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Remembering the Past to Imagine the Future: A Cognitive Neuroscience Perspective

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A function of memory that has been overlooked until recently concerns its role in allowing individuals to imagine or simulate possible future events. However, a growing number of recent studies show that imagining possible future events depends on much of the same cognitive and neural machinery as does remembering past events. This linkage has potentially important implications for understanding decision-making and performance under stress, which may impair the ability to make use of past experiences to simulate or predict upcoming events. This article considers recent neuroimaging, neuropsychological, and cognitive studies that reveal shared processes underlying remembering the past and imagining the future.

Memory is typically viewed as a process that is concerned with the past. Experimental and theoretical analyses of memory usually focus on understanding how people retain and remember past experiences and attempt to specify the cognitive and neural processes that are used to recover stored information. While such research has produced many valuable insights into the nature of memory, the heavy focus on retrieval of past experiences has, until recently, led researchers to overlook a potentially important function of memory: its role in allowing individuals to imagine, envisage, or simulate possible future events. Thinking about and preparing for future events is a critically important cognitive function that is highly relevant to real-world situations in which decisions must be made about upcoming situations. A rapidly growing number of recent studies are beginning to show that imagining possible future events depends on much of the same cognitive and neu-

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ral machinery as does remembering past events (Schacter, Addis, & Buckner, 2007). This linkage between past and future has potentially important implications for understanding decision-making and performance under stress, where conditions such as fatigue may impair the ability to effectively make use of past experiences to simulate or predict upcoming events. In this article, we provide a brief overview of recent research from our laboratory that reveals shared neural processes underlying remembering the past and imagining the future.

NEUROIMAGING OF PAST AND FUTURE EVENTS

Several recent studies have used modern neuroimaging techniques such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) to examine brain activity when people remember past events and imagine future events (Okuda et al., 2003; Szpunar, Watson, & McDermott, 2007). We summarize here an fMRI study from our laboratory (Addis, Wong, & Schacter, 2007) that used a novel methodological approach to explore the issue by dividing the past and future tasks into two phases: (a) an initial construction phase during which participants generated a past or future event in response to an event cue (e.g., "dress") and made a button-press when they had an event in mind; and (b) an elaboration phase during which participants generated as much detail as possible about the event. We hypothesized that specific cognitive processes contributing to the completion of such past and future tasks might be differentially engaged during the different phases of the task. Thus, if a particular neural difference between past and future events is only evident during one phase, collapsing across both phases (as in previous studies) could potentially obscure such differences. The same logic also applies to the search for common neural activity, if the common network is engaged during only one, but not another, phase of the task.

Overall, there was striking overlap between the past and future tasks. This overlap was most apparent during the elaboration phase, when participants are focused on generating details about the remembered or imagined event. Perhaps most intriguing, there was common activation in the hippocampus, a structure long known to be involved in aspects of memory, possibly reflecting the retrieval and/or integration of event details into the representation. This finding fits well with related evidence showing that amnesic patients with hippocampal damage, who have great difficulty remembering past events, are also impaired when they are asked to imagine novel scenes (Hassabis, Kumaran, Vann, & Maguire, 2007). In addition, a variety of other brain regions that have previously been implicated in the retrieval of episodic memories (Maguire, 2001) showed common activation for past and future events, including parahippocampal/retrosplenial cortices, left frontopolar cortex, and left anterior temporal cortex (for further discussion, see Addis et al., 2007; Schacter & Addis, 2007a).

The construction phase was associated with some common past–future activity in posterior visual regions and left hippocampus, which may reflect the initial interaction between visually presented cues and hippocampally mediated pointers to memory traces (Moscovitch, 1992). Even so, this phase also revealed some neural differentiation of past and future events in a number of regions. Most interestingly, the right hippocampus was engaged to a greater extent by the future than a past event task, which may reflect the additional relational processing required when one must recombine disparate details into a coherent future event, the novelty of future events, or some combination of the two.

Notably, in all regions exhibiting significant past–future differences, future events were associated with more activity than past events, as also observed by Szpunar et al. (2007). We propose that this apparent regularity across neural regions and across studies reflects the more intensive constructive processes required by imagining future events relative to retrieving past events. Both past and future event tasks require the retrieval of information from memory, engaging common memory networks. However, only the future task requires that event details gleaned from various past events are flexibly recombined into a novel future event and further, that this event is plausible given one's intentions for the future. Thus, additional regions supporting these processes are recruited by the future event task.

Although the elaboration of past and future events recruited a common neural network, it is possible that regions within this network may respond differentially to event characteristics, such as the amount of detail generated and temporal distance, depending on whether the event is in the past or future. To investigate this possibility, we (Addis & Schacter, 2008) examined the relationship between brain activity and the amount of detail reported for past and future events, as well as temporal distance of those events (i.e., near or distant past or future). We used parametric modulation analyses with temporal distance and detail as covariates and focused on the medial temporal lobes and frontopolar cortex. The analysis of detail (independent of temporal distance) showed that the left posterior hippocampus was responsive to the amount of detail comprising both past and future events. In contrast, the left anterior hippocampus responded differentially to the amount of detail comprising future events, possibly reflecting the recombination of details into a novel future event. The analysis of temporal distance revealed that the increasing recency of past events correlated with activity in the right parahippocampus gyrus, whereas activity in the bilateral hippocampus was significantly correlated with the increasing remoteness of future events. We proposed that the hippocampal response to the distance of future events reflects the increasing disparateness of details likely included in remote future events and the intensive relational processing required for integrating such details into a coherent episodic simulation of the future.

FUTURE EVENTS AND THE CONSTRUCTIVE EPISODIC SIMULATION HYPOTHESIS

How can we think about the findings from neuroimaging studies indicating that past and future events are associated with activity in a number of similar brain regions, including the hippocampal region? Schacter and Addis (2007a, 2007b) have put forward the constructive episodic simulation hypothesis. By this view, past and future events draw on similar information stored in episodic memory and rely on similar underlying processes; episodic memory supports the construction of future events by extracting and recombining stored information into a simulation of a novel event. Such a system is adaptive because it enables past information to be used flexibly in simulating alternative future scenarios without engaging in actual behavior. However, one potential cost of such a system is that it is vulnerable to memory errors, such as misattribution and false recognition (see, for example, Schacter & Addis 2007a, 2007b).

Because the constructive episodic simulation hypothesis specifically emphasizes the importance of flexibly relating and recombining information from past episodes, it is supported by the evidence discussed earlier that links hippocampal function with future event simulation. The hippocampal region is thought to support relational memory processes that link together disparate bits of information (e.g., Eichenbaum & Cohen, 2001), and these processes are hypothesized to be crucial for recombining stored information into future event simulations. Further support along these lines comes from a behavioral study of future event simulation in older adults. Addis, Wong, and Schacter (2008) provided younger and older adults with event cues and gave them 3 minutes to generate, in as much detail as possible, episodes from specified periods in the past or future. Consistent with previous work (Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002), older adults reported less detailed episodic memories of past events than did younger adults. Importantly, the same effect occurred for future events: the episodes imagined by older adults also contained sparser episodic information compared to younger adults. Critically, as predicted by the constructive episodic simulation hypothesis, the ability of older adults to generate episode-specific details of both the past and future events was correlated with a measure of their ability to integrate information and form relations between items—that is, with their relational memory performance.

CONCLUDING COMMENTS

The data and ideas reviewed in this article indicate that imagining or simulating future events shares much in common with remembering past events. We believe that these observations have important theoretical implications for understanding the constructive nature of the human memory system. Memory-related processes are active not only when we remember the past but also when we engage in the constructive activities necessary to imagine possible future scenarios. A next step in this line of research should be to examine how people use information stored in memory to imagine and prepare for upcoming events in real-world, stressful settings such as those that are the focal point of much of this volume.

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