



# DIGITAL ACCESS TO SCHOLARSHIP AT HARVARD

## Episodic future thinking and episodic counterfactual thinking: Intersections between memory and decisions

The Harvard community has made this article openly available.  
[Please share](#) how this access benefits you. Your story matters.

<b>Citation</b>	Schacter, Daniel L., Roland G. Benoit, Felipe De Brigard, and Karl K. Szpunar. 2013. "Episodic Future Thinking and Episodic Counterfactual Thinking: Intersections Between Memory and Decisions." <i>Neurobiology of Learning and Memory</i> (2013 Dec 25.) pii: S1074-7427(13)00263-3.
<b>Published Version</b>	<a href="https://doi.org/10.1016/j.nlm.2013.12.008">doi:10.1016/j.nlm.2013.12.008</a>
<b>Accessed</b>	February 19, 2015 4:07:34 PM EST
<b>Citable Link</b>	<a href="http://nrs.harvard.edu/urn-3:HUL.InstRepos:12363920">http://nrs.harvard.edu/urn-3:HUL.InstRepos:12363920</a>
<b>Terms of Use</b>	This article was downloaded from Harvard University's DASH repository, and is made available under the terms and conditions applicable to Open Access Policy Articles, as set forth at <a href="http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#OAP">http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#OAP</a>

*(Article begins on next page)*

Running head: Episodic future and counterfactual thinking

Episodic future thinking and episodic counterfactual thinking:

Intersections between memory and decisions

Daniel L. Schacter<sup>a</sup>, Roland G. Benoit<sup>a</sup>, Felipe De Brigard<sup>a,b</sup> and Karl K. Szpunar<sup>a</sup>

<sup>a</sup>Department of Psychology, Harvard University, Cambridge, MA 02138, United States

<sup>b</sup>Present address: Department of Philosophy, Center for Cognitive Neuroscience, and  
Duke Institute for Brain Sciences, Duke University, Durham, NC 27708, United States

Keywords: Episodic memory, Episodic future thinking, Episodic counterfactual thinking,

Core network, Default network, Hippocampus

**Corresponding author:** Daniel L. Schacter  
Email: [dls@wjh.harvard.edu](mailto:dls@wjh.harvard.edu)  
Phone: 1-617-495-3855

## Abstract

This article considers two recent lines of research concerned with the construction of imagined or simulated events that can provide insight into the relationship between memory and decision making. One line of research concerns *episodic future thinking*, which involves simulating episodes that might occur in one's personal future, and the other concerns *episodic counterfactual thinking*, which involves simulating episodes that could have happened in one's personal past. We first review neuroimaging studies that have examined the neural underpinnings of episodic future thinking and episodic counterfactual thinking. We argue that these studies have revealed that the two forms of episodic simulation engage a common core network including medial parietal, prefrontal, and temporal regions that also supports episodic memory. We also note that neuroimaging studies have documented neural differences between episodic future thinking and episodic counterfactual thinking, including differences in hippocampal responses. We next consider behavioral studies that have delineated both similarities and differences between the two kinds of episodic simulation. The evidence indicates that episodic future and counterfactual thinking are characterized by similarly reduced levels of specific detail compared with episodic memory, but that the effects of repeatedly imagining a possible experience have sharply contrasting effects on the perceived plausibility of those events during episodic future thinking versus episodic counterfactual thinking. Finally, we conclude by discussing the functional consequences of future and counterfactual simulations for decisions.

It is widely acknowledged that memory and decisions are closely related, but it is only relatively recently that the neural processes linking memory and decision-making have been the targets of systematic study. One emerging line of research that can potentially illuminate the relationship between memory and decisions centers on the role of a particular kind of memory – episodic memory, or the recollection of specific happenings in one’s personal past (Tulving, 1983, 2002) - in the construction of imagined or simulated events. This line of work has focused on the process of *episodic simulation* (Schacter, Addis, & Buckner, 2008), where one draws on elements of past experiences in order to envisage hypothetical scenarios that might occur in one’s personal future or might have occurred in one’s personal past. In line with this general characterization, we can distinguish between two major kinds of episodic simulation: *episodic future thinking* and *episodic counterfactual thinking*. Episodic future thinking involves the construction of possible future personal episodes or scenarios (Atance & O’Neil, 2001; Szpunar, 2010), whereas episodic counterfactual thinking involves simulating alternative versions or outcomes of past personal episodes that could have happened but did not occur (De Brigard & Giovanello, 2012; see Table 1 for definitions of these and other key terms). During the past few years, there has been an explosion of research concerning episodic future thinking, motivated to a large extent by the observation that a common core brain network is involved in both episodic memory and episodic future thinking (for a recent review, see Schacter, Addis, Hassabis, Martin, Spreng, & Szpunar, 2012). Though there has been less research concerning episodic counterfactual thinking, several recent papers have explored aspects of the phenomenon and its relationship to episodic memory (e.g., De Brigard & Giovanello, 2012; De Brigard, Addis, Ford,

Schacter, & Giovenello, 2013; De Brigard, Szpunar, & Schacter, 2013; Gerlach, Dornblaser, & Schacter, 2013; Van Hoeck, Ma, Ampe, Baetens, Vandekerchove, & Van Overwalle, 2013).

Insert Table 1 about here

It is important to note that episodic future and episodic counterfactual thinking appear to be distinct from general future and counterfactual thinking, whereby the contents of the mental simulations involve only impersonal and non-autobiographical events. Hypothetical reasoning—of which future and counterfactual thinking are subclasses—has been an active area of research in social psychology and behavioral economics for the last few decades. However, much of that research, if not all, has been conducted using vignettes depicting hypothetical scenarios with little to no autobiographical relevance to the experimental subject (e.g., Roese and Olson, 1995). Although it is typically assumed that the results obtained in these studies also apply to personally relevant future and counterfactual simulations, recent studies raise questions about the extent to which the results from studies using impersonal and non-autobiographical vignettes are applicable to the process of future and counterfactual simulations about one's own personal life. In the case of counterfactual thinking, for instance, recent studies have shown that some effects that were found when participants had to think about alternative outcomes to impersonal and non-autobiographical events described in vignettes do not hold when participants have to think about alternative ways in which their own past personal events could have occurred (Giroto, Ferrante, Pighin, & Gonzalez, 2007; Pighin, Byrne, Ferrante, Gonzalez, & Giroto, 2011).

The extent to which episodic future and episodic counterfactual thinking share cognitive processes is still an open question. Nonetheless, we believe there is now enough evidence to hypothesize that episodic versions of these kinds of hypothetical simulations constitute a psychological phenomenon distinguishable from their more generic counterparts, and that both

depend extensively on episodic memory. The main purpose of the present article is to discuss the relationship between episodic future thinking and episodic counterfactual thinking. Specifically, we will focus on two broad domains in which there has been experimental research on both forms of episodic simulation. First, we will consider neuroimaging studies of episodic future thinking and episodic counterfactual thinking with a view toward assessing the extent to which they engage the same or different brain regions and networks, and what role particular brain regions might play in each type of simulation. Second, we will consider behavioral studies that have delineated cognitive properties of each kind of episodic simulation, discussing specifically phenomenological properties of simulations, the effect of simulations on memory accuracy, and the effects of repetition on the subjective plausibility of simulations. We will conclude by considering the functional consequences of episodic future thinking and episodic counterfactual thinking for decision making and related processes. We also note two points about what the present article does not cover. First, in line with the foregoing comments concerning the distinction between episodic future and episodic counterfactual thinking on the one hand and their more general counterparts on the other, we do not attempt in this brief article to cover the vast literature on hypothetical reasoning and non-episodic forms of counterfactual and future thinking. Second, we do not provide a general review of findings and perspectives concerning the now-substantial literature on episodic future thinking because several other recent reviews have done so (cf., Addis & Schacter, 2012; Klein, 2013; Schacter et al., 2012; Szpunar, 2010).

#### Neuroimaging studies of episodic future thinking and episodic counterfactual thinking

The first neuroimaging study of episodic future thinking was reported by Okuda et al. (2003). Participants were scanned (using PET) while talking about either the near past or future (i.e., the last or next few days) or the distant past or future (i.e., the last or next few years).

Okuda et al. (2003) reported similar activity during past and future conditions in several prefrontal regions, as well as in the medial temporal lobe, including right hippocampus and bilateral parahippocampal gyrus. While the past/future overlap observed in this study was striking, given the rather open-ended instructions to talk about the past or future, it was not clear whether or to what extent participants were engaged specifically in episodic remembering or episodic future thinking – i.e., recollecting or simulating specific events – as opposed to retrieving general or semantic information about the past or future.

However, subsequent neuroimaging studies using more constrained and controlled behavioral paradigms focusing on specific personal events have shown similar kinds of neural overlap between episodic memory and episodic future thinking. For example, Addis, Wong, and Schacter (2007) provided participants with word cues and instructed them to remember or imagine specific personal events from particular time periods in the past or future. The past and future tasks were divided into an initial construction phase during which participants generated a past or future event in response to the word cue and pressed a button when they had an event in mind, and an elaboration phase during which participants generated as much detail as possible about the event. Relative to non-episodic control conditions, Addis et al. (2007) reported extensive neural overlap during the past and future tasks in both the construction and elaboration phases: remembering the past and imagining the future were associated with activity in a network of regions including medial temporal (hippocampus and parahippocampal gyrus) cortex, medial prefrontal cortex, posterior cingulate and retrosplenial cortex, as well as lateral temporal and prefrontal regions. Szpunar, Watson, & McDermott (2007) reported a similar neural activation pattern using a task in which participants were instructed to remember specific past personal events, imagine specific future personal events, or imagine specific events involving a

familiar individual (Bill Clinton). Again, there was striking overlap in activity associated with past and future events in most of the same regions observed in the studies by Addis et al. (2007) and Okuda et al. (2003). Importantly, these regions were not activated to the same magnitude when imagining events involving Bill Clinton, providing evidence that activity in the engaged regions is related to the construction of specific events in one's personal past or future.

These observations have been replicated and extended in more recent studies (e.g., Abraham, Schubotz, & von Cramon, 2008; Addis, Pan, Vu, Laiser, & Schacter, 2009; Addis, Roberts, & Schacter, 2011; Andrews-Hanna, Reidler, Sepulcre, Poulin, & Buckner, 2010; Botzung, Denkova, & Manning, 2008). The collection of regions that show similarly increased activity during episodic memory and episodic future thinking – most prominently, medial temporal cortex, medial prefrontal cortex, posterior cingulate, retrosplenial cortex, and lateral temporal and prefrontal regions – have been referred to as a “core network” (Schacter, Addis, & Buckner, 2007). This core network, in turn, overlaps substantially with the extensively studied *default network* (e.g., Raichle, MacLeod, Snyder, Powers, Gusnard, & Shulman, 2001), which has been linked with internally focused thought and attention (for reviews, see Buckner, Andrews-Hanna, & Schacter, 2008; Andrews-Hanna, 2012).

Within the core network, it is also possible to distinguish subsystems that are preferentially associated with remembering and imagining, respectively (Addis et al., 2009). Indeed, several neuroimaging studies have revealed neural differences between remembering the past and imagining the future, with most such studies showing greater activity in regions such as the hippocampus and frontopolar cortex during imagining compared with remembering (for review, see Schacter et al., 2012). Considerable attention has been paid in particular to understanding the basis for increased hippocampal activity during future imagining, with recent

evidence indicating a possible role of encoding future simulations into memory (Martin, Schacter, Corballis, & Addis, 2011) as well as a role for the hippocampus in the initial construction of an imagined events, even when encoding processes are controlled (Gaesser, Spreng, McLelland, Addis, & Schacter, 2013; for general discussion, see Addis & Schacter, 2012; Buckner, 2010; Hassabis & Maguire, 2009; Schacter & Addis, 2009). Recent evidence has also addressed the role of specific core network regions in supporting specific aspects of future event simulations. For example, Szpunar, St. Jacques, Robbins, Wig, and Schacter (2013) used a repetition suppression procedure in which participants repeatedly simulated future events involving specific people, objects, or locations, which were either changed or held constant across repetitions. Repetition-related reductions in neural activity are thought to reveal which brain regions are sensitive to processing specific kinds of stimuli or features (e.g., Grill-Spector, Henson, & Martin, 2006; Schacter, Wig, & Stevens, 2007). Based on such logic, Szpunar et al. demonstrated that distinct regions are sensitive to simulating the people (dorsomedial prefrontal cortex), objects (inferior frontal and premotor cortices), and locations (retrosplenial, parahippocampal, and posterior parietal cortices) that typically constitute episodic simulations of future experiences (for related results, see also Hassabis, Spreng, Rusu, Robbins, Mar, & Schacter, 2013).

Given the consistent observation of core network activity during episodic future thinking, an important question is whether this same network is implicated in episodic counterfactual thinking. Some evidence consistent with this possibility was reported by Addis et al. (2009), who examined neural activity associated both with imagining possible future events and imagining events that might have occurred in the past (but never did). Addis et al. (2009) found that the same subsystem of the core network associated with imagining future events (including regions

within medial prefrontal cortex, inferior frontal gyrus, medial temporal lobe and medial parietal cortex) was engaged when participants imagined possible past events.

While the results of Addis et al. (2009) suggest that episodic counterfactual thinking may recruit much the same network as episodic future thinking, the imaginary past events in their study not only had never occurred but were also unlikely, thus differing from episodic counterfactual thoughts, where the outcome of an actual past event is mentally mutated to create a likely alternative version. More recent neuroimaging studies have focused specifically on episodic counterfactual thinking. Van Hoeck et al. (2013) asked participants to remember positive or negative past experiences, imagine possible positive or negative future experiences, or generate “upward” counterfactual simulations in which they imagined how a past negative event might have turned out better (e.g., “If I had left the office earlier, I wouldn’t have missed my train.”). fMRI results revealed that episodic counterfactual thinking, just like episodic remembering and future thinking, recruited core network regions that had been observed in previous studies of remembering the past and imagining the future.

A related fMRI study by De Brigard, Addis, Ford, Schacter, and Giovanello (2013) also documented an association between episodic counterfactual and key regions within the core network, and further provided information concerning how brain activity is modulated by the likelihood of a counterfactual outcome. In this study, prior to scanning participants recalled specific episodes characterized by either a positive or a negative outcome. During scanning, participants recalled some of these episodes, and also engaged in three different types of counterfactual simulations regarding other episodes. In the *positive* condition, they imagined what would have happened if a reported event whose outcome was negative instead had a positive outcome (i.e., *upward counterfactual*); in the *negative* condition, they imagined what

would have happened if a reported event whose outcome was positive instead had a negative outcome (i.e., *downward counterfactual*); and in the *peripheral* condition, they imagined an alternative way in which the experienced outcome could have been brought about by changing a peripheral detail of the event. Participants also provided ratings of the subjective likelihood of the counterfactual events, thus allowing comparison of brain activity associated with counterfactual events that participants rated as likely versus those that they rated unlikely. Brain activity in these conditions was compared with activity from a control task, where participants constructed sentences that compared the sizes of different objects (cf., Addis et al., 2009).

Consistent with the observations of Van Hoeck et al. (2013), results of a multivariate analysis (partial least squares) revealed a latent variable that distinguished patterns of brain activity during the remember, positive counterfactual, and negative counterfactual conditions relative to the non-episodic control condition. The pattern of brain activity common to the three experimental conditions was comprised entirely of core network regions identified in earlier work on remembering the past and imagining the future. No latent variable was uncovered that distinguished between positive and negative counterfactuals. However, a second latent variable did emerge that distinguished remembering and likely counterfactuals from unlikely counterfactuals. Moreover, the data suggest that likely counterfactuals preferentially recruited core network regions more strongly associated with remembered episodes, whereas unlikely counterfactuals preferentially engaged regions more strongly associated with imagined episodes (cf., Addis et al., 2009). This pattern of results shows that episodic counterfactuals deemed as likely recruited regions of the core brain network that were significantly more similar to those recruited during episodic recollection than to the brain regions recruited during episodic counterfactual thoughts that were deemed unlikely. Thus, in the context of this experimental

design, the activation pattern of likely counterfactuals was somewhat more like episodic memory than unlikely counterfactuals.

Overall, despite the fact that only a few relevant studies have been reported, it seems safe to conclude that episodic future thinking and episodic counterfactual thinking both engage regions that are also recruited when people remember specific past experiences from their everyday lives. On a general level, the overlap of this core-network with the default network is consistent with theoretical perspectives that have emphasized the role of this network in supporting various kinds of mental simulations (e.g., Buckner & Carroll, 2007; Schacter & Addis, 2007; Schacter et al., 2007). On a more specific level, the joint recruitment of the core network is consistent with the proposal that it supports processes that can be generally employed to construct episodes, irrespective of whether they have happened or not (Schacter & Addis, 2007; Hassabis & Maguire, 2009).

However, though both episodic future thinking and episodic counterfactual thinking require similar constructive processes, these operate on material that is differentially constrained by reality. The future is inherently uncertain, and thus there are many degrees of freedom in simulating prospective episodes. By comparison, counterfactual thoughts are more constrained by the context of the past episodes, and any mental mutation of the past may clash with our knowledge of the event's wider context. The two forms of episodic simulations may thus require different cognitive processes to cope with the specific nature of the imagined events, and may thus also partly differ in the associated pattern of neural activation. For example, Van Hoeck et al. (2013) reported that relative to episodic memory and future thinking, episodic counterfactual thinking preferentially engaged posterior aspects of medial frontal cortex, which the authors suggested reflected processes associated with conflict detection.

Another potentially intriguing difference between the two forms of simulations has been observed in the hippocampus. Studying episodic counterfactual simulations, De Brigard, Addis, et al. (2013) found that activity in anterior regions of the right hippocampus *increased* as a function of how likely participants perceived the simulated counterfactual event. In other words, the hippocampus was more strongly engaged during likely relative to unlikely episodic counterfactuals (although this effect was only observed for downward counterfactuals). In contrast, in a study on episodic future thinking, Weiler, Suchan, and Daum (2010) reported a *decrease*—rather than an increase—in anterior hippocampal activity for episodic future thoughts that were perceived as more likely to occur. Although a replication of this dissociation would be desirable, the pattern suggests that regions commonly recruited for episodic future and counterfactual thoughts may nonetheless be sensitive to differences in the nature of the specific episode being simulated (for further discussion, see De Brigard, Addis et al., 2013). However, much more work is required before it will be possible to offer confident theoretical interpretations of these differences.

#### Behavioral studies of episodic future thinking and episodic counterfactual thinking

Numerous recent behavioral studies have compared the cognitive properties of remembered past events and imagined future events (for reviews, see Klein, 2013; Schacter et al., 2008; Suddendorf & Corballis, 2007; Szpunar, 2010). These studies have revealed many similarities between the two, including such findings as parallel responses to experimental manipulations that increase the availability or vividness of episodic details (e.g., D'Argembeau & Van Der Linden, 2004; Madore, Gaesser, & Schacter, in press; Szpunar & McDermott, 2008) and reductions in the episodic specificity of remembered and imagined events in a variety of populations, including older adults (e.g., Addis, Wong, & Schacter, 2008; Gaesser, Sacchetti,

Addis, & Schacter, 2011), schizophrenics (e.g., D'Argembeau, Raffard, & Van der Linden, 2008), depressed individuals (e.g., Williams, Ellis, Tyers, Healy, Rose, & MacLeod, 1996), patients with post-traumatic stress disorder (e.g., Brown, Addis et al. 2013; Brown, Root, Romano, Chang, Bryant, & Hirst, 2013), and amnesic patients (e.g., Hassabis, Kumaran, Vann, & Maguire, 2007; Klein, Loftus, & Kihlstrom, 2002; Race, Keane, and Verfaellie, 2011; but see also Squire, van der Horst, McDuff, Franscino, Hopkins, & Mauldin, 2010). Analogous studies have not yet been reported with episodic counterfactual thinking, so it is still not possible to determine whether the correlated changes in episodic memory and episodic future thinking observed in the above populations extend to episodic counterfactual thinking.

Despite many similarities in the cognitive properties of episodic remembering and future thinking, differences have also been documented, and here relevant evidence does exist concerning episodic counterfactual thinking. Specifically, several studies have shown that remembered past events are subjectively experienced as more vivid and rich in sensory detail than are imagined future events (e.g., D'Argembeau & van der Linden, 2004) or imagined events in general (e.g., Johnson, Foley, Suengas, & Raye, 1988). Similarly, studies that have used objective methods for characterizing the amount of episodic detail that participants provide when remembering or imagining have documented greater levels of episodic detail in remembered past events than imagined future events (e.g., Addis et al., 2008). De Brigard and Giovanello (2012) recently compared both subjective properties and objective features of remembered events with episodic counterfactual simulations as well as episodic future simulations, and reported evidence that remembered events were experienced as clear and more detailed, and objectively contained more episodic details than did either counterfactual or future simulations. However, although in most respects the phenomenological characteristics of episodic future thinking and episodic

counterfactual thinking did not differ from one another, De Brigard and Giovanello (2012) found that participants reported experiencing a lower emotional intensity during episodic counterfactual thinking relative to both episodic past and future simulation regardless of the valence of the simulated event.

The foregoing results suggest that episodic counterfactual thinking and episodic future thinking share at least some phenomenological features. Another similarity concerns the consequences of imagining future events or constructing counterfactual simulations of past events for subsequent memory. It has been demonstrated that repeatedly imagining that one is going to perform an action can lead to false memories of actually having performed the action (e.g., Goff & Roediger, 1998). A recent study by Gerlach et al. (2013) indicates that constructing counterfactual simulations can also lead to subsequent memory distortion. For example, in one experiment younger and older adults selected and performed different actions. They then recalled performing some of those actions, counterfactually imagined that they had performed alternative actions to some of the selected/performed actions, and did not recall or imagine others. On a later memory test, participants were more likely to falsely remember counterfactual actions as previously performed relative to actions they had not previously considered performing, and the effect was especially pronounced in older adults.

In contrast to the foregoing similarities between episodic future thinking and counterfactual thinking, recent evidence also highlights sharp differences between the two. For instance, Ferrante, Giroto, Stragga, and Walsh (2013) had participants randomly assigned to one of two conditions: counterfactual and future. In both conditions, participants had to solve scramble-word puzzles. However, no participant was able to solve all the puzzles successfully and they were asked to think about their failures as they prepared to receive another set of

puzzles. Participants in the counterfactual condition were asked to reflect on their failures by thinking counterfactually about how things would have been better for them. Conversely, participants in the future condition were asked to reflect on their failures by thinking about how things will be better for them in the next trial. Ferrante et al. (2013) found that when participants thought counterfactually, their thoughts focused on uncontrollable features of the puzzle (e.g., “Things would have been better for me if the allocated time were longer”), whereas participants in the future condition thought about controllable features of the puzzle (e.g., “Things will be better for me if I concentrate more”). The authors interpret this asymmetry in temporal simulations as reflecting different constraints in the way each kind is deployed for strategizing about future actions. By their account, “the possibility to still realize a future outcome may constrain mental simulation of the future more than mental simulation of the past (Ferrante et al., 2013, p. 24). While this observation is broadly consistent with the idea we suggested earlier that episodic future thinking and episodic counterfactual thinking involve similar constructive processes that are differently constrained by reality, we noted that counterfactual thinking tends to be *more* constrained by reality than future thinking because it operates on representations of what actually happened rather than representations of what might happen. By contrast, Ferrante et al. (2013) focused on the idea that the controllability of hypothetical events may be more constrained in the future because the imagined hypothetical event might actually happen, whereas past hypothetical events cannot actually happen.

Intriguingly, future versus counterfactual simulations show opposite effects of repetition on the perceived plausibility or likelihood of the imagined episodes. A number of studies have shown that when people repeatedly imagine a future event, they come to believe that the event is more likely to occur. For example, Carroll (1978) showed that participants who imagined that

Jimmy Carter would win the 1976 presidential election were more likely to predict that Carter would win the election over Gerald Ford, whereas participants who imagined that Ford would win the election were more likely to predict a Ford victory. Subsequent studies extended this finding to other kinds of events, such as imagining winning a contest, contracting a disease, or performing an action such as donating blood: repeatedly imagining the target event was associated with an increase in the subjective likelihood that event would actually occur (e.g., Anderson, 1983; Gregory, Cialdini, & Carpenter, 1982; Sherman, Cialdini, Schwartzman, & Reynolds, 1985; for review, see Koehler, 1991).

More recently, Szpunar and Schacter (2013) examined the effects of repeated simulation on specific, everyday future experiences – interpersonal interactions comprised of people, locations, and objects. Participants generated a series of familiar people, locations, and objects in an initial experimental session, and in a subsequent session simulated imaginary future experiences for each person-location-object combination and generated a brief title for each event. One-third of the imagined future experiences were emotionally positive, one-third were emotionally negative, and one-third were neutral. In a final, third experimental session, participants imagined half of these events three times prior to a final trial in which they imagined these target events once more, and along with events that had not been simulated during that session. On the final trial, participants provided ratings concerning the subjective plausibility of the simulated events, as well as valence, ease, detail, and arousal. Szpunar and Schacter (2013) found that repeated simulation was associated with a significant increase in the subjective plausibility that the simulated experiences would actually occur. However, this increased plausibility was observed only for positive or negative emotional events and not for neutral events. Further, increases in plausibility for positive events were associated with increases in

arousal, and increases in plausibility for negative events were associated with increases in valence and ease of simulation (see Szpunar and Schacter, 2013, for discussion of possible cognitive mechanisms involved).

De Brigard, Szpunar, et al. (2013) adapted the experimental paradigm used by Szpunar and Schacter (2013) to investigate the effects of repetition on the plausibility of counterfactual simulations. In an initial session, participants generated a series of negative, positive, and neutral autobiographical memories, each consisting of a critical person, location, and object. In a second session, participants engaged in upward, downward, and neutral counterfactual simulations about individual memories. For upward counterfactuals, participants imagined an alternative better way in which a negative episode could have occurred; for downward counterfactuals, participants imagined an alternative worse way in which a positive episode could have occurred; and for neutral counterfactuals, participants imagined an alternative way in which a neutral episode could have occurred without altering the emotional value of the actual event.

In a third experimental session, participants re-simulated half of the upward, downward, and neutral counterfactuals three times each. Finally, they re-simulated all counterfactuals, and for each one, completed phenomenological ratings like those in the study by Szpunar and Schacter (2013) that assessed such features as detail, ease, and valence of the simulations and, most critically, their perceived plausibility. The key result from this experiment is that episodic counterfactual thoughts that were simulated repeatedly were rated as significantly *less* plausible than those that were simulated only once. The decrease in plausibility as a consequence of repetition occurred similarly for upward, downward, and neutral counterfactuals, thus indicating that the effect of repetition was independent of the direction in which simulated events were altered.

These results thus contrast sharply with those obtained for episodic future thinking, both in the study by Szpunar and Schacter (2013) and in earlier studies. Importantly, De Brigard, Szpunar, et al. (2013) also found that even though the perceived plausibility of episodic counterfactual thoughts decreased as a function of repeated simulation, both ratings of detail and ease *increased* with repetition, as observed in previous studies of future thinking (see Koehler, 1991, for review). Thus in addition to highlighting a potentially important difference between episodic future and counterfactual thinking, these results also indicate that an increase in the perceived plausibility of imagined events is not a direct or inevitable consequence of an increase in detail and ease of simulation.

De Brigard, Szpunar, et al. (2013) suggested a possible reason for the contrasting effects of repetition on episodic future and counterfactual thinking based on theories of counterfactual thinking (e.g., Byrne, 1997; Byrne, 2002; Johnson-Laird & Byrne, 2002). Such theories hold that when people generate counterfactual thoughts they contrast mental representations of what is “true” (in the case of episodic counterfactual thoughts, an autobiographical episodic recollection) with a distinct mental representation that minimally deviates from the “true” one. Thus, when people first generate a counterfactual simulation the divergence from an actual autobiographical memory is minimal, so the perceived plausibility of the altered event is relatively high. With repetition, however, more attention can be given to details of the altered event. Consequently, the divergence from the actual memory would increase as a result, thereby rendering the simulated event less plausible to the individual. The critical difference from episodic future thinking is that in the latter kind of simulation, there is no actual or “true” representation against which to contrast an imagined event. Thus there is no divergence between

a real and an imagined event that could influence the perceived plausibility of the imagined event.

### Implications for memory and decision making

The evidence we have considered so far reveals both neural and cognitive similarities between episodic future thinking and episodic counterfactual thinking, along with some differences. We conclude by considering some implications for thinking about the relation between memory and decisions.

The process of decision making is usually surrounded by uncertainty. To hedge this uncertainty, we tend to strategize either by envisioning possible scenarios that might occur as a result of a future choice, or by simulating alternative scenarios that might have occurred as a result of having chosen differently in the past (Kahneman & Tversky, 1982). Both strategies are highly dependent on episodic memory, and as such are also prone to memory-related biases (Morewedge, Gilbert and Wilson, 2005).

However, given the results reviewed earlier, indicating that in addition to commonalities there are a number of important differences between episodic future and episodic counterfactual simulation, it is an open question how these related simulation processes influence actions and behaviors. For instance, although the research considered earlier indicates that much has recently been learned about how repeated simulations of future and alternative past events influence the perceived plausibility of specific events, next to nothing is known about how repeated simulations influence subsequent behavior. If repeatedly simulated future events are perceived as more plausible than events that are not repeatedly simulated, then it is reasonable to hypothesize that people might be more likely to act on the contents of repeated as compared to non-repeated simulations of the future. Conversely, if repeated simulations of alternative past experiences are

subjectively experienced as less plausible, then it is reasonable to predict that people might be less likely to rely on the contents of repeated counterfactuals when making decisions. Instead, repeated counterfactuals may lead people to accept that the future will turn out like the past, and use that information to guide their behavior accordingly (e.g., Ersner-Hershfield, Galinsky, Kray, & King, 2010; Kray, George, Liljenquist, Galinsky, Tetlock, & Roese, 2010; for related discussion, see Hershfield, 2013). Alternatively, repeated counterfactuals may lead people to identify new and better courses of future action. Identifying direct links between simulation, perceived likelihood, and behavior represents an exciting avenue for future research.

Episodic simulations may have a particular impact on decisions that have long-term consequences, because they allow us to “prefeel” what it may be like to be in a specific future situation (Gilbert and Wilson, 2007), i.e., they can convey the emotional state of the anticipated episode. To the degree that this state is positive, it may motivate farsighted choices that would make it more likely to actually experience the simulated future event. This hypothesis was tested by Benoit, Gilbert, and Burgess (2011), who used the phenomenon of *temporal discounting* as a measure of shortsighted decision making. Temporal discounting refers to our tendency to devalue a reward with the delay until its delivery (e.g., Green and Myerson, 2004). For example, \$10 has a greater subjective value when it could be received immediately than when it would only be delivered after a week. This psychological property becomes important when people have to choose between options that would pay off after different delays: people tend to prefer smaller rewards that they can receive immediately (e.g., \$10 today) over larger rewards that they would only get later (e.g., \$13 in a week). A possible reason for our tendency to devalue delayed rewards is that, at the moment of the choice, we do not experience the emotional impact associated with the future reward option (e.g., Rick and Loewenstein, 2008).

Simulating the future episode enables us to bridge that gap between the moment of choosing and the moment of reward delivery, and thus allows for an immediate experience of the anticipated event's affective impact. The experienced emotional state may then increase the valuation of the imagined reward, and thus effectively attenuate its discounting (Boyer, 2008; see also Berns, Laibson, & Lowenstein, 2007). To test this hypothesis, Benoit et al. (2011) instructed participants to imagine specific episodes of spending money (e.g., £35 in 180 days at a pub), or to merely estimate what the money could purchase in the scenario. Thus, both conditions shared similar semantic retrieval demands, but only the imagine task required participants to simulate what it would be like to be in the respective episodes. Following each trial, participants indicated their preference for either the delayed reward option that they had just considered (e.g., £35 in 90 days), or for a smaller reward that they would receive immediately (i.e., £25 now). Consistent with the hypothesized mechanism, participants were more likely to choose the delayed reward option following episodic simulations (see also Peters and Büchel, 2010). Moreover, episodic simulations were particularly effective in biasing subsequent decisions in cases where they induced a strong emotional experience, suggesting that the phenomenological qualities of the simulation were instrumental in mediating this effect.

Intriguingly, those individuals who benefited the most from imagining future scenarios typically care relatively little about the future consequences of their actions. This latter trait has been shown to predict, among other things, the relationship between planning and actually quitting smoking (Kovač and Rise, 2007), and between beliefs regarding environmental consequences of commuting by car and preferences to take public transport (Joireman, Van Lange, & Van Vugt, 2004). A better understanding of the motivational consequences of episodic future simulations might thus help to optimize everyday decisions that have economic,

environmental, and public health-related consequences (e.g., Oluyomi Daniel, Stanton, & Epstein, in press).

Using fMRI, Benoit et al. (2011) implicated components of the core network in mediating this effect. Activation in rostromedial prefrontal cortex reflected the undiscounted reward magnitude of the imagined episode, and those individuals who exhibited greater reward sensitivity in this region also showed a stronger attenuating effect on discounting. The reduction in discounting was also associated with increased coupling between the rostromedial prefrontal cortex and hippocampus (see also Peters & Büchel, 2010). Therefore, the effect of episodic simulations on farsighted decisions appears to be mediated by interactions between the hippocampus, a region involved in mentally constructing future scenarios, and the rostromedial prefrontal cortex, a region involved in the representation of the imagined rewards.

Taken together, these data indicate that processes mediated by the core network can be utilized to imagine the future consequences of one's actions (e.g., having \$35 at one's next visit to the pub). The immediate experience of the anticipated future emotional state associated with that episode, in turn, can influence one's decisions. Given that similar constructive processes are likely employed in counterfactual thinking, the question arises whether considering alternative outcomes of past events could also influence one's future-oriented decisions.

A typical consequence of upward counterfactuals is the feeling of regret (Roese et al., 2009), and there is some intriguing evidence for the impact of regret on monetary decisions. Camille, Coricelli, Sallet, Pradat-Diehl, Duhamel, and Sirgiu (2004) asked participants to make repeated choices between two risky gambles, and assessed the emotional reactions to the outcome. Unsurprisingly, volunteers were happier when their choice resulted in a gain rather than a loss. However, their emotional experience was not only determined by the outcome of

their actual choice but also by a comparison with the outcome of the alternative, foregone option. That is, the same nominal win induced happiness when the rejected gamble would have led to a loss, but it actually could induce unhappiness when the alternative gamble would have led to a greater win. Thus, the comparison between what had been and what could have been triggered the emotion of regret. Camille et al. (2004) further modeled participants' choices and demonstrated that their decisions were not only influenced by the expected values of the two gambles but also by the avoidance of anticipated regret. Critically, this was not the case for a group of patients with lesions including the orbitofrontal cortex. They neither reported regret nor did their choices reveal the disposition to avoid regret. In the long-term, the healthy volunteers accumulated greater wins, indicating that –in the context of this task– the experience of regret and its subsequent avoidance biased decisions towards more farsighted choices. In a follow-up fMRI study, Coricelli, Critchley, Joffily, O'Doherty, Sirgiu, & Dolan (2005) associated greater regret with enhanced activation in regions including medial prefrontal cortex and the hippocampus, i.e., in core network structures similar to those reported by Benoit et al. (2011).

Though participants in the studies on regret may not have simulated elaborate counterfactual episodes, these data are consistent with the possibility that a mechanism may have supported the effect of regret on decisions that is akin to the one shown to effectively attenuate discounting via future simulations (Benoit et al., 2011). Both “prefeeling” a possible future scenario and reminiscing about foregone past choices could thus provide motivational incentives that foster more farsighted decisions.

However, this mechanism need not always enhance the probability of making choices that are beneficial in the long run. For example, often our simulations of the future are erroneous, because they do not take into account that the context of the actual event may be different from

the current context (Gilbert and Wilson, 2007). Moreover, simple fantasizing about a possible future episode by itself may not be sufficient to attain a strong goal commitment (Oettingen and Stephens, 2009). These and related pitfalls of episodic simulations of future events remind us that their impact on decision making may not always be beneficial (for review and discussion, see Schacter, 2012). Nonetheless, a growing body of research has revealed that episodic simulations can usefully support a variety of adaptive functions, including the aforementioned effects on farsighted decision making (Schacter, 2012). Thus, a critical task for future research will be to identify the efficacy and boundary conditions of episodic simulations in improving decisions. Given the critical role that memory plays in generating episodic simulations, such research should enhance our broader understanding of the relation between memory and decisions.

### Acknowledgments

Preparation of this article was supported by grants from the National Institute of Mental Health (MH060942) and National Institute on Aging (AG08441) to DLS. We thank Molly Evans for help with preparation of the manuscript.

## References

- Abraham, A., Schubotz, R.I., and von Cramon, D.Y. (2008). Thinking about the future versus the past in personal and non-personal contexts. *Brain Research*, *1233*, 106-119.
- Addis, D. R., Pan, L., Vu, M. A., Laiser, N., & Schacter, D. L. (2009). Constructive episodic simulation of the future and the past: Distinct subsystems of a core brain network mediate imagining and remembering. *Neuropsychologia*, *47*, 2222-2238.
- Addis, D.R. Roberts, R.P, & Schacter, D.L. (2011). Age-related neural changes in autobiographical remembering and imagining. *Neuropsychologia*, *49*, 3656-3669.
- Addis, D. R., & Schacter, D. L. (2012). The hippocampus and imagining the future: Where do we stand? *Frontiers in Human Neuroscience*, *5*, 173. doi: 10.3389/fnhum.2011.00173
- 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, C.A. (1983). Imagination and expectation: The effect of imagining behavioral scripts on personal intentions. *Journal of Personality and Social Psychology*, *45*, 293-305.
- Andrews-Hanna, J.R. (2012). The brain's default network and its adaptive role in internal mentation. *Neuroscientist*, *18*, 251-270.
- Andrews-Hanna, J.R, Reidler, J.S, Sepulcre, J, Poulin, R., & Buckner, R.L. (2010). Functional-anatomic fractionation of the brain's default network. *Neuron*, *65*, 550-602.
- Atance, C. M., and O'Neill, D. K. (2001). Episodic future thinking. *Trends in Cognitive Sciences*,

5, 533-539.

Benoit, R. G., Gilbert, S. J., & Burgess, P. W. (2011). A neural mechanism mediating the impact of episodic prospection on farsighted decisions. *Journal of Neuroscience*, *31*, 6771-6779.

Berns, G. S., Laibson, D., & Loewenstein, G. (2007). Intertemporal choice--toward an integrative framework. *Trends in Cognitive Sciences*, *11*, 482-488.

Botzung, A., Denkova, E., and Manning, L. (2008). Experiencing past and future events: Functional neuroimaging evidence on the neural bases of mental time travel. *Brain and Cognition*, *66*, 202-212.

Boyer, P. (2008). Evolutionary enomics of mental time travel? *Trends in Cognitive Sciences*, *12*, 219-224.

Brown, A.D., Root, J.C., Romano, T.A., Chang, L.J., Bryant, R.A., & Hirst, W. (2013). Overgeneralized autobiographical memory and future thinking in combat veterans with posttraumatic stress disorder. *Journal of Behavior Therapy and Experimental Psychiatry*, *44*, 129-134.

Brown, A.D., Addis, D.R., Romano, T.A., Marmar, C.R., Bryant, R.A., Hirst, W., et al. (2013). Episodic and semantic components of autobiographical memories and imagined future events in posttraumatic stress disorder. *Memory*.  
doi.org/10.1080/09658211.2013.807842

Buckner, R.L. (2010). The role of the hippocampus in prediction and imagination. *Annual Review of Psychology*, *61*, 27-48.

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network: Anatomy, function, and relevance to disease. *The Year in Cognitive Neuroscience, Annals of the New York Academy of Sciences*, *1124*, 1-38.

- Buckner, R.L. & Carroll, D. C. (2007). Self-projection and the brain. *Trends in Cognitive Sciences, 11*, 49-57.
- Byrne, R.M.J. (1997). Cognitive processes in counterfactual thinking about what might have been. *The Psychology of Learning and Motivation: Advances in Research and Theory, 37*, 105 - 154.
- Byrne, R.M.J. (2002). Mental models and counterfactual thoughts about what might have been. *Trends in cognitive sciences, 6*, 426 - 431
- Camille, N., Coricelli, G., Sallet, J., Pradat-Diehl, P., Duhamel, J. R., & Sirigu, A. (2004). The involvement of the orbitofrontal cortex in the experience of regret. *Science, 304*, 1167-1170.
- Carroll, J. S. (1978). The effect of imagining an event on expectations for the event: An interpretation in terms of the availability heuristic. *Journal of Experimental Social Psychology, 14*, 88-96.
- Coricelli, G., Critchley, H. D., Joffily, M., O'Doherty, J. P., Sirigu, A., & Dolan, R. J. (2005). Regret and its avoidance: a neuroimaging study of choice behavior. *Nature Neuroscience, 8*, 1255-1262.
- 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., and 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.
- De Brigard, F., & Giovanello, K. S. (2012). Influence of outcome valence in the subjective experience of episodic past, future and counterfactual thinking. *Consciousness and*

*Cognition*, 21, 1085–1096.

De Brigard, F., Addis, D.R., Ford, J.H., Schacter, D.L., & Giovanello, K.S. (2013).

Remembering what could have happened: Neural correlates of episodic counterfactual thinking. *Neuropsychologia*. doi: 10.1016/j.neuropsychologia.2013.01.015

De Brigard, F., Szpunar, K.K., & Schacter, D.L. (2013). Coming to grips with the past: Effects of repeated simulation on the perceived plausibility of episodic counterfactual thoughts. *Psychological Science*, 24, 1329-1334.

Ersner-Hershfield, H., Galinsky, A., Kray, L., & King, B. (2010). Country, company, connections: Counterfactual origins increase patriotism, organizational commitment, and social investment. *Psychological Science*, 21, 1479-1486.

Ferrante, D., Giroto, V., Straga, M., & Walsh, C. (2013). Improving the past and the future: A temporal asymmetry in hypothetical thinking. *Journal of Experimental Psychology: General*, 142, 23-27.

Gaesser, B., Sacchetti, D. C., Addis, D. R., & Schacter, D. L. (2011). Characterizing age-related changes in remembering the past and imagining the future. *Psychology and Aging*, 26, 80-84.

Gaesser, B., Spreng, R.N., McLelland, V.C., Addis, D.R., & Schacter, D.L. (2013). Imagining the future: Evidence for a hippocampal contribution to constructive processing. *Hippocampus*. doi/10.1002/hipo.22152/pdf

Gerlach, K.D., Dornblaser, D.W., & Schacter, D.L. (2013). Adaptive constructive processes and memory accuracy: Consequences of counterfactual simulations in young and older adults. *Memory*. doi:10.1080/09658211.2013.779381

Gilbert, D. T., & Wilson, T. (2007). Prospection: Experiencing the future. *Science*, *317*, 1351-1354.

Giroto, V., Ferrante, D., Pighin, S., & Gonzalez, M. (2007). Postdecisional counterfactual thinking by actors and readers. *Psychological Science*, *18*, 510-515.

Goff, L.M., and Roediger, H.L. (1998). Imagination inflation for action events: Repeated imaginings lead to illusory recollections. *Memory & Cognition*, *26*, 20-33.

Green, L. & Myerson, J. (2004). A discounting framework for choice with delayed and probabilistic rewards. *Psychological Bulletin*, *130*, 769-792.

Gregory, W.L., Cialdini, R.B., & Carpenter, K.M. (1982). Self-relevant scenarios as mediators of likelihood estimates and compliance: Does imagining make it so? *Journal of Personality and Social Psychology*, *43*, 89-99.

Grill-Spector, K., Henson, R., & Martin, A. (2006). Repetition and the brain: neural models of stimulus-specific effects. *Trends in Cognitive Sciences*, *10*, 14-23.

Hassabis, D., Kumaran, D., & Maguire, E. A. (2007). Using imagination to understand the neural basis of episodic memory. *Journal of Neuroscience*, *27*, 14365-14374.

Hassabis, D., Kumaran, D., Vann, D. S., and Maguire, E. A. (2007). Patients with hippocampal amnesia cannot imagine new experiences. *Proceedings of the National Academy of Sciences USA*, *104*, 1726-1731.

Hassabis, D., and Maguire, E.A. (2009). The construction system of the brain. *Philosophical Transactions of the Royal Society (B)*, *364*, 1263-1271.

Hassabis, D., Spreng, R.N., Rusu, A.A., Robbins, C.A., Mar, R.A., & Schacter, D.L. (2013). Imagine all the people: How the brain creates and uses personality models to predict behavior. *Cerebral Cortex*. doi: 10.1093/cercor/bht042

Hershfield, H.E. (2013). What might have been and what could be. *Psychology Today*.

<http://www.psychologytoday.com/blog/the-edge-choice/201306/what-might-have-been-and-what-could-be>

Johnson, M. K., Foley, M. A., Suengas, A. G., & Raye, C. L. (1988). Phenomenal characteristics of memories for perceived and imagined autobiographical events. *Journal of Experimental Psychology: General*, *117*, 371-376.

Johnson-Laird, P.N. & Byrne, R.M.J. (2002) Conditionals: A theory of meaning, pragmatics and inference. *Psychological Review*, *109*, 646 - 678.

Joireman, J. A., Van Lange, P. A. M., Van Vugt, M. (2004). Who cares about the environmental impact of cars?: Those with an eye toward the future. *Environment and Behavior*, *36*, 187–206

Kahneman, D. & Tversky, A. (1982). The simulation heuristic. In Kahneman, D., Slovic, P., & Tversky, A. (Eds.). *Judgment under uncertainty: Heuristics and biases* (pp. 201-211). Cambridge: Cambridge University Press.

Klein, S. B. (2013). The complex act of projecting oneself into the future. *Wiley Interdisciplinary Reviews - Cognitive Science*, *4*, 63-79.

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.

Koehler, D.J. (1991). Explanation, imagination, and confidence in judgment. *Psychological Bulletin*, *110*, 499-519.

- Kovac, V. B. & Rise, J. (2007). The relation between past behavior, intention, planning, and quitting smoking: the moderating effect of future orientation. *Journal of Applied Biobehavioral Research, 12*, 82–100.
- Kray, L.J., George, L.J., Liljenquist, K.A., Galinsky, A.D., Tetlock, P.E., & Roese, N.J. (2010). From what might have been to what must have been: Counterfactual thinking creates meaning. *Journal of Personality and Social Psychology, 98*, 106-118.
- Koehler, D.J. (1991). Explanation, imagination, and confidence in judgment. *Psychological Bulletin, 110*, 499-519.
- Mandel, D., Hilton, D., & Catellani, P. (2005). *The psychology of counterfactual thinking*. London: Routledge.
- Madore, K.P. Gaesser, B., & Schacter, D.L. (in press). Constructive episodic simulation: Dissociable effects of a specificity induction on remembering, imagining, and describing in young and older adults. *Journal of Experimental Psychology: Learning, Memory, & Cognition*.
- Martin, V. C., Schacter, D. L., Corballis, M. C., & Addis, D. R. (2011). A role for the hippocampus in encoding simulations of future events. *Proceedings of the National Academy of Sciences of the United States of America, 108*, 13858-13863.
- Morewedge, C. K., Gilbert, D. T. & Wilson, T. D. (2005). The least likely of times: How remembering the past biases forecasts of the future. *Psychological Science, 16*, 626-630.
- Oettingen, G., & Stephens, E. J. (2009). Fantasies and motivationally intelligent goal setting. In G. B. Moskowitz & H. Grant (Eds.), *The psychology of goals* (pp. 153-178). New York: Guilford Press.

- Okuda, J., Fujii, T., Ohtake, H., Tsukiura, T., Tanji, K., Suzuki, K., et al. (2003). Thinking of the future and the past: The roles of the frontal pole and the medial temporal lobes. *NeuroImage*, *19*, 1369-1380.
- Oluyomi Daniel, T., Stanton, C.M., & Epstein, L.H. (in press). The future is now: Reducing impulsivity and energy intake using episodic future thinking. *Psychological Science*, doi:10.1177/0956797613488780
- Perry, D., Hendler, T., & Shamay-Tsoory, S.G. (2011). Projecting memories: The role of the hippocampus in emotional mentalizing. *NeuroImage*, *54*, 1669-1676.
- Peters, J., & Büchel, C. (2010). Episodic future thinking reduces reward delay discounting through an enhancement of prefrontal-mediotemporal interactions. *Neuron*, *66*, 138-148.
- Pighin, S., Byrne, R.M.J., Ferrante, D., Gonzalez, M. & Giroto, V. (2011). Counterfactual thoughts about experienced, observed, and narrated events. *Thinking and Reasoning*, *17*(2): 197-211.
- Race, E., Keane, M.M., and Verfaellie, M. (2011). Medial temporal lobe damage causes deficits in episodic memory and episodic future thinking not attributable to deficits in narrative construction. *Journal of Neuroscience*, *31*, 10262-10269.
- Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America*, *16*, 676-682.
- Rick, S. Loewenstein, G. (2008). Intangibility in intertemporal choice. *Philosophical Transactions of the Royal Society of London B*, *363*, 3813-3824.

- Roese, N. J., Epstude, K., Fessel, F., Morrison, M., Smallman, R., Summerville, A., et al. (2009). Repetitive regret, depression, and anxiety: Findings from a nationally representative survey. *Journal of Social and Clinical Psychology, 28*, 671-688.
- Roese, N.J., & Olson, J.M. (1995). *What might have been. The social psychology of counterfactual thinking*. N.J.: Lawrence Erlbaum.
- Schacter, D.L. (2012). Adaptive constructive processes and the future of memory. *American Psychologist, 67*, 603-613.
- 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. (2009). On the nature of medial temporal lobe contributions to the constructive simulation of future events. *Philosophical Transactions of the Royal Society B, 364*, 1245-1253.
- 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. *The Year in Cognitive Neuroscience, Annals of the New York Academy of Sciences, 1124*, 39-60.
- Schacter, D.K., Addis, D.R., Hassabis, D., Martin, V.C., Spreng, R.N., & Szpunar, K.K. (2012). The future of memory: Remembering, imagining, and the brain. *Neuron, 76*, 677-694.
- Schacter, D.L., Wig, G.S., & Stevens, W.D. (2007). Reductions in cortical activity during priming. *Current Opinion in Neurobiology, 17*, 171-176.
- Sherman, S.J., Cialdini, R.B., Schwartzman, D.F., & Reynolds, K.D. (1985).

- Imagining can heighten or lower the perceived likelihood of contracting a disease: The mediating effect of ease of imagery. *Personality and Social Psychology Bulletin*, *11*, 118-127.
- Squire, L. R., van der Horst, A. S., McDuff, S. G. R., Frascino, J. C., Hopkinse, R. O., & Mauldin, K. N. (2010). Role of the hippocampus in remembering the past and imagining the future. *Proceedings of the National Academy of Sciences of the United States of America*, *107*, 19044-19048.
- Suddendorf, T., & Corballis, M. C. (2007). The evolution of foresight: What is mental time travel and is it unique to humans? *Behavioral and Brain Sciences*, *30*, 299-313.
- Szpunar, K. K. (2010). Episodic future thought: An emerging concept. *Perspectives on Psychological Science*, *5*, 142-162.
- Szpunar, K.K. & McDermott (2008). Episodic future thought and its relation to remembering: Evidence from ratings of subjective experience. *Consciousness and Cognition*, *17*, 330-334.
- Szpunar, K. K., & Schacter, D. L. (2013). Get real: Effects of repeated simulation and emotion on the perceived plausibility of future interpersonal experiences. *Journal of Experimental Psychology: General*, *142*, 323-327.
- Szpunar, K.K., St. Jacques, P.L., Robbins, C.A., Wig, G.S., & Schacter, D.L. (2013). Repetition-related reductions in neural activity reveal component processes of mental simulation. *Social, Cognitive, and Affective Neuroscience*. doi: 10.1093/scan/nst035
- Szpunar, K. K., Watson, J. M., & McDermott, K. B. (2007). Neural substrates of envisioning the future. *Proceedings of the National Academy of Sciences of the United States of America*, *104*, 642-647.

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

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology*, 53, 1-25.

Van Hoeck, N., Ma, N., Ampe, L., Baetens, K., Vandekerckhove, M., Van Overwalle, F.

(2013). Counterfactual thinking: An fMRI study on changing the past for a better future. *Social Cognitive and Affective Neuroscience*. doi:10.1093/scan/nss031

Weiler, J.A., Suchan, B., and Daum, I. (2010). Foreseeing the future: Occurrence probability of imagined future events modulates hippocampal activation. *Hippocampus* 20, 685-690.

Williams, J.M., Ellis, N.C., Tyers, C., Healy, H., Rose, G., & MacLeod, A.K. (1996). The specificity of autobiographical memory and imageability of the future. *Memory & Cognition*, 24, 116–12.

Table 1

## Definitions of Key Concepts

Concept	Definition
Episodic future thinking	Imagining or simulating a specific episode that might occur in one's personal future
Episodic counterfactual thinking	Imagining or simulating alternative versions or outcomes of past personal episodes that could have happened but did not occur
Counterfactual thinking	Imagining alternatives to reality that need not involve future or past personal episodes
Downward counterfactual	Imagining that an event had a more negative outcome than it actually did
Upward counterfactual	Imagining that an event had a more positive outcome than it actually did
Episodic memory	Memory for specific past personal experiences
Semantic memory	Memory for facts and general knowledge
Autobiographical memory	Memory for past personal experiences that can include both episodic and semantic knowledge