The Principle of Bottleneck Structures

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Memory is one of the most complex and important human brain functions. It can be subdivided along dimensions time (e.g., short and long-term memory) or contents (e.g., episodic and semantic memory), and according to the stages of information processing (encoding, consolidation, storage, and retrieval of information). It is assumed that in different memory processes specific brain structures, so called ‘bottleneck structures’ (e.g., Markowitsch, 1995b), are primarily involved. Amnesic syndromes can therefore occur as a consequence of widespread brain damage, such as in Alzheimer’s disease, as well as after tiniest lesions or functional alterations of the brain.

This paper addresses the following questions: What are the bottleneck structures for different memory aspects? And accordingly: What kind of brain damage will lead to specific memory impairments, such as anterograde or retrograde amnesia?

Classification of Memory

Traditionally, memory is divided along the dimension of time, for instance into short-term, intermediate and long-term memory (Rosenzweig, Bennett, Colombo, Lee, & Serrano, 1993). In the last decade of the 20th century a further classification of memory – along the contents of memory systems – was introduced by Tulving (1995). Four different, long-term memory systems are postulated: episodic memory, semantic memory, procedural memory, and priming (see Markowitsch, 1995a; Tulving, 1995, Fig. 1). The episodic memory system represents events and
episodes of a person with respect to time and locus. The knowledge system consists of facts without personal reference (e.g., arithmetical rules, world knowledge). Skills are the components of procedural memory (e.g., riding a bike, playing tennis), and priming describes the improved recognition or reproduction of information that was already experienced before. Retrieval of episodic memories occurs explicitly or intentional, while the other forms of memory retrieval are incidental (Tulving, 1995).

**Figure 1.** The four long-term memory systems (modified from Markowitsch, 1996)

Our knowledge of interdependencies between brain regions and memory aspects has increased in the last years. An expansion of different methods to study brain functions and their combination (e.g., neuroimaging methods and neuropsychological investigations) as well as studies on brain lesioned animals substantiate the growth of information on brain-memory interactions. Nevertheless, most of our knowledge stems from detailed descriptions of brain damaged patients.

When drawing inferences from brain damaged patients, the time period between lesion acquisition and testing is of crucial importance (Barbizet, 1970, Fig. 2) as is that of distinguishing between anterograde and retrograde amnesia (Fig. 3).

**Amnesic Syndromes**

**Medial Temporal Lobe Amnesia**

Case H.M. constitutes probably the most extensively studied patient, who became persistently anterograde amnesic after bilateral resection of major portions of the medial temporal lobes (Scoville & Milner, 1957). Preoperatively, he suffered from a pharmacologically intractable