Preface

“Spatial Processing in Navigation, Imagery and Perception”

Since the decade of the brain cognitive processes have found their way to the study of brain functions and an increasing number of research studies are dealing with the aspect of spatial processing. In fact, a tremendous part of the cognitive domains studied pertain to spatial processing. However, there is also a growing tendency for diversification in relation to the subprocesses underlying spatial processing. Not only are there studies looking at the well known place cells in rats, rabbits and other animals, there is also an increasing number of studies looking at related topics in humans and monkeys such as spatial orientation, spatial construction, and spatial imagery. These studies, although diverse at first glance, have many aspects in common. We are now on the root to understand the underlying neuroanatomy and neurophysiology much better than ever before. This is made possible by the advent of novel techniques such as structural and functional in vivo anatomy, modeling, and several sophisticated behavioral research tools such as virtual reality techniques and simulators.

Spatial processing is fundamental for understanding human cognition. However, compared to other domains such as memory, language, and attention the exploration of spatial functions has been understudied in the past years. Besides the fact that the neural underpinnings of spatial processing are much more complex than they have been conceived before it has turned out that spatial functions have been shown to be involved in almost any cognitive function, even in auditory processing (e.g., music perception). Moreover, a modular organization of cognitive functions is challenged by recent findings showing that cognitive functions are nested and intertwined.

Since the processing of spatial information is so centrally involved in controlling cognitive functions it might help to understand better how basic cognitive functions operate such as language, attention, perception, movement control and mental imagery. Recent research has shown that perception and action are well linked with spatial processing. Visual representations of tools are obviously located in the parietal lobe because they are automatically linked to tool use. Not only the parietal lobe is delineated in a much more precise way, it is now evident that its connections to frontal areas play a major role in spatial processing. Spatial processing is distributed in complex cortical and sub-cortical structures. For example, it also involves sensory information of vestibular origin, the role of which has been widely neglected in previous research using cognitive tasks.

On the one hand modern techniques from the neurosciences have been shown to be the catalyst of this research, there is on the other hand a revival of behavioral approaches. It is in fact the fruitful combination of both why this exciting field has progressed so far and is still progressing for many years to come. The importance of research on spatial processing does not only concern basic researchers it is rather most important for its application in professional areas. It has gotten tremendously important to know how the human brain is accomplishing spatial tasks in real life scenarios such as driving a car, orienting oneself in large scale cities, postural control or playing various sports like baseball, soccer or tennis. Several researchers are devoted to develop strategies to cure people from various diseases or to learn more about how to counteract against the declining spatial functions with age. A promising applied area for research on spatial processing will be the plasticity and training related influences on spatial functions (e.g., stimulation of the parietal cortex can enhance spatial functions to a certain degree). Demands are substantially increasing in our culture with a steadily growing use of computer games, simulator techniques and video oriented teaching tools. Thus, a better understanding of the spatial functions is a necessary prerequisite for efficiently inserting new technologies in everyday life.

Despite the fact that the environment strongly influences spatial behavior more emphasis needs to be given to the genetic underpinnings. This track of research will benefit from tying together genetic screening and brain imaging (genetic brain imaging of spatial functions). Hopefully, this approach may be included in a future edition of this book. This book aims to provide a common platform for researchers from different fields or disciplines studying spatial functions. We were successful in having as chapter authors the most respected and internationally renowned researchers in the field.

The first chapter written by Stephen Kossslyn, Jennifer Shephard and William Thompson is entitled "*Spatial processing during mental imagery: A neurofunctional theory*". Based on the neuroscience of the human visual system the authors propose a model that consists of seven processing subsystems, each of which has a coarsely defined anatomical localization. The model describes key functions of visual perception and – most importantly – it explains how mental images can be generated from memory and how patterns in images are interpreted.

In chapter 2, Cecilia Guariglia and Luigi Pizzamiglio focus on the relation between disorders in mental representation of space and environmental navigation ("*The role of imagery in navigation: Neuropsychological evidence*"). The authors focus on the crucial role mental imagery plays in navigation as it is shown in patients with unilateral neglect who are impaired in their use of cognitive maps.

The nature of spatial images is addressed in the third chapter, entitled "*Functional equivalence of spatial images produced by perception and spatial language*". Jack Loomis, Roberta Klatzky, Marios Avraamides, Yvonne Lippa and Reginald Golledge favor the hypothesis that spatial images are based on amodal representations. They present studies showing that behavioral performance is widely independent of source modality such as vision, spatial hearing or language.

Ranxiao Frances Wang has written a chapter (4), entitled "*Spatial processing and view-dependent representations*". She discusses the relationship between different types of view-dependent representations. Based on previous studies and new data, she proposes a model that contains an egocentric spatial working memory and a representation stored in long-term memory.

Thomas Barkowsky's chapter (5) is concerned with "*Modeling mental spatial knowledge processing*" from an artificial intelligence perspective. After discussion of the existent models of intelligent spatial processing he presents a novel architecture as a framework for modeling spatial reasoning with mental models and mental images.

In chapter 6 entitled "*Optic ataxia: A gateway to the human visual action system*" Marc Himmelbach und Hans-Otto Karnath review the anatomical foundations of optic ataxia allowing the identification of brain areas necessary for the control of hand in space. In addition, they evaluate behavioral findings in patients with optic ataxia and patients with visual form agnosia. On this background, the actual validity of the "two-visual stream-model" is discussed.

Chapter 7 is authored by Bruce Bridgeman and Brian Lathrop: "*Interactions between cognitive space and motor activity*". The authors present data on the relationship between unconscious spatial processing of a spatial frame and subsequent conscious perception and action.

"*Cross-modal involvement of visual cortex in tactile perception*" is the title of chapter 8, written by K. Sathian and Simon Lacey. It is nowadays clear that visual cortical areas are not only involved in visual discrimination tasks but also then when the input modality is tactile. The authors discuss their own studies and those of other groups in the light of different perspectives such as mental imagery or cross-modal plasticity, which could account for the recruitment of visual cortex during tactile perception.

Lutz Jäncke is focusing in chapter 9 (entitled "*Neuroanatomy of the parietal cortex*") on the anatomical underpinnings of parietal functions. Specific emphasis is given to anatomical connections of the parietal lobe with frontal brain areas. In addition, a refined anatomical description of the parietal areas is given.

Lynn Robertson reviews in chapter 10 entitled "*Spatial maps, feature integration and parietal function: Implications from the study of spatial deficits*" how spatial awareness and spatial functions are intermingled with various other psychological functions. In particular she demonstrates how spatial processing is involved in binding surface features such as color and shape and how multiple spatial maps can guide attention.

Michael Corballis, Branka Milivojevic and Irina Harris describe in chapter 11 (entitled "*Pigs in space: How we recognize rotated objects*") how mental rotation functions are part of a general perception process. In particular they argue that mental rotation of objects is a fundamental strategy to recognize familiar visual objects. Their argumentation is based on a review of mental rotation research including behavioral and brain-imaging experiments.

In chapter 12 entitled "*Functional neuroanatomy of mental rotation performance*" Lutz Jäncke and Kirsten Jordan review the current knowledge about the functional neuroanatomy of mental rotation performance. In this chapter the authors also argue about the relationship between mental rotation and other spatial functions, with particular emphasis on the role of different strategies to solve mental rotation tasks and their relation to cortical activation patterns.

In chapter 13 Charles Oman ("*Spatial orientation and navigation in microgravity*") describes the spatial disorientation problems and navigation difficulties astronauts and cosmonauts experience during exposure to microgravity. He relates them to ground-based research findings on human spatial orientation and animal models on navigation.

In chapter 14 entitled "*Spatial representations in the rat: Case study or perspective on episodic memory?*" Françoise Schenk, Delphine Preissmann and Chiara Sautter focus on the rat hippocampus and its role in spatial behavior. They argue that the study of spatial memory in mammals, and more precisely in laboratory rats, sheds light on the development and evolution of other memory systems, in particular on episodic memory.

The brain needs to know head orientation relative to gravity. For this, it must parse the afferent information from the otolith signals into its gravitational and inertial components. The contribution of Bernhard Hess (chapter 15: "*Sensorimotor transformations in spatial orientation relative to gravity*") describes the computational steps necessary to resolve the ambiguous vestibular sensory information, and thus providing reliable spatial orientation and appropriate motor behavior.

The control functions of a hominoid robot capable of performing sensorimotor tasks are described by Thomas Mergner, Christoph Maurer and Georg Schweigart in their chapter (16), entitled "*Sensorimotor control of human dynamic behavior in space implemented into a hominoid robot*". Using a systems approach, their modeling is based on psychophysical research and implements an internal reconstruction of the external physics required for sensorimotor feedback control of coordinated motor behavior. The robot will be used for simulations with the aim to better understand sensorimotor deficits in neurological patients and to develop new clinical therapy designs.

Vittorio Gallese's chapter (chapter 17, entitled "*The ventro-dorsal stream: Parieto-premotor neural circuits and their role in primate cognition*") is a demonstration of how primate research fosters the understanding of human brain functions. He reviews anatomical and functional findings suggesting that visual processing is carried out along three distinct streams. Two of them include the parietal lobe, and one of them includes the inferotemporal lobe. These three streams are qualified as dorso-dorsal, ventro-dorsal and ventral streams.

Fred Mast, Laura Bamert and Nathaniel Newby review the most recent research on motor imagery, entitled: "*Mind over matter? Imagined body movements and their neuronal correlates*" (chapter 18). Numerous clinical and neuroimaging studies suggest that many areas involved in the process of motor execution, planning, and preparation are also drawn upon during motor imagery. This concerns not only imagined movements of body parts but also when one imagines a movement of the whole body. The authors present new empirical evidence showing an influence of imagined whole body movements on vestibular perception.

In chapter 19 entitled "*Bottom-up effects of sensory conflict and adaptation on mental imagery: Sensorimotor grounds for high level* *cognition?*" Gilles Rode, Sophie Jacquin-Courtois, Patrice Revol, Laure Pisella, Anne Sylvie Sacri, Dominique Boisson and Yves Rossetti review the current status on neglect research. They emphasize new findings suggesting an important influence low-level sensorimotor transformations can have on higher cognitive levels of space representation. Thus, they explain why cognitive deficits like neglect may be positively modulated by passive physiological stimulation such as caloric vestibular stimulation or via a prism adaptation procedure.

John Rauschecker has written a chapter (20) entitled "*Cortical processing of auditory space: pathways and plasticity*" in which he describes current knowledge on anatomical and functional auditory spatial processing. He presents the concept of a "where"- and "what"- stream in the auditory systems.

George Mangun and Sean Fannon highlight in their chapter (21) entitled "*Networks for attentional control and selection in spatial vision*" the special role attentional processes play in spatial vision. In particular, they focus on the neural mechanisms underlying voluntary visual spatial attention. They propose specialized neural mechanisms for voluntary spatial attention.

Fred Mast and Lutz Jäncke