IMAGES AND REASONING

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Introductory Remarks

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This interdisciplinary book aims to raise the question of the possible non-linguistic aspects of reasoning. It is based on the symposium "Images, reason and reasoning" held in Paris on March 15th 2004 and co-organized by Keio University of Tokyo and the Ecole Normale Supérieure of Paris. Within the framework of cognitive science, the computational theory of mind, views cognition as a symbol processing system. It has been argued (Fodor, 1975) that this conception requires the use of a language of thought. Thus, in this perspective, the cognitive processes, in particular reasoning, take place in such a language. Besides, from the perspective of logic, reasoning and inferences are modelled as relations between sentences. Both perspectives have lead either to focusing on the only linguistic aspects of reasoning or to the idea that reasoning strongly depends on language. This situation has evolved recently, with the development of a new field of research called "Diagrammatic Reasoning". This undertaking gathers cognitive psychologists, logicians, AI researchers as well as philosophers whose goal is to understand how images are used and can be used by humans and machines in problem solving and reasoning (see, Glasgow, Hari Narayanan & Chandrasekaran, 1995; Anderson, Meyer & Olivier, 2002). As this trend considers mainly cases in high level human cognition, we propose in this book to broaden the approach on reasoning by discussing low-level cognition cases (e.g. inferences in animals) as well as high-level cases such as mathematical reasoning. The papers assembled in this volume focus on the non-linguistic aspects of reasoning, in particular when reasoning has to deal with images, is performed through visuospatial cognitive processes, and on the case of animal reasoning. The aim is to raise the issue of the continuity between human and animal reasoning and to provide new grounds to think about language as a necessary condition for inferences. The term "reasoning" is understood here in a broad sense, it covers topics such as categorization, inference in humans and animals, mathematical thinking (these topics are dealt with by *The Cambridge Handbook of Thinking and Reasoning* (Holyoak, K., & Morrison, R., 2005) under the namings: "Concepts", "Reasoning" and "Ontogeny, Phylogeny, Language and Culture").

By non-linguistic reasoning we mean the following three cases:

- reasoning is not constrained by an actual language, this language can be a natural language (this eventuality is known as the 'Whorf-Sapir' hypothesis,

Whorf, B. L., 1956) or a formal language (this is the case when reasoning is modelized by mathematical logic in a first-order language);
- reasoning is not constrained by an abstract language as the 'Language of thought hypothesis', introduced by Jerry Fodor (1975), argues for.
- both.

While reasoning, besides the information conveyed in the linguistic medium, human beings have often to deal with visual information presented in the format of images. Those images can be external representations or stimuli or mental images. Moreover, animals as well may have to perform some cognitive tasks, similar to reasoning, on the basis of images. In this case, the role of images seems particularly relevant to reasoning because animals are not traditionally considered to possess any linguistic abilities. Although there exists evidences that animals, in particular primates, exhibit language like behaviour (e.g. Kanzi, the Bonobo studied by Sue Savage-Rumbaugh), one of the issues raised by these evidences is the problem of the continuity from gesture to speech (see Rizzolatti & Arbib, 1998). The relation between image, gesture, language and reasoning is one of the issues we aim to tackle in this volume. The underlying problem in the symposium was how to characterize reasoning and inferences and during the discussion, the following considerations have emerged.

Some Issues Raised in the Symposium

Three aspects of the problem were particularly emphasized: the use of images in humans, the use of images in animals, the comparison between human and animal reasoning.

Images in Humans

B. Tversky raised a distinction between human and animal cognition which is not related to language but to a particular kind of images: diagrams. According to her, diagrams are tools which use elements, like arrows or cross intersection, and spatial relations among them to convey meaning quite directly. Because diagrams are spatial they can capitalize on human ability to make spatial inferences therefore, they augment cognition. In such a view, this ability is unique to humans. Diagrams may be inherently or metaphorically visual (or spatial). The claim of B. Tversky seemed to be that elements and space in diagrams have a natural interpretation. As the elements and use of space in diagrams constrain meaning, or even suggest a range of meanings, they can be readily understood among different cultures. A question raised during the symposium was whether elements and space in diagrams are combined on the basis of some kind of rules and/or a translation into language, natural or symbolic. Such a possibility would imply that inferences, even when performed with images are to be characterized by the use of rules. Another possibility would be that the production/comprehension of diagrams might be based on some cognitive principles, non linguistic, depending on our visuospatial cognitive system. A proposed answer was that producing and understanding diagrams in a communication context don't need to express rules in some language. Semantic and syntactic rules are implicit and the result of

exchange. In the case of diagrams they have been developed independently of language and are based on non linguistic cognitive principles (for example: metaphorical use of space and natural interpretation of elements to convey meaning). However such diagrams are always associated with language, they have a key. To express how the meaning is conveyed (in case of ambiguity for example: one element is used in different ways in the same diagram) rules must be explicated in language.

B.Teissier argued for the thesis according to which when a mathematician understands a theorem, his mental activity does not match the logical explanation of the proof. Thus, because mathematical logic does not account for this experience, it is not a good model of mathematical reasoning, in other words mathematical reasoning cannot only be characterized by logic. B.Teissier claimed that mathematical reasoning makes use of some 'proto-mathematical' constructions, like the mathematical line, which are of preverbal nature. That is why some animals may have, according to B.Teissier, some of these proto-mathematical abilities. In this view, the case of apes tying knots described by D. Lestel seems to be, according to him and B. Tessier, an example of the expression of proto-mathematical abilities by animals. Those constructions, like the mathematical line for example, rely on our perceptual system as a way to understand our environment and "have nothing to do with language". Moreover, because they are obtained by a kind of metaphor of some properties of our perceptual system, these constructions help us to understand proofs when they are used in mathematical reasoning. This is a non linguistic aspect of mathematical reasoning.

Thus the hypothesis emerged that properties of images in human reasoning do not rely on linguistic resources but on some cognitive principles based on some features of our perceptual system. The use of these principles has been developed and refined within a community. Moreover the properties of images are essential to human reasoning, in particular in mathematical proofs. However, images always come with language, and it remains to analyse at which step of the reasoning activities language becomes necessary.

Images in Animals

Two alternatives were proposed to argue for continuity between human and animal cognition. The first one, presented L. Huber, is related to concept formation. It relies on evidences given to account for the ability of animals to form classes on the basis of non pictorial features of images. This ability of categorization may be shared, although at different levels of complexity, among different species and may be used as an argument for the non-linguistic nature of concepts. The second alternative, defended by D. Lohmar, does not rely on concepts to argue for the human animal continuity. Rather, D. Lohmar has proposed that the ability to constitute, in perception, objects with their properties is based on a system of representations and synthetic functions which works on the basis of what he calls weak phantasmata, a kind of sketch-in of our imagination into sensuality. It seems that therefore weak phantasmata are essential to the formation of concepts. This phantasmatic system of representations seems to be independent of language and is possibly shared by all animated beings. It is essential to perception and therefore to decision

making in human and animals. According to D. Lohmar, this hypothesis constitutes a valuable alternative to the idea that language and general concepts are the most important basis for the acquisition of knowledge. Thus categorization

Human and Animal Reasoning

Three points are to be emphasized: first, proto-mathematical abilities are not linguistic, not unique to humans; indeed they may be shared by other primates. The capacity of some apes to tie knots is an example. Second, characterization of reasoning would be better done using the hypothesis of a dual process rather than trying to exhibit a unique one and asking if animals use it. This dual process recovers two systems: one evolutionary old and shared by animals, the other one evolutionary recent and perhaps unique to humans. Third, social complexity would be a more accurate criterion than the linguistic ability itself to characterize reasoning from the perspective of differences in performance among animals, and between humans and animals.

Hypothesis

After the symposium, it seemed that most of the participants needed to make a hypothesis in order to characterize reasoning on the basis of the three aspects presented above. This hypothesis is as follows: the nature of reasoning would be better understood, in particular the question of the continuity between animal and human reasoning, if we distinguish between an implicit reasoning ability and an explicit reasoning ability (as stated above some researchers in psychology of reasoning have proposed that reasoning is a dual process, see (Sloman, 1996) for a survey). For example, the capability to discriminate different classes of objects and the capability to give rules for this discrimination seem to be carried out with different processes. Some birds are able of the first kind of tasks but no bird is able of the latter. Another example is the difference between retrieving the meaning of a pictorial representation and giving the principles according to which, this representation conveys its meaning. This kind of principles may be based on some syntactic and semantic rules. We propose to call “implicit reasoning” the first ability. It is activated, for example, when humans or animals form a concept or a category based on images, understand the meaning of diagram, and understand a theorem or a mathematical construction. It may rely on preverbal abilities or cognitive principles related to the perceptual system. This ability might be shared by humans and animals. In contrast, we propose to name “explicit reasoning” the second ability. It corresponds to the stage at which we have to give the rules for discrimination between classes, or when we have to explain how a graphical representation conveys a particular meaning. This ability has a public or a social scope and so is related to language not intrinsically but as reflecting a social context. It is distinct of the implicit reasoning ability.

Organization of the Book

Considering the hypothesis presented above as a guideline, the different speakers were then proposed to write a paper based on their talk and the post-talk discussion. Thus, the book is a collection of these papers focusing on the underlying problem in the symposium: how to characterize reasoning and inferences, in particular is a distinction between logical reasoning (by application of rules) and visual spatial reasoning (through visual spatial processing) relevant? Three aspects of this problem are considered, each of which correspond to a section in the book.

Section 1 deals with the comparison of the uses of linguistic representations and images in human reasoning.

The first chapter by B. Tversky focuses on imagistic representations as a manifestation of thought that can be described at one level as structured like language is structured: constituted of elements and relations among elements. However the specificity of images is that they can carry meaning in a different way than language: by resemblance of elements and spatial proximity among them. Many examples of the concepts that are conveyed by diagrams and of the way they are conveyed are given. So images are able to transform abstract problems into spatial ones in which humans have to perform spatial transformations in order to make inferences. B. Tversky proposes that this confers an advantage to reasoning with images over reasoning with language since humans have to rely on such spatial transformations in their life in order to survive. Moreover, not only reasoning in space precedes language but structures of language themselves can be viewed as based on structures used to act in the spatial world.

Chapter 2, by P. Grialou and M. Okada, focuses on the cognitive models of deduction. Its aim is to raise some questions on the two most discussed theories of reasoning, namely the mental model theory (MMT) which predicts that reasoning is semantic and involves visuospatial processing and the formal rule theory (FRT), according to which reasoning is syntactic, and often interpreted as predicting reasoning to be a verbal process. This project is carried out by taking the viewpoint of the implementation of reasoning in the brain on one hand, and by taking the viewpoint of diagrammatic reasoning on the other hand. The authors emphasize how recent brain scanning data on deductive tasks, showing a dissociation between abstract and content-belief based tasks, can raise difficulties for both theories. Moreover, the authors propose that if abstract verbal reasoning is to be processed by formal inference rules, then this process may involve, to some extent, visuospatial processing rather than verbal processing. Thus, if FRT is to be a model of deductive reasoning it should be interpreted not as a verbal theory but as a visuospatial theory. On the other hand, if content based tasks are to be processed by mental models, as predicted by MMT, then this process is underlain by a verbal processing. This leads to interpret MMT as a verbal theory of reasoning.

As for the perspective of diagrammatic reasoning, the authors discuss how the specificities of images, tackled by the chapter 1 and chapter 2, can influence the cognitive processes of deduction and how this can be accounted for by MMT and FRT.

The Appendix to Chapter 2 focuses on diagrammatic reasoning. The authors report an experiment, using a behavioural genetic method, on solving

syllogism with verbal representations and a representation with Euler circles. The aim is to compare the influence of respectively verbal and graphical representation on the performance of people when they solve syllogisms; to compare the cognitive abilities involved in solving intelligence tests and the cognitive abilities required to solve syllogisms in order to investigate whether solving syllogisms requires visuospatial abilities. Finally, the experiment proposes to investigate the genetic sources of the cognitive abilities involved in syllogism solving. The authors show that the results can be interpreted as supporting the neuroimaging data on reasoning discussed in Chapter 2.

J. Benoist's chapter 3 also deals, from a philosophical point of view, with the comparison of images and propositions of language. While images can be analysed, in their symbolic structure, as a language (as it is emphasized in chapter 1), the question addressed by J. Benoist is: what is the particularity of images, as images, to carry meaning? The author deals with this question from the perspective of the problem of syntax in Wittgenstein's theory of the proposition as an image. While in language it is always possible to have combinations of signs which do not make any sense (in other words combinations that do not obey to the syntax) without being aware of it, with images it is to be seen whether the representation obeys to the laws of syntax. This "privilege" of images over language relies on the laws of spatial representation.

Section 2 focuses on the spatial and visual origins of logical and mathematical reasoning.

An important point of the first two papers of this section is the role of meaning in mathematics. Both consider that meaning for subjects is based on space and perception, however B. Teissier's chapter can be interpreted as considering meaning to be absent of logic while G. Longo aims to show that it is only absent of a formalistic view of logic.

Chapter 4, by G. Longo, takes place in a project which aims to examine foundations of mathematics from the point of view of cognition. The author proposes to analyse two central aspects of mathematical reasoning, namely mathematical concepts and the structure of mathematical proofs. These two features are developed within language as an exigency of intersubjectivity in the context of communication. However the paper shows, by using the example of recent "concrete" results of mathematical incompleteness, how they strongly rely on some particular features of cognition strongly tied to the perception of space by humans, (that is gestures and images in a broad sense). The author gives two examples of such features showing how they are involved in the construction of mathematical concepts (e.g. well order) and the devices used in proofs (principle of induction). Moreover the structure of the proof itself, that is to say the deductive process, relies on such gestures. So the aim of this chapter is to show that the explicit deductive process, as a result of the exigency of communication, is constrained by language but involve implicitly gestures, i.e. the way humans (and animals) perceive and act in space. Against a formalistic view of logic, logic itself has spatial roots.

Chapter 5, by B.Teissier, aims to criticize logic as a satisfying model of mathematical reasoning. Part of the latter, in particular at the implicit level, is

of a preverbal nature and strongly tied to space and perception, while the former is considered by the author to be purely linguistic. The problem of logic is to ignore significance which is crucial to mathematical reasoning. Thus an underlying assumption in the chapter is the opposition between language and the cognitive bases of perception. Meaning, which is considered, to some extent, to be preverbal is also not to be found in language but in these cognitive bases. Thus mathematics for which meaning is crucial is to be examined from the viewpoint of these cognitive bases rather than from language, that is to say, according to the author, rather than from logic. Significance (meaning) lies according to B.Teissier in the cognitive bases of the perception of their environment by humans and other animals. The paper focuses on the perception of space and defend this thesis by using the example of the mathematical line to show how much mathematical reasoning relies on non-verbal (here spatial) thought.

Chapter 6, by D. Lestel & C. Hertzfeld, reports observations of a female orang-utan able to tie and untie knots. This ability is interpreted by the authors as a protho-mathematical ability. They argue that roots of mathematical activity are to be found in the explorations of properties of space rather than language, consistently with the two previous chapters, for which perception of space is crucial to mathematical activity. This hypothesis is used to argue that animals may have cultural activities, here mathematics. This kind of study is considered by the authors to be crucial for the understanding of the history of mathematics.

Section 3 considers reasoning from the point of view of a comparison between human and animal cognitive abilities.

In Chapter 7, D. Lohmar, taking a phenomenological point of view based on results of empirical psychology, focuses on animal and visual perception. The author claims that the notion of weak phantasmata, independent of human language, is a function of imagination necessary for perception. Then the author argues that weak phantasmata rather than language and concepts may be the most important basis for acquiring knowledge in humans and other animals as well. To support this thesis two systems, able to account for human cognitive performance are considered. The first one, low level, is independent of language is shared by humans and higher animals. The second, higher level is based on language and concepts and involves the manipulation of rules. The author considers that although the higher level is often used before communication, most of the cognitive acts, in particular reasoning can be carried out on the lower level. In this view, the function of weak phantasmata belongs to the lower level of processes of knowledge acquisition. It is a way to avoid considering the boundary of language and arguing for continuity between humans and other animals from the general perspective of the analysis of the processes of knowledge acquisition (including reasoning). Thus this paper can be viewed as providing an epistemological justification to the comparative analysis of human and animal (in particular primates, see Lestel and Hertzfeld) cognition.

While the previous paper by D. Lohmar may be interpreted as considering that concepts are necessarily bound to language, chapter 8, by U. Aust, W. Apfalter and L. Huber, proposes, from an animal psychology viewpoint, to

consider the more general case of categorization in non-linguistic species refuting the idea that this ability depends on language. Five different levels of categorization are considered, where abstract relations, in particular concepts formation, belong to the higher. The chapter proposes a survey of many evidences of some levels of categorization in animals, analyses the possible criteria (such as pictorial features of objects and visual scenes) used for it and raises the issue whether concepts, as the higher level of categorization, depends on language and if language training in animals may improve categorization abilities. The interpretation of the surveyed evidences by the authors is that boundaries in animal abilities occurs when categorization require knowledge only accessible through language.

With its kind of provocative title, chapter 9, by S. Watanabe, raises the issue of the possibility of logically sound animal behaviour. Two ways to account for animal behaviour are distinguished: ethological rules relying on innate mechanisms and psychological rules relying on the adaptative process of learning based on animal's experience. The paper reports two kinds of studies showing evidence that animal behaviour is not logically sound. The first type of studies focuses on the phenomenon of contrafreeloading which is based for a large part on global, i.e. innate, mechanisms rather than local logic (adaptative). The second type of studies focuses on the learning of abstract relations by animals. While this ability is considered in chapter 8 as constrained by language, S. Watanabe propose alternative hypotheses to account for animal 'limits' in learning abstract relations.

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