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INTRODUCTION TO THE SECTION ON

MEMORY

Memory is many things, even if not everything that has been labelled memory corresponds to what cognitive neuroscientists think of as memory.

Memory is a gift of nature, the ability of living organisms to retain and to utilize acquired information or knowledge. The term is closely related to 'learning,' in that memory in biological systems always entails learning (the acquisition of information) and in that learning implies retention ('memory') of such information.

Memory is a trick that evolution has invented to allow its creatures to compress physical time. Owners of biological memory systems are capable of benefitting at a later time T2 from their experiences at an earlier time T1, a feat not possible for organisms without memory.

Memory is a biological abstraction. There is no place in the brain that one could point at and say, "Here is memory." There is no single activity, or a class of activities, of the organism that could be identified with the concept that the term denotes. There is no known molecular change that corresponds to memory, no known cellular activity that represents memory, no behavioral response of a living organism that 'is' memory. Yet the term 'memory' encompasses all these changes and activities.

Memory is a convenient chapter heading designating certain kinds of problems that scientists study. Methods of science have been brought to bear on the problems of memory for over a hundred years, in many different organisms, and at many different levels of analysis, extending from molecular mechanisms to phenomena of conscious awareness.

The eight chapters in the MEMORY section of The Cognitive Neurosciences provide summaries of and glimpses into contemporary memory research. The overarching concern has been the search for the identity of the neural substrates of 'memory,' and for the understanding of the correlation between neural mechanisms and memory processes.

Two recent conceptual developments have played an especially significant role in shaping the temper of today's research. One represents a consequence of the analytical and empirical separation of encoding, storage, and retrieval processes in human memory. As a result, it is now no more adequate to talk about, say, variables affecting 'memory performance,' or conditions responsible for 'memory impairment.' 'Performance' and 'impairment' now have to be specified in terms of specific memory processes and their interaction. The other development concerns the discovery, or the emergence of the concept, of different dissociable forms of memory, or multiple memory systems. Against the backdrop of traditional thought, this is a radical idea whose eventual implications and ramifications may well exceed all current expectations.

Although one finds suggestions in the earlier literature that learning and memory may assume different forms, the prevalent even if unarticulated view used to be that the underlying mechanisms of all learning and memory are basically the same. This unitarian view, rooted in the desire to adhere to the principle of parsimony, succeeded in escaping inimical data for a long time. Yet it overlooked the fact that nature itself is seldom parsimonious, and that, as has been noted, evolution is a tinkerer, not an engineer. Facts that are difficult to fit into the unitarian framework, under the rubric of task dissociations, have been appearing on the scene with accelerated frequency.

The new concepts of memory processes and memory systems have considerably changed the way cognitive neuroscientists pursue their mission. The quest for the understanding of the identity and localization of the neural substrates of 'memory' has metamorphosed into the search for the neural correlates of encoding, consolidation, storage, and retrieval, separately for the different, dissociable forms of memory. Thus, for instance, it is now reasonably clear that the hippocampal structures are necessary for the encoding and consolidation of some but not other kinds of input, but that they do not play a significant role in retrieval of any kind of stored information. All eight chapters that constitute the MEMORY section of The Cognitive Neurosciences are concerned with some aspect of this basic issue of the identity and localization of different processes of different forms of memory.

Historically, the basic questions regarding the neural substrates of 'memory' were two. The first one was: "Are memories localized in the brain?" The 'localizationists,' who included Broca, Fritsch, Hitzig, and Ferrier, said yes, their detractors, the 'integrationists,' whose roster included Flourens, Franz, and Lashley, said no. As in all difficult-to-decide issues, the fortunes of the two sides have waxed and waned indecisively over time, and are likely to continue to do so in the foreseeable future. In our Memory section, Squire represents the 'localizationist' camp, whereas Markowitsch holds aloft the 'integrationist' banner. The second question was raised by those who adopted the affirmative position regarding localization: "Where are memories localized?" During much of the history of the science of memory, the relevant evidence on this question was derived from brain-damaged patients whose lesions could be identified. After the famous case of H.M. appeared on the scene, with well-documented bilateral surgical lesions in the medial temporal lobes, including the hippocampus, the hippocampal structures that were already known to be implicated in memory disorders, were rapidly elevated to the position of prime candidate of the 'seat of memory.'

Today's consensus holds that the limbic system, including the hippocampal structures, play a critical role in certain forms of memory, even if that role and the exact identity of the 'certain forms' are not yet clear. In addition the consensus holds that some other brain regions are also involved in memory processes. One of the most thoroughly studied of these other regions is the frontal lobes, although their role in memory has been somewhat controversial. Shimamura's chapter provides a contemporary review of some of the issues and some of the evidence.

Lesion analysis has yielded a great deal of valuable intelligence about the brain/mind interaction. But it is not without problems, as its critics have been fond of pointing out. This is why recent technological developments that allow objective observation of the activity of living brains engaged in cognitive tasks have been eagerly welcomed by students of memory. Two chapters in the present collection cover these developments. Rugg discusses the promise of, and problems with, the use of evoked (event- related) potentials to track the happenings at the neural level that accompany memory processes, while Roland presents an overview of the recent achievements of, and remaining difficulties with, the use of positron emission tomography (PET) in identifying brain regions that are involved in various operations of memory.

The other chapters bring to the reader the latest word on the 'kinds' of memory that localizationists, integrationists, electrophysiological recorders, and brain imagers have to keep apart in their probes into memory. Baddeley presents an analysis of working memory, the human brain/mind's executive functions which integrate cognitive information from a variety of sources, including recent inputs, for the use in meeting the needs of the present. Schacter provides an overview of some of the latest discoveries in the domain of implicit memory, which is currently one of the 'hottest' areas of memory research. Tulving presents a classificatory scheme of five major human memory systems and considers their interrelation in terms of the seriality, parallelism, and independence of the processes of information acquisition, storage, and retrieval.

The advances that have been made over the last one hundred years in the understanding of the brain/mind of memory have been steady and substantial, even if at times they have appeared to be frustratingly slow. Over the last twenty years or so, however, the pace of discovery has quickened. The painstaking early studies have now laid a solid foundation on which to build, the new techniques and methods will deepen our understanding of the workings of the brain/mind, and, perhaps most important, new insights into the basic character of memory, and the character of the scientific problem of memory, will help to guide research into even more rewarding directions.

Endel Tulving