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Issue: *The Emerging Science of Consciousness: Mind, Brain, and the Human Experience***Memory: sins and virtues**

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Memory plays an important role in everyday life but does not provide an exact and unchanging record of experience: research has documented that memory is a constructive process that is subject to a variety of errors and distortions. Yet these memory “sins” also reflect the operation of adaptive aspects of memory. Memory can thus be characterized as an *adaptive constructive process*, which plays a functional role in cognition but produces distortions, errors, or illusions as a consequence of doing so.

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**Introduction**

Memory is essential for our ability to function in everyday life. The importance of memory for everyday life is dramatically illustrated by cases in which brain injury interferes with the ability to form new memories, or recall old ones, with devastating consequences for the afflicted individuals that severely affect their ability to function independently.<sup>1,2</sup> Yet despite its functional importance, memory does not provide an exact and unchanging record of experience: decades of laboratory research have established that memory is subject to a variety of pitfalls. In an attempt to organize and classify these pitfalls, I suggested that memory’s errors could be grouped into seven fundamental categories or “sins.”<sup>3,4</sup> Three of the sins entail different kinds of forgetting: *transience* (loss of retention over time), *absentmindedness* (failures of attention that result in memory loss), and *blocking* (inability to retrieve information that is available in memory). Three other sins involve different kinds of distortion, that is, cases where memory is present but wrong: *misattribution* (attributing memory to an incorrect course), *suggestibility* (implanted memories resulting from suggestion or misleading information), and *bias* (distorting effects of current knowledge, beliefs, and feelings on memory). The final sin, *persistence*, concerns intrusive recollections that people cannot forget.

When I wrote about the seven sins over a decade ago, there was already considerable experimental evidence illustrating their existence and providing insights into their nature. During the past decade, we have learned a great deal more about each of the seven sins, and thus about how and why people forget and distort the past.<sup>5–8</sup> We have also learned a lot more about some basic properties of memory that can make it prone to error. For example, there has been a great deal of research recently concerning the phenomenon of *reconsolidation*, where reactivated memories enter a transient state of instability in which they are prone to disruption or change.<sup>9</sup> Reconsolidation is an extension of the well-established phenomenon of memory consolidation (i.e., processes that render a memory resistant to forgetting): when a memory is retrieved or reactivated it needs to be consolidated anew, raising the possibility that the reconsolidated memory may include new information not present in the original (for reviews, see Refs. 10–12). Although evidence for reconsolidation has come mainly from studies of nonhuman animals, findings consistent with reconsolidation in humans have also been reported (e.g., Refs. 13 and 14). Indeed, recent evidence shows that the process of memory reactivation can lead directly to memory distortion.<sup>15</sup>

As I noted in my initial discussions of the seven sins,<sup>3,4</sup> when considering evidence showing the

pervasiveness of memory errors, it is easy to conclude that memory is a fundamentally flawed process. Those sentiments are only heightened by evidence linking memory errors with such important real-life phenomena as eyewitness misidentifications, which played a role in more than 75% of the first 250 cases in which DNA evidence was used to exonerate individuals following convictions for crimes they did not commit.<sup>16</sup> Importantly, the legal system has begun to recognize that memory's imperfections can impact witness accuracy, as illustrated by a recent decision from the New Jersey Supreme Court that has led to improved jury instructions that explicitly inform jurors concerning a variety of conditions under which memory is prone to error (for discussion, see Ref. 17).

Despite the prevalence and practical importance of memory's sins, I also argued that memory errors could be thought of as costs that are associated with beneficial or adaptive aspects of memory that contribute to its efficient functioning.<sup>3,4</sup> The sin of persistence provides a good example. It is well established that intrusive recollections result from the occurrence of traumatic events and that these recollections contribute to such disabling conditions as posttraumatic stress disorder (e.g., Ref. 18). At the same time, however, the fact that our memory systems establish vivid and durable recollections of potentially life-threatening events that can imperil our survival is clearly adaptive—a useful feature of the system that also makes it vulnerable to intrusive recollections. The same type of analysis can be applied to memory distortions. For example, as noted above, the process of reconsolidation is thought to make memories temporarily vulnerable to disruption and change. However, it has also been hypothesized that reconsolidation plays a role in the adaptive process of *updating* memories in order to make them current by incorporating new information.<sup>11,12</sup>

Consider also the misattribution error known as *false recognition*, which occurs when people incorrectly recognize as old a novel item that is perceptually or conceptually similar to an item that they encountered previously. A dramatic illustration of false recognition is provided by the Deese/Roediger-McDermott or “DRM” paradigm<sup>19,20</sup> (for a review, see Ref. 21). Here, participants study lists of words (e.g., *tired, bed, awake, rest, dream, night, blanket, doze, slumber, snore, pillow, peace, yawn, and drowsy*) that are related to a non-presented lure word (e.g.,

*sleep*). On a subsequent old–new recognition test containing studied words (e.g., *tired, dream*), new words that are unrelated to the study list items (e.g., *butter*), and new words that are related to the study list items (e.g., *sleep*), participants frequently claim that they previously studied the related lure words. In similar paradigms using nonverbal materials, participants frequently claim that they studied objects (e.g., Refs. 22–25) or shapes (e.g., Ref. 26) that had not been presented earlier but that were visually similar to studied items.

False recognition errors reflect, in part, a breakdown in source monitoring processes that normally allow us to specify the origin of a memory.<sup>27,28</sup> However, it has also been suggested that false recognition errors occur when people make a memory decision based on their memory of the general features or gist of what happened (e.g., Refs. 22–25 and 28). Indeed, neuroimaging studies that have examined the neural correlates of accurate and inaccurate memories have typically revealed that many of the same brain regions are active during true and false recognition, though some differences can be detected (for reviews, see Refs. 29–31).

False recognition errors can thus be viewed as adaptive because they reflect retention of useful information concerning the meaning or critical features of an experience, which in turn can aid the ability to abstract and generalize on the basis of that experience (e.g., Refs. 3, 4, 28, and 32). In fact, recent evidence indicates that these kinds of errors are linked with adaptive processes such as creativity<sup>33</sup> and problem solving<sup>34</sup> (for further discussion, see Refs. 8 and 35).

Adaptive considerations can also help in thinking about a related misattribution error called *imagination inflation*: imagining an event results in increased confidence that the event actually occurred and, in some cases, produces a detailed false memory of the event (e.g., Refs. 36 and 37). Although imagination inflation, like false recognition, is attributable in part to a breakdown in source monitoring processes that people rely on to sort out events that actually happened from those that were only imagined,<sup>27</sup> an adaptive perspective on the phenomenon emerges from considering a recent line of research on the role of memory in imagining or simulating future events.

The capacity to simulate experiences that might occur in the future is potentially adaptive because it allows us to mentally try out different versions of

how an event might play out.<sup>38–43</sup> Several lines of evidence indeed demonstrate that imagining future events can play an adaptive role in various cognitive processes, including planning, decision making, and coping.<sup>44</sup> Importantly, considerable evidence also demonstrates a tight linkage between memory and future simulations. For example, neuroimaging studies have revealed extensive overlap in the neural processes that are engaged when people remember past events and imagine future events or novel scenes (for recent reviews, see Refs. 45 and 46). Behavioral studies have shown that deficits in remembering the past are often accompanied by parallel deficits in imagining the future in various brain-damaged patients (for review, see Refs. 45 and 47), as well as in the normal and pathologically aging (for review, see Ref. 48). Similarly, studies of patients with various kinds of psychological disorders have shown that such individuals tend to both remember the past and imagine the future in less specific detail than healthy individuals (e.g., Refs. 49 and 50). These similarities between remembering and imagining help us to understand why the two are easily confused: they share many common neural and cognitive underpinnings.

On the basis of this and related evidence, Schacter and Addis<sup>41</sup> proposed the *constructive episodic simulation hypothesis*, which maintains that remembering the past and imagining the future draw on similar information stored in episodic memory (i.e., memory for personal experiences), which in turn supports the construction of future events by extracting and recombining stored information into a simulation of a novel event. Schacter and Addis<sup>41</sup> claimed that such a system is adaptive because it enables past information to be used flexibly in simulating alternative future scenarios without engaging in actual behaviors, and that such flexibility comes at a cost of vulnerability to errors and distortions that result from mistakenly combining elements of imagination and memory (for related ideas, see Refs. 42 and 51).

This characterization captures key features of what I have recently termed *adaptive constructive processes*, which play a functional role in memory and cognition but produce distortions, errors, or illusions as a consequence of doing so.<sup>44</sup> The idea that memory distortions sometimes reflect the operation of adaptive constructive processes can be traced at least to the pioneering work of Bartlett,<sup>52</sup>

who contended that remembering “is an imaginative reconstruction or construction” (p. 213) that depends heavily on the operation of a schema, which Bartlett<sup>52</sup> defined as “an active organisation of past reactions, or of past experiences, which must always be supposed to be operating in any well-adapted organic response” (p. 201). A schema helps to organize the world by extracting regularities from experience, but in so doing can contribute to memory distortions that result from relying on this organized but compressed representation of knowledge.

Consistent with the general thrust of Bartlett’s ideas, thinking of memory as an adaptive constructive process helps us to appreciate both memory’s virtues and its sins, and to understand how and why they are inextricably linked with one another. This approach is also promising because it encourages us to explore memory in relation to other cognitive processes, such as imagination and future thinking, and to ask questions about the functions that memory serves (cf. Refs. 8, 10, 12, 35, 43, 44, 53, 54). Attempting to understand memory’s sins in the context of its virtues should allow us to develop a deeper understanding of how we use the past to understand the present and imagine the future.

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## Conflicts of interest

The author declares no conflicts of interest.

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