



# Neural Correlates of Thinking

Eduard Kraft  
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*Editors*



PARMENIDES BOOK SERIES  
**ON THINKING**

 Springer

# **On Thinking**

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# Series Preface

## What is Thinking?—Trying to Define an Equally Fascinating and Elusive Phenomenon

Human thinking is probably the most complex phenomenon that evolution has come up with until now. There exists a broad spectrum of definitions, from subsuming almost all processes of cognition to limiting it to language-based, sometimes even only to formalizable reasoning processes. We work with a “medium-sized” definition according to which thinking encompasses all operations by which cognitive agents link mental content in order to gain new insights or perspectives. Mental content is, thus, a prerequisite for and the substrate on which thinking operations are executed. The largely unconscious acts of perceptual object stabilization, categorization and emotional evaluation—and retrieving all the aforementioned from memory inscriptions—are the processes by which mental content is generated, and are, therefore, seen as prerequisites for thinking operations.

In terms of a *differentia specifica*, the notion of “thinking” is seen as narrower than the notion of “cognition” and as wider than the notion of “reasoning.” Thinking is, thus, seen as a subset of cognition processes; and reasoning processes are seen as a subset of thinking. Besides reasoning, the notion of thinking includes also nonexplicit, intuitive and associative processes of linking mental content.

According to this definition, thinking is not dependent on language, for example, also many animals and certainly all mammals show early forms of thinking. The emergence of more complex syntactical structures, however, led to a self-accelerating expansion—or not to say “explosion”—of thinking skills. Syntax boosts the possibility to deal with complex relations and enables the understanding of conceptual hierarchies as well as of self-referential structures. The latter may be directly related to the development of an autobiographic self.

The purpose of thinking can be defined in a twofold way: from a biological point of view it can be characterized as the most advanced form of ensuring homeostasis; from a philosophical point of view it can be characterized as the crucial means by which the richness of reality unfolds for us. These different descriptions do not

constitute a contradiction; they rather articulate the complementary perspectives of asking for the function and of asking for the sense of thinking.

Logic, which has long been seen as the core feature of thinking, is an important, but nevertheless rather small part of what thinking really is. It refers only to the coherence of explicitly reviewable linkages made by thinking operations. In contrast, metaphors and analogies constitute a highly content related way of connecting mental content that is extremely important for thinking, though they often escape a rigorous logical analysis.

### ***The Relevance of the Phenomenon of Thinking***

Complex thinking skills are probably the most characteristic feature of humans, and the following four appear to be of particular importance:

1. Thinking is the crucial mechanism through which the richness, interrelatedness and coherence of reality unfold for us. Thinking can be seen as the “crown” of evolutionary sophistication and it is crucial for answering the question: “What makes us human?”
2. Thinking and what we refer to as reality shape themselves mutually. Major breakthroughs in many of today’s most fascinating scientific issues (from trying to grasp how consciousness works to bridging the conceptual gap between quantum physics and gravity) require a better understanding of how thinking shapes reality and how reality shapes thinking.
3. Ever-increasing complexity and a self-accelerating pace of change characterize our modern world. The highly complex, interrelated dynamics of technological, economical, political and sociocultural developments constitute new challenges that require further advancements in our thinking skills in order to cope with them.
4. In an increasingly knowledge based economy, thinking as the process by which new knowledge is generated will become the main value-generation process.

Being aware of the importance of thinking, it is astonishing how little we understand about how complex thinking actually works and how it is implemented in the human brain. The task of the Parmenides Foundation is to enable advanced, interdisciplinary research on this topic.

### ***The Parmenides Foundation and its Research Agenda***

The overall purpose of the Parmenides Foundation is to advance our understanding of one of the most fascinating, characteristic and relevant faculties of human beings: complex thinking. The Foundation was established in 2000 as a charitable institution for basic research.

The main activity of the Parmenides Foundation is to run the Parmenides Center for the Study of Thinking, which was established in co-operation with the Ludwig Maximilian University of Munich. The Parmenides Center is organized similarly to a Max Planck Institute. It tries to provide optimal conditions for basic research and interdisciplinary co-operation, with minimized bureaucratic distractions and optional teaching activities at the university. The work of the Parmenides Foundation is based on an interdisciplinary core team of approximately 15 scientists at present, a guest fellow program and an international faculty of about 30 members. The faculty unites outstanding experts from the neurosciences, neuroinformatics, philosophy, cognitive psychology, linguistics and evolutionary biology.

At present we focus on the following areas of basic and applied research on thinking. The main topics of basic research are:

- To develop a conceptual framework (or taxonomy) for the understanding of thinking
- To identify and analyze the neural and neurobiological correlates of thinking
- To understand the complementary features of human cognition such as syntactic language and (self-)consciousness
- To become able to reconstruct key aspects of complex thinking by modeling
- To learn more about the ontogenesis of complex thinking in childhood
- To learn more about the phylogenesis of complex thinking during evolution
- To study the structural constraints of thinking and their relation to problems in the categorical foundations of science

The main topics of applied research are:

- To develop new approaches and methodologies for supporting the acquisition of thinking skills in early and later childhood
- To develop new approaches and methodologies for supporting the human brain in dealing with tasks of high complexity
- To develop new approaches and methodologies for analyzing and improving the knowledge metabolism of institutions
- To develop new approaches and methodologies for supporting strategy development and decision making in a brain-adequate way
- To develop new approaches and methodologies for the medical reconstruction or restitution of advanced thinking skills

The book series *On Thinking* was established to present new insights and findings, as well as ongoing discussions to a wider readership. The volumes are edited by authors from the Parmenides Foundation and faculty as well as by guest authors and present the progress in this important field for society.

Munich  
March 2008

*Ernst Pöppel*  
*Albrecht von Müller*

# Preface

The idea of the present book emerged on the island of Elba in the summer of 2006 during an enjoyable and very fruitful workshop on thinking with the participation of most of the contributors of the present volume.

The main intention behind the book is to address thinking by surveying the contribution of various functional neuroimaging methods to our understanding of the neural underpinnings of thinking. The major focus is on the methods applicable to the neurobiological study of human thinking, since much of what we consider complex thinking has to be considered as a part of the distinctive features of human nature.

Despite the fact that we are far from a full understanding of the modularity of the human brain, the use of functional imaging techniques is obviously based on the premise that brain functions are modular.

We are grateful to the distinguished authors, coming from different backgrounds, for their commitment to this project, which represents a true interdisciplinary approach, as is mandatory for this fascinating and challenging topic. We are also proud to have been able to recruit an outstanding worldwide team of contributors.

We also wish to thank Anette Lindqvist and Dieter Czechlik from Springer Science+Business Media for their enthusiasm and constant support. Without their optimism and tireless efforts this volume would not have been possible.

Munich, Germany  
Stockholm, Sweden  
Munich, Germany  
June 2008

*Eduard Kraft*  
*Balázs Gulyás*  
*Ernst Pöppel*



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# Introduction

# Neural Correlates of Thinking

Eduard Kraft(✉), Balázs Gulyás, and Ernst Pöppel

## 1 Introduction

In April 1918, Korbinian Brodmann moved to Munich to join the Deutsche Forschungsanstalt für Psychiatrie, the first interdisciplinary brain research institute in the world.<sup>1</sup> Brodmann published what is now regarded as one of the major “classics” of neurological literature, a monograph entitled *Vergleichende Lokalisationslehre der Grosshirnrinde*. (An English translation by Laurence Garey was published in 1994: *Brodmann’s Localisation in the Cerebral Cortex*.) Although the cortical map Brodmann described was purely based on histomorphological criteria, it was an important landmark for future work on functional localization.

From our present perspective Brodmann’s work remains a seminal landmark for localizing activity in neuroimaging research, since most functional imaging studies still refer to Brodmann’s areas when they describe the localization of peak activities and the extent of the activated fields in the human brain.

In the light of all this, a historical reference to Brodmann seems to be an appropriate starting point when launching the first book of a series promoted by the Parmenides Foundation, in particular when the book addresses the question of how modern imaging techniques can contribute to our understanding of complex thinking.

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<sup>1</sup> The founding of this institute was almost a logical consequence of a scientific tradition, which has been known as the “Munich School of Neuroanatomy and Neuroscience”, and was started in the late nineteenth century by Bernhard von Gudden (Danek 2006). An upcoming volume of the Parmenides book series will be dedicated to this historical and fascinating period of brain research.