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Retrieval-induced forgetting is associated with increased positivity when imagining the future

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People often think of themselves and their experiences in a more positive light than is objectively justified. Inhibitory control processes may promote this positivity bias by modulating the accessibility of negative thoughts and episodes from the past, which then limits their influence in the construction of imagined future events. We tested this hypothesis by investigating the correlation between retrieval-induced forgetting and the extent to which individuals imagine positive and negative episodic future events. First, we measured performance on a task requiring participants to imagine personal episodic events (either positive or negative), and then we correlated that measure with retrieval-induced forgetting. As predicted, individuals who exhibited higher levels of retrieval-induced forgetting imagined fewer negative episodic future events than did individuals who exhibited lower levels of retrieval-induced forgetting. This finding provides new insight into the possible role of retrieval-induced forgetting in autobiographical memory.

Keywords: Episodic future thinking; Positivity bias; Retrieval-induced forgetting; Inhibition; Autobiographical memory.

> . . . the man who remembers or hopes must always be haunted by a certain image of that which he remembers or hopes . . . so it follows that all pleasures consist either in perceiving things present, or in remembering things past, or in hoping things future. Now remembered things are pleasant, not only in those cases in which they were pleasant at the time, but sometimes, though they were unpleasant; provided that their sequel be noble and good. (Aristotle, trans. Jebb, 1909)

Of the many cognitive skills that humans possess, one of the most intriguing is the ability to engage in mental time travel: delving into the past, through the present, and on to the future. We can consciously reexperience, through *autonoetic* awareness and subjective time (see Tulving, 1985, 2001, 2002), past happenings and engage in episodic future thinking (Atance & O'Neill, 2001, 2005; Buckner & Carroll, 2007; Schacter & Addis, 2007a; Suddendorf & Corballis, 2007; Wheeler, Stuss, & Tulving, 1997). This ability to direct our

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attention toward a specific event in the past and to construct a hypothetical episode in the future, using the mechanisms and resources of episodic and semantic memory, allows us to regulate our future behaviour in ways that would otherwise be impossible (e.g., Davies & Stone, 1995; Kahneman & Miller, 1986; Pham & Taylor, 1999; Taylor, Pham, Rivkin, & Armor, 1998; Taylor & Schneider, 1989). The ability to conceptualize alternative past and future episodes, for instance, may be used to achieve what Nietzsche (see Ramadanovic, 2001) called the greatest happiness of humans: the ability to forget and discern what was advantageous in the past and what is disadvantageous for the present and future. That is, if the information retrieved is important or the events and experiences recalled are positive and self-affirming, then it is advantageous to keep such knowledge accessible.

Several researchers have suggested that memory has evolved to retain information when it is likely to be useful or important in the future (J. R. Anderson & Schooler, 1991; Bjork & Bjork, 1988; Schacter, 2001). Indeed, a growing literature has built on this argument by highlighting the adaptive nature of a constructive memory system that allows for flexible extraction, recombination, and reassembly of past and present elements to aid our preparation for the future (Schacter & Addis, 2007b; Suddendorf & Corballis, 2007). This process, sometimes referred to as prospection, or mental time travel, is believed to rely on much of the same cognitive and neural resources whether we are attempting to remember the past or imagine the future (e.g., Addis, Wong, & Schacter, 2007, 2008; D'Argembeau & Van der Linden, 2004, 2006; Schacter, Addis, & Buckner, 2007, 2008; Szpunar, 2010; Szpunar, Watson, & McDermott, 2007).

The flexible nature of such a constructive memory system, however, also provides a means —through incomplete data gathering, imagination-induced memory distortions, biases, selective forgetting, and so forth—by which to remember the past (and imagine the future) in ways that better suit our personal or subjective needs even if it is at the expense of objective accuracy (Conway, 2005; Conway & Pleydell-Pearce, 2000; Fiske & Taylor, 1984; Schacter, 2012; Schacter, Guerin, & St. Jacques, 2011; Taylor, 1989; Taylor & Brown, 1988). Individuals, for example, often seek out positive experiences and avoid negative ones, leading them to view past (and future) life events in an overly positive light (Sharot, 2011; Sharot, Riccardi, Raio, & Phelps, 2007; Walker, Skowronski, & Thompson, 2003; Weinstein, 1980). Indeed, information or feelings associated with negative experiences tend to fade more quickly over time than information or feelings associated with positive experiences (Holmes, 1970; Szpunar, Addis, & Schacter, 2012; Taylor, 1991; Thompson, 1930; Walker & Skowronski, 2009).

Recent research has suggested that this positivity bias could arise, in part, through the inhibitory processes that underlie retrieval-induced forgetting (Storm & Jobe, 2012). Retrieval-induced forgetting is observed when the selective retrieval of some information causes the forgetting of other information (M. C. Anderson, Bjork, & Bjork, 1994; for a review of some of the many instantiations of retrieval-induced forgetting, see Storm et al., 2015). According to the inhibitory account of retrieval-induced forgetting, nontarget items can become activated in response to a retrieval cue, causing competition, and inhibition acts to resolve this competition by rendering the nontarget items less accessible—both in the moment and after a delay (M. C. Anderson, 2003; Murayama, Miyatsu, Buchli, & Storm, 2014; Storm & Levy, 2012).

In the study by Storm and Jobe (2012), a common version of the retrieval-practice paradigm was administered to measure individual differences in retrieval-induced forgetting. Then, to examine differences in autobiographical memory, participants were presented with 20 neutral keywords (e.g., "pool", "medicine") and were asked to generate either positive or negative memories associated with those keywords. Participants who exhibited high levels of retrieval-induced forgetting recalled significantly fewer negative memories than did participants who exhibited low levels of retrieval-induced forgetting, whereas a nonsignificant correlation was observed in the opposite direction for

positive memories. In fact, participants who exhibited high levels of retrieval-induced forgetting were found to show a strong positivity bias, whereas participants who exhibited low levels of retrieval-induced forgetting were found to show a nonsignificant negativity bias.

Storm and Jobe (2012) speculated that the inhibitory process underlying retrieval-induced forgetting may play a direct role in facilitating a positivity bias in autobiographical memory. More specifically, the argument is that when people encounter a given retrieval cue, inhibitory processes may prevent negative or otherwise undesirable memories from coming to mind—in much the same way that inhibition is presumed to prevent nontarget items from coming to mind in the retrieval-practice paradigm. A cue such as *birthday party*, for example, is likely to be associated to an array of memories (some of which are positive and others that are negative)—and to the extent that autobiographical memory is biased toward remembering positive events over negative events, inhibition may act to reduce the accessibility of the negative memories in order to better facilitate access to the positive memories (see also Bjork, Bjork, & Anderson, 1998, for similar speculations regarding possible inhibitory mechanisms underlying varieties of goal-directed forgetting). Of course, it is also possible that some other factor—such as executive control or working memory capacity—is related to both retrieval-induced forgetting and positivity in autobiographical memory, and it may be this third factor that is responsible for the observed correlation. Regardless of the exact underlying mechanism, the results by Storm and Jobe suggest that individuals who are more susceptible to retrieval-induced forgetting remember the past more positively than do individuals who are less susceptible to retrieval-induced forgetting.

Our goal was to extend the work of Storm and Jobe (2012) by investigating whether individual differences in retrieval-induced forgetting would also predict differences in how people imagine the future. If similar processes underlie remembering and episodic future thinking, and if retrieval-induced forgetting (or some related factor) facilitates the remembering of more positive than negative past experiences, then it stands to reason that retrieval-induced forgetting (or some related factor) may also facilitate the construction of more positive than negative future experiences. Indeed, to the extent that memories of the past serve as building blocks in the construction of future thoughts, any mechanism that influences the type of memories that can come to mind should, in so doing, influence the type of episodic simulations that can be constructed. To test this hypothesis, we measured each participant's ability to imagine either positive or negative events taking place in the future and examined the correlation between that measure and retrieval-induced forgetting. We expected our results to mirror those reported by Storm and Jobe (2012). Specifically, we expected participants exhibiting high levels of retrieval-induced forgetting to construct fewer negative simulations (and more positive simulations) of the future than participants exhibiting low levels of retrieval-induced forgetting.

EXPERIMENTAL STUDY

Method

Participants and design

A total of 132 individuals were recruited to participate in the experiment via the internet using Amazon's Mechanical Turk (Mturk), a website that allows a diverse population to sign up to complete small tasks for payment (for the validity of this methodology, see Buhrmester, Kwang, & Gosling, 2011; Gosling, Vazire, Srivastava, & John, 2004). The sample consisted of 86 women and 46 men (M years of age = 35, SD = 10). Only English-speaking individuals in the United States were allowed to participate. The valence (positive vs. negative) of the future events to be imagined was manipulated between subjects such that a randomly assigned half of the participants attempted to generate positive events, and the other randomly assigned half attempted to generate negative events. All participants completed the future thinking portion of the study first, followed by the retrieval-practice task to measure retrieval-induced

forgetting. The entire study was completed via Mturk.

Measuring future event construction

All participants were presented with the same set of 20 neutral keywords (i.e., ball, bathroom, bite, blanket, book, bridge, candle, car, clock, envelope, ice, knife, leg, medicine, money, pool, ring, scarf, television, tree) to use as the basis for their generation of future events. Participants assigned to the positive condition were instructed to imagine specific personal future events that might make them feel "happy, proud, pleased, or gratified". In contrast, participants assigned to the negative condition were instructed to imagine specific personal future events that might make them feel "sad, embarrassed, or disappointed". Each keyword was presented and remained on the computer screen for 25 s while participants imagined and typed in a description of a corresponding future event. They were asked to imagine and write down only future events or scenarios that were novel, yet plausible, and not to write anything if nothing came to mind. Participants were also asked to use as many words as possible to describe each future event. The proportion of keywords (out of the set of 20) that elicited a future episodic event was calculated for each participant. Only events that were deemed by the rater, who was blind to each individual's retrieval-induced forgetting score, to be both episodic and appropriate to the target valence were coded as a successful episodic construction. One-word responses or instances in which the event was clearly nonepisodic (e.g., "I like cheese") or of the inappropriate valence ("I fell down and got bit by a dog" when asked to think of a positive future event) were not counted as successful constructions.

Measuring retrieval-induced forgetting

A measure of retrieval-induced forgetting was obtained for each participant using the same paradigm as that employed by Storm and Jobe (2012). Participants first studied a list of 48 category–exemplar pairs (e.g., *fruit:banana; metal:silver)*, composed of six exemplars from each of eight categories, with pairs presented one at a time and in a different random order for each subject. Then, during retrieval practice, participants attempted to retrieve new exemplars associated with half of the studied categories (semantic generation). The cues employed during retrieval practice consisted of a category name plus a two-letter-stem cue of an associated exemplar of relatively low taxonomic frequency (e.g., *fruit:gu___*, for *guava*). Three rounds of retrieval practice were conducted, with participants generating an appropriate response on 53% ($SD = 15\%$) of the trials. Then, after a 5-min delay (filled with playing Tetris), participants were tested on all 48 originally studied (but not practised) exemplars. In this final test, the cues employed were the category name plus the first letter of the exemplar (e.g., *fruit:b____*). Retrieval-induced forgetting was calculated by subtracting final recall performance for exemplars from practised categories from that for nonpractised categories. Thus, positive values indicate greater amounts of retrieval-induced forgetting, whereas negative values indicate lower amounts of retrieval-induced forgetting.

Results

Overall, a significant effect of retrieval-induced forgetting was observed: Unpractised exemplars from practised categories ($M = .62$, $SE = .02$) were recalled less well than unpractised exemplars from unpractised categories ($M = .69$, $SE = .01$), $t(131) = 7.32$, $p < .001$, $d = 0.64$. Additionally, a significant effect of valence was observed such that more future events ($M = .85$, $SE = .02$) were elicited in the negative condition than in the positive condition ($M = .79$, $SE = .02$), $t(130) = 2.14$, $p = .03$, $d = 0.37$.

A regression analysis examined the proportion of variance in future episodic thinking explained by valence, retrieval-induced forgetting, and the Valence × Retrieval-Induced Forgetting interaction. Valence was entered as a dummy variable indicating condition (positive vs. negative). The complete model was significant, $F(3, 128) = 4.33$, $p = .01$, $R^2 = .09$. More importantly, the interaction term explained significant variance above and beyond that explained by valence and

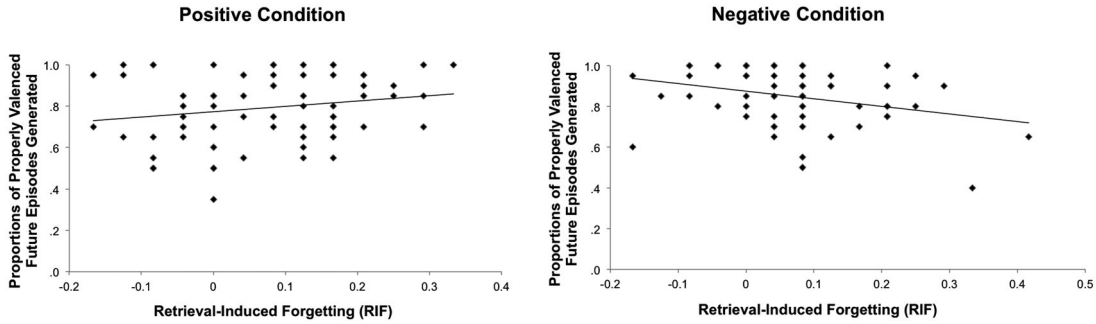

Figure 1. *Scatter plots (with best fitting regression lines) illustrating the proportions of properly valenced future episodes generated in relation to retrieval-induced forgetting. Generated future episodes for each valence were operationally defined as the proportion of keywords resulting in the generation of an episodic future event of that valence; values on the* x*-axis are raw retrieval-induced forgetting scores. The relation between retrieval-induced forgetting and the generation of negative future episodes is shown in the left panel, and the relation between retrieval-induced forgetting and the generation of positive future episodes is shown in the right panel.*

retrieval-induced forgetting alone. Specifically, the Valence × Retrieval-Induced Forgetting term accounted for significant additional variance, $F(1, 128) = 8.15$, $p = .005$, $\Delta R^2 = .06$, suggesting that the correlation between retrieval-induced forgetting and future episodic thinking was significantly different in the positive and negative valence conditions. As shown in Figure 1, a significant negative correlation was observed between retrieval-induced forgetting and episodic future thinking in the negative condition, ($r = -.31$, $p = .01$; Spearman's rho $= -.30$, $p = .02$), whereas a nonsignificant positive correlation was observed between retrieval-induced forgetting and episodic future thinking in the positive condition ($r = .19$, $p = .11$; Spearman's rho $= .19$, $p = .13$).[1] These results almost perfectly match the results reported by Storm and Jobe (2012; Experiment 1). Specifically, they observed Pearson's correlations of −.31 and .17 in the negative and positive autobiographical remembering conditions, respectively.

To explore the data further, we examined the number of words that participants used while reporting their episodic constructions. On average, participants in the negative condition used more words to describe each episodic future event ($M = 15.3$, $SE = 0.8$) than did participants in the positive condition ($M = 13.5$, $SE = 0.5$), $t(130) = 2.03$, $p < .05$, $d = 0.35$. Moreover, a significant negative correlation was observed in the negative condition such that participants exhibiting greater levels of retrieval-induced forgetting used fewer words than did participants exhibiting lower levels of retrieval-induced forgetting ($r = -.26$, $p = .04$). No such correlation was observed in the positive condition ($r = -.02$, $p = .86$).

GENERAL DISCUSSION

Recollection of the past and expectations of the future are often positively biased (Brown, MacLeod, Tata, & Goddard, 2002; Sharot et al., 2007; Walker et al., 2003; Weinstein, 1980), but not all individuals succeed in promoting and

[1]Spearman's rho is less susceptible to the influence of outliers than Pearson's *r* because it is calculated using rank order instead of actual scores. To further control for the influence of outliers we re-ran the regression analysis after removing subjects who exhibited retrieval-induced forgetting scores or episodic future thinking scores that deviated from the mean in a given condition by more than three standard deviations (only one subject in the negative condition needed to be removed). The results of this analysis mirrored those of the full analysis. Specifically, the complete model was significant, $F(3, 127) = 3.87$, $p = .01$, $R^2 = .08$, and the interaction term explained significant variance above and beyond that explained by valence and retrieval-induced forgetting alone, $F(1, 127) = 5.10$, $p = .03$, $\Delta R^2 = .04$.

maintaining this bias (e.g., Storm & Jobe, 2012; Taylor & Brown, 1988). The present study examined the extent to which individual differences in retrieval-induced forgetting are correlated with the capacity to imagine positive or negative episodic events taking place in the future. Specifically, participants were given neutral keywords and were asked to imagine either positive or negative future events associated with those keywords. Participants who exhibited greater levels of retrieval-induced forgetting were less prone to imagining negative events than were participants who exhibited reduced levels of retrieval-induced forgetting. This finding is consistent with earlier work by Storm and Jobe (2012), who found that individuals exhibiting greater levels of retrieval-induced forgetting were also less prone to remembering negative memories from the past than were individuals who exhibit reduced levels of retrieval-induced forgetting.

The present findings, along with those of Storm and Jobe (2012), are consistent with the idea that inhibition, or some other factor related to retrieval-induced forgetting, acts to prevent negative autobiographical experiences from coming to mind, with such an effect occurring regardless of whether people attempt to mentally time travel into the past or into the future. The fact that retrieval-induced forgetting correlated with episodic future thinking in the same way that it correlated with episodic remembering is also consistent with work showing that remembering the past and constructing the future rely on similar cognitive and neural processes (Schacter et al., 2007, 2008). By determining which memories of the past come to mind, the processes underlying or related to retrieval-induced forgetting may in turn determine the type of episodic simulations that can be constructed. According to the episodic simulation hypothesis, elements of past memories are flexibly extracted and recombined to construct simulations of future events. Thus, any mechanism that influences the accessibility of memories from the past should also influence the way in which one thinks about the future. On the other hand, it is also possible that the construction of negative episodic future events is limited in a more direct way that is independent from what is, or is not, accessible in memory. There may be an implicit bias in the constructive process to avoid negative or self-threatening thoughts, for example, and inhibition or executive control may help to enforce this bias. A third possibility is that participants simply recasted past events as events occurring in the future, in which case it would not be surprising that we observed the same correlation as that in Storm and Jobe (2012). Unfortunately, because we did not collect a measure of novelty or of how distinctive a future event was from experienced past events, it is impossible to rule out this possibility.

Up until this point, our discussion has largely assumed that inhibition underlies retrieval-induced forgetting and that individual differences in retrieval-induced forgetting reflect individual differences in the capacity to inhibit nontarget items in memory. Although there is good evidence to support this assumption (e.g., M. C. Anderson, 2003; Murayama et al., 2014; Storm & Levy, 2012), some researchers believe that retrieval-induced forgetting can be sufficiently explained by noninhibitory mechanisms, such as associative interference or inappropriate contextual cueing (see, e.g., Jonker, Seli, & MacLeod, 2013; Raaijmakers & Jakab, 2013; Verde, 2012). According to most noninhibitory accounts, retrieval-induced forgetting occurs because retrieval practice strengthens a subset of items, and it is this strengthening that blocks the accessibility of other, nonstrengthened items at test. Interpreting the present results in this context, it is possible that individuals who exhibit greater levels of retrieval-induced forgetting recall and construct fewer negative episodic events than positive episodic events because such events are particularly prone to noninhibitory sources of forgetting. For example, although it is not immediately clear why this would be the case, negative events could be more susceptible to blocking than their positive counterparts.

Individual differences in retrieval-induced forgetting aside, it is somewhat surprising that participants imagined negative future events at a higher rate than they imagined positive future events—a finding that appears to be inconsistent with earlier

work showing positivity biases in autobiographical memory and future thinking. Although we do not have a clear explanation for this finding, we can entertain several possibilities. First, studies have shown that negative information can be remembered more easily and with a greater sense of vividness and detail than positive information (e.g., Kensinger, 2009; Mickley & Kensinger, 2008), and our particular instructions may have emphasized the need to generate the type of vivid details during episodic simulation that are more easily associated to negative than to positive events. Moreover, limiting the time that participants had to respond on each trial might have favored the negative condition, as imagining a positive future event may have required placing an experience in a more elaborate context than imagining a negative future event. Finally, it may be important that our sample was recruited via MTurk. Not only might individuals who use MTurk be different from individuals who typically participate in laboratory studies, but the anonymity afforded by MTurk may provide participants greater freedom in the way in which they respond to autobiographical memory tests.

Concluding comment

It is important to emphasize that the correlation between retrieval-induced forgetting and the ability to generate episodic future events may be driven by any number of different variables, such as those related to attentional control or working memory capacity (e.g., Aslan & Bäuml, 2011; Schilling, Storm, & Anderson, 2014) or to psychiatric disorders, such as depression or anxiety (e.g., MacLeod & Cropley, 1995; MacLeod, Tata, Kentish, Carroll, & Hunter, 1997; Raune, MacLeod, & Holmes, 2005). Moreover, although our results suggest that retrieval-induced forgetting may play a role in promoting a positivity bias in autobiographical memory, because they are correlational, they do not on their own provide evidence for a causal relationship. Future research may seek to examine how manipulating a person's capacity to inhibit nontarget items (and thus retrieval-induced forgetting) influences the ways in which the past is remembered, and the future is constructed (e.g., Sharot et al., 2012). Such necessary cautions notwithstanding, however, the present findings mesh nicely with theories that emphasize the importance of adaptive inhibitory processes that promote psychological well-being (Taylor, 1991), and the observed link between inhibitory control and imagining future events holds the promise of helping us to understand the mechanisms underlying imagining and planning for the future.

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