MEMORY AND MIND

COURSE DESCRIPTION

COURSE OBJECTIVES

This summer school will bring together world-class experts of different subfields. It focuses on a truly cross-disciplinary issue: how memory is constructed and represented in our brain –- which is a topic discussed in a wide range of scientific fields as different as mathematics, sociology, biology, psychology, computer science, psychiatry and education sciences. In addition, the topic has contributions to such distant areas as anthropology, history, cultural evolution, the study of consciousness and various forms of arts. True to this cross-disciplinarity, the course will attempt to investigate this complex topic from many different viewpoints thereby providing a critical analysis of reigning dogmas and emerging new results in a number of related but very different fields, such as language acquisition, interpretation of visual scenes, infant development, the role of emotions and culture in learning, the origin of the concept of numbers, and the emergence of consciousness.

The design of the course stresses highly interactive forms of teaching where apart from the standard lecture format, the faculty will be encouraged to have open discussions about the relevant issues amongst each other as well as with students, there will open debate sessions, and opportunities for hand-on experience with various experimental tools exploring related questions. This should demonstrate the link between the high level concepts presented and various ways of exploring these concepts empirically.

The fundamental philosophy of the course is to demonstrate that some basic principles of structure learning can provide a unifying framework for explaining human cognition both in simple as well as in the most complex domains of behavior. In addition, the course will present how these basic principles of behavior could be implemented in the neural hardware of the brain, thereby addressing the issue of how to bridge scientifically the gap between mind and body. To achieve this, lectures will progress via domains of gradually increasing abstraction that humans deal with starting from the perceptual domain of vision, through language, concepts, numbers and finally to conscious thinking.

THREE KEY MODULES

The first module will focus on the structure of the outside world of visual scenes, languages, numbers, and abstract categories. The lectures will highlight the common features and structurally significant differences between the different domains. We will investigate the following questions: Is there any order in the visual scenes one experiences? Are humans sensitive to that? Does language follow a universal grammar? How do we represent small numbers? And large ones? Can we measure how similar the representation of one structure in our head is to another? Moving from more concrete domains (sensory perception) to more abstract ones (numbers and concepts), we will gradually introduce the idea of objective and subjective definition of structure and the consequences of this dichotomy in terms of perceived structures as constrained by individual as well as cultural experience.

In the **second module**, the lectures will focus on what is known about the emergence of internal representations of these domains: models of visual learning, language learning, number learning, concept learning, and emergence of consciousness will be introduced and critically evaluated. In this module, we will review the dominant theories of learning in each of the domains and evaluate how our conclusions in Module 1 can be related to these learning models. Do we learn everything we experience? Are we making abstractions automatically? Is there a limit to what we can learn? Does every infant develop the same representation of the outside world and if yes, how? Why are we learning?

Finally, the **third module** will deal with the feasibility of implementing in the brain the models reviewed in the second module. The lectures in this module will discuss the likely candidates of cortical representations

of vision, space, language, numbers, and consciousness. We will review what is known about the likely representations and how they can subserve the abstract models we discussed in Module 2.

COURSE FORMAT

The principal format of the course will be seminars given by the core faculty. There will be a discussion session after each module where participants will be encouraged to formulate a coherent view based on the lectures. Participants will be expected to critically evaluate competing views represented by a series of papers. In addition, when possible, there will be computer demonstrations of the relevant concepts. Since all the core faculty come from the broad area of brain and cognitive sciences, and represent a somewhat similar philosophy, we also plan to broaden the discussion of these topics by organizing round table discussions with representatives of disciplines that are in secondary connection with the main topic of the course. These guest discussants will come from areas such as psychoanalysis, history and arts, and they will provide their view on whether we learn a canonical representation of the structure of our experience and how it is represented in our brain. We also plan a round-table where the dichotomy of learning versus innately coded representations will be discussed. There will be a final project, in which students will be required to carry out a mini-research project in small groups. The group will select a particular issue and develop their own opinion whether it can be fit in the emerging view on structure learning and if so, how.

READINGS

MODULE 1

- Biederman, I. (1987). Recognition-by components: A theory of human image understanding. Psychological Review, 94(2), 115-147
- Bulthoff, H. H., Edelman, S. Y., & Tarr, M. J. (1995). How are 3- dimensional objects represented in the brain. Cerebral Cortex, 5(3), 247-260
- Field, D. J. (1987). Relations between the statistics of natural images and the response properties of cortical cells. Journal of the Optical Society of America. A, Optics and Image Science, 4, 2379-2394.
- Sigman, M., Cecchi, G. A., Gilbert, C. D., & Magnasco, M. O. (2001). On a common circle: Natural scenes and Gestalt rules. Proceedings of the National Academy of Science, 98, 1935-1940
- Stanislas Dehaene, Véronique Izard, Elizabeth Spelke, and Pierre Pica. (2008). Log or linear? Distinct intuitions of the number scale in Western and Amazonian indigene cultures. Science, 320(5880): 1217-1220.

MODULE 2:

- Hummel, J. E., & Biederman, I. (1992). Dynamic binding in a neural network for shape recognition. Psychological Review, 99(3), 480-517
- Véronique Izard, Ghislaine Dehaene-Lambertz, and Stanislas Dehaene. Distinct cerebral pathways for object identity and number in human infants.. PLoS Biology, 6(2):e11, February 2008.
- Marc D. Hauser, Noam Chomsky, W. Tecumseh Fitch: The Faculty of Language: What Is It, Who Has It, and How Did It Evolve? Science vol 298. (2002)
- Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. Science, 274, 1926-1928
- Marcus, G. F., Vijayan, S., Bandi Rao, S., & Vishton, P. M. (1999). Rule-learning by seven-month-old infants. Science, 283, 77-80.

- Orbán, G., Fiser, J., Aslin, R. A., & Lengyel, M. (2008). Bayesian learning of visual chunks by human observers. Proceedings of the National Academy of Science, 105, 2745-2750.
- Kemp, C., & Tenenbaum, J. B. (2008). The discovery of structural form. Proceedings of the National Academy of Sciences of the United States of America, 105(31), 10687-10692.
- Biederman, I., & Vessel, E. A. (2006). Perceptual pleasure and the brain. American Scientist, 94(3), 247-253.

MODULE 3:

- Olshausen, B. A., & Field, D. J. (2005). How close are we to understanding V1? Neural Computation, 17(8), 1665-1699.
- Fiser, J., Chiu, C. Y., & Weliky, M. (2004). Small modulation of ongoing cortical dynamics by sensory input during natural vision. Nature, 431, 573-578
- Ji, D. Y., & Wilson, M. A. (2007). Coordinated memory replay in the visual cortex and hippocampus during sleep. Nature Neuroscience, 10 (1), 100-107.
- Stanislas Dehaene and Laurent Cohen (2007). Cultural recycling of cortical maps.. Neuron, 56(2):384--398.
- Gilbert, C. D., & Sigman, M. (2007). Brain states: top-down influences in sensory processing. Neuron, 54, 677-696.