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Insights from child development on the relationship between episodic and semantic memory

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Abstract

The present study was motivated by a recent controversy in the neuropsychological literature on semantic dementia as to whether episodic encoding requires semantic processing or whether it can proceed solely based on perceptual processing. We addressed this issue by examining the effect of age-related limitations in semantic competency on episodic memory in 4–6-year-old children ($n = 67$). We administered three different forced-choice recognition memory tests for pictures previously encountered in a single study episode. The tests varied in the degree to which access to semantically encoded information was required at retrieval. Semantic competency predicted recognition performance regardless of whether access to semantic information was required. A direct relation between picture naming at encoding and subsequent recognition was also found for all tests. Our findings emphasize the importance of semantic encoding processes even in retrieval situations that purportedly do not require access to semantic information. They also highlight the importance of testing neuropsychological models of memory in different populations, healthy and brain damaged, at both ends of the developmental continuum.

Keywords: Episodic memory; Semantic memory; Serial parallel independent processing model; Multiple input processing model; Child development

The study of human memory has evolved from an assumption that memory is one encompassing system, to the idea that there are several distinct memory systems. The focus of the current study is on episodic memory, and its relation to the perceptual and semantic memory systems. The episodic memory system is thought to be responsible for encoding, storage, and retrieval of information that extends beyond the borders of perceptual and semantic memory systems. Specifically, it is thought to process information about events and episodes that occurred at a particular time and place. According to Tulving (2001, 2002), episodic memory is the only system that allows individuals to remember and to re-experience events from their remote and recent past. Unlike the perceptual and semantic memory systems, episodic memory is tied uniquely to the individual and encompasses autonoetic awareness and subjectively sensed time.

Semantic memory encompasses factual knowledge about the world, such as the meaning of words, dates, or facts, and is shared among members of a community (Tulving, 1983). Notably, retrieval of information from semantic memory does not require any reference to the time or place at which this information was acquired. Retrieval is thought to be associated with noetic rather than autonoetic awareness; or with 'knowing' rather than with 'remembering'. Perceptual memory involves retention of modality-specific information in 'perceptual representation systems' (PRS) that keep records of encountered stimuli as a by-product of the perceptual analysis. Again, retrieval of information from PRS does not require any explicit reference to the study episode (Tulving & Schacter, 1990).

Much attention has been directed at the relationship between episodic, semantic, and perceptual memory systems (Craik & Lockhart, 1972; Kapur et al., 1994; Moscovitch & Nadel, 1999; Nadel & Moscovitch, 1997; Nadel, Samsonovich, & Moscovitch, 2000; Nyberg, 1994; Nyberg et al., 2003; Tulving et al., 1994). In particular, it has been proposed that the episodic system is responsible for the highest level of processing in a hierarchy (Graham, Simons, Pratt, Patterson, & Hodges, 2000; Tulving, 2001) in which semantic and perceptual systems are subordinate. There are two main models that explain how processing in these lower level systems supports higher level

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processing in the episodic system: the serial parallel independent processing model (Tulving, 2001) and the multiple input processing model (Graham et al., 2000).

Tulving's serial parallel independent (SPI) model holds that the relationship between episodic, semantic, and perceptual systems depends upon the specific process at hand. Encoding is thought to involve a serial relationship, storage is thought to take place in parallel in these systems, and retrieval is considered to occur independently (Tulving, 2001). According to the SPI model, the three memory systems are arranged hierarchically for this process in that encoding at the higher levels builds upon encoding processes in the lowers systems. Physical features of objects or events are processed in the PRS. Encoding of factual information in the semantic memory system cannot proceed unless perceptual encoding processes in the PRS have been initiated. The episodic memory system relates the factual and perceptual information to the self in subjectively sensed time, and encodes the actual experience of the event. Episodic encoding depends upon the quality of encoding in the semantic system. However, due to the hierarchical nature of the SPI model, the opposite is not true. The current study will address the assertion derived from this model that, when semantic encoding is poor, episodic memory will also be impaired.

There is already some support for the hierarchical nature of the systems posited by the SPI model. One source of evidence stems from developmental neuropsychological research. Several studies in developmental cases of anterograde amnesia have shown that focal brain damage in the hippocampus early in life can result in impaired episodic memory that contrasts with the normal functioning of the semantic memory system in these individuals (Baddeley, Vargha-Khadem, & Mishkin, 2001; De Haan, Mishkin, Baldeweg, & Vargha-Khadem, 2006; Maguire, Vargha-Khadem, & Mishkin, 2001; Vargha-Khadem et al., 1997). In an influential study, Vargha-Khadem et al. (1997) investigated three children suffering from anterograde amnesia associated with hippocampal damage that was acquired at birth, the age of 4 years, or 9 years. All three patients, when tested in adolescence or early adulthood, displayed severe impairments in remembering daily episodes and in performing laboratory tasks of episodic memory despite a relatively normal ability to acquire semantic information, measured with vocabulary and general world knowledge tests. The authors suggested that the preserved semantic learning competency in these children was supported by parahippocampal gyrus structures adjacent to the hippocampus that were intact in these individuals. The results from these neuropsychological studies follow the pattern predicted by the SPI hierarchy. It is worth noting that similar findings have also been reported in amnesic patients with an adult onset of their neurological condition that was associated with relatively selective hippocampal damage (Kitchener, Hodges, & McCarthy, 1998; Verfaellie, Koseff, & Alexander, 2000).

It is important to note that the reverse pattern of performance, namely impaired semantic memory that co-exists with normally functioning episodic memory, would pose a challenge to the hierarchical SPI model. Such evidence has recently been reported by Graham et al. (2000) in patients suffering from semantic dementia. Semantic dementia (SD) is a degenerative neurological disorder occurring in late adulthood in which semantic memory deteriorates so that patients have severe deficits on tasks that require picture naming, the categorization of objects, or retrieval of factual knowledge and vocabulary (Hodges, Patterson, Oxbury, & Funnell, 1992). The condition is typically associated with atrophy of the anterior temporal lobe, including but not limited to perirhinal cortex in the parahippocampal gyrus (Chan et al., 2001; Davies, Graham, Xuereb, Williams, & Hodges, 2004; Davies et al., 2005). Behavioural and neuropsychological evidence indicates that, particularly in early stages of the disorder, the cognitive impairments are selective to processing of semantic information; other cognitive domains such as nonverbal problem solving, phonological and syntactic processing, visual–spatial skills, and perception are typically spared (Hodges et al., 1992; Snowden, Goulding, & Neary, 1989). Of particular interest to the current discussion is the remarkable evidence for disproportionately well-preserved episodic memory functioning in these patients on most tasks (Hodges & Graham, 2001; Snowden, Griffiths, & Neary, 1996).

Graham et al. (2000) found evidence that led them to conclude that SD patients can rely on perceptual encoding when successfully performing episodic memory tasks. They obtained this evidence by varying the nature of a recognition memory test for pictures of objects. In the most typical version, the target items used to assess recognition in the test phase are identical to those encountered at study. In a variation of the standard test, Graham et al. employed target items at the test time that were perceptually different from those at study. For example, participants would have encountered one particular exemplar of a telephone at study and would be required to respond 'yes' to any telephone at the time of test, irrespective of whether it was the same exemplar. In this type of recognition test, SD patients could not rely on perceptually encoded information at the time of recognition; instead they were required to rely on semantically encoded information (i.e. the name of the target object). When comparing the performance of patients with SD to that of healthy age-matched control individuals, Graham et al. found no group differences for the standard recognition test but significantly impaired performance in SD patients on the altered semantic version. In addition, SD patients only showed an advantage in recognizing known items over unknown ones in the altered recognition test, in which performance relied on semantically encoded information; no such advantage was observed in the standard recognition test (Graham et al., 2000). This pattern of findings, complemented by similar evidence from subsequent studies (Graham, Patterson, Powis, Drake, & Hodges, 2002; Gold et al., 2005; Simons, Graham, Galton, Patterson, & Hodges, 2001; Simons, Graham, & Hodges, 2002), led Graham et al. to propose the multiple input (MI) processing model to describe the relationship between perceptual memory, semantic memory, and episodic memory. According to this model episodic encoding can be supported by both the semantic and the perceptual memory systems (Graham et al., 2000). When semantic encoding is poor, as in SD patients with an impaired semantic memory system, perceptual encoding can help to acquire new episodic information directly.