanzees, bonobos) and human children are let to spontaneously manipulate objects, only 8% of the primates’ sequence routines showed a sign of hierarchy [21–23]. Active serial ordering strategies can be investigated by the method of nesting cups, which is a task to combine cups that can be nested into one another, using the alternative strategies of pairing, the pot and the subassembly methods. Capuchin monkeys, apes and human children performed differently on the task. Although the subassembly strategy was demonstrated to them, only children got to use it as their predominant strategy [24]. There seems to be an evolutionary trend toward increasing competence to handle hierarchies in general [25]. Not surprisingly, the latter investigation also hints at a possible connection between performing hierarchical actions and linguistic competence (reviewed by [17]). Broca’s aphasic patients seem to have serious problems with sequential learning. Training such patients on non-linguistic hierarchical tasks improves their linguistic competence. Among others, these facts also indicate the close and intricate relatedness of two indispensable components of both complex and innovative tool use and language generation: the ability of sequential task performance and the capacity of handling hierarchies.

On our progress towards explaining these essential questions about the evolution of human intelligence, the study of monkey with behavioural tests in combination with functional neuroimaging techniques is a very promising asset.

REFERENCES


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