ADDRESS BY DOCTOR JOËL FAGOT
RECIPIENT OF THE INTERNATIONAL PRIZE 2017 OF FYSSEN FOUNDATION

Primate cognition

Dear President of the Fyssen Foundation,
Dear Members of the Board of Directors,
Dear Members of the Scientific Council,
Dear Director-General of the Fyssen Foundation
Dear Colleagues,
Dear Friends,
Ladies and Gentlemen,

This award is a wonderful recognition of my scientific activity, and I feel particularly honored to receive it today. I am thankful to the members of the Scientific Council for having chosen me as a laureate in 2017. I am also thankful to Professor Stanislas Dehaene for recommending my name as a potential laureate.

I will present here in a few minutes my scientific background and some of my main results. Before all, I would like to emphasize that Science is a collaborative process, and that nothing would have been possible without the essential contribution of all my students and collaborators. I will not be able to cite the name of every collaborator during this speech, but I want to thank all of them for their respective contributions. I want to acknowledge here the role played by the CNRS in my research. The CNRS has always been a support for my research. I have also a thought for my family members, namely Fabienne, and my two children, Julie and Jérémie. I want to thank them for their comprehension and supports.

The scientific question

My first exposure to non-human primates dates back from 1984, when I was a young student looking for internships. At that time, I had the great chance to get an internship at the primate station in Rousset-sur-Arc, under the supervision of Jacques Vauclair who will later become my Phd advisor. This first exposure to non-human primates had a major impact on my scientific career. On the one hand, I quickly realized that non-human primates have complex social and nonsocial behaviors, suggesting that they have a particularly rich mental world. On the other hand, these animals do not have our language, and their representations of the word must therefore be very different from ours. My career has been entirely devoted to the understanding of this cognition “without language”, and to the comparison of the human and non-human primate cognitive systems.

The paradigm

From a theoretical standpoint, I had an initial training in Cognitive Psychology, and have therefore chosen to study primate cognition by adopting the principles and concepts of Cognitive Psychology. Thus, my work is based on the idea that cognition can be understand as as a chain of cognitive processes including perception, attention, short- and long-term memory, as well as categorization, and reasoning. In my laboratory, I have explored all these processes in a comparative perspective.

The methods

Regarding the methods, I have always been convinced that the behavior of animals provides the best and most immediate information on their cognition. I have thus developed a research program in which I inferred primate cognition from the study of their behaviors. In the late eighties, I began to use computers to test baboons in behavioral studies. Use of computers allowed procedures based mental chronometry which were new at that time in comparative studies.

Researchers working with animals must be also concerned by animal welfare. I have thus recently imagined a new type of laboratory improving animal welfare during cognitive studies. In my current laboratory, the non-human primates (baboons) live in their social groups and can interact freely with computers presented *ad-libitum*. Each baboon is identified by a microchip, and the test program recognizes the subject when it enters an experimental box. The computer can therefore display an experimental task to the subject which depends on the identity and level of performance of the baboon. The major advantage of this innovative procedure is that we no longer must capture the primates for the research. In addition, the automation of the laboratory, which is running 24 hours a day, allows the collection of a considerable number of trials in our cognitive tasks (about 30 000 trials recorded/day). Such large databases provide accurate and detailed information on primate cognition, and on the different variables that affect cognitive performance.

Numerous similarities with humans

We have conducted dozens of experiments in my laboratory to study the mechanisms of perception, attention, memory, categorization and reasoning in baboons. Some of these works showed remarkable similarities with humans. Others show remarkable differences.

With my colleague Robert Cook from Tufts University, I run an experiment aimed at studying long-term memory storage in baboons. We presented pictures on the screen, and trained the baboons to associate one response (binary choice) to each image. The test design increased progressively the number of images to be learned. The baboons could learn and remember up to 6000 different images in this task. Baboons have therefore impressive long-term memory capabilities. This experiment was subsequently replicated in a human by an American colleague and the two studies showed remarkably similar results. Thus, the two species memorized approximately the same number of images and had similar rates of forgetting. Also, our study revealed human-like primacy and recency effects in baboons. All these results suggest that the long-term memory system is phylogenetically ancient, and shares many similarities in humans and baboons.

Let me present a second study that illustrates amazing similarities in cognitive processing between humans and baboons. It was conducted with Dr. J. Grainger, Johannes Ziegler and other colleagues from the laboratory. In this study, I trained baboons to discriminate four-letter real words from four-letter non-words. After thousands of training trials, the baboons could sort correctly these two kinds of stimuli in two categories. They could even do so correctly at the first presentation of words that they had never seen before. In this kind of tasks, humans typically detect the presence of frequent bigrams or trigrams in the vocabulary, and give their word vs. non-word responses on that basis. Deep learning models revealed that the baboons used a human-like strategy in this task. Thus, baboons also based their responses on the presence of frequent bigrams or trigrams that are distinctive characteristics of words. We also found that the baboons are, like humans, sensitive to the orthographic distance between words and non-words. We conclude from this study that this type of treatment requiring the detection of statistical regularities within strings of letters is also shared by humans and baboons.

Significant cognitive differences with humans

All these similarities should not mislead us. Monkeys do no systematically use the same strategies as us, and our experiments often reveal important differences between humans and baboons. Let me illustrate this type of differences with the following study.

In this study, the subject firstly saw two stimuli which are displayed on the left of the screen, and had to touch one pre-defined shape in this display. A second screen is then presented, with two stimuli on the right, and the subject must select another predefined stimulus. Two different cognitive strategies are possible in this task. A first strategy is to associate each stimulus to its position on the screen. This is an “object-centered” mode of encoding. The second strategy is to encode the relation between the two stimuli that they must touch. The baboons used the first “object-centered” strategy, and therefore encoded the position of the objects in priority. Because of this strategy, they became unable to respond correctly when the two stimuli were shifted. By contrast, humans encoded in priority the relation between these two elements, and therefore continued to solve the task when their positions were shifted. This experiment reveals one of the many cognitive biases of the baboons: The baboons process in priority the properties of the objects at the expense of more abstract relational properties between objects. Humans give more importance to relational information in the same task, in comparison to baboons.

Abstract thought

Are baboons completely unable to develop an abstract or relational thought? We have conducted dozens of experiments in this field and the answer is that they can also show advanced capacities for abstract reasoning.

To investigate abstract thinking, I have tested baboons with the relational matching task which is a standard test to study the emergence of analogical reasoning in children. Each trial involved two phases in this task. In the first phase, a pair of objects is presented and the baboons must memorize if these two objects are identical or different. In the second phase, the baboons perceive two other pairs of objects, composed of other stimuli, and the baboons must touch the stimulus pair showing the same (same or different) relation as the initial sample pair. Thus, to solve this task, the monkey must process the relation between relations (second-order relational processing). We have shown that baboons can learn this task. Not every baboon can learn it, but some do after thousands of training trials. After training, the baboon can also generalize its behavior to novel stimuli never seen before, suggesting some flexibility in the strategies they have learned.

To summarize, these studies showing similarities and differences with humans define the extents and the limits of the cognitive system of non-human primates. Moreover, this comparative approach also reveals some of the properties of human cognition, that would be undetectable otherwise. For example, demonstration of shared functions in humans and non-human animals allow us to conclude that language is probably not essential for these functions in humans.

On the evolution of language

All these studies also bring important information on the evolution of the cognitive systems. Let me illustrate that last point by focusing on the emergence of language. The emergence of language is probably one of the most debated topic in Science. There are many theories on language evolution, and most of them share the idea that language appeared suddenly because of a major and sudden biological or cognitive change in modern humans.

Philip Lieberman's theory on the descent of the larynx is probably a case study in this context. In the late sixties, Philip Lieberman and colleagues hypothesized that non-human primates are anatomically unable to produce the sounds of speech due to a too high larynx. In humans, the larynx would have descended in the vocal tract approximately 100,000 years ago, allowing the production of the sounds of speech. With Louis-Jean Boe from the Gipsa-Lab in Grenoble, and other colleagues with exceptional scientific skills in the domain of acoustics and speech processing, we recorded more than 2000 spontaneous vocalizations in baboons. Our analyzes of these recordings focused on the presence of formants, in other words, on the acoustic signatures that characterize vowels in speech. Our study combined an investigation of the anatomy of the baboon's vocal tract, a modeling of their vocal tract's acoustic potential, and acoustic analyzes of the vocalizations. We found that the baboon can produce at least five distinctive vowel-like sounds. Interestingly, these five sounds cover a large portion of the baboon's vocal spaces, and were not restricted to the central "schwa" (as expected by the descent of larynx theory). All these data invalidate Philip Lieberman's hypothesis of an anatomical incapacity in non-human primates to produce the sounds of speech. They rather support the idea that the baboons use a vowel proto-system that might be a precursor of speech.

There are other precursors of language than the ability to produce the sounds of speech. We have recently studied some of them in baboons using cognitive tasks. These studies were conducted with Raphaelle Malassis, Arnaud Rey, and Stanislas Dehaene. Our studies used serial response time tasks, requiring the subjects to simply follow a dot that moves in sequence on the screen. With such tasks, we can expose the subjects to sequences sharing some of the properties of the language. By manipulating the sequences, we can therefore verify how the monkeys behave when these properties are violated.

We know from the work of Jenny Saffran that children process the transitional probabilities among words to segment the flow of speech. Using the serial response time task with baboons, we found that the monkeys are also sensitive to transitional probabilities in sequences. Another important phenomenon for language is the detection of long-distance associations. To understand the sentence "The dog in this house barks", for instance, we need to detect the long-distance association between the subject "(dog") and the verb ("barks"), despite intervening ("in this house") words. We have also recently found that the baboons can also learn non-adjacent associations within sequences. A third property of human language is its hierarchical organization. In the laboratory, we have also recently found that monkeys process correctly mirror-image sequences which have a hierarchical organization. However, our works also highlight cognitive limitations in baboons. In another recent study, we presented humans and baboons with long 9-dot sequences composed of three sub-sequences of three dots each (or triplets). Comparing the treatment of these sequences in humans and baboons, we discovered that humans treat the full sequence whereas baboons limit their processing at the level of the triplets. This difference is probably due to working memory limitations in baboons.

These results, and the many others collected in our laboratory, allow three majors conclusions. My first conclusion is that the hypothesis of evolutionary continuity seems the most reasonable one, and the most supported by the data collected so far in my laboratory. My second conclusion is based on the idea that the shared mechanisms in baboons and humans did not originally serve the language function, because the baboon does not have our language. I therefore conclude that most of these functions serving language in humans were exapted, and that their functions have been reassigned in humans for serving the language function. My last conclusion will refer to the fact that the baboons are rarely as efficient as humans in our tasks. One may wonder what would happen if we could equip the baboons with a cognitive routine allowing recursive thinking (i.e., Hauser, Fitch and Chomsky, 2002), or if they were suddenly given a low larynx (i.e., Lieberman et al., 1969). Would they have in that case all the cognitive resources necessary for the emergence of a language? I do not think so. This remark suggests that the emergence of language has certainly also been prepared by a general expansion of cognitive functions in the phylogeny.

To conclude

I believe that one important contribution of my works has been to introduce a change in the experimental procedures in my scientific domain. One reason of satisfaction is that the protocols we have developed in my laboratory begin to be used in other domains of science, especially in Neurosciences. In a more theoretical perspective, theories on the evolution of intelligence and language focused mostly on discontinuities between humans and the other animals when I started my career more than 30 years ago. Another reason of satisfaction is that my experimental works have favored more continuous views on the evolution of intelligence within the primate order. Please allow me to interpret this prize as an encouragement to continue this work that you found interesting.

Again, I thank you for this wonderful prize, and thank you all for your attention.

Joël Fagot