MEMORY, 2012, 20 (3), 224–235

Psychology Press
Taylor & Francis Group

Remembering the past and imagining the future: Examining the consequences of mental time travel on memory

Benjamin C. Storm and Tara A. Jobe

Department of Psychology, University of Illinois at Chicago, Chicago, IL, USA

Cognitive, neuropsychological, and neuroimaging evidence suggests that remembering the past and imagining the future rely on overlapping processes in episodic memory. The three experiments reported here examine the consequences of remembering the past and imagining the future on the accessibility of other information in memory. Participants first studied events associated with a specific context and then either (a) retrieved past autobiographical events associated with that same context or (b) imagined future autobiographical events associated with that same context. Replicating and extending evidence of retrieval-induced forgetting, remembering autobiographical events from the past caused participants to forget the related studied events. However, imagining future autobiographical events failed to cause participants to forget the related studied events. These results suggest an important difference in the memorial consequences of remembering and imagining.

Keywords: Memory; Future episodic thinking; Retrieval-induced forgetting; Inhibition.

In many important ways, human memory is nothing like a video camera or computer (E. L. Bjork & Bjork, 1988; R. A. Bjork, & Bjork, 1992; Schacter, 2001). Rather than reproduce or replicate prior experience, human memory functions to reconstruct prior experience by flexibly extracting and recombining elements in memory (Bartlett, 1932; Tulving, 1983). A benefit of memory's constructive nature is that we can simulate or imagine events that have yet to occur. For example, episodic memory does much more than provide a means by which to re-experience the past, it provides a means by which to imagine or pre-experience the future. In this sense episodic memory can be thought of as a vehicle for mental time travel, a vehicle that can take one into the past, or into the future (Tulving, 1985, 2005).

Supporting this view of episodic memory is recent research showing that remembering the past and imagining the future rely on many of the same cognitive and neural processes (for reviews see Schacter & Addis, 2007; Schacter, Addis, & Buckner, 2007, Szpunar, 2010). For example, individuals experience past and future events similarly (e.g., D'Argembeau & Van der Linden, 2004, 2006), populations with deficits in episodic memory—such as amnesic patients, schizophrenic patients, and older adults—suffer from corresponding deficits in remembering the past and imagining the future (e.g., Addis, Wong, & Schacter, 2008; Klein, Loftus, & Kilstrom, 2002; D'Argembeau, Raffard, & Van der Linden, 2008), and both activities engage a common neural network (e.g., Addis, Pan, Vu, Laiser, & Schacter, 2009; Addis & Schacter, 2008; Addis, Wong, & Schacter, 2007; Szpunar, Watson, & McDermott, 2007). This converging evidence led Schacter and Addis (2007) to put forth the *constructive episodic simulation hypothesis*, which posits that episodic memory is a flexible and constructive system

Address correspondence to: Benjamin C. Storm, Department of Psychology, University of Illinois at Chicago, 1007 W Harrison St (MC 285), Chicago, IL 60607-7137, USA. E-mail: bstorm@uic.edu

http://www.psypress.com/memory http://dx.doi.org/10.1080/09658211.2012.654796

that allows one to flexibly extract and recombine details from memory in order to both re-experience the past and pre-experience the future.

Although the constructive nature of episodic memory may make us susceptible to forgetting and memory distortion, such a system has several important advantages over a purely reproductive memory system (E. L. Bjork & Bjork, 1988; Schacter, 1999). For example, selection processes in a reproductive system would be increasingly difficult as memory would become cluttered with trivial and irrelevant details. Moreover, reproductive access to individual past events would fail to efficiently (or even accurately) inform ongoing behaviour and decision making. In other words it may be more important to have access to the overall gist of prior experiences than to have access to any individual past experience (see McClelland, 1995). The constructive episodic simulation hypothesis also suggests that the constructive nature of episodic memory is adaptive in that it provides a mechanism to simulate or imagine the future. Although the past may repeat itself to some extent, future events are almost never replicas of past events. Thus, to more accurately simulate the future, one must be able to flexibly recall and recombine details in a future-looking, context-specific way (Schacter & Addis, 2007).

Over the past few years, a burgeoning body of research has developed on the constructive episodic simulation hypothesis and, more generally, on the cognitive and neural processes that underlie future episodic thinking. To date, however, no research has examined the consequences of imagining or simulating future events on other information in memory. Work on retrieval-induced forgetting has shown that the retrieval of some items from memory can cause the forgetting of other items in memory (Anderson, Bjork, & Bjork, 1994). Given the common processes involved in remembering and future episodic thinking, it is possible that imagining the future might cause forgetting as well.

RETRIEVAL-INDUCED FORGETTING

In the paradigm often used to study retrieval-induced forgetting, participants study a series of category–exemplar pairs (e.g., *fruit–lemon, weapon–tank, fruit–banana, weapon–sword*) and then retrieve a subset of exemplars from a subset of categories via category-plus-two-letter-stem retrieval cues (*fruit–le*_____). This selective retrieval practice creates three types of items: practised exemplars from practised categories (Rp+ items), non-practised exemplars from practised categories (Rp– items), and non-practised exemplars from non-practised categories (Nrp items). Finally, participants are given a cued-recall test for all exemplars from the original study phase. The positive consequences of retrieval practice are apparent in the superior recall of Rp+ items relative to Rp– and Nrp items. The negative consequences of retrieval practice (i.e., retrieval-induced forgetting) are apparent in the inferior recall of Rp– items relative to Nrp items.

Retrieval-induced forgetting has been observed in many contexts and with a wide range of materials (for reviews see Anderson, 2003; Levy & Anderson, 2002). Although the empirical observation of retrieval-induced forgetting is well established, debate continues regarding theoretical mechanism. To date the best-supported account of retrieval-induced forgetting is that Rp– items are inhibited during the retrieval practice of Rp+ items (Anderson, 2003; Storm, 2011). A given retrieval practice cue may activate many items in memory, not only the target exemplar (Rp+ items) but non-target exemplars as well (Rp– items). According to the inhibitory account, inhibition is elicited to suppress these non-target exemplars, causing them to be forgotten in order to facilitate the retrieval of the target exemplar. In this sense retrieval-induced forgetting is the consequence of an adaptive process that functions to resolve competition in memory.

In contrast, others have argued against the need to postulate a role for inhibition to explain retrieval-induced forgetting (see e.g., Camp, Pecher, & Schmidt, 2007; Camp, Pecher, Schmidt, & Zeelenberg, 2009; Jakab & Raaijmakers, 2009; C. M. MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003; Williams & Zacks, 2001). Most non-inhibitory accounts contend that retrieval-induced forgetting is the consequence of strengthening Rp+ items during retrieval practice, which has the side effect of interfering with the recall of Rp– items on the final test. However, evidence that retrieval-induced forgetting is cue-independent (e.g., Anderson & Spellman, 1995; M. D. MacLeod & Saunders, 2005) and strength-independent (e.g., Anderson, Bjork, & Bjork, 2000; Bäuml, 2002; Storm, Bjork, Bjork, & Nestojko, 2006) is very difficult for non-inhibitory accounts to explain. Furthermore, recent neuroimaging work (see Kuhl & Wagner, 2009) and studies examining individual

differences (e.g., Soriano, Jiménez, Román, & Bajo, 2009; Storm & Angello, 2010; Storm & White, 2010) have provided additional support for the inhibitory account.

Finally it is worth noting that retrieval-induced forgetting is not limited to retrieval practice tasks in which participants must retrieve specific items from an earlier phase of the experiment. Rather, forgetting has been observed in a variety of situations that require one to bypass inappropriate responses in order to select, retrieve, or generate a weaker, yet desirable, response (e.g., semantic generation, Bäuml, 2002; Storm et al., 2006; language selection, Levy, McVeigh, Marful, & Anderson, 2007; mental image generation, Saunders, Fernandes, & Kosnes, 2009; and creative problem solving, Storm, Angello, & Bjork, 2011).

DOES IMAGINING THE FUTURE CAUSE FORGETTING?

If remembering the past and imagining the future involve an overlapping set of cognitive processes, then imagining the future should cause forgetting in the same way that remembering the past causes forgetting. In both situations a cue or set of cues is provided that may activate context-appropriate and context-inappropriate information in memory, and in both situations inhibition may act to select against or suppress the inappropriate information in order to facilitate access to the appropriate information. However, whether future episodic thinking causes forgetting may depend on the extent to which context-inappropriate information causes competition. Competition is a critical and defining feature of the inhibitory account of retrieval-induced forgetting (Storm, 2011)—non-target items are assumed to suffer retrieval-induced forgetting only to the extent that they compete during retrieval practice and therefore need to be inhibited (e.g., Anderson et al., 1994; Storm, Bjork, & Bjork, 2007; but see Jakab & Raaijmakers, 2009). Thus, if inappropriate information does not cause competition while imagining the future, then that information may not suffer retrieval-induced forgetting.

In fact, consideration of several boundary conditions on retrieval-induced forgetting suggests there are reasons to predict that imagining the future may not cause the forgetting of other information in memory. For example, the retrieval of one item fails to cause the forgetting of another item if those items are well integrated—either due to encoding instructions or to the nature of the materials (e.g., Anderson, Green, & McCulloch, 2000; Anderson & McCulloch, 1999; Chan, McDermott, & Roediger, 2006; Little, Storm, & Bjork, 2011; Migueles & García-Bajos, 2007). Integration has been shown to reduce competition between information in memory (Postman, 1971; Radvansky & Zacks, 1991) and in so doing may effectively eliminate the need for inhibition. Another boundary condition that has been argued to allay competition is item-specific or distinctive processing. For example, when people are told to focus on the differences among items within a category, competition is reduced, thereby eliminating the need for inhibition (Smith & Hunt, 2000). Thus information that is distinctive, similar, or well integrated with to-be-imagined future events may fail to compete with the constructive process and may, therefore, not need to be inhibited.

More generally, it is possible that generating future events will be less likely to rely on the structures and processes of autobiographical memory compared to remembering past events (see Conway, 2005, 2009). In constructing the future one may not necessarily need to search through autobiographical memory in a way that activates inappropriate or unwanted episodes, which would prevent the need for inhibition to suppress such episodes. Rather, one may simply use the information that is activated or readily available to construct the future simulation. Said differently, when imagining a future event there are an unlimited number of potentially viable events that one might construct—possibly making any item a potential mediator (rather than competitor) in the constructive process. Furthermore, there may be less need for constructions to correspond or cohere with reality or with one's life experiences (Conway, 2005; Conway, Singer, & Tagini, 2004), which would further reduce the constraints on how a future simulation might be constructed. Given these considerations, it is possible that imagining the future will not trigger the involvement of inhibitory control processes to the same degree as remembering the past.

RATIONALE OF THE CURRENT STUDY

In each of the present experiments we employed a modified version of the retrieval practice paradigm to examine the memorial consequences

of remembering the past and imagining the future on other information in memory. Participants studied sets of events associated with a given set of contextual retrieval cues. Then, using a subset of those cues, participants were asked to either retrieve past events from autobiographical memory or construct self-referential, novel, yet plausible future events. Following a brief delay, participants were given a cued-recall test for the studied events from each set. If remembering the past does cause forgetting, then studied events associated with cues used to remember the past should become less recallable on the final memory test. Likewise if imagining the future causes forgetting, then studied events associated with cues used to imagine the future should become less recallable on the final memory test.

We expect the results of this investigation to have important implications for understanding the nature and dynamics of both retrieval-induced forgetting and future episodic thinking. In regard to retrieval-induced forgetting, research has shown that after having participants retrieve multiple autobiographical memories associated to a given cue, practising the retrieval of a subset of those memories can cause the forgetting of the other memories related to that cue (e.g., Barnier, Hung, & Conway, 2004; Wessel & Hauer, 2006). However, the present study is the first to examine whether the *initial* retrieval of events from autobiographical memory can cause forgetting. Such a demonstration would also be the first to show that remembering self-relevant information can cause the forgetting of other-person-relevant information, provided that the information is associated to the same retrieval cues. These demonstrations are important for extending evidence of retrieval-induced forgetting beyond the standard paradigm and standard set of materials. Finally, an important question in the retrieval-induced forgetting literature concerns the type of processes that cause forgetting versus those that do not. On one hand, future episodic thinking is similar to other types of generative tasks that have been shown to cause forgetting (e.g., Bäuml, 2002; Saunders et al., 2009; Storm et al., 2006)—all of which involve the need to generate a target item in the face of competition from related, yet inappropriate items. On the other hand, as discussed above, certain aspects of imagining the future may make inhibition unnecessary.

The current study also has the potential to inform theoretical accounts of future episodic thinking. Based on a wide array of evidence, researchers have convincingly argued that remembering the past and imagining the future involve a highly similar set of cognitive and neural processes (for reviews see Schacter et al., 2007, 2008; Szpunar, 2010). If this is the case then it stands to reason that remembering the past and imagining the future should have similar consequences on the accessibility of other information in memory. If we were to find that remembering the past causes forgetting but imagining the future does not, then such a result would provide evidence that there may be an important difference between the two processes.

EXPERIMENT 1

Method

Participants. A total of 40 undergraduate students (13 male and 27 female) from the University of Illinois at Chicago (M age = 19.7) participated for partial credit in an introductory psychology course.

Materials. A total of 20 sets of events were created for participants to study. Each set was associated with a specific individual and a specific context. The contexts were common settings or occurrences experienced by most individuals (e.g., *The Park*, *Supermarket*, *Laundry*). Each set consisted of three sentences that applied to a single individual within a context (e.g., *Mario; The Park*), and each sentence described a single event that consisted of two key elements (e.g., *Mario fed hotdogs to the pigeons*). These elements (i.e., *fed hotdogs, to the pigeons*) were used in the scoring of recall on the final test.

Procedure. The experiment consisted of two main phases: retrieval/imagining and cued-recall. The retrieval/imagining phase consisted of 20 trials.[1] On each trial three events associated

[1] It should be noted that this paradigm differs somewhat from the standard retrieval–practice paradigm (Anderson et al., 1994). In the standard paradigm participants are first exposed to all items in an initial study phase and then, in a separate phase, engage in retrieval practice for a subset of those items. In the current paradigm a trial by trial procedure was employed such that participants engaged in retrieval practice immediately following the study of information on some trials but not on other trials. Importantly, retrieval-induced forgetting has been reliably demonstrated using this type of paradigm (e.g., Storm, Bjork, & Bjork, 2005, 2007; Storm & Nestojko, 2010).

with a given individual/context were presented on the computer screen, and participants were given 30 seconds to study those events. Participants were warned that they might be tested on the events later in the experiment. On five of the trials participants were asked to retrieve episodic events from autobiographical memory that were associated with the studied context. For example, if a participant studied events associated with *Mario* and *The Park*, then that participant would subsequently be given 15 seconds to recall an autobiographical episodic memory that took place at the park during the past year. This process was repeated four times successively, such that participants retrieved four unique autobiographical memories associated with that particular context. On another five trials participants were asked to imagine themselves in the future by constructing episodic simulations that were also associated with the studied context. As in the past retrieval condition, participants were given 15 seconds to imagine each of four novel, yet plausible, future simulations that might take place in the next year. Importantly, participants were instructed to remember/imagine events different from those which they had just studied. Participants were asked to rate each past and future construction in terms of clarity, detail, emotion, and perspective. Clarity, detail, and emotion were rated on a 6-point scale, with 1 indicating a low degree of that characteristic, and 6 indicating a high degree of that characteristic. Participants rated perspective by indicating whether they experienced their recollection/image from the perspective of an outside observer (observer perspective) or from the perspective of actually being there (field perspective).

Ten trials served as baseline. On these trials participants studied the set of events but did not engage in any form of past retrieval or future imagining. The baseline trials were interleaved with the past retrieval and future imagining trials in a semi-random order such that participants could not predict the condition that a given study set was in. The sets of studied events were counterbalanced across participants such that each served equally often in the past retrieval, future imagining, and respective baseline conditions. The first half of the trials always consisted of five baseline trials interleaved with either five past retrieval trials or five future imagining trials. Consequently, the second half of the trials always consisted of five baseline trials interleaved with the type of trials that was not included in the first half. The order of the past retrieval and future imagining conditions was counterbalanced across participants, and, importantly, recall performance for events associated with past retrieval and future imagining was compared to recall performance for events associated with adjacent baseline trials.

After completing the retrieval/imagining phase, participants were given a 3-minute nonverbal distractor task, followed by a final cued-recall task for the studied events. Participants were provided a context label and individual name (e.g., *Mario: Park*) and then given 20 seconds to recall out loud to the experimenter the three studied events associated with that context and name. This was repeated for each of the 20 event sets, with the order of the sets determined via blocked randomisation. All responses were recorded and scored as correct if both key elements from a single event were recalled. Responses were scored as incorrect if only one key element was recalled, or if a key element was recalled in association to the wrong retrieval cue. We used this scoring method to ensure that participants were recalling the same events that had been studied, and not recalling parts of the events or constructing new events using pieces of the events that had been studied. It is important to note that participants were never tested on their ability to recall the autobiographical events that they either retrieved or imagined.

Results

Ratings of past and future episodic events. As can be seen in Table 1, participants rated their past retrievals to be somewhat more clear, detailed, and emotional than their future imaginings. The difference was statistically significant in terms of clarity, $t(39) = 2.27$, $p < .05$, $d = .36$, and detail, $t(39) = 2.29$, $p < .05$, $d = .36$, but not in terms of emotionality, $t(39) = 1.20$, $p > .05$, $d = .19$. No significant difference was observed in terms of perspective, $t(39) = 1.49$, $p > .05$, $d = .24$; participants experienced past retrievals and future imaginings from a field perspective 68% and 63% of the time, respectively. These small differences are consistent with what has been observed in prior research (D'Argembeau & Van der Linden, 2004, 2006).

TABLE 1
Means (*SD*) for clarity, detail, and emotionality of participants' past and future event generations, Experiments 1–3

Condition	*Clarity* *M (SD)*	*Detail* *M (SD)*	*Emotionality* *M (SD)*
Experiment 1			
Past retrieval	4.14 (.76)	3.92 (.77)	3.39 (1.02)
Future imagining	3.87 (.81)	3.67 (.79)	3.24 (.90)
Experiment 2			
Past retrieval	4.07 (.61)	4.02 (.52)	3.51 (.69)
Future imagining	3.86 (.72)	3.79 (.68)	3.40 (.79)
Experiment 3			
Past imagining	3.95 (.68)	3.85 (.70)	3.41 (.72)

Final cued recall. The mean proportions of studied events recalled on the final test are shown in Figure 1 as a function of whether they were associated with trials involving past retrieval, future imagining, or baseline. A 2 (Baseline vs Retrieval/Imagining) × 2 (Past vs Future) repeated measures Analysis of Variance (ANOVA) revealed a significant interaction, $F(1, 39) = 5.31$, $MSE = .08$, p B .05, $h^2 = .12$. Studied events associated with remembering the past ($M = .30$; $SE = .03$) were recalled significantly worse than baseline studied events ($M = .39$; $SE = .04$), $t(39) = 3.24$, p B .01, $d = .53$. However, studied events associated with imagining the future ($M = .35$; $SE = .03$) were not recalled differently from baseline ($M = .35$; $SE = .04$), $t(39)$ B 1, p □ .05, $d = .02$. In other words, retrieving past autobiographical memories caused the forgetting of studied information, whereas imagining future autobiographical simulations did not.

We believe it is most appropriate to compare recall performance in the past and future conditions with their own respective baseline conditions. Nevertheless, it is somewhat peculiar that baseline recall was lower in the future condition than in the past condition. Thus we re-analysed the data by comparing performance in the remembering and future imagining conditions with the average baseline performance, combined across the experimental conditions ($M = .37$, $SE = .03$)—studied events associated with remembering the past were still recalled significantly worse than baseline, $t(39) = 2.97$, p B .01, $d = .47$, whereas studied events associated with imagining the future were not, $t(39)$ B 1, p □ .05, $d = .14$.

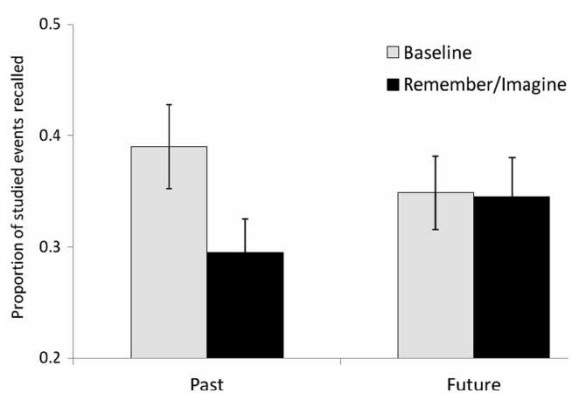

Figure 1. Proportion of studied events recalled correctly in the past retrieval and future imagining conditions of Experiment 1. Error bars represent standard errors.

EXPERIMENT 2

Results from the first experiment suggest an important difference between remembering the past and imagining the future. Whereas retrieving past autobiographical events caused the forgetting of studied events associated with the same contextual cues, imagining future autobiographical events did not. The forgetting observed in the past condition replicates and extends evidence of retrieval-induced forgetting by demonstrating for the first time that retrieval from autobiographical memory can cause the forgetting of related studied information. The fact that imagining the future failed to cause forgetting is, from one perspective, somewhat surprising. Participants were instructed to imagine novel, yet plausible, future events, which should presumably have required the inhibition and forgetting of the studied events associated with that context. However, from another perspective these results are not surprising as aspects of the task may have obviated any need for inhibition by reducing competition. Furthermore, it is possible that

participants were able to effectively use the studied events to mediate the constructive process. That is, participants may have used the studied events as cues by which to generate the future simulations. Work on retrieval-induced forgetting has shown that if retrieval practice is designed in such a way that non-target items mediate the retrieval of target items, then retrieval of the target items will not cause the forgetting of the non-target items (e.g., Chan et al., 2006).

The second experiment sought to replicate the results of the first experiment while applying greater control over how participants went about remembering the past and imagining the future. Specifically, participants were provided two keywords to guide their retrieval and imagining efforts. For example, rather than being asked to simply remember or imagine an episodic event experienced at the *park*, participants were asked to remember or imagine an episodic event experienced at the *park* that involved *swings* and *friends*. This subtle yet important change should reduce differences in how participants go about remembering the past and imagining the future. In particular, the keywords should guide participants to retrieve/imagine episodic events different from those presented in the study set and thus make participants less likely to use the studied events as mediators in the constructive process.

Method

A total of 40 undergraduate students (13 male and 27 female) from the University of Illinois at Chicago (M age = 19.3) participated for partial credit in an introductory psychology course. The materials and procedure were identical to those employed in Experiment 1 except for one important difference: in addition to being provided a context (e.g., *The Park*) during past retrieval and future imagining, participants were also provided two keywords (e.g., *Swings*, *Friends*). A different pair of keywords was provided for each of the four retrievals/imaginings on a given trial. Participants were instructed to use the keywords to guide their retrieval/imagining efforts. Importantly, the keywords were unrelated to any of the three events within the associated set and, once again, participants were instructed to only remember/imagine events different from those that were studied.

Results

Ratings of past and future episodic events. Clarity, detail, and emotionality ratings are shown in Table 1. As in the first experiment, participants rated their past retrievals to be somewhat more clear, detailed, and emotional than their future generations. The difference was statistically significant in terms of clarity, $t(39) = 2.34$, $p < .05$, $d = .38$, and detail, $t(39) = 2.37$, $p < .05$, $d = .39$, but not in terms of emotionality, $t(39) = 1.03$, $p > .05$, $d = .17$. A significant difference was observed in terms of perspective, $t(39) = 3.81$, $p < .001$, $d = .63$. Participants experienced past retrievals from a field perspective on 76% ($SE = .02$) of the trials, whereas they experienced future imaginings from a field perspective on only 61% ($SE = .04$) of the trials. Once again, these differences are consistent with what has been observed in prior research (D'Argembeau & Van der Linden, 2004, 2006).

Final cued recall. The mean proportions of studied events recalled on the final test are shown in Figure 2 as a function of experimental condition. A 2 (Baseline vs Retrieval/Imagine) × 2 (Past vs Future) repeated-measures ANOVA revealed a significant interaction, $F(1, 39) = 6.92$, $MSE = .09$, $p < .05$, $h^2 = .15$. In a nearly perfect replication of Experiment 1, studied events associated with remembering the past ($M = .28$; $SE = .03$) were recalled significantly worse than baseline ($M = .37$; $SE = .03$), $t(39) = 3.59$, $p < .001$, $d = .57$, whereas studied events associated with imagining the future ($M = .32$; $SE = .04$) were not recalled differently from baseline ($M = .32$; $SE = .03$), $t(39) < 1$, $p > .05$, $d = .01$. Once again, retrieval of past

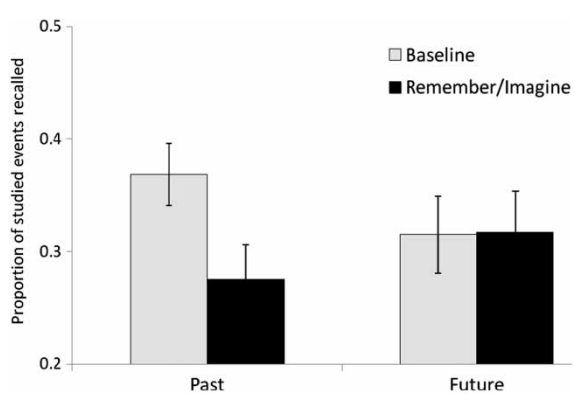

Figure 2. Proportion of studied events recalled correctly in the past retrieval and future imagining conditions of Experiment 2. Error bars represent standard errors.

autobiographical memories caused forgetting, whereas imagining future autobiographical simulations did not. Interestingly, as in the first experiment, baseline recall was lower in the future condition than in the past condition. However, when we re-analysed the data by comparing performance in the remembering and future imagining conditions with the average baseline performance, combined across the experimental conditions ($M = .34$, $SE = .02$), once again we found that studied events associated with remembering the past were recalled significantly worse than baseline, $t(39) = 3.02$, $p < .01$, $d = .48$, whereas studied events associated with imagining the future were not, $t(39) < 1$, $p > .05$, $d = .16$.

One might wonder why baseline performance differed across the remembering and imagining conditions. One possibility is that aspects of the task made it more difficult for participants to recall studied items interleaved with future imagining compared to studied items interleaved with past remembering. Perhaps the imagining task was distracting or interfered with the encoding or retrieval of the studied information. Although we cannot say for sure what caused this difference in recall, we can assume that it influenced both the baseline items as well as the items associated with subsequent imagining/remembering. Thus the difference in baseline cannot explain the observed interaction. Even if imagining future events caused the adjacent studied events to become less recallable (relative to remembering past events), this does not explain why we failed to find a difference between the studied events that were associated with future imagining and those that were not associated with future imagining.[2]

[2] Interestingly, the difference in baseline recall in the past and future conditions only emerged in the second half of the trials. Thus by analysing only the initial 10 trials in the first two experiments we can compare the consequences of remembering the past and imagining the future on a between-participants basis and with nearly equivalent baseline performance. A 2 (Baseline vs Retrieval/Imagine) × 2 (Past vs Future) mixed-design ANOVA revealed a significant interaction, $F(1, 78) = 6.09$, $MSE = .11$, $p < .05$, $h^2 = .07$. Studied events associated with remembering the past ($M = .25$; $SE = .03$) were recalled significantly worse than baseline ($M = .34$; $SE = .03$), $t(39) = 3.16$, $p < .01$, $d = .50$, whereas studied events associated with imaging the future ($M = .34$; $SE = .03$) were not recalled worse than baseline ($M = .32$; $SE = .03$), $t(39) < 1$, $p > .05$, $d = .08$. These results provide additional evidence that the interaction between forgetting in the past and future conditions is not driven by differences in baseline performance.

EXPERIMENT 3

The first two experiments demonstrate that retrieving a past episodic event from autobiographical memory can cause the forgetting of related information, whereas imagining a novel, yet plausible, future event does not. As pointed out by Addis et al. (2009), however, comparisons between remembering the past and imagining the future suffer from a subtle experimental confound—namely, imagining the future is different from remembering the past in two respects: first, it involves imagining novel events as opposed to recalling experienced events; and second, it involves mental time travel into the future, as opposed to the past. To address this issue Addis et al. (2009) created a new condition in which participants were instructed to imagine the past, unconfounding process (remembering vs imagining) from temporal direction (past vs future). They found that imagining the past and imagining the future relied on the same neural system, the *imagining subsystem*, which is presumed to underlie the processes necessary to recombine details from memory into an imagined episodic event, regardless of whether that event takes place in the past or future. To address the confounding between process and temporal direction, we asked participants in the third experiment to imagine novel, yet plausible, events in their own past.

Method

Participants, materials, and procedure. A total of 40 undergraduate students (9 male and 31 female) from the University of Illinois at Chicago (M years of age = 18.8) participated for partial credit in an introductory psychology course. The materials and procedure were identical to those employed in Experiment 2 except for two important differences: first, participants were asked to imagine novel, yet plausible, past events associated with the context cues and keywords provided; second, there were only 10 trials in total. Five trials involved imagining past events, the other five trials served as baseline.

Results

Ratings of past episodic events. As can be seen in Table 1, clarity, detail, and emotionality ratings

were very similar to those observed in the future imagining condition of Experiment 2, suggesting from a phenomenological standpoint that participants experienced past and future imaginings in a similar way. Participants experienced past imaginings from a field perspective 68% of the time ($SD = 14\%$).

Final cued recall. A planned *t*-test comparison demonstrated that studied events associated with contexts used to imagine the past ($M = .35$; $SE = .03$) were not recalled differently from studied events in the baseline condition ($M = .34$; $SE = .03$), $t(39) \geq 1$, $p > .05$. Just as imagining the future failed to cause forgetting, so imagining the past also failed to cause forgetting. This finding strongly suggests that the temporal component in imagining the future is not responsible for protecting related information from being forgotten.

GENERAL DISCUSSION

Experiments 1 and 2 replicated and extended evidence of retrieval-induced forgetting in episodic memory (Anderson et al., 1994). Participants first studied a series of events associated with a particular context. Then, during what would normally be referred to as retrieval practice, participants were asked to retrieve, from their own autobiographical past, episodic events associated with that context. This remembering caused the forgetting of the studied events. More specifically, participants became less likely to remember the studied events than they would have been had they not been asked to remember their own autobiographical memories. However, when participants were asked to imagine novel, yet plausible, episodic events in the future, that imagining failed to cause the forgetting of the studied events. Experiment 3 showed that this failure had nothing to do with the imagining task being directed towards the future; imagining the past also failed to cause forgetting. This pattern of results is both clear and compelling—whereas remembering experienced autobiographical events causes forgetting, imagining non-experienced autobiographical events does not. This finding provides evidence of a potentially important difference in the consequences of remembering and imagining.

Although we failed to find forgetting in the imagining conditions, it is important to note that we did observe forgetting in the remembering conditions. To date only a handful of studies have examined retrieval-induced forgetting in relation to the self or autobiographical memory. In one study, Macrae and Roseveare (2002) had participants study a list of objects by either imagining themselves purchasing them as gifts or imagining others purchasing them as gifts. Whereas gifts "purchased" by others suffered retrieval-induced forgetting, gifts "purchased" by the participants did not. Although this finding appears to suggest that self-relevant information is not susceptible to retrieval-induced forgetting, later work has found that autobiographical memories can suffer retrieval-induced forgetting, especially negative autobiographical memories (Barnier et al., 2004; Wessel & Hauer, 2006). The current study extends this line of work, demonstrating for the first time that retrieving events from autobiographical memory can cause the forgetting of related information about other people. This finding has potentially important implications for generalising evidence of retrieval-induced forgetting to real-world contexts and for understanding the competitive dynamics involved in memory for the self and others (for a discussion see Harris, Sutton, & Barnier, 2010).

It is somewhat surprising that imagining future (and past) events failed to cause forgetting in the same way that remembering the past caused forgetting. There is substantial evidence that imagining future events (or imagining plausible past events) engages the same cognitive and neural processes that are engaged in remembering real events from the past (Conway, Pleydell-Pearce, Whitecross, & Sharpe, 2003; Schacter et al., 2007, 2008). Moreover, it seems plausible that participants in the current study might have generated true autobiographical events in the imagining condition and then altered those events to conform to the task instructions by changing some aspect of them or placing them in a future context. If imagining involves remembering, and if remembering causes forgetting, then it logically follows that imagining should cause forgetting. The fact that forgetting was not observed in the current experiments suggests that people may not have used true autobiographical memories to mediate the construction of their future and past imaginings.

The failure to observe forgetting in the imagining conditions is also surprising given evidence that processes such as semantic generation and mental imagery can cause forgetting (e.g., Bäuml,

2002; Johnson & Anderson, 2004; Saunders et al., 2009; Storm et al., 2006). Even if participants imagined future and past events in a distinctly different way than they remembered true events from the past, it seems plausible that the generative processes involved in such imagining would have been sufficient to cause forgetting. One possible explanation is that the way in which participants imagined events in the current study failed to elicit the type or amount of competition necessary for inhibitory-based retrieval-induced forgetting to occur. There is evidence that retrieval-induced forgetting is competition-dependent (for a review see Storm, 2011)—that only information that interferes or competes with retrieval needs to be inhibited, and that it is only such information that suffers retrieval-induced forgetting. Thus, if participants failed to experience competition from the studied events while imagining the future (or past), then those studied events would not be expected to be inhibited or forgotten.

So why might imagining a past or future episodic event fail to elicit competition? One possible explanation is that the studied events mediated the constructive process, thereby facilitating the generation of imagined past or future events. Arguing against this explanation, however, are the results of Experiments 2 and 3. Participants were explicitly instructed to generate novel events different from those that they had studied and, moreover, they were provided additional cues to ensure that they did so. Self-report data taken during debriefing also suggested that these controls were effective, as the vast majority of participants reported not thinking about the studied events while imagining events in the past and future. A more straightforward explanation is that there is an important difference in the way people engage in remembering the past and imagining the future. When attempting to remember an actual event from autobiographical memory, there are constraints that delineate what is relevant or appropriate and what is not relevant or appropriate. However, when attempting to construct a plausible past or future simulation, there may be fewer constraints on what is relevant or appropriate, thus reducing the need for control processes to inhibit the particular information that is available or that might become activated. Said differently, because there is not necessarily a right or wrong way to go about constructing a novel episodic event, there may be less competition involved in the constructive process and, as a consequence, less need to recruit the type of inhibitory processes that underlie retrieval-induced forgetting.

CONCLUDING COMMENTS

Regardless of the theoretical explanation, each of the three experiments reported here provides clear evidence that imagining the past or future does not cause the forgetting of related information in memory. This finding suggests that the memorial consequences of remembering and imagining are not the same—that under conditions in which remembering an experienced event does cause forgetting, imagining a non-experienced event does not. Although speculative, one might wonder if this lack of forgetting is in some way adaptive. Retrieval has been argued to be a powerful mechanism by which long-term memory is updated (e.g., R. A. Bjork & Bjork, 1992). Information that is retrieved becomes more recallable, whereas related information that is not retrieved becomes less recallable. The negative consequences of retrieval are adaptive inasmuch as they facilitate more efficient access to the information that has been retrieved more recently and more often as opposed to information that has been retrieved less recently and less often. However, if imagining non-experienced events also caused forgetting then we might find ourselves increasingly unable to recall truly experienced information at the cost of being able to recall imagined information. Thus it is possible that episodic simulation provides a means by which to explore future contingencies without inadvertently altering access to information and events that were genuinely experienced.

Manuscript received 3 October 2011
Manuscript accepted 14 December 2011
First published online 23 February 2012

REFERENCES

Addis, D. R., Pan, L., Vu, M. A., Laiser, M., & Schacter, D. L. (2009). Constructive episodic simulation of the future and past: Distinct subsystems of a core brain network mediate imagining and remembering. *Neuropsychologia*, *47*, 2222–2238.

Addis, D. R., & Schacter, D. L. (2008). Constructive episodic simulation: Temporal distance and detail of past and future events modulate hippocampal engagement. *Hippocampus*, *18*, 227–237.

Addis, D. R., Wong, A. T., & Schacter, D. L. (2007). Remembering the past and imagining the future: Common and distinct neural substrates during event construction and elaboration. *Neuropsychologia*, *45*, 1363–1377.

Addis, D. R., Wong, A. T., & Schacter, D. L. (2008). Age-related changes in the episodic simulation of future events. *Psychological Science*, *19*, 33–41.

Anderson, M. C. (2003). Rethinking interference theory: Executive control and the mechanisms of forgetting. *Journal of Memory & Language*, *49*, 415–445.

Anderson, M. C., Bjork, R. A., & Bjork, E. L. (1994). Remembering can cause forgetting: retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*, 1063–1087.

Anderson, M. C., Bjork, E. L., & Bjork, R. A. (2000). Retrieval-induced forgetting: Evidence for a recall specific mechanism. *Psychonomic Bulletin & Review*, *7*, 522–530.

Anderson, M. C., Green, C., & McCulloch, K. C. (2000). Similarity and inhibition in long-term memory: Evidence for a two-factor theory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 1141–1159.

Anderson, M. C., & McCulloch, K. C. (1999). Integration as a general boundary condition on retrieval-induced forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*, 608–629.

Anderson, M. C., & Spellman, B. A. (1995). On the status of inhibitory mechanisms in cognition: Memory retrieval as a model case. *Psychological Review*, *102*, 68–100.

Barnier, A. J., Hung, L., & Conway, M. A. (2004). Retrieval-induced forgetting of emotional and unemotional autobiographical memories. *Cognition and Emotion*, *18*, 457–477.

Bartlett, F. C. (1932). *Remembering*. Oxford, UK: Oxford University Press.

Bäuml, K-H. (2002). Semantic generation can cause episodic forgetting. *Psychological Science*, *13*, 356–360.

Bjork, E. L., & Bjork, R. A. (1988). On the adaptive aspects of retrieval failure in autobiographical memory. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory II* (pp. 283–288). London, UK: Wiley.

Bjork, E. L., Bjork, R. A., & Anderson, M. C. (1998). Varieties of goal directed forgetting. In J. M. Golding & C. M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 103–137). Mahwah, NJ: Lawrence Erlbaum Associates.

Bjork, R. A., & Bjork, E. L. (1992). A new theory of disuse and an old theory of stimulus fluctuation. In A. F. Healy, S. M. Kosslyn, & R. M. Shiffrin (Eds.), *From learning processes to cognitive processes: Essays in Honor of William K. Estes* (Vol. 2, pp. 35–67). Hillsdale, NJ: Lawrence Erlbaum Associates.

Camp, G., Pecher, D., & Schmidt, H. G. (2007). No retrieval-induced forgetting using item-specific independent cues: Evidence against a general inhibitory account. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 950–958.

Camp, G., Pecher, D., Schmidt, H. G., & Zeelenberg, R. (2009). Are independent probes truly independent? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*, 934–942.

Chan, J. C. K., McDermott, K. B., & Roediger, H. L. (2006). Retrieval-induced facilitation: Initially nontested material can benefit from prior testing of related material. *Journal of Experimental Psychology: General*, *135*, 553–571.

Conway, M. A. (2005). Memory and the self. *Journal of Memory and Language*, *53*, 594–628.

Conway, M. A. (2009). Episodic memories. *Neuropsychologia*, *47*, 2305–2313.

Conway, M. A., Pleydell-Pearce, C. W., Whitecross, S. E., & Sharpe, H. (2003). Neurophysiological correlates of memory for experienced and imagined events. *Neuropsychologia*, *41*, 334–340.

Conway, M. A., Singer, J. A., & Tagini, A. (2004). The self and autobiographical memory: Correspondence and coherence. *Social Cognition*, *22*, 491–529.

D'Argembeau, A., Raffard, S., & Van der Linden, M. (2008). Remembering the past and imagining the future in schizophrenia. *Journal of Abnormal Psychology*, *117*, 247–251.

D'Argembeau, A., & Van der Linden, M. (2004). Phenomenal characteristics associated with projecting oneself back into the past and forward into the future: Influence of valence and temporal distance. *Consciousness and Cognition*, *13*, 844–858.

D'Argembeau, A., & Van der Linden, M. (2006). Individual differences in the phenomenology of mental time travel: The effect of vivid visual imagery and emotion regulation strategies. *Consciousness and Cognition*, *15*, 342–350.

Harris, C., Sutton, J., & Barnier, A. (2010). Autobiographical forgetting, social forgetting, and situated forgetting: Forgetting in context. In S. Della Salla (Ed.), *Forgetting* (pp. 253–284). Hove, UK: Psychology Press.

Jakab, E., & Raaijmakers, J. G. W. (2009). The role of item strength in retrieval-induced forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*, 607–617.

Johnson, S. K., & Anderson, M. C. (2004). The role of inhibitory control in forgetting semantic knowledge. *Psychological Science*, *15*, 448–453.

Klein, S. B., Loftus, J., & Kihlstrom, J. F. (2002). Memory and temporal experience: The effects of episodic memory loss on an amnesic patient's ability to remember the past and imagine the future. *Social Cognition*, *20*, 353–379.

Kuhl, B. A., & Wagner, A. D. (2009). Forgetting and retrieval. In G. G. Berntson & J. T. Cacioppo (Eds.), *Handbook of neuroscience for the behavioral sciences*. New York, NY: John Wiley & Sons.

Levy, B. J., & Anderson, M. C. (2002). Inhibitory processes and the control of memory retrieval. *Trends in Cognitive Science*, *6*, 299–305.

Levy, B. J., McVeigh, N. D., Marful, A., & Anderson, M.C. (2007). Inhibiting your native language: The role of retrieval-induced forgetting

during second-language acquisition. *Psychological Science*, *18*, 29–34.

Little, J. L., Storm, B. C., & Bjork, E. L. (2011). The costs and benefits of testing text materials. *Memory*, *19*, 346–359.

MacLeod, C. M., Dodd, M. D., Sheard, E. D., Wilson, D. E., & Bibi, U. (2003). In opposition to inhibition. *The Psychology of Learning and Motivation*, *43*, 163–214.

MacLeod, M. D., & Saunders, J. (2005). The role of inhibitory control in the production of misinformation effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 964–979.

Macrae, C. N., & Roseveare, T. A. (2002). I was always on my mind: The self and temporary forgetting. *Psychonomic Bulletin & Review*, *9*, 611–614.

McClelland, J. L. (1995). Constructive memory and memory distortions: A parallel-distributed processing approach. In D. L. Schacter (Ed.), *Memory distortion* (pp. 69–90). Cambridge, MA: Harvard.

Migueles, M., & García-Bajos, E. (2007). Selective retrieval and induced forgetting in eyewitness memory. *Applied Cognitive Psychology*, *21*, 1157–1172.

Postman, L. (1971). Organization and interference. *Psychological Review*, *78*, 290–302.

Radvansky, G. A., & Zacks, R. T. (1991). Mental models and the fan effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*, 940–953.

Saunders, J., Fernandes, M., & Kosnes, L. (2009). Retrieval-induced forgetting and mental imagery. *Memory & Cognition*, *37*, 819–828.

Schacter, D. L. (1999). The seven sins of memory: Insights from psychology and cognitive neuroscience. *American Psychologist*, *54*, 182–203.

Schacter, D. L. (2001). *The seven sins of memory: How the mind forgets and remembers*. Boston, MA: Houghton, Mifflin & Company.

Schacter, D. L., & Addis, D. R. (2007). The cognitive neuroscience of constructive memory: remembering the past and imagining the future. *Philosophical Transactions of the Royal Society B*, *362*, 773–786.

Schacter, D. L., Addis, D. R., & Buckner, R. L. (2007). Remembering the past to imagine the future: The prospective brain. *Nature Reviews Neuroscience*, *8*, 657–661.

Schacter, D. L., Addis, D. R., & Buckner, R. L. (2008). Episodic simulation of future events: concepts, data, and applications. *Annals of the New York Academy of Sciences*, *1124*, 39–60.

Smith, R. E., & Hunt, R. R. (2000). The effects of distinctive processing on retrieval induced forgetting. *Memory & Cognition*, *28*, 503–508.

Soriano, M. F., Jiménez, J. F., Román, P., & Bajo, M.T. (2009). Inhibitory processes in memory are impaired in schizophrenia: Evidence from retrieval induced forgetting. *British Journal of Psychology*, *100*, 661–673.

Storm, B. C. (2011). Retrieval-induced forgetting and the resolution of competition. In A. Benjamin (Ed.), *Successful remembering and successful forgetting: A festschrift in honor of Robert A. Bjork* (pp. 351–368). New York, NY: Psychology Press.

Storm, B. C., & Angello, G. (2010). Overcoming fixation: Retrieval-induced forgetting and creative problem solving. *Psychological Science*, *21*, 1263–1265.

Storm, B. C., Angello, G., & Bjork, E. L. (2011). Thinking can cause forgetting: Memory dynamics in creative problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *37*, 1287–1293.

Storm, B. C., Bjork, E. L., & Bjork, R. A. (2005). Social metacognitive judgments: The role of retrieval-induced forgetting in person memory and impressions. *Journal of Memory and Language*, *52*, 535–550.

Storm, B. C., Bjork, E. L., & Bjork, R. A. (2007). When intended remembering leads to unintended forgetting. *The Quarterly Journal of Experimental Psychology*, *60*, 909–915.

Storm, B. C., Bjork, E. L., Bjork, R. A., & Nestojko, J. F. (2006). Is retrieval success a necessary condition for retrieval-induced forgetting? *Psychonomic Bulletin & Review*, *13*, 1023–1027.

Storm, B. C., & Nestojko, J. F. (2010). Successful inhibition, unsuccessful retrieval: Manipulating time and success during retrieval practice. *Memory*, *18*, 99–114.

Storm, B. C., & White, H. A. (2010). ADHD and retrieval-induced forgetting: Evidence for a deficit in the inhibitory control of memory. *Memory*, *18*, 265–271.

Szpunar, K. H. (2010). Episodic future thought: An emerging concept. *Perspectives on Psychological Science*, *5*, 142–162.

Szpunar, K. K., Watson, J. M., & McDermott, K. D. (2007). Neural substrates of envisioning the future. *Proceedings of the National Academy of Sciences USA*, *104*, 642–647.

Tulving, E. (1983). *Elements of episodic memory*. New York, NY: Oxford University Press.

Tulving, E. (1985). How many memory systems are there? *The American Psychologist*, *40*, 385–398.

Tulving, E. (2005). Episodic memory and autonoesis. In H. Terrance & J. Metcalfe (Eds.), *The missing link in cognition: Origins of self-reflective consciousness* (pp. 3–56). New York, NY: Oxford University Press.

Wessel, I., & Hauer, B. (2006). Retrieval-induced forgetting of autobiographical memory details. *Cognition and Emotion*, *20*, 430–447.

Williams, C. C., & Zacks, R. T. (2001). Is retrieval-induced forgetting an inhibitory process? *The American Journal of Psychology*, *114*, 329–354.