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Episodic Future Thinking: Mechanisms and Functions

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Abstract

Episodic future thinking refers to the capacity to imagine or simulate experiences that might occur in one's personal future. Cognitive, neuropsychological, and neuroimaging research concerning episodic future thinking has accelerated during recent years. This article discusses research that has delineated cognitive and neural *mechanisms* that support episodic future thinking as well as the *functions* that episodic future thinking serves. Studies focused on mechanisms have identified a core brain network that underlies episodic future thinking and have begun to tease apart the relative contributions of particular regions in this network, and the specific cognitive processes that they support. Studies concerned with functions have identified several domains in which episodic future thinking produces performance benefits, including decision making, emotion regulation, prospective memory, and spatial navigation.

Introduction

During the past decade, one of the most rapidly growing areas of research in cognitive neuroscience and psychology has focused on *episodic future thinking*: the capacity to imagine or simulate events that might occur in one's personal future (cf., 1–3). This surge of research has been fueled in part by experimental demonstrations of striking cognitive and neural similarities when people are asked to imagine future experiences and remember past experiences (for detailed review, see 4). Here we review recent studies of episodic future thinking in human adults that have yielded new insights into the *mechanisms* that support episodic future thinking and the *functions* that it serves (for recent research on episodic future thinking in children and non-human primates, see 5–7).

Episodic future thinking is just one of several forms of future thinking or *prospection* (8). A recently proposed taxonomy (9) distinguishes among four basic forms of future thinking:

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simulation (construction of a specific mental representation of the future), *prediction* (estimation of the likelihood of a future outcome), *intention* (setting of a goal), and *planning* (organization of steps for achieving a goal). Each form of future thinking is proposed to vary according to its representational contents on a gradient from *episodic* (specific autobiographical experiences that may happen in the future, such as a meeting with a friend that will take place next week) to *semantic* (more general or abstract states of the world that may occur in the future, such as the political landscape of the United States after an upcoming election). In the context of this taxonomy, episodic future thinking could potentially refer to episodic simulation, prediction, intention, or planning. In practice, however, studies of episodic future thinking almost always focus on episodic simulation; indeed, the terms episodic future thinking and episodic simulation are frequently used interchangeably (cf., 2–3), and we will follow that practice here.

Mechanisms of episodic future thinking

We first discuss recent research on cognitive mechanisms of episodic future thinking and then turn to research on neural mechanisms.

Cognitive mechanisms

It has been proposed that episodic future thinking depends critically on the episodic memory system, which is thought to underlie an individual's ability to recollect past personal experiences (10). One formulation of this view, referred to as the *constructive episodic simulation hypothesis* (11), holds that episodic memory supports future simulation by allowing people to flexibly retrieve and recombine elements of past experiences into novel representations of events that might occur in the future. Moreover, this view holds that flexible retrieval and recombination abilities, though adaptive for purposes of constructing episodic simulations, also may create memory errors that can result from mistakenly combining elements of distinct past experiences, such as source misattribution and false recognition. Consistent with this idea, recent experimental evidence points toward similar constructive mechanisms operating during episodic memory and future thought (12), and directly links flexible retrieval/recombination processes with source memory errors that result from mixing up elements of related episodes (13; see also, 14).

Some of the key cognitive evidence supporting a role for episodic memory in future imagining comes from studies using the Autobiographical Interview (AI; 15). In this procedure, individuals recall past and imagine future personal experiences. The details that they produce are then categorized as either *internal* (episodic details such as what happened, where it happened, and so forth) or *external* (facts/semantic details, commentary). For example, studies that have used the AI to compare healthy older adults with young adults consistently show that older adults produce fewer internal/episodic details and more external/semantic details for both remembered past events and imagined future events, suggesting a common role of episodic memory in both event types (for review of early studies, see 16, and for recent and related evidence, see 5, 17–21). Reductions in episodic detail for both past and future events using the AI and related procedures have also been documented in various patient populations, including in recent studies of patients with depression (22), post-traumatic stress disorder (23), amnesic syndrome (24–27; but see 28 for relatively preserved future imagining in amnesics), Alzheimer's disease (29–30), unilateral temporal lobe epilepsy (31), schizophrenia (32), prefrontal lesions (33), and long-term opiate users (34).

While these and other findings point toward a role for episodic memory in future imagining, procedures such as the AI can be influenced by non-episodic factors. For example, in one study (35) that used pictures of everyday scenes as cues, young and old participants either recalled a past experience or imagined a future experience related to the picture (tasks that are thought to tap episodic memory), or simply described the picture (a task that should not involve episodic memory). Older adults produced fewer internal but not external details on the memory and imagination tasks, replicating earlier results, but they also showed the same pattern on the picture description task. Although this study also revealed effects of aging on memory and imagination above-and-beyond picture description performance, such findings nonetheless suggest that non-episodic factors that similarly impact remembering, imagining, and describing, such as narrative style or cognitive control, are at least partly responsible for similarities between remembering past experiences and imagining future experiences on tasks such as the AI (for discussion, see 16, 35). Other evidence similarly points toward picture description deficits in amnesic patients (27; but see 36 for contrasting results) and indicates that age effects on episodic future thinking are related to changes in more general cognitive functions (5).

In light of these considerations, a critical issue for theoretical interpretation is to identify episodic influences on task performance and to distinguish them from non-episodic influences. One recently developed approach to accomplishing this objective is via the use of an *episodic specificity induction* (ESI): brief training in recollecting details of past experiences (37–38). As discussed in Box 1, several experiments have shown that the ESI selectively dissociates the contributions of episodic retrieval to future imagining from such non-episodic factors as semantic retrieval and narrative style.

Box 1

Episodic specificity induction: Selective effects on remembering and imagining

The approach known as *episodic specificity induction* (ESI; 37) involves administering a detailed interview that encourages people to focus on retrieving specific episodic details of a past experience (i.e., people, objects, and actions in a recently viewed videotape of an everyday event). According to the logic of the ESI approach, if a cognitive task relies at least in part on episodic retrieval, then performance on that task should be affected by an ESI administered just prior to the task (compared with a control induction). By contrast, if performance on a cognitive task does not rely on episodic retrieval, then task performance should not be influenced by a prior ESI. In an initial study using ESI (37), young and old participants viewed a videotape of people performing routine actions in a kitchen and received either an ESI or a control induction (providing their general impressions of the video). After each induction, participants received picture cues and either remembered a related past experience, imagined a related future experience, or described the picture (as in 35). Protocols were scored for internal and external details using the AI.

As shown in Figure 1, an ESI boosted subsequent production of internal details on the memory and imagination tasks, but had no effect on internal details in the picture description task and had no effect on the production of external details on any of the three tasks (effects of induction are collapsed across young and old participants because they were nearly identical for the two groups). Thus, ESI dissociated performance on the two tasks thought to draw on episodic retrieval (memory and imagination) from the non-episodic task (picture description), and also dissociated retrieval of episodic details from retrieval of semantic details during memory and imagination. These results were replicated in a subsequent experiment using different cues and procedures (97), and effects of ESI have also been extended to other tasks that draw on episodic retrieval and simulation, including social problem solving and divergent creative thinking (for discussion, see 38).

The foregoing observations indicate a distinct role for episodic retrieval in imagining future experiences, and various suggestions have been advanced concerning the precise nature of episodic mechanisms that support future thinking (cf., 4, 10, 38–39). Nonetheless, it seems clear that episodic future thinking is not simply a direct expression of episodic memory (39). In addition to the evidence for an impact of non-episodic factors considered earlier, other studies indicate that patients with semantic dementia, who typically exhibit severe problems with semantic memory despite relatively preserved episodic memory, exhibit marked impairments when imagining future experiences along with an intact ability to remember past experiences (30). These findings have led to the *semantic scaffolding hypothesis*, which holds that semantic memory provides a framework that guides future thinking, including episodic future thinking (for discussion, see 30).

A related role for higher-order (e.g., semantic and organizational) mechanisms is indicated by studies that have distinguished components of episodic future thinking. When constructing a future episode people typically access general personal knowledge before generating episodic details (40), organize episodic future thoughts into event clusters that reflect the influence of higher-order schematic, conceptual, and affective knowledge (41–42), and indicate a stronger subjective sense of “pre-experiencing” for future events that are associated with personal goals than for those that are not (43). Thus the construction of episodic details and integration of those details with higher-order autobiographical knowledge may represent distinct components of episodic future thinking (43).

Neural mechanisms

An important observation linking episodic future thinking with memory comes from neuroimaging studies indicating that a common *core network* of brain regions show increased activity when people remember past experiences and imagine future experiences (e.g., 44). This core network, comprising regions in the medial temporal lobe (MTL), the posterior cingulate including retrosplenial cortex, medial prefrontal cortex, and lateral temporal and parietal regions largely corresponds to the well-known default network (45).

Recent meta-analyses have confirmed that the core/default network is engaged during episodic simulation (46) and further that it is jointly engaged during episodic simulation and episodic memory (47).

In addition, the latter meta-analysis also revealed that core network regions including left posterior inferior parietal lobe and posterior dorsolateral prefrontal cortex show increased activity during episodic simulation compared with episodic memory, as do several regions that are part of a distinct fronto-parietal control network (47). Related evidence reveals differences in functional connectivity among regions within the default network during episodic remembering and future imagining (48) and indicates that some default network regions (i.e., parahippocampal and retrosplenial cortices) show increased activity during episodic remembering relative to future imagining, likely reflecting enhanced contextual processing for the former compared with the latter (49).

A critical task for research focused on neural mechanisms is to characterize the contributions of specific brain regions to episodic future thinking. Although this issue was addressed in several early studies of episodic future thinking (for review, see 4), novel approaches have appeared during the past few years (42, 50, 51). One involves adapting the widely used fMRI *repetition suppression* paradigm (52), where repetition-related reductions in neural activity are taken as indications that specific brain regions are involved in the processing of particular types of stimuli, by varying the content and frequency of future event simulation. In two experiments (53), participants simulated future events involving interactions with familiar *people* (social scenarios) or *objects* (non-social scenarios) in personally familiar *locations*. The frequency with which the participants simulated particular people, objects, and locations was manipulated, and reduced fMRI signal in a specific region as consequence of repeating a particular element was taken as evidence for the involvement of that region in processing the repeated element. Results revealed that distinct regions contribute to simulation of people (medial prefrontal cortex), interactions with objects (inferior frontal and premotor cortices) and locations (posterior cingulate/retrosplenial, parahippocampal and lateral parietal cortices). Moreover, simulated social scenarios (i.e., location-specific interactions with people) were linked with medial prefrontal, posterior cingulate, temporal–parietal and middle temporal cortices. The hippocampus, however, was responsive to entirely novel events for which all elements (i.e., person, place, and scenario) had not been previously simulated, pointing toward a link between hippocampal activity and event novelty, a finding that was also reported in an independent fMRI study of repeated event simulations (54). The repetition suppression technique has also been used to identify brain regions that contribute to emotional future simulations, with initial results linking the pulvinar nucleus of the thalamus to simulations of negative future events and the orbitofrontal cortex to positive events (55).

The ESI procedure described earlier in behavioral experiments was recently applied to the analysis of neural mechanisms in an fMRI study in which participants were scanned as they imagined possible future experiences following either an ESI or a control induction (56). Participants exhibited significantly more activity in several core network regions during the construction of imagined events after the ESI than control induction. These regions included the left anterior hippocampus, right inferior parietal lobule, right posterior cingulate cortex, and right ventral precuneus. Further, a parametric modulation analysis indicated that induction-related differences in the episodic detail of imagined events were related to induction-related differences in the engagement of left anterior hippocampus and right inferior parietal lobule during the construction of imagined events. Resting-state functional connectivity analyses seeded in these two regions further revealed stronger coupling with core network regions following ESI compared with the control induction.

These findings point toward a link between hippocampal activity and the construction of specific and detailed imaginary future episodes, which strengthen previous observations along similar lines (57–60). Other fMRI studies have linked hippocampal activity during imagining to the process of scene construction (61–62), encoding of episodic simulations into long-term memory (63), and detail recombination (64). Mapping these subtly different cognitive constructs onto task manipulations can pose challenges. For example, Addis et al. (57) manipulated whether participants imagined specific events (e.g., proposing marriage) or general/routine events (e.g., commuting to a job), and documented increased hippocampal activity in the former condition compared with the latter. More recently, Palombo et al. (61) used a nearly identical manipulation that they characterized as high vs. low scene construction, and reported extremely similar hippocampal results to those of Addis et al. (57). Although they did not cite the Addis et al. paper, Palombo et al. nonetheless acknowledged that it is unclear whether their findings are a consequence of imagining specific vs. general events or high vs. low scene construction demands (for further discussion, see 65). An important task for future research is to try to disentangle these and other closely related cognitive constructs (see also 4, 34, 50).

Complimentary studies of neuropsychological patients have reported that some amnesic patients with hippocampal damage also exhibit deficits when imagining future experiences (25–26), but not all studies reveal such deficits (28). Thus questions concerning the precise role of the hippocampus in episodic future thinking continue to be debated, with the evidence suggesting that different subregions of the hippocampus make distinct contributions to particular subprocesses that comprise episodic future thinking and related phenomena (59–60, 62).

Finally, neuroimaging and patient studies have also begun to delineate the role of another key core network region in episodic future thinking, the ventromedial prefrontal cortex (vmPFC). These studies suggest that the vmPFC contributes to both accessing schematic knowledge used in episodic simulations as well signaling their affective value (see Box 2).

Box 2

Contributions of the vmPFC to episodic simulation

The vmPFC is part of the core network involved in episodic simulation (47), yet relatively little is known about the exact processes supported by this region. The vmPFC has been implicated in various different functions, including memory but also the representation of value and affect (98). Recent evidence suggests that during episodic simulation, vmPFC may support the intersection of those functions. Activation in rostral and ventral mPFC signals the emergent affective value of an imagined episode, and this value signal is difficult to account for by the nominal values of the individual elements that make up the episode (e.g., its location and present people or objects; 99–100). By signaling the anticipated value of an event, the vmPFC can mediate farsighted decisions (68–69).

Importantly, the contribution of the vmPFC is insufficiently characterized as valuating imagined scenarios because it also plays a role in constructing such scenarios. Lesions to this region can reduce the episodic detail and coherence of imagined events (101–102). This impairment seems to be particularly pronounced when patients have to imagine a broad scenario (e.g., hosting a dinner), because such patients have been shown to perform within the normal range of healthy controls when they are instructed to focus on a circumscribed moment within such a scenario (e.g., cutting vegetables; 25). However, there were also other important differences between the aforementioned studies, such as center of lesion overlap, etiology, and amnesic status of the patients. Nonetheless, the pattern suggests that the vmPFC supports access to schemata or conceptual knowledge of the respective scenarios that then foster the ability to construct specific episodes (101; see also 103). Consistent with this interpretation, fMRI data indicate that the vmPFC particularly supports simulations that can draw on rich knowledge (99) and that a more dorsal part of the mPFC is similarly more strongly engaged during simulations of episodes that are part of the same event cluster (42).

Taken together, the evidence suggests that the contribution of the vmPFC to episodic simulation may be twofold: accessing schematic knowledge and processing anticipated affect. Further research is needed to examine interactions between the two.

Functions of episodic future thinking

Evidence from thought sampling procedures indicates that episodic future thoughts occur frequently in everyday life and tend to be positively biased (66). Early laboratory and clinical studies provided initial evidence that they serve a range of functions, including decision making, emotion regulation, intention formation, and planning (67), and recent work has both strengthened and broadened this evidence.

An impact of episodic future thinking on decision making has been clearly revealed in studies on inter-temporal choice, where people make decisions regarding two reward options that differ in magnitude and delay until delivery, such as a smaller but more proximal vs. a larger but more distal reward. Typically, future rewards are devalued in relation to the extent of delay (i.e., temporally discounted), often leading to shortsighted choices of the smaller reward option. However, when people simulate consuming the larger reward, they become more patient and shift to favoring this more farsighted choice (68–70). Such effects have been extended to the domain of eating behavior, where engaging in episodic future thinking reduces calorie intake in both female undergraduates (71) and in overweight or obese women (72–73), thus biasing dietary decisions away from immediate food rewards and toward fulfilling longer-term health goals related to weight loss (72). Analogous effects have been observed on consumption of hypothetical alcoholic drinks in individuals with alcohol dependency problems (74) and on cigarette consumption in smokers (75). Recent studies have shown that such effects of episodic future thinking are more pronounced when the simulated event is related to the respective decision (e.g., imagining the future moment of buying a computer when making monetary choices or of an upcoming meal when being tempted by readily available snacks; 70–71). The observation that the impact of episodic future thinking is contingent on the content of the imagined event indicates that it does not merely reflect a generic change in future orientation.

Initial fMRI evidence pointed toward a role for the hippocampus in mediating effects of simulation on temporal discounting (68–69; 76). These observations have been supported by some evidence from patients with hippocampal damage (77) or atrophy following Alzheimer's disease (76) showing that temporal discounting is not attenuated by situations requiring episodic future thinking in these populations (see also [78] for similar findings in healthy older adults). However, another study of amnesic patients (79) provided seemingly contradictory results, i.e., patients showed attentuation of temporal discounting in a situation also thought to induce episodic future thinking. This outcome may have occurred because in the latter study (79), amnesics could have benefited from mere semantic (rather than episodic) future thinking (see also 80). Consistent with this interpretation, recent fMRI evidence indicates that the role of the hippocampus may be less pronounced when people imagine familiar personal scenarios, i.e., in cases where they can draw on prior semantic knowledge (81).

Episodic future thinking has also been linked to emotional regulation, partly on the basis of evidence of reduced specificity and vividness of episodic future thinking in anxious individuals with emotion regulation problems (82–84). Recent evidence indicates that administering the ESI procedure described earlier just before individuals simulate possible solutions to personally worrisome future events has beneficial effects on emotion regulation: following ESI versus a control induction, participants generated more constructive steps to address a future worrisome event, were better able to reappraise the event, and showed improvements on several measures of subjective well-being (85). However, other evidence indicates that it can also be beneficial to instead s*uppress* simulations of events that people fear may happen in their life (86): such suppression caused forgetting of details typically associated with the dreaded events, hindered the ability to subsequently imagine the events and, critically, also reduced apprehensiveness. People that were particularly efficient at down-regulating their fears of the future by suppression were also less trait-anxious, suggesting that suppression constitutes a natural coping mechanism. It will be important for future work to identify the relative benefits of simulation versus suppression. Related work shows that vivid and detailed episodic simulations of helping behaviors can facilitate empathy or prosocial intentions toward individuals in need (87–88).

Several studies have shown that episodic future thinking can boost prospective memory, i.e., the ability to remember carrying out a designated intention (e.g., action) at a future time. Simulating performing an upcoming intention makes it more likely that this intention will actually be carried out (89–91). These beneficial effects were of similar magnitude in older and younger adults despite the existence of episodic future thinking deficits in older adults (89), but were reduced in heavy social drinkers, who also show episodic simulation deficits (91). Overall these findings both highlight a functional benefit of episodic future thinking for prospective memory and also suggest a link between the two forms of prospection, which is further supported by a study that revealed significant positive correlations between episodic future thinking and prospective memory abilities in both young and old adults (19).

Finally, cognitive evidence points toward a role for episodic future thinking in shaping an individual's sense of self and identity (92–93), both cognitive and neuroimaging evidence indicate a connection between episodic future thinking and divergent creative thinking (94–95), and studies of spatial navigation show that episodic simulation makes an important functional contribution to planning routes and achieving navigational goals (see Box 3).

Box 3

Episodic future thinking and simulation in navigational planning

A possible role for hippocampal-dependent episodic future thinking in route planning has been suggested by experiments with rats revealing the involvement of hippocampal place cells in representing future locations during spatial navigation (for a recent example, see 104). These findings have been extended to humans by using fMRI to scan participants while they perform a virtual navigation task: multi-voxel pattern analysis revealed that hippocampal activity patterns were linked to prospective navigational goals as participants planned their routes, and that the strength of these goal-related representations was associated with goal-related activity in other core network regions (105). Related work has shown, intriguingly, that imagined spatial navigation is accompanied by fMRI signals in entorhinal cortex that display features characteristic of grid cells (106).

Evidence for a functional/adaptive role of navigation-related episodic simulations comes from behavioral experiments in which participants first became familiar with a virtual environment by taking a virtual walk through it streets, and after this encoding phase, simulated which route they would take prior to engaging in a goal-directed navigation task (107). An initial experiment showed that simulation times were positively correlated with navigation times. Importantly, participants mentally simulated a route at a much faster rate (2.39 times) than their time to actually navigate the route, that is, their episodic simulations exhibited temporal compression. A second experiment tested the hypothesis that such temporal compression reflects an adaptive feature of episodic simulations by varying the speed at which the spatial environment was initially encoded prior to simulation. If episodic simulations are adaptive, then they should be particularly compressed following slower initial encoding of a route, because such compression would allow people to simulate navigation of an upcoming route more quickly than if they were rigidly tied to the slow initial encoding time. Consistent with this hypothesis, there was a higher compression rate after a slow vs. a fast encoding condition (but no difference between a medium and slow encoding condition, perhaps because an optimal compression rate had already been achieved in the medium encoding condition). Importantly, faster simulation was positively related to how effectively and efficiently participants navigated a virtual route. Overall, these data indicate a functional role for episodic simulation in navigational planning.

Conclusions

During the past few years, the pace of research concerning episodic future thinking has accelerated, continuing a trend that began about a decade ago. There has been significant progress in characterizing the mechanisms that support episodic future thinking, and in identifying functions that episodic future thinking serves (see Figure 2).

Some key issues remain controversial, such as the nature of hippocampal contributions to episodic future thinking, and the related question of the extent to which neural and cognitive signatures of episodic future thinking are specific to imagining *future* experiences as opposed to atemporal imagining or imagining counterfactuals to past experiences (cf., 4, 28, 34, 39, 50, 58–61, 65, 96). Nonetheless, we believe that further attempts to integrate cognitive, neuropsychological, and neuroimaging evidence will eventually resolve such issues. Research regarding the functions of episodic future thinking has, if anything, accelerated even more rapidly. By linking episodic future thinking to an expanding range of functions and populations reviewed here, this research has opened up new questions and broadened the potential impact of studies focused on mechanisms. The future of research on episodic future thinking thus seems to us quite bright.

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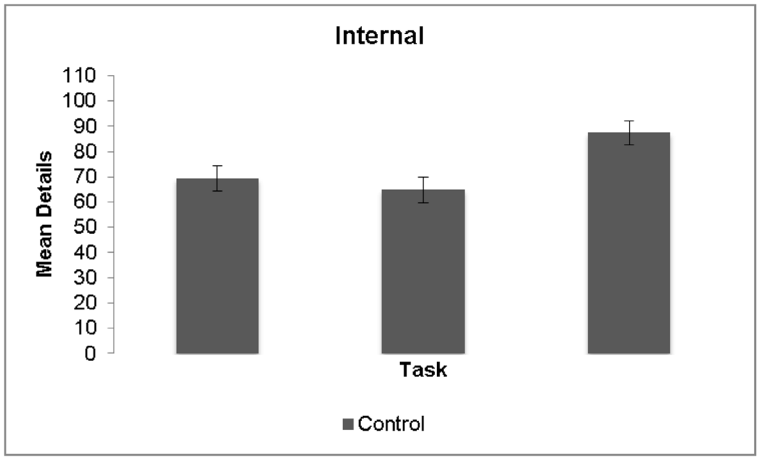
Highlights

- Research on episodic future thinking has increased dramatically during the past decade
- Cognitive studies have begun to separate the contributions of episodic retrieval from non-episodic processes
- Studies of patient populations have shown episodic future thinking deficits in various conditions
- Neuroimaging studies are identifying the role of individual regions in a core brain network that supports episodic future thinking
- Episodic future thinking serves diverse functions, ranging from decision making to spatial navigation

A.



B.

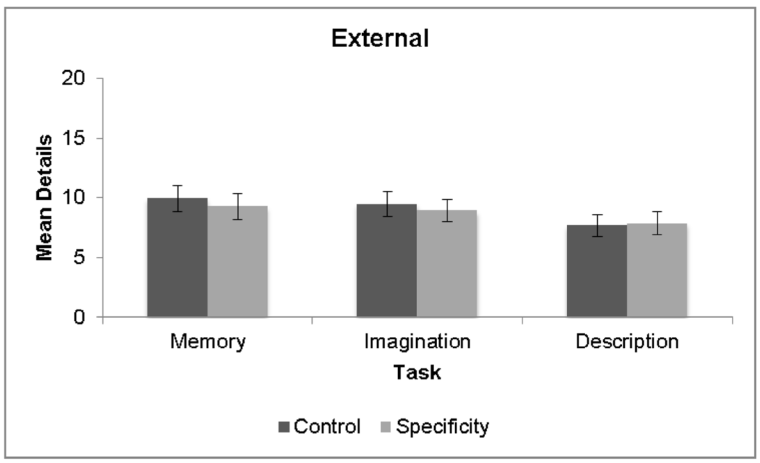


Figure 1.

Mean internal (A) and external (B) details generated as a function of induction and task (collapsed across young and older adults). Error bars represent one standard error. Reproduced from K.P. Madore, B. Gaesser, & D.L. Schacter, “Constructive episodic simulation: Dissociable effects of a specificity induction on remembering, imagining, and describing.” J Exp Psychol: Learn Mem Cognit, 40, 609–622. Published by American Psychological Association, reprinted with permission.

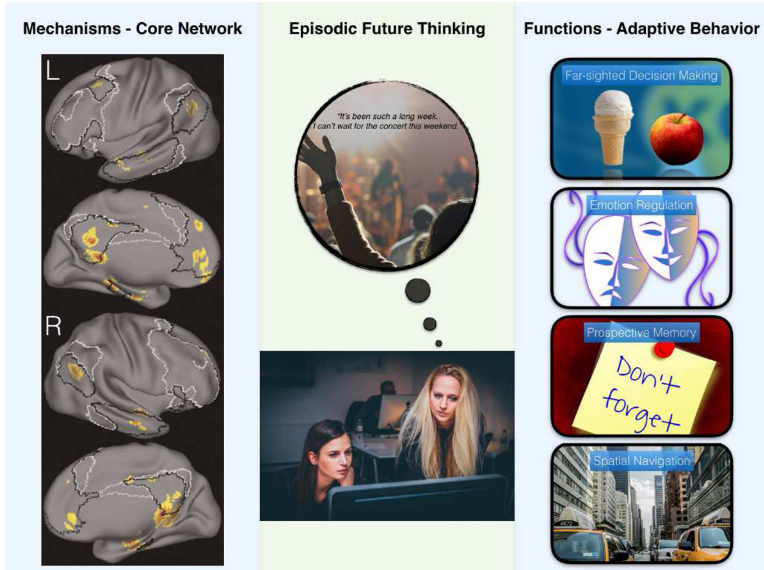


Figure 2. Mechanisms and functions of episodic future thinking

Middle panel. Episodic future thinking is the capacity to imagine or simulate specific events that may take place in the personal future. *Left Panel*. The capacity to simulate events is supported by cognitive mechanisms that involve extracting elements of past experiences (e.g., familiar people, places, and objects) and using that information to form novel mental representations that are projected into the future. A core network of brain regions that include medial and lateral aspects of the frontal, parietal, and temporal lobes enable this ability to extract past experience in the service of simulating the future. The core network largely falls within the brain's default network (dark borders) [Taken from Benoit, R.G., Schacter, D.L. (2015, p. 454) Specifying the core network supporting episodic simulation and episodic memory by activation likelihood estimation. *Neuropsychologia*, *75*, 450–457]. L = left. R = right. *Right Panel*. Simulation of future events has been shown to support a variety of adaptive behaviors. *Far-sighted decision making*. Imagining desired health outcomes (e.g., healthy weight) facilitates the ability to make decisions that support those outcomes (e.g., choosing healthy over unhealthy snacks; 71–73). *Emotion regulation*. Imagining possible positive outcomes related to a worrisome event reduces anxiety about that event (85). *Prospective memory*. Simulating an upcoming intention (e.g., picking up bread on the way home from work) makes it more likely that the intention will be remembered and carried out (89–91). *Spatial navigation*. Simulating traveling along a particular route can support planning and navigational goals (105–107).