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SHORT REVIEW

Interdependence of episodic and semantic memory: Evidence from neuropsychology

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Abstract

Tulving's (1972) theory of memory draws a distinction between general knowledge (semantic memory) and memory for events (episodic memory). Neuropsychological studies have generally examined each type of memory in isolation, but theorists have long argued that these two forms of memory are interdependent. Here we review several lines of neuropsychological research that have explored the interdependence of episodic and semantic memory. The studies show that these forms of memory can affect each other both at encoding and at retrieval. We suggest that theories of memory should be revised to account for all of the interdependencies between episodic and semantic memory; they should also incorporate forms of memory that do not fit neatly into either category. (*JINS*, 2010, *16*, 748–753.)

Keywords: Semantic dementia, Memory disorders, Temporal lobe, Hippocampus, Review, Amnesia

INTRODUCTION

Tulving's influential theory (Tulving, 1972, 1983, 2001) proposes that human memory can be divided into at least two subtypes. *Semantic memory* consists of a "mental thesaurus" that provides "the memory necessary for the use of language" (Tulving, 1972, p. 386), whereas *episodic memory* consists of memory for "temporally dated episodes or events, and the temporal-spatial relations" among them (Tulving, 1972, p. 385). Thus, when we state that bicycles are two-wheeled conveyances with pedals and handlebars, we are drawing on semantic memory; when we remember being chased by a dog during yesterday's bike ride around a pond—or even when we remember that "bicycle" was on the second list of words we just read—we are drawing on episodic memory. As this example suggests, the two kinds of memory differ in the kind of conscious experience they involve: episodic memory requires recollection of a prior experience, but semantic memory does not (Tulving, 1985). Although the episodic-semantic distinction has not escaped criticism (McKoon & Ratcliff, 1986; Toth & Hunt, 1999; see Tulving, 2002, for a response), it has clear heuristic value, and it harks back to similar distinctions that philosophers and psychologists have made since Aristotle (Hermann, 1982; Tulving, 1983).

Neuropsychological investigations have supported this distinction and improved our understanding of each form of memory. Patients with damage to the medial temporal lobes (MTL), for example, have a severe episodic memory impairment that affects both anterograde and retrograde memory: They have little or no ability to acquire new episodic memories, and they have a deficit of premorbid episodic memory that can cover anything from several years (Bayley, Hopkins, & Squire, 2006) to the entire lifespan (Rosenbaum et al., 2008). Moreover, this impairment affects not only the ability to reconstruct the past but also the ability to imagine specific future events (Hassabis, Kumaran, Vann, & Maguire, 2007). At the same time, MTL amnesics' premorbid semantic memory is largely spared except for knowledge acquired in the immediate premorbid period (Manns, Hopkins, & Squire, 2003). This dissociation provides support for the episodic-semantic distinction and suggests that episodic memory typically relies on MTL structures whereas semantic memories, once consolidated, rely on the neocortex instead.

Additional evidence comes from studies of semantic dementia (SD), a variant of frontotemporal dementia. Patients with SD exhibit progressive neocortical degeneration, particularly in the anterolateral temporal lobe, as well as

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gradual deterioration of semantic memory. They have difficulty with the verbal identification of stimuli, often giving superordinate names (Hodges, Graham, & Patterson, 1995). The deficit is evident in all modalities that have been tested (including odor and taste; Luzzi, Snowden, Neary, Coccia, Provinciali, & Lambon Ralph, 2007) but may be most severe for verbal material, a finding that has sparked debate about the organization of the semantic store (Simmons & Martin, 2009). By contrast, episodic memory and the MTL, while not normal, are not as severely affected (Chan et al., 2001; Graham & Hodges, 1997). Thus, patients with SD have a broad and severe impairment of semantic memory but relatively unimpaired episodic memory—essentially the complement of the deficit in MTL amnesia.

In general, neuropsychological studies of episodic and semantic memory have concentrated on dissociations—that is, situations in which one form of memory is impaired while the other is relatively intact. This approach is in accord with neuropsychological tradition, and it has clearly been fruitful: By showing that episodic and semantic memory are doubly dissociable, neuropsychological studies have provided strong evidence for the distinction between the two. At the same time, this focus on dissociations has meant that neuropsychologists have devoted less attention to the ways in which one form of memory might influence the other. Although a few studies have demonstrated associations between episodic and semantic tasks (Kopelman, 1989; Kopelman, Stanhope, & Kingsley, 1999) it remains unclear if these associations reflect parallel impairments or actual interdependencies. The possible existence of such interdependencies has received relatively little attention in the neuropsychological literature.

Memory theorists, by contrast, have traditionally taken a broader view. Several authors have suggested that these two forms of memory do not necessarily operate in isolation, but frequently influence each other in interesting and theoretically important ways. In his original essay, for example, Tulving (1972) observed that the acquisition of a new episodic memory (as in paired associate learning) is affected by information in semantic memory (such as the degree of association between the two words). This notion was elaborated in the SPI model (for *serial* encoding, *parallel* storage, and *independent* retrieval). This model holds that information is encoded serially—it must pass from the perceptual system to semantic memory before it can be encoded into episodic memory (although see Simons, Graham, & Hodges, 2002, for a contrary argument). Once encoded, the information is stored in parallel and can be retrieved independently. Thus the model specifies different kinds of interdependencies for encoding, storage, and retrieval. Baddeley (1988) has taken a different view; he has suggested that semantic memory might represent the "accumulated residue" (p. 180) of multiple learning episodes, meaning that it consists of information that has been abstracted and dissociated from the various spatiotemporal contexts in which it has been encountered. The model of Reder, Park, & Kieffaber (2009) maintains that episodic memories depend on the binding of semantic concepts to the general or specific context in which they appear (see also Mayes & Roberts, 2001); in other words, episodic memory involves a synergy between semantic memory and contextual information.

Thus, the views on the interdependence of episodic and semantic memory vary from theorist to theorist, but there is broad agreement that such interdependence exists. As Tulving (1983) observed, this interdependence is "variable rather than constant: it should be possible to identify situations in which the interdependence is pronounced as well as those in which it is negligible" (Tulving, 1983, p. 26). In the remainder of the study, we review neuropsychological studies that have revealed a range of interdependencies between episodic and semantic memory. These findings go beyond the straightforward (and banal) observation that every task involves multiple forms of memory to some degree or other. Rather, they highlight systematic interdependencies in a variety of tasks: they show, for instance, that the contribution of episodic memory varies across different types of semantic retrieval, and that the encoding of new episodic memories varies with the integrity of the semantic knowledge base. These interdependencies are of critical importance to the development of a comprehensive theory of episodic and semantic memory.

Interdependence at Encoding

Early investigations of semantic-episodic interdependence focused on the role of episodic memory in the acquisition of new semantic information. New semantic learning is impaired in amnesia, and the impairment is correlated with the degree of MTL damage (Verfaellie, 2000). Nevertheless, certain procedures, such as the introduction of stimulus variability and the use of errorless learning techniques, appear to facilitate the acquisition and integration of new semantic knowledge (Stark, Gordon, & Stark, 2008; Tulving, Hayman, & Macdonald, 1991). Furthermore, some patients, particularly those with early-onset amnesia, can acquire substantial semantic information postmorbidly (Kitchener, Hodges, & McCarthy, 1998; Vargha-Khadem, Gadian, Watkins, Connelly, Van Paesschen, & Mishkin, 1997), although other patients cannot (e.g., Bayley & Squire, 2005). Even when patients with MTL amnesia can learn new information, their acquisition is slow and laborious, however, and the newly acquired information is often hyper-specific and not well integrated into the semantic store. The interpretation of this finding remains controversial. According to one view, these results indicate that new semantic learning depends on the MTL and is therefore impaired or entirely abolished when the MTL is damaged (see Levy, Bayley, & Squire, 2004, for a review), although this view is difficult to reconcile with the observation that patients with extensive MTL damage can learn new information in the absence of episodic memory (Bayley, O'Reilly, Curran, & Squire, 2008). In our view, these results suggest that, in normal controls, episodic memory facilitates the acquisition of new semantic memory as well as the transfer and consolidation of

information into neocortical regions; when the MTL is damaged and episodic memory impaired, new semantic learning is still possible but must rely solely on slow neocortical learning systems instead.

Other work suggests that an intact semantic knowledge base can facilitate the acquisition of new episodic memories. We recently provided evidence for this type of interaction by asking healthy controls and MTL amnesics to study prices of grocery items (Kan, Alexander, & Verfaellie, 2009). (These patients had damage arising from encephalitis or anoxia; full details of their lesions are available in Kan et al., 2009.) Some of the prices were congruent with the participants' prior knowledge (e.g., $3.85 for a gallon of milk), and some were not ($7.59 for a dozen eggs). Participants then took a forced-choice test in which they were asked to choose the correct price from a set of four that included three close foils (e.g., $3.40, $3.85, $4.19, $4.90). Controls showed a congruency benefit—they were more accurate when the prices were consistent with their prior knowledge. The patients, however, showed two different patterns of performance. One subset of patients had a relatively intact semantic store, as evidenced by good performance on a pretest of price knowledge; these patients showed a congruency benefit. Another subset of patients had a compromised semantic store; they did not show a benefit. Neuroimaging analyses showed that the former group had damage limited to the MTL, while the latter group had damage that also extended into lateral temporal regions. The results supported the idea that intact semantic knowledge can provide a framework or scaffolding that facilitates the acquisition of new episodic information. In accordance with this view, evidence from dyslexia, SD, and aphasia has shown that the impairment of this semantic framework impairs the acquisition of new episodic memories, at least in the verbal modality (Graham, Simons, Pratt, Patterson, & Hodges, 2000; Kinsbourne, Tocci Rufo, Gamzu, Palmer, & Berliner, 1991; Ween, Verfaellie, & Alexander, 1996).

Interdependence at Retrieval

The above studies illustrate interdependencies between episodic and semantic memory at encoding, but other work has shown that these forms of memory can interact at retrieval as well. In a recent study (Greenberg, Keane, Ryan, & Verfaellie, 2009), we tested MTL amnesics and controls on a semantic fluency task. Participants were asked to generate exemplars of three types of categories. One type of categories generally elicited retrieval strategies that were autobiographical and spatial (e.g., people generating kitchen utensils tended to think about their own kitchen). Another type elicited autobiographical but nonspatial retrieval strategies (e.g., people generating "things given as birthday presents" tended to think about what they themselves had given and received). A third type elicited neither spatial nor autobiographical strategies (e.g., people generating "things that are usually the color red" simply listed off whatever sprang to mind). The amnesic patients were more impaired on the two autobiographical types than on the nonautobiographical and nonspatial type. Furthermore, after covarying for phonemic fluency, the impairment was selective to the categories that elicited autobiographical strategies. These results suggest that, in normal controls, episodic memory facilitates semantic retrieval by providing an organizational strategy or an efficient route of access; in amnesia, the MTL damage prevents this facilitation *via* impaired episodic retrieval.

Similar evidence comes from a study by Westmacott, Black, Freedman, and Moscovitch (2004). The authors compiled a set of famous names from a range of time periods. Some of the names were autobiographically significant—they were typically linked to a memory of a specific event, and were thus represented in episodic memory. The remaining names were not autobiographically significant; participants simply knew something about the individual in question. Healthy controls showed a performance advantage for autobiographically significant names on a variety of tasks, including fame judgment and speeded reading tasks; however, MTL amnesics showed no such facilitation. Westmacott and colleagues (2004) concluded that the patients' episodic memory impairment reduced their ability to access semantic knowledge (see Kopelman et al., 1999, for a similar argument about famous news events).

Finally, research on autobiographical memory in SD has examined the effect of semantic decline on the retrieval of episodic memories. Although early work suggested that memories of personally-experienced events were spared in SD, later investigations have shown that these memories tend to be devoid of specific detail (Piolino et al., 2003). Longitudinal studies have found that the autobiographical impairment grows more severe as the semantic impairment worsens (Maguire, Kumaaran, Hassabis, & Kopelman, 2010). These observations are consistent with the view that autobiographical memories are constructed in part out of semantic knowledge, and that the decline of semantic memory is associated with the decline of episodic memory as well.

Implications

The studies reviewed here have provided evidence for a range of interdependencies between semantic and episodic memory. Semantic memory facilitates the acquisition of new episodic memories, and episodic memory facilitates the addition of new information to the semantic store. Similarly, episodic memories facilitate the retrieval of information from semantic memory, and semantic memories are the basic material from which complex and detailed episodic memories are constructed.

These findings have implications for the rehabilitation of individuals with memory disorders. In patients with episodic memory disorders, for instance, the evidence reviewed here suggests that the success of rehabilitation programs will depend not only on the severity of the episodic deficit but also on the integrity of the semantic knowledge base, and the extent to which novel information can be thematically integrated with already existing knowledge. Similarly, the

progressive semantic degeneration in SD may undermine efforts to help patients relearn information by relying on their (relatively preserved) episodic memory. Further research is needed to assess the effects of episodic-semantic interdependencies on programs of rehabilitation.

These studies have theoretical implications as well. Some authors have suggested that the existence of such interdependencies argues against the utility of the episodic-semantic distinction, and that it should therefore be discarded (e.g., Toth & Hunt, 1999). We take a different view: The distinction has strong heuristic value, providing us with a clear and intuitive framework in which to conceptualize the different forms of memory impairment seen in patients with MTL amnesia and those with SD. Nevertheless, we suggest that current models of memory need to be broadened and revised in light of this evidence.

First, we suggest that the distinction between episodic and semantic memory is not as clear as it may seem. Many memories do not fit neatly into either category; in fact, these types of memory may actually represent two extremes, with many memories falling somewhere in between. In our study of category fluency, for instance (Greenberg et al., 2009), we tested participants on a range of categories, some of which tended to elicit autobiographical memories. In some cases, these memories really were episodic, as when a participant generated makes of cars by thinking about the car dealerships he had passed on his drive to the lab. In other cases, however, the classification is not as clear, as when a participant generates kitchen utensils by imagining what he used in his own kitchen on a daily basis. What kind of memory is this? On the one hand, this memory has no specific temporal date and is not an event; thus it does not quite qualify as episodic. On the other hand, the specific spatial context indicates that it has not been decontextualized and thus is not quite semantic. Similarly, the participant does not seem to be conscious of a *particular* prior conscious experience, but instead seems to be conscious of an amalgam of several prior conscious experiences. Memories like these are not explicitly addressed in the classic episodic-semantic model, but they appear to fit Neisser's (1981) concept of "repisodic memory," Barsalou's (1988) idea of summarized or extended events, or Conway's (2001) "general events" level of autobiographical knowledge. They are also fairly common; in a study of autobiographical memory in college students, over 30% of elicited memories were of this type (Rubin, Schrauf, & Greenberg, 2003). These memories can be treated as points on a continuum (Cabeza & St. Jacques, 2007; Kazui, Hashimoto, Hirono, & Mori, 2003; Kopelman & Kapur, 2001) or as a qualitatively different type of memory (Conway & Pleydell-Pearce, 2000). While several authors have justifiably cautioned against the endless multiplication of memory types (Roediger & Blaxton, 1987; Weldon, 1999), there is at least some utility to focusing on such general memories; individuals with SD or major depression can produce them even though they have great difficulty generating memories that meet the strict definition of "episodic."

Second, we suggest that these findings have implications for models of memory. Some phenomena, such as the facilitation of new episodic learning by the semantic knowledge base, are consistent with many existing views, including Tulving's (2001) suggestion that encoding proceeds serially from the perceptual system to semantic memory to episodic memory. The finding that episodic memory can facilitate new semantic learning is harder to reconcile with the notion of serial encoding, although it is consistent with Baddeley's (1988) view that semantic memories may arise from the decontextualization of episodic memory. Similarly, the observation that the degeneration of semantic memory is associated with impoverished and overgeneral episodic memory is difficult to reconcile with the idea of parallel storage; it is more consistent with the view that episodic and semantic memory are interlinked, with episodic memory involving a binding between contextual information and information stored in semantic memory (Reder et al., 2009). The evidence so far suggests that there are important interdependencies between memory types at every stage from encoding to retrieval. Neuropsychological case studies will continue to be vital in the attempt to clarify these issues.

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