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Implicit Memory, Constructive Memory, and Imagining the Future: A Career Perspective

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Abstract

In this article I discuss some of the major questions, findings, and ideas that have driven my research program, which has examined various aspects of human memory using a combination of cognitive, neuropsychological, and neuroimaging approaches. I do so from a career perspective that describes important scientific influences that shaped my approach to the study of memory, and discusses considerations that led to choosing specific research paths. After acknowledging key early influences, I briefly summarize a few of the main takeaways from research on implicit memory during the 1980s and 1990s, and then move on to consider more recent ideas and findings concerning constructive memory, future imagining, and mental simulation that have motivated my approach for the past two decades. A main unifying theme of this research is that memory can impact psychological functions in ways that go beyond the simple, everyday understanding of memory as a means of revisiting past experiences.

Keywords

Priming; memory errors; episodic memory; episodic simulation; prospection

For the past forty years and more, my work has focused on the analysis of human memory. During this time, memory has increasingly become a multidisciplinary pursuit as well as a central focus in numerous areas of psychology. When I entered the field in the 1970s, cognitive psychologists tested models of memory based on experimental studies of healthy individuals, neuropsychologists studied brain-damaged patients with memory problems, and neuroscientists studied non-human animals in an attempt to specify the neural mechanisms that make memory possible, but there was little interaction among these researchers. During the 1980s, cognitive psychologists, neuropsychologists, and neuroscientists interested in memory began to interact (see, for example, Cermak, 1982; LeDoux & Hirst, 1986; Weinberger, McGaugh, & Lynch, 1985), ultimately providing the foundations for a cognitive neuroscience approach to memory that has developed explosively over the past two decades (for an overview, see Slotnick, 2017). At the same time, analyses of memory started to occupy an increasingly prominent role in areas ranging from social cognition (e.g., Srull & Wyer, 1989) to developmental psychology (e.g., Brainerd & Pressley, 1985) and psychopathology (e.g., Williams & Scott, 1988). More recently, promising new connections

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have developed between the study of memory and investigations of such cognitive functions as decision making (e.g., Redish & Mizumori, 2015; Shohamy & Daw, 2015), theory of mind (e.g., Buckner & Carroll, 2007; Spreng, Mar, & Kim, 2009) and future thinking or prospection (e.g., Atance & O'Neil, 2001; Gilbert & Wilson, 2007; Schacter, Addis, & Buckner, 2007, 2008; Seligman, Railton, Baumeister, & Sripada, 2013; Suddendorf & Corballis, 2007).

I begin this article by stressing the broad relevance of memory research across numerous areas of psychology because I believe that much of my work has been linked together by an interest in the reach of memory across multiple domains of mental life; more specifically, how manifestations of memory impact psychological functions in ways that go beyond the everyday, common sense understanding of memory as a means of revisiting past experiences. I first pursued this interest in early work on what Graf and Schacter (1985) termed implicit memory, where recent experiences impact performance on subsequent tasks that do not require conscious recollection of those experiences (Schacter, 1987a). More recently, I have focused on very different ways in which memory impacts performance on tasks that are not typically thought of as 'memory tasks' in the traditional sense of the term, but instead tap aspects of prospection, imagination, problem solving, and creativity (Schacter, Benoit, & Szpunar, 2017; Schacter & Madore, 2016). I have approached these latter studies in the context of a conceptual framework that characterizes memory as a fundamentally constructive act (following Bartlett, 1932, and many others since), prone to various kinds of errors and distortions that reveal the operation of adaptive processes (Schacter, 1996, 2001b, 2012; Schacter, Guerin, & St. Jacques, 2011). Linking these two perspectives – the reach of memory into 'non-mnemonic' domains on the one hand and constructive aspects of memory on the other – has occupied much of my theoretical and empirical attention for the past two decades.

This article considers some of the key findings, ideas, and questions produced by this approach from a career perspective, i.e., placing my research program in the context of some important influences that led me down the main research paths I have chosen and reflecting on some of the scientific choices I have made. I will first consider formative experiences that were crucial in instilling a particular scientific mindset that has guided my subsequent research and theorizing. Next, I will briefly summarize some early work on implicit memory. I will then turn to the empirical and theoretical issues concerning constructive memory, imagination, and prospection that have been central to more recent work in my laboratory.

Early Career Influences

My path to a career in memory research began in 1974, after completing an undergraduate psychology degree at the University of North Carolina at Chapel Hill focused mainly on clinical psychology. I had the good fortune to be hired as a research assistant by the late Herbert Crovitz, an experimental psychologist at Duke University and the nearby Veterans Affairs Medical Center in Durham. I knew next to nothing about memory, but Crovitz had just begun to study memory disorders that result from brain damage. In my capacity as a research assistant, I tested some intriguing cases of amnesia – patients whose severe memory deficits contrasted with their relatively intact abilities in the domains of perception, language, and other non-mnemonic cognitive functions. Exposure to those patients, and stimulating discussions about them with Crovitz, sparked my interest in human memory.

Herb Crovitz was also instrumental in the next step of my scientific journey: deciding to pursue graduate studies at the University of Toronto, beginning in fall 1976. Crovitz greatly admired Endel Tulving, the eminent memory researcher who had just returned to Toronto after several years at Yale University. I was fortunate that Tulving took me on as a graduate student at a time when the environment at Toronto for studying human memory was unsurpassed, including numerous established luminaries as well as up-and-coming young researchers who provided broad exposure to a variety of methodological and theoretical approaches.

These early experiences shaped my approach to the study of memory in many ways, but perhaps most important was the orientation toward memory research in particular, and scientific research in general, that Crovitz and Tulving shared. Both stressed the value of finding a question that could lead one to previously uncharted territory, where one could discover something new, theoretically revealing, and hopefully surprising. Both had little time for experiments that followed up incrementally on existing findings or used workman-like procedures to make a small point that was unlikely to make much of a difference in the grand scheme of things. As anyone who has spent much time with Endel Tulving knows, the first question one could expect from him upon proposing a new project was simple, predictable, and critically important: What will we know after you complete this project that we did not know before and that is worth knowing? Tulving set a high bar for what is ‘worth knowing’, so thinking about this simple question with that high bar in mind could help one to rule out paths that might be easy to pursue but were ultimately not worth pursuing. Note that this emphasis on novelty should not be at odds with the equally important need to replicate one’s findings and take small steps to systematically characterize a phenomenon; ideally one strives to combine novelty and rigor. Indeed, decades before the existence of the recent replication crisis, Tulving often emphasized to his students that replication is a necessary and critical part of science, and I have frequently taken the approach of attempting to replicate and explore the characteristics of a new phenomenon.

Crovitz and Tulving shared another interest that impacted me: curiosity about, and respect for, the history of our field. Crovitz wrote a delightful (and in my view under-appreciated) book, *Galton’s Walk* (Crovitz, 1970), which paid homage to the contributions of the great 19^{th}-century psychologist Sir Francis Galton and used them as a starting point for developing novel approaches to memory, thought, and creativity. Tulving was an avid reader of history and philosophy of science, and highly knowledgeable about the history of memory research. He changed my intellectual life by including a brief reference to the work of a little-known German biologist named Richard Semon in a book chapter titled “Ecphoric processes in recall and recognition” (Tulving, 1976). Semon had coined the term “ecphory” – roughly equivalent to “memory retrieval” – in two early 20th-century books on memory that few researchers other than Tulving had noticed. Curious about Tulving’s use of the term ecphory, in early 1977 I read the English translations of Semon’s two books on memory (Semon, 1921, 1923), and discovered to my surprise that he had put forth a systematic theory of memory that anticipated many modern views (and had also coined the better-known term "engram" for memory trace). Discussions of these books with Tulving and fellow graduate student Eric Eich resulted in an article where we discussed Semon's ideas in the context of then-current thinking in memory research (Schacter, Eich, & Tulving, 1978). Intrigued by the fascinating and sometimes tragic story of Semon's life, and the historical issues raised by the long neglect of his prescient theory, I went on to write a book about Semon that told his story and used it as a springboard for addressing a variety of related issues in memory research, as well as in the history and psychology of science (Schacter, 1982; reissued with a foreword by Tulving in Schacter, 2001a).

I wrote that book while I was a graduate student – an admittedly risky pursuit for someone whose day job centered on doing memory experiments. But, spurred on by Tulving's encouragement and respect for history of science, I completed a task about which I had become quite passionate, that cemented my interest in the history of our field, and that broadened my perspective in a way that has remained with me (I also take some pleasure in a recent mini-revival of interest in Semon's ideas by neuroscientists who have developed sophisticated new tools for analyzing the engram; see, for example, Josselyn, Köhler, & Frankland, 2017).

One general lesson that stuck with me from this early experience of book writing is that intellectual passions and curiosity take priority over just about all other considerations (setting aside personal/family issues) when developing a career as a psychological scientist. Was it a wise move from a career development perspective to spend so much time writing a historical book that did not directly contribute to the list of experimental publications I would need to establish myself as a memory researcher? Probably not – it was a perilous undertaking that could easily have interfered with developing the kind of track record expected of a young experimental psychologist. But should I have set aside my deep interest in the subject matter or the galvanizing energy I felt when pursuing the project because of strategic concerns about career advancement? For me, the answer was, and still is, no. If intellectual passion and curiosity drive one's engagement with a project – book, experiment, or otherwise – then strategic career considerations will likely work themselves out. Developing a successful career requires both passion/curiosity and strategic planning, but in my case at least, the former has always driven the latter.

Thankfully, I also managed to complete an experimental dissertation project in 1981 (eventually published in Schacter, 1983), and along with Endel Tulving and Morris Moscovitch, receive funding during that same year to establish a Unit for Memory Disorders at the University of Toronto. I was responsible for directing the Unit and was able to focus almost entirely on research (along with occasional teaching in the Department of Psychology at Toronto). I thus managed to avoid some of the non-research responsibilities that come with a more standard tenure-track faculty position, such as a full teaching load and committee work. Even though I was in a virtually ideal situation for maximizing research productivity, remaining at the same institution at which I had received my PhD degree, and continuing to collaborate on some studies with my PhD advisor, inevitably raised issues about scientific independence. Thus, after six highly productive years at the Unit for Memory Disorders, I decided that the time had come to venture out more fully on my own. In 1987, I began a tenured Associate Professor position in the Department of Psychology at the University of Arizona, which was rapidly building an exciting new program in cognitive science. Leaving the supportive and productive environment at Toronto entailed some risk, but I felt that it was worth taking for the potential benefits of a novel scientific and collegial environment. I spent nearly four stimulating years at Arizona before accepting a position as Professor of Psychology at Harvard University, where I have remained since 1991.

Implicit Memory

The major line of work that my colleagues and I pursued at the Unit for Memory Disorders focused on what came to be known as implicit memory (Graf & Schacter, 1985; Schacter, 1987a). My interest in this topic had been sparked in Crovitz's lab by reading early literature indicating that amnesic patients' behavior and performance reflected influences of recent experiences that they could not recall consciously (e.g., Claparède, 1911/1951). I became even more interested in these phenomena when I was a visiting graduate student at Oxford University in 1978 (made possible by Endel Tulving's sabbatical there). Tulving and I met regularly with the late Lawrence Weiskrantz, whose pioneering studies with Elizabeth Warrington had produced some fascinating observations suggestive of preserved implicit memory in amnesics (e.g, Warrington & Weiskrantz, 1968). Our conversations frequently focused on how to think about their intriguing findings.

After returning to Toronto, Tulving and I continued to discuss the issues that had arisen in our meetings with Weiskrantz. These discussions led to a study with healthy young adults that showed that priming effects on a word fragment completion test could be dissociated experimentally from performance on a standard old/new recognition memory test and even appeared to occur independently of conscious recognition (Tulving, Schacter, & Stark, 1982). That study, along with related work from others that dissociated priming from conscious memory in both healthy individuals (e.g., Graf, Mandler, & Haden, 1982; Jacoby & Dallas, 1981) and amnesic patients (e.g., Cohen & Squire, 1980), pointed toward the existence of a largely unexplored but potentially rich domain of memory where important discoveries could be made.

During the decade that followed, my colleagues and I (at Toronto, Arizona, and Harvard) intensively explored implicit memory in behavioral and neuroimaging studies of normal individuals, and behavioral studies of amnesic and other neuropsychological patients. We focused mainly on priming effects in tasks ranging from completing visual word stems with the first word that pops to mind (e.g., Graf & Schacter, 1985; Schacter, Alpert, Savage, Rauch, & Albert, 1996; Schacter, Rapcsak, Rubens, Tharan, & Laguna, 1990) to identifying auditory words masked in noise (e.g., Church & Schacter, 1994; Schacter, Church, & Treadwell, 1994) and making decisions about whether novel visual shapes constitute possible or impossible objects (e.g., Schacter, Cooper, & Delaney, 1990; Schacter, Reiman, Uecker, Polster, Yun, & Cooper, 1995). Building on previous findings, we found that 1) a variety of experimental manipulations (e.g., type of encoding task, study-test changes in sensory modality) had different effects on priming versus standard explicit memory tasks; 2)

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various kinds of brain damage often spared priming while impairing explicit memory; and 3) neuroimaging techniques revealed distinct neural signatures of priming and explicit memory.

These dissociations led my colleagues and I to propose that distinct systems support performance on the two classes of tasks (e.g., Schacter, 1990; Tulving & Schacter, 1990; for an alternative view, see Roediger, 1990, and for an attempted resolution of the two approaches, see Schacter, 1992). We also delineated related, striking phenomena in which effects of a prior experience could be demonstrated despite reduced or absent recollection of that experience, such as source amnesia (Schacter, Harbluk, & McLachlan, 1984) and the ability of amnesic patients to learn such complex tasks as computer programming despite in some cases entirely lacking explicit memory for having performed the task previously (e.g., Glisky, Schacter, & Tulving, 1986; Glisky & Schacter, 1987).

This work was exciting because of the sheer novelty of the implicit memory phenomena we were studying and the importance of the theoretical issues that those phenomena raised concerning the nature and basis of different forms of memory (cf., Cohen & Eichenbaum, 1993; Schacter & Tulving, 1994; Sherry & Schacter, 1987; Squire, 1992). However, the focus of my research program soon changed as a result of unanticipated developments that pointed toward another domain in which novel phenomena could be discovered and important theoretical issues were at stake.

The Cognitive Neuroscience of Constructive Memory

In 1994, the neuropsychologist Bill Milberg referred a patient to me, BG, who had sustained a focal right frontal lobe infarction. The patient was of particular interest at the time because recently published neuroimaging studies had revealed a surprising link between right frontal lobe activation and episodic memory retrieval (e.g., Tulving, Kapur, Craik, Moscovitch, & Houle, 1994). Collaborating with Milberg, post-doc Tim Curran, and several others, we quickly discovered an unexpected but striking finding: BG exhibited pathologically high levels of false recognition. In a variety of paradigms where he was initially shown a series of words or pictures, BG made many more false alarms to items that he had not been shown previously than any of the control participants, claiming to have detailed recollections of these non-studied items (Curran, Schacter, Norman, & Galluccio, 1997; Schacter, Curran, Galluccio, Milberg, & Bates, 1996). Follow-up experiments revealed that BG inappropriately based his recognition decisions on general similarity between the kinds of items he had studied and the characteristics of a particular test item (e.g., if BG saw a list of common words, then simply presenting a common word as a test item was often sufficient for him to endorse either an old or a new word as previously studied; but he would not endorse a nonsense word as previously studied). These and related findings from similar patients (e.g., Parkin, Bindschaedler, Harsent, & Metzler, 1996) raised intriguing theoretical questions about the neural basis of false recognition that had not received much attention in the literature, suggesting a role for prefrontal regions in setting decision criteria when people make old/new and related kinds of memory judgments.

At around the same time, questions concerning false memories took on a broader significance as a consequence of the exploding controversy concerning the accuracy of recovered memories of childhood sexual abuse (e.g., Loftus, 1993). The emerging societal importance of understanding issues related to memory accuracy and distortion called for a broad approach that combined insights from different disciplines. As part of Harvard's new interdisciplinary program in Mind, Brain, and Behavior, I and several colleagues organized a conference in 1994 devoted to exploring the nature of memory distortion at multiple levels of analysis, including contributions from neurobiologists, psychologists, sociologists, and historians. The conference provided the basis for the publication of an edited volume that appeared the following year (Schacter, 1995).

In light of the fascinating and relatively unexplored questions concerning the neural basis of false recognition that were raised by our studies of patient BG, and the rich psychological and social implications of the broad issue of memory distortion, it became clear to me that there was much that we did not know, and that would be worth knowing, about the cognitive neuroscience of constructive memory. Thus I changed the focus of my research program to put more emphasis on this relatively unexplored scientific territory. While at the time I had misgivings about de-emphasizing the study of implicit memory, the scientific excitement associated with pursuing a new and likely productive direction for my lab outweighed any risks associated with a reduced emphasis on a familiar and rewarding pursuit, such as concerns about jeopardizing my grant funding, which at the time was heavily oriented toward implicit memory research (and I did continue with some work on implicit memory; e.g., Dobbins, Schnyer, Verfaellie, & Schacter, 2004; Schacter, Wig, & Stevens, 2007). A lesson here worth noting explicitly is that not all aspects of a research career are carefully planned in advance – in this instance, an unexpected case referral from a colleague ultimately led to a decision to fundamentally change the direction of my research program.

One immediate consequence of this decision was to focus on developing different kinds of cognitive neuroscience evidence to complement the work we had initiated with patient BG. To get started, we used the Deese-Roediger-McDermott or "DRM" paradigm, a procedure for reliably producing false memories that was initially reported by Deese (1959), and was revived and expanded by Roediger and McDermott (1995). In this paradigm, participants study semantic associates of a nonstudied critical lure word (e.g., *candy, sour, sugar, bitter, good, taste*, etc. for the lure word *sweet*), and subsequently exhibit high levels of false recall and recognition of the critical lure. In experiments examining DRM false recognition in amnesic patients with damage to the medial temporal lobe and related structures, we consistently found that amnesics not only showed poorer true recognition of studied items than did matched controls, but also showed lower levels of false recognition of the critical lure word (e.g., Schacter, Verfaellie, & Pradere, 1996). These findings contrasted sharply with our and others' findings concerning elevated false recognition levels after damage to regions within prefrontal cortex, and further suggested that medial temporal lobe structures play a role in encoding and/or retrieving the kind of information that supports false recognition of related lure words, which we suggested involved retaining the semantic gist of the list (cf., Reyna & Brainerd, 1995).

To obtain converging evidence on the neural basis of false recognition, we initiated neuroimaging studies to examine DRM false recognition in non-amnesic individuals. Relying on both positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), we reported evidence of activation within the medial temporal lobe during both true and false recognition, broadly consistent with evidence of reduced DRM true and false recognition in amnesic patients (Cabeza, Rao, Wagner, Mayer, & Schacter, 2001; Schacter, Reiman et al., 1996). Further, these studies also implicated regions within prefrontal cortex in retrieval monitoring processes, consistent with observations concerning elevated false recognition in BG and similar patients. At the same time, we initiated similar studies of false recognition with healthy older adults, finding strong evidence for age-related increases in false recognition in the DRM paradigm (Norman & Schacter, 1997) and in a categorized pictures paradigm developed in my laboratory (Koutstaal & Schacter, 1997). In light of related evidence pointing toward frontal lobe dysfunction as an important contributor to age-related memory declines in source monitoring paradigms (e.g., Glisky, Polster, & Rothieaux, 1995; Schacter, 1987b), our findings on age-related increases in false recognition converged nicely with our neuropsychological and neuroimaging findings.

The general picture painted by these studies was one in which false recognition thrives when people retain mainly memory for the general features of studied items and rely on this information at the time of retrieval. It thus follows that conditions that promote encoding of specific or distinctive features of target information should help to reduce such gist-based false recognition. Consistent with this perspective, we showed that when DRM lists are encoded in the form of pictures that heighten reliance on distinctive information when making old/new recognition decisions, false recognition of critical lure items is significantly reduced (Israel & Schacter, 1997), reflecting the use of what we subsequently referred to as a *distinctiveness heuristic* (Schacter, Israel, & Racine, 1999; see also, Dodson & Schacter, 2002): a retrieval orientation in which people expect to remember vivid details of a past experience and make recognition judgments based on this metacognitive expectation.

In an attempt to pull together these emerging findings, and conceptualize them in the context of related earlier observations of confabulations in brain-damaged patients (e.g., Moscovitch, 1995) as well as ideas about the role of medial temporal and frontal regions in memory encoding and retrieval processes (cf., Johnson, Hahstroudi, & Lindsay, 1993; McClelland, McNaughton, & O'Reilly, 1995; Schacter, 1987b; Squire, 1992), we formulated a *constructive memory framework* (Schacter, Norman, & Koutstaal, 1998). Key ideas in this framework included the role of pattern separation at the time of encoding and the importance of formulating a focused or specific description of a target event at the time of retrieval; failures at either stage could produce the kind of gist or similarity-based false recognition delineated in the foregoing studies.

This integrative effort also led me to think broadly about different kinds of memory errors and failures. Psychologists had studied forgetting since the groundbreaking studies of Ebbinghaus (1885) and memory distortions since Bartlett's (1932) pioneering efforts; the literature was full of papers describing different ways in which memory can fail or lead us astray. But it was equally clear that there had been few attempts to organize or classify the different ways in which memory can go wrong. I proposed such a scheme in an article and subsequent book concerning what I termed the seven 'sins' of memory (Schacter, 1999, 2001b), comprising three sins of omission that refer to different kinds of forgetting (*transience, absent-mindedness, blocking*) and four sins of commission that refer to forms of memory distortion (*misattribution, suggestibility, bias*) and intrusive memories (*persistence*). Considering all these sins together, and the havoc that they can wreak in everyday life, could easily lead one to conclude that human memory is hopelessly and fundamentally flawed. But it makes little sense that evolution would have yielded such a deeply flawed system. Thus, taking a lead from earlier analyses of adaptive aspects of forgetting (Anderson & Milson, 1989; Bjork & Bjork, 1988), I proposed that each of the seven sins could be viewed as by-products of otherwise adaptive features of memory. For example, I argued that the memory sin that most closely corresponds to false recognition – misattribution – often arises because we do not need to record every detail of every experience, and instead extract the central features, meaning, or gist of past experiences, which is fundamental to such critical functions as our ability to categorize and generalize (cf., McClelland, 1995; Reyna & Brainerd, 1995). This focus on adaptive aspects of memory errors was an important part of the 'seven sins framework', although my original arguments (Schacter (1999, 2001b) were based more on broad conceptual analyses than on direct experimental evidence. Nonetheless, that conceptual focus helped me to crystallize two key questions that played a critical role in the next stage of my research program: 1) What are the functions of a constructive memory? and 2) How can we address such a question experimentally?

Remembering the Past and Imagining the Future

My laboratory's focus on the cognitive neuroscience of constructive memory continued into the first decade of the 21st century and beyond. We relied increasingly on the use of neuroimaging techniques to address key questions, resulting in studies that employed novel paradigms to examine the neural systems underlying true vs. false recognition (e.g., Aminoff, Schacter, & Bar, 2008; Guerin, Robbins, Gilmore, & Schacter, 2012; Gutchess & Schacter, 2012; Slotnick & Schacter, 2004), delineate the neural correlates of the distinctiveness heuristic that we had previously characterized only behaviorally (Gallo, Kensinger, & Schacter, 2006), and dissociate different kinds of prefrontal-based retrieval monitoring mechanisms (Dobbins, Foley, Schacter, & Wagner, 2002).

At the same time, I began to think about constructive memory with respect to a striking phenomenon that I had observed two decades earlier at the Unit for Memory Disorders in Toronto. There we intensively studied a profoundly amnesic patient, KC, who had sustained a head injury in a motorcycle accident (for an overview of research with KC, see Rosenbaum et al., 2005). Although he showed robust priming effects and other manifestations of implicit memory, KC could not explicitly recollect any particular event that had happened in his past – in other words, he had a complete lack of episodic memory (Tulving, 1985). During a testing session in the early 1980s at which I was present, Endel Tulving asked KC a seemingly simple yet important question: What will you be doing tomorrow? KC drew a blank, just as when he was asked to remember what he did yesterday, thus suggesting that an inability to remember past episodes has a devastating impact on the ability to imagine future episodes (Tulving, 1985).

That observation stuck with me, and from time-to-time over the ensuing years I thought about how to investigate the role of memory in imagining future experiences. However, my lab was fully occupied with studies of implicit memory and memory distortion, as well as various other related pursuits, including research on the neural underpinnings of memory encoding (e.g., Wagner et al., 1998), metamemory (e.g., Maril, Simons, Mitchell, Schwartz, & Schacter, 2003; Chua, Schacter, Rand-Giovanetti, & Sperling, 2006) and emotional influences on memory (e.g., Kensinger, & Schacter, 2006).

Consequently, my interest in initiating studies of future imagining remained on the back burner until 2005–2006, when two things happened. First, Donna Rose Addis, who had done fMRI research focused on neural correlates of autobiographical memory for her graduate work (e.g., Addis, Moscovitch, McCrawley, & McAndrews, 2004), arrived in my lab as a post-doctoral fellow. We discussed ways in which the approaches she had taken to studying autobiographical memory could be extended to studying how people imagine future episodes, soon resulting in the development of a new fMRI paradigm that allowed us to directly compare the two. During scanning, participants received word cues and were asked to remember a past personal experience, imagine a future personal experience, or perform control tasks involving non-personal visuo-spatial or semantic processing. The study revealed similarly increased activation for the past and future event tasks compared with the control tasks in a set of brain regions that overlap substantially with the well-known default mode network (for reviews, see Buckner, Andrews-Hanna, & Schacter, 2008; Raichle, 2015), including medial temporal and frontal lobes, posterior cingulate and retrosplenial cortex, and lateral parietal and temporal areas (Addis, Wong, & Schacter, 2007; cf., Okuda et al., 2003; Szpunar, Watson, & McDermott, 2007). Based on these observations, Schacter, Addis, and Buckner (2007) suggested that the aforementioned regions comprise a core neural network that underpins remembering past experiences, imagining future experiences, and related kinds of mental simulations (for a recent meta-analysis that confirms this idea based on a larger sample of studies, see Benoit & Schacter, 2015).

Second, although initially this new work on future imagining felt theoretically disconnected from my earlier work, as we moved forward with it I began to see that this work might be related in an important way to a key question raised by my earlier theorizing about adaptive aspects of the seven sins of memory: What are the functions of a constructive memory? There were several kinds of evidence suggesting a tight linkage between episodic memory and future imagining, including the above-noted neuroimaging evidence, Tulving’s (1985) observations concerning patient KC, and other related observations (for reviews, see Klein, 2013; Mullally & Maguire, 2014; Schacter et al., 2008, 2012, 2017; Szpunar, 2010). Adopting a functional perspective, Schacter and Addis (2007a, 2007b) hypothesized that episodic memory enables past experiences to be used flexibly to imagine novel future scenarios by allowing us to recombine bits and pieces of past experiences into simulations of novel situations that might occur in the future. The ability to flexibly use past experiences to construct mental simulations is potentially highly adaptive because it allows us to mentally ‘try out’ different approaches to a future situation without having to engage in actual behaviors (cf., Ingvar, 1979; Jing, Madore, & Schacter, 2017). We further hypothesized that the flexibility of episodic memory that makes it adaptive for simulating future experiences comes at the cost of vulnerability to errors and distortions that result from mistakenly combining elements of imagination and memory. We called this set of ideas the *constructive episodic simulation hypothesis* (Schacter & Addis, 2007a, 2007b; for related views, see Dudai & Carruthers, 2005; Suddendorf & Corballis, 2007) Once again, an opportunity presented itself to pursue a new research direction offering the potential for making novel empirical discoveries and addressing significant theoretical questions. This new line of work felt particularly promising because I viewed it as closely related conceptually to our research on the cognitive neuroscience of constructive memory during the previous decade. Therefore, it was an easy decision to focus much of my laboratory's efforts on attempting to understand the processes that support our ability to imagine or simulate future and other hypothetical experiences, and how this ability is related to remembering past experiences.

Of course, the general topic of future thinking, more recently referred to as *prospection* (cf., Buckner & Carroll, 2007; Gilbert & Wilson, 2007; Seligman et al., 2013), comprises a vast psychological terrain that has been of interest to psychologists for decades (see Oettingen, Sevincer, & Gollwitzer, 2018). Szpunar, Spreng, and Schacter (2014) offered a preliminary taxonomy that distinguishes among four basic forms of prospection: *simulation* (constructing a detailed mental representation of the future), *prediction* (estimating the likelihood of, or one's reaction to, a specific future outcome), *intention* (setting a future goal), and *planning* (identifying and organizing steps to achieve a goal). Szpunar et al. further suggested that the representational contents underlying each of the four forms of future thinking could vary on a gradient from *episodic* (simulations, predictions, intentions, or plans that relate to specific autobiographical events that might occur in the future) to *semantic* (simulations, predictions, intentions, and plans that relate to more general or abstract states of the world that might occur in the future). From this perspective, the term *episodic future thinking* (Atance & O'Neil, 2001; Szpunar, 2010) encompasses episodic simulation, prediction, intention, or planning. As a practical matter, however, our studies of episodic future thinking have nearly always focused on episodic simulation, so here I will use the terms episodic future thinking and episodic simulation interchangeably.

Mechanisms of Episodic Simulation and Future Thinking

Much of our recent research has attempted to test a central tenet of the constructive episodic simulation hypothesis, namely that episodic memory processes are key drivers of the observed cognitive and neural similarities between remembering past experiences and imagining future experiences. In addition to the aforementioned neuropsychological and neuroimaging evidence favoring this idea, another line of evidence from my lab that initially supported this view came from cognitive research examining young and older adults. In a study by Addis, Wong, and Schacter (2008), young and older adults remembered past experiences and imagined future experiences in response to word cues. The details of their remembered and imagined experiences were coded using the well-established Autobiographical Interview (Levine, Svoboda, Hay, Winocur, and Moscovitch, 2002), which distinguishes between internal or episodic details (e.g., details about actions, settings, and people in an event) and external details, which include semantic details, commentary, and the like. Older adults produced fewer internal and more external details than young adults both when they remembered past experiences and imagined future experiences. In light of much prior evidence that episodic memory is impaired in older compared with younger adults, we interpreted these results as support for the idea that age-related deficits in episodic retrieval are responsible for reduced internal details during both remembering and imagining, consistent with the constructive episodic simulation hypothesis. That interpretation fit well with other evidence that a variety of psychiatric and neurological patient populations show similar reductions in episodic detail when they remember past experiences and imagine possible future experiences (for review, see Schacter et al., 2008, 2012).

However, it was not long before a new series of experiments cast doubt on this seemingly straightforward state of theoretical affairs. Gaesser, Sachetti, Addis, and Schacter (2011) replicated age-related reductions in internal details for remembering past experiences and imagining future experiences in experiments using pictures (i.e., photos of everyday scenes served) as cues for remembering and imagining. Critically, however, we also found similar age-related reductions when young and older adults simply described what they saw in the pictures: older adults provided fewer internal details (i.e., details physically present in the picture) and more external details (semantic information, commentary) than did younger adults. Describing a picture does not require retrieving episodic details from past experiences. Consequently, these findings suggested that non-episodic factors that change with age and could plausibly influence performance on the memory, imagination and description tasks we used, such as narrative style or communicative goals (e.g., Trunk & Abrams, 2009), might account for the observed age effects on all three tasks, rather than changes in episodic retrieval.

These findings constituted a clear challenge to the constructive episodic simulation hypothesis, not only with respect to findings from older adults, but also more broadly: perhaps many or all of the documented similarities between remembering past experiences and imagining future experiences could be attributed to non-episodic rather than episodic influences. While it is jarring when an experimental result calls into question fundamental aspects of one's theoretical thinking, it is also exciting because such a result demands new experiments that one would not have thought about doing otherwise. To address the issue, we needed a way of to distinguish episodic from non-episodic influences on tasks such as future imagination or picture description. The approach we adopted was to *manipulate* the involvement of episodic memory on these tasks by attempting to 'prime' episodic retrieval processes and test for the influence of such 'priming' on subsequent tasks.

To accomplish this objective, we adapted a well-known procedure, the Cognitive Interview (CI; Fisher & Geiselman, 1992), which has been used successfully in forensic contexts to elicit detailed episodic retrieval of crime events in eyewitnesses (for a meta-analysis, see Memon, Meissner, & Fraser, 2010). We referred to our adapted version of the CI as an *episodic specificity induction* (ESI; for review, see Schacter & Madore, 2016). In our procedure, participants first view a video of an everyday scene, and then receive either an ESI or a control induction. During ESI, participants are given a variety of CI probes to elicit detailed episodic retrieval of events in the video, such as generating mental images of what they had seen, and recalling in as much detail as possible people, actions, the arrangement of objects, and so on. In the control induction, participants provide their general impressions of the video but do not engage in detailed episodic retrieval (in some experiments, the control induction involves completing math problems). After these inductions, participants complete unrelated tasks, such as imagining a future experience or describing a picture. We reasoned that if a task draws on episodic memory, performance should be increased by a prior ESI (relative to the control induction), whereas if a task does not draw on episodic memory, it should be uninfluenced by a prior ESI. Consistent with this prediction, ESI boosted the number of internal/episodic details that both young and old participants provided when asked to remember past experiences or imagine future experiences in response to picture cues, whereas it had no impact on either type of detail when participants described the picture cue (Madore, Gaesser, & Schacter, 2014). These results provide strong evidence for the selective involvement of episodic retrieval in remembering past experiences and imagining future experiences, in line with the constructive episodic simulation hypothesis, and further suggest that performance on the picture description task is driven by non-episodic processes such as communicative goals or narrative style – processes that change with age and therefore impact the performance of older adults (for detailed discussion, see Schacter, Devitt, & Addis, in press). The general lesson here has broad implications: when using narrative tasks to assess remembering, imagining, and related process, it is theoretically crucial to assess and distinguish between episodic and non-episodic processes. In addition to behavioral effects of ESI, we have also documented neural effects in core network regions previously linked to episodic retrieval. Administering ESI just before participants imagine future experiences during fMRI scanning both replicated previous behavioral results and produced significant increases in hippocampus and inferior parietal lobule compared with control conditions, and also produced subsequent changes in resting-state functional connectivity between these regions and other core network regions (Madore, Szpunar, Addis, & Schacter, 2016). To obtain even stronger *causal* evidence for a role of episodic retrieval in future imagining, we have also manipulated episodic retrieval by using transcranial magnetic stimulation (TMS) to temporarily disrupt the activity of a region thought to be critical for both episodic memory and simulation: the left angular gyrus, a part of the inferior parietal lobule in the core network linked previously with aspects of episodic retrieval (e.g., Yazar, Bergstrom, & Simons, 2014). Following TMS to this region, participants provided fewer internal details and more external details when remembering a past experience or imagining a future experience in response to word cues compared with TMS to a control site (the vertex; Thakral, Madore, & Schacter, 2017). Moreover, TMS to the angular gyrus had no effect on a control task that required generating semantic associates to word cues.

Collectively, these findings establish a critical role for episodic retrieval processes in constructing mental simulations of the future. In related lines of work, we have provided additional fMRI evidence that helps to characterize the role of several key core network regions in episodic future simulation, including the hippocampus (e.g., Campbell, Benoit, Madore, Thakral, & Schacter, 2018; Gaesser, Spreng, McLelland, Addis & Schacter, 2013; Martin, Schacter, Corballis, Addis, 2011; Thakral, Benoit, & Schacter, 2017; for review, see Schacter, Addis, & Szpunar, 2017) and subregions within the medial prefrontal cortex (Benoit, Szpunar, & Schacter, 2014; St. Jacques, Carpenter, Szpunar, & Schacter, 2018; Szpunar, St. Jacques, Robbins, Wig, & Schacter, 2014). We have also established that the core/default network that underpins episodic future simulation is involved when people generate counterfactual simulations regarding how past events could have turned out differently (e.g., De Brigard, Spreng, Mitchell, & Schacter, 2015), and that it can support more complex forms of autobiographical planning by coupling with executive networks involved in cognitive control (e.g., Gerlach, Spreng, Gilmore, & Schacter, 2011; Spreng, Stevens, Chamberlain, Gilmore, & Schacter, 2010; Spreng & Schacter, 2012).

From a career perspective, this work has been particularly rewarding because it has led to investigations of novel issues that have broadened my thinking about how memory and simulation contribute to a variety of psychological functions. For example, in a collaboration with Demis Hassabis in London, we examined brain activity during an episodic simulation task where people tried to predict the behavior of four individuals with distinct personality traits (Hassabis, Spreng, Rusu, Robbins, Mar, & Schacter, 2014). Results showed extensive core network activity during these predictive episodic simulations and distinguished between core regions involved in social and non-social aspects of episodic simulations (cf., Szpunar et al., 2014). Moreover, multivariate pattern classification analyses identified which of the four individuals was being imagined based solely on activity patterns in the medial prefrontal cortex. Another nice example comes from a recent collaboration with the laboratory of Dahua Wang and Xiancai Cao in Beijing, where we tested the constructive episodic simulation hypothesis by asking whether episodic memory and simulation play a role in attachment processes that distinguish individuals characterized by secure and insecure attachments in close relationships (Cao, Madore, Wang, & Schacter, 2018). In an experiment using Autobiographical Interview procedures, secure individuals generated more internal and fewer external details both when remembering past and imagining future attachment-relevant experiences (i.e., experiences involving a significant other) compared with attachment-irrelevant experiences (i.e., experiences involving strangers or more distant acquaintances). In contrast, these parallel attachment-driven effects on past and future events were not seen in insecure individuals. The findings provide novel support for the constructive episodic simulation hypothesis and also have interesting implications for the longstanding construct of internal working models of attachment (e.g., Bowlby, 1969) by providing evidence for the idea that such models can bridge past and future experiences of close relationships (Cassidy, 2000).

Extensions to Problem Solving and Creativity

Having established that episodic retrieval contributes to future simulation, we have also examined the possibility that episodic memory retrieval might play a role in other tasks that we do not ordinarily think of as “episodic memory tasks” (for a related perspective, see Moscovitch, Cabeza, Winocur, & Nadel, 2016). For example, the means-end problem solving task developed by Platt and Spivak (1975) provides hypothetical scenarios that begin with a person experiencing a social problem (e.g., friends are avoiding her) and end with the individual solving that problem (friends like her again). The participants’ task is to generate steps that are relevant to solving the problem (e.g., asking a friend what is wrong). Research by Sheldon, McAndrews, and Moscovitch (2011) suggested a role for episodic retrieval in generating relevant steps, leading us to predict that ESI would increase the number of relevant steps that participants provide. That is exactly what we found for both young and old adults (Madore & Schacter, 2014). Extending this finding to the domain of personally worrisome experiences, Jing, Madore, and Schacter (2016) documented that ESI not only boosted the number of relevant steps that participants generate to solve problems that worry them, it also produced increases in well-being toward the worrisome experience (for related findings on the ability to generate alternative future scenarios, see Jing et al., 2017).

We have also extended this approach to the domain of divergent creative thinking: the ability to generate creative ideas by combining diverse kinds of information in novel ways. Although creativity research has typically focused on the contributions of semantic memory, just as with means-end problem solving there was some evidence suggesting that episodic memory might play a role in divergent creative thinking. Gilhooly, Fioratou, Anthony, and Wynn (2007) had reported that people occasionally draw on episodic memories when performing a divergent thinking task, Duff, Kurczek, Rubin, Cohen, and Tranel (2013) reported that amnesic patients with episodic memory deficits also exhibit divergent thinking deficits, and work in my lab revealed a positive correlation between divergent thinking and episodic future simulation (Addis, Pan, Musicaro, & Schacter, 2016; for review, see Beaty, Benedek, Silvia, & Schacter, 2016). This linkage was unexpected given the focus on semantic memory in the creativity literature, but nonetheless raised the intriguing possibility that episodic retrieval might extend into a novel domain that had been largely overlooked by memory researchers. Our previous work with ESI suggested that it could be a useful tool for providing a strong test of the possible contribution of episodic retrieval to divergent creative thinking. We thus tested this idea by administering ESI or a control induction prior to having participants complete the Alternate Uses Test (AUT), a standard tool for assessing divergent thinking that requires people to generate novel but appropriate uses for common objects (e.g., brick, paperclip). ESI boosted the number of such uses that participants provide on the AUT while having no impact on an object association task that requires participants to generate familiar associates of the target objects (Madore, Addis, & Schacter, 2015). Similar to future imagining, we also provided fMRI evidence that administering an ESI increases subsequent hippocampal activity during performance of the AUT (Madore, Thakral, Beaty, Addis, & Schacter, 2017). Importantly, this study also revealed that ESI produced activation increases during AUT performance in prefrontal regions associated with cognitive control, as well as increases in functional connectivity (both task-based and resting-state) between the core/default network and an executive control network. These results converge nicely with other neuroimaging studies that have shown that connectivity increases between default and control networks are consistently observed during tasks that tap creative cognition (for review, see Beaty et al., 2016). More recently, we have provided direct evidence for neural commonalties among divergent thinking, imagining future experiences, and remembering past experiences by showing that, within a single experiment, all three processes engage some of the same core network regions, including hippocampus and parahippocampal gyrus (Beaty, Thakral, Madore, Benedek, & Schacter, 2018).

From a career perspective, these new lines of work have helped to broaden my empirical and theoretical horizons, raised novel questions about how memory fits in the larger landscape of cognition, and more generally contributed to the scientific vitality of my research program.

Adaptive Constructive Processes and Memory Errors

As mentioned earlier, a question that was central to the conceptualization of the seven sins of memory has continued to remain at the forefront of my theoretical approach: What are the functions of a constructive memory? On the one hand, several lines of evidence from my lab and others support the functional utility of the mental simulation processes that we have linked with episodic retrieval, including the aforementioned work on social problem solving (Jing et al., 2016; Madore & Schacter, 2014; Sheldon et al., 2011) as well as studies showing that episodic simulation boosts prosocial intentions (e.g., Gaesser & Schacter, 2014), emotion regulation (e.g., Jing et al., 2016, 2017), farsighted decision making (e.g., Benoit, Gilbert, & Burgess, 2011), and prospective memory performance (e.g., Spreng, Madore, & Schacter, 2018; for detailed review, see Schacter, 2012; Schacter et al., 2017). On the other hand, my lab and others have also shown that episodic simulations and related forms of imagination can contribute to various kinds of memory distortions (e.g., Devitt, Monk-Fromont, Schacter, & Addis, 2016; Devitt & Schacter, 2018; Garry, Manning, Loftus, & Sherman, 1996; Gerlach, Dornblaser, & Schacter, 2014; Hyman & Pentland, 1996; Loftus, 2003). Taken together, these two kinds of findings support a characterization of episodic simulation as an *adaptive constructive process*, that is, a cognitive process that plays a functional role in cognition but produces distortions or illusions as a consequence of doing so (Schacter, 2012). The constructive episodic simulation hypothesis (Schacter & Addis, 2007a, 2007b) embodies this idea because it proposes that flexible episodic retrieval processes that support the adaptive function of simulating future experiences by recombining elements of past experiences to construct novel event representations can also contribute to memory errors.

We have recently provided what we believe to be some of the strongest evidence to-date in support of this view by showing that *within a single experimental paradigm*, the same flexible retrieval/recombination processes that support an adaptive cognitive function also increase memory errors (Carpenter & Schacter, 2017, 2018). The adaptive cognitive function in these experiments is *associative inference* (Zeithamova & Preston, 2010), that is, the ability to link separate experiences that share a common element. In Carpenter and Schacter's (2017) paradigm, in order to make associative inferences participants need to combine information across distinct scenes comprised of people, objects, and settings; individuals are linked to one another because each is paired with the same object in a different background setting (e.g., a man and a toy in one living room; a boy and the same toy in a different living room). When asked about details of the setting in which each person appeared, participants made more source memory errors in which they mixed up elements of the two background settings after they *correctly* inferred that the two individuals were associated than after they *incorrectly* inferred that there was no association between the individuals (Carpenter & Schacter, 2017; see Carpenter & Schacter, 2018, for a similar pattern of inference-related memory errors concerning high- and low-value individuals).

While we have focused on exploring the functions and consequences of adaptive constructive processes in the context of work on episodic simulation, we have also examined similar issues in related domains of memory. For example, we have used both behavioral and fMRI methods to show that reactivating memories of a recent experience can produce memory errors when novel information presented during reactivation becomes confused with a prior experience; we have argued that this memory error reflects the operation of a functionally useful updating process (St. Jacques, Olm, & Schacter, 2013; St. Jacques & Schacter, 2013). We have also shown that false memories in the DRM paradigm can be predicted from characteristics of a semantic neural code in the anterior temporal lobe, a region that underpins functionally critical semantic processing and memory functions (Chadwick, Anjum, Kumaran, Schacter, Spiers, & Hassabis, 2016). These findings, together with our work on flexible recombination and episodic simulation, suggest that there is no single answer to the question I posed earlier regarding the function of a constructive memory. A number of adaptive processes, including episodic simulation, memory updating, and semantic coding, produce memory errors that are consequences of the functions they perform (see also, Howe, 2011; Newman & Lindsay, 2009; Schacter et al., 2011).

Concluding Comments

If someone had asked me 40 years ago what I would be studying in 2018, I am not sure what I would have said. But I am reasonably certain that I would have mentioned very few, if any, of the questions, paradigms, or approaches described in this article (or other recent projects in my lab, such as studies of mind wandering that fit well with our work on prospection and episodic simulation; e.g., Maillet, Seli, & Schacter, 2017; Seli, Smilek, Ralph, & Schacter, 2018). And that underscores one of the main satisfactions of a long career as a psychological scientist: the enjoyment of being surprised by where one goes next, and the ensuing satisfaction when a new direction turns up something that we did not know before and that is worth knowing. For me, the surprising moments and new directions have almost invariably been the product of collaborations with graduate students, post-docs, and other colleagues whose insights and efforts have helped to take the work to places that it would not have gone otherwise. Those collaborative efforts themselves have constituted some of the most satisfying experiences of my career as a psychological scientist, and continue to be an ongoing source of satisfaction as my colleagues and I move forward with ongoing projects that will hopefully lead to future surprises and insights.

Of course, in a long career one inevitably faces challenges and disappointments, and I am no exception: experiments don’t work, articles are rejected, and grants are not funded. Those experiences are rarely pleasant, and can be demoralizing, but to sustain over the long-term I think it is important to try to view them as sources of teaching signals. A failed experiment may reveal an important but correctable flaw in our thinking; a rejected article or non-funded grant may expose technical or interpretative problems with methods and/or data, a conceptual limitation in our framing of an issue, or a communicative limitation in how we portray it to others. Trying to take away useable lessons from a disappointment can help to minimize future disappointments. Ultimately, however, disappointments and challenges are more bearable if we can experience satisfaction and excitement from a surprising finding or promising new idea, and knit together an accumulating number of surprises into a coherent story that points toward further promising directions to pursue. In these times of justified focus on important issues related to reproducibility, rigor, and open science, we would do well to remember that surprise and excitement still count as key elements of a career in psychological science.

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