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Remembering the past and imagining the future in the elderly

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Abstract

Recent research has demonstrated commonalities between remembering past events and imagining future events. Behavioral studies have revealed that remembering the past and imagining the future depend on shared cognitive processes, whereas neuropsychological and neuroimaging studies have shown that many of the same brain regions are involved in both remembering the past and imagining the future. Here, we review recent cognitive and neuroimaging studies that examine remembering the past and imagining the future in elderly adults. These studies document significant changes in elderly adults' capacities to imagine future events that are correlated with their memory deficits; most strikingly, older adults tend to remember the past and imagine the future with less episodic detail than younger adults. These findings are in line with the constructive episodic simulation hypothesis, which holds that that past and future events draw on similar information and rely on similar underlying processes, and that episodic memory supports the construction of future events by extracting and recombining stored information into a simulation of a novel event. At the same time, however, recent data indicate that non-episodic factors also contribute to age-related changes in remembering the past and imagining the future. We conclude by considering a number questions and challenges concerning the interpretation of age-related changes in remembering and imagining, as well as functional implications of this research for everyday concerns of older adults.

Keywords

Episodic Memory; Imagination; Simulation; Aging; Functional magnetic résonance Imaging; Hippocampus

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A great deal of research has examined how elderly adults remember their pasts. By contrast, relatively little work has explored how older individuals imagine their futures. However, questions concerning this issue have come to the forefront of aging research during the past few years as a result of recent studies that have examined how memory is used to imagine or simulate experience that might occur in the future. These studies have revealed striking commonalities between remembering the past and imagining the future: behavioral studies with young adults have documented that remembering the past and imagining the future rely on a number of shared cognitive processes, neuropsychological research has shown that a variety of patients with memory deficits also exhibit deficits in imagining future events, and neuroimaging studies with young adults have shown that many of the same brain regions that are active when remembering the past are also active when imagining the future (for reviews, see [1,2]).

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Based on the above commonalities between remembering the past and imagining the future, Schacter and Addis [3] proposed the *constructive episodic simulation hypothesis*. This idea attempts to develop an adaptive approach to understanding "constructive" aspects of memory – memory distortions where elements of prior experience are confused – by linking them to memory's role in simulating future events. The constructive episodic simulation hypothesis holds that past and future events draw on similar information and rely on similar underlying processes, and that episodic memory supports the construction of future events by extracting and recombining stored information into a simulation of a novel event. From this perspective, a critical function of a constructive memory system is to make information available for simulation of future events. Using past experiences to anticipate possible future happenings should be highly adaptive because it allows individuals to mentally "try out" alternative approaches to an upcoming situation without having to expend the resources necessary to engage in actual behaviors, and indeed there is considerable evidence that imagining future experiences – though not error free – serves adaptive functions [4]. While the constructive nature of memory allows past information to be used flexibly when simulating alternative future scenarios, this very flexibility may also result in vulnerability to memory distortions.

We recently applied the constructive episodic simulation hypothesis to the study of cognitive aging: we have conducted a series of experiments that examine directly how aging affects the processes that support imagining future events, and compared these effects to age influences on autobiographical memories. This article reviews our research to-date, and some relevant work by others, in light of the constructive episodic simulation hypothesis. As we will see, our work documents significant changes in elderly adults' capacities to imagine future events that are correlated with their memory deficits. These findings provide empirical support for the constructive episodic simulation hypothesis, but at the same time, raise a number of questions and challenges concerning interpretation of age-related changes in remembering and imagining. We conclude by discussing some possible implications of recent studies that we believe have the potential to offer novel perspective on cognitive aging.

Aging and Future Event Simulation: Experimental Evidence

As noted earlier, it is well documented that normal aging is associated with a decline in various aspects of episodic memory. While many of these deficits have been documented on tests involving word lists and related material, there is also evidence of age-related declines for autobiographical memories of everyday experiences: older adults sometimes exhibit less specific memories of past experiences than do younger adults. This point was documented clearly in a study by Levine, Svoboda, Hay, Winocur, and Moscovitch [5] using a procedure they developed known as the Autobiographical Interview (AI). During the AI, young adults and older adults were asked to recall past personal events in response to probes over a period of five minutes. Transcriptions were segmented into distinct details that were classified as either internal (episodic) or external (semantic). Internal details involve the "episodic core" of the retrieved experience: specific details concerning who, what, where, and when. External details involve related facts, elaborations, or references to other events. Levine and colleagues found that when remembering past experiences during the AI, older adults generated fewer internal and more external details than younger adults [5].

Because the constructive episodic simulation hypothesis posits a close relationship between episodic memory and imagining future events, we thought that the procedures and findings of Levine and colleagues provided a useful basis for initiating studies concerning future event simulation in older adults and testing the constructive episodic simulation hypothesis. We have completed four studies using the AI to examine remembering the past and imagining the future in healthy older adults and patients with Alzheimer's disease (AD), which we now consider in turn.

Healthy Aging and Constructive Episodic Simulation: Initial Observations

We began by asking a simple question: Do the findings of Levine et al. [5] showing reduced episodic specificity of autobiographical memories with age also characterize imagined future events? One possibility is that the deficit observed by Levine and collaborators reflects processes uniquely associated with memory for actual autobiographical experiences and would not be observed with simulated, imaginary events. However, based on the constructive episodic simulation hypothesis, we predicted that age-related changes for remembered past events would indeed extend to imaginary future events.

To assess this hypothesis, we developed an adapted version of the AI [6]. Sixteen younger and sixteen older adults (in this experiment and the others from our lab discussed in this chapter, the mean age for younger adults was in the early 20s and for older adults was in the early 70s) generated eight events in each of four conditions (past few weeks, past few years, next few weeks and next few years) in response to a cue word. During each trial, participants were instructed to recall or imagine an event, and to generate as much detail as possible within three-minutes. The event generated in response to a cue word did not have to strictly involve the named object, but each event had to be temporally and contextually specific (i.e., episodic), occurring over minutes or hours but not more than one day. Future events had to be plausible given the participant's plans, and novel, that is, not previously experienced by the participant. The relevant cue word was displayed on a computer screen along with the task instruction ("recall past event" or "imagine future event") and time-period for the duration of the trial. If needed, general probes were given to clarify instructions and encourage further description of details.

Recordings of remembered and imagined events were transcribed, and four events from each condition were scored by three raters blind to group membership, using the standardized AI scoring procedure [5] in which details were categorized as *internal* (episodic information relating to the central event) or *external* (non-episodic information including semantic details, extended events and repetitions). Inter-rater reliability was high (Cronbach's alpha: internal, .96; external, .92).

The key results of the experiment are depicted in Figure 1. Replicating the findings first reported by Levine et al. [5], we observed that older adults produced fewer internal and more external details than young adults for remembered past events (Figure 1A). Critically, we found the identical pattern for imagined future events. Note that these age differences in past and future events cannot be explained by group differences in the temporal distance of events: age groups did not differ significantly for temporal distance (in weeks) from the present for either past or future events.

In addition to the similar effects of aging on the memory and imagination tasks, we observed that past and future scores were highly positively correlated with each other for both internal and external details (Figure 1B). By contrast, internal and external detail scores were uncorrelated with one another, suggesting that an age-related reduction in internal details cannot be easily attributed to increased time or cognitive resources devoted to generating external details. Overall, then, these initial results indicate that aging has similar effects on remembering the past and imagining the future, consistent with predictions made by the constructive episodic simulation hypothesis.

We obtained additional support consistent with these initial results in a subsequent study in which we used a different method of eliciting remembered and imagined events. In this *experimental recombination paradigm* [7], participants first provide a set of autobiographical memories, each comprised of a person, place, and object, that are recombined by the experimenter to provide stimuli for imagination trials. Participants then return for a separate session in which they are cued to remember some of the original episodes in as much detail as possible, or are asked to imagine in as much detail as possible a novel event involving the recombined person, place, and object. This procedure yielded a very similar pattern of results to that obtained in our initial study, with older adults producing fewer internal and more external details for both remembered and imagined events. These results are of theoretical interest because similarities between remembering the past and imagining the future in our earlier study might have been attributable to younger and older adults "recasting" entire memories of past events into the future. For example, when asked to imagine a future event involving a "vacation", a participant might remember last year's vacation and then simply imagine the same episode occurring again next year; the adapted AI paradigm used in our initial study did not allow us to control whether subjects recombined or recast past events. The experimental recombination procedure allows such control, and thus provides stronger evidence for an age-related deficit in recombining episodic details into novel future scenarios, in line with the constructive episodic simulation hypothesis.

Age-Related Changes in Remembering and Imagining: How General Are They?

The above findings are broadly consistent with predictions made by the constructive episodic simulation hypothesis. Nonetheless, the observed age-related deficits could also be attributable to general factors outside the domain of episodic memory that are related to constructing past and future autobiographical events. Gaesser, Sachetti, Addis, and Schacter [8] noted that studies from the verbal discourse literature have shown that older adults sometimes generate more "off topic" speech that is irrelevant to the assigned task than do younger adults; there may be some overlap between external details on the AI and irrelevant or off-topic speech. In a related vein, Gaesser et al. [8] also cited studies suggesting that production of off-topic speech could result from age-related deficits in inhibitory control or differences in narrative style and communicative goals when describing personal events. For example, older adults may be more focused on conveying the general significance and meaning of experiences than younger adults, resulting in more external and fewer internal details during both memory and imagination.

The foregoing considerations highlight contrasting perspectives derived from the constructive episodic simulation hypothesis, which explains age differences in memory and imagination by appealing to processes within the domain of episodic memory, and from the inhibitory deficit or narrative style accounts, which point toward more general, non-episodic influences as the source of the age differences in memory and imagination we have documented on the AI. To provide experimental evidence that bears on these perspectives, Gaesser et al. [8] conducted experiments in which older and younger adults were instructed to describe a complex picture of a natural scene in as much detail as possible. The same pictures were used either to cue simulations of imagined events or memories of past events. We scored the resulting protocols for internal and external details using an adapted version of the AI. For the picture description task, details that described the depicted scene were classified as internal and details that were inferred were classified as external. In contrast, for the imagination and memory tasks, details that went beyond the picture to an imagined or remembered experience were considered internal while details that simply described the depicted scene were considered external. We reasoned that if previously documented age-related declines in internal details during memory and imagination reflect the influence of either inhibitory deficits or changes in narrative style, then a) similar patterns should be observed on the picture description task, and b) no effects of aging should be observed in imagination and memory conditions after controlling for picture description performance. On the other hand, if age differences in memory and imagination revealed by the AI are explained by changes in episodic memory, then a) age differences should be greater on the imagination and memory tasks than on the picture description task, and b) there should be effects of aging in imagination or memory conditions even after controlling for picture description performance.

We conducted two experiments bearing on these ideas, but since the results were nearly identical, we focus here on Experiment 2 in Gaesser et al. [8]. In this experiment, 15 young and 15 healthy older adults were shown colored photographs that depict people engaged in a particular activity or set of activities, and were instructed either to *describe* the different people, objects, and environment in the picture and their relationship to one another, or *imagine* events that could possibly occur in the next few years with the picture as the general setting, or *remember* a personal experience that occurred in the last few years, using the picture as a cue to help focus on an event. Similar to our previous studies using word cues, events generated in response to a picture cues did not have to strictly involve elements of scene, but rather served to help subjects' focus on a single event. There were four pictures per condition, and for each picture, participants were given three minutes to describe, imagine, or remember. Instructions in the picture description condition emphasized - and were further reinforced during practice trials - that participants should provide a literal description of picture contents without embellishment.

The main results, presented in Figure 2, are straightforward: older adults generated fewer internal and more external details than younger adults in all three experimental conditions. These results, then, are in line with the idea that the age-related changes during memory and imagination observed in our previous studies reflect a more general pattern that also occurs on a picture description task that does not require episodic memory.

To explore further whether there is a contribution of aging to imagination and memory performance beyond a general ability to describe events tapped by the picture description task, we conducted a series of hierarchical multiple regression analyses. There were several key outcomes of these analyses: 1) the number of internal details on the picture description task was a significant predictor of the number of internal details on the imagination and memory tasks; 2) when age was added as a predictor, it significantly – though modestly – improved the model's ability to account for variance in memory and imagination performance; 3) there was a small age-deficit in imagination performance even after controlling for picture description and memory performance. Thus, while the results of this study highlight that non-episodic factors contribute to age-related changes in remembering the past and imagining the future, not all age-related reductions in episodic details during memory and imagination were accounted for by picture description performance, in line with the constructive episodic simulation hypothesis.

Remembering and Imagining in the Aging Brain

The results of the foregoing studies revealed tightly correlated age-related declines in remembering the past and imagining the future. Moreover, both remembering and imagining are associated with a *core brain network* that includes medial and lateral temporal, prefrontal, and parietal regions [9]. Intriguingly, these same regions are ones that exhibit pathology early in AD [10], which suggested to us that AD patients should exhibit similar deficits in remembering the past and imagining the future. To test this hypothesis, Addis, Sacchetti, Ally, Budson, & Schacter [11] used an adapted version of the AI from our initial study of healthy older adults that maintained the main features of the design described earlier, but was simplified to make it appropriate for AD patients. Scoring of internal and external details for past and future events followed the same protocol as described earlier. The study participants included 16 patients with a diagnosis of mild AD (mean age=77.1 yrs.) and 16 age-matched older controls (mean age=78. 8 yrs.) with no significant history of other neurological or psychiatric impairment.

Temporal distance of past and future events from the present did not differ between groups, indicating that any group differences on the AI cannot be accounted for by differences in temporal distance. Compared with healthy older adults, AD patients showed a marked decrease in internal details for both past and future events, and a more modest decrease in external details for both event types. Given the overall reduction in detail for the AD patients, it becomes important to determine whether these differences are attributable to more general problems in verbal fluency that are often observed in AD patients. We tried to control for these deficits by including verbal fluency scores as covariates in the analysis of internal and external details, and we found that the group differences in internal details for past and future events was not affected, whereas the smaller difference in external details were even further reduced.

Neuroimaging studies are beginning to illuminate the basis of remembering the past and imagining the future in healthy elderly adults. One particularly interesting question is whether such studies would reveal any age-related changes in the hippocampus during experimental paradigms like those that we have used to document hippocampal activation during remembering imagining in young adults (for review, see [12]). If reduced generation of internal details during remembering and imagining in AD patients is associated with hippocampal functioning, we might expect to see changes in hippocampal activity during remembering and imagining in healthy elderly. Another possibility is that older adults may engage regions mediating conceptual autobiographical information, such as anterior lateral temporal cortices (e.g. [13]), more so than young adults in order to support the increased generation of external details.

Viard and colleagues [14] reported fMRI evidence that when remembering the past and imagining the future, healthy older adults show significant activation in most of the same core network structures previously observed in studies of young adults, including the hippocampus. However, because Viard et al. did not include a young control group in their study, it was not possible to determine whether age differences exist in any of these regions.

Addis, Roberts, and Schacter [15] addressed this issue by directly comparing old and young adults with an experimental fMRI paradigm that had previously revealed robust core network activation during remembering the past and imagining the future in young adults [16]. The study participants included 14 young and 14 older adults; all reported no history of neurological or psychiatric impairments. While in the MRI scanner, participants were shown a series of cue words similar to those used in our adapted version of the AI. Each word cue was accompanied by an instruction to either remember a specific past event from the past few years related to the cue, or to imagine a novel and plausible future event that might occur in the next few years. On average, young and older adults generated an event approximately 7 seconds after the cue appeared, and this reaction time did not differ across age groups. Once an event was in mind, the participants elaborated and fleshed out the event for approximately 20 seconds before rating how detailed the event was on a five point scale (1=vague; 5=vivid).

Consistent with our behavioral findings that the past and future events generated by older adults are not completely devoid of episodic detail, our fMRI data indicated that older adults activated many regions of the core network engaged by young adults, including bilateral medial and lateral parietal cortices, medial temporal (including hippocampus) and lateral temporal lobes. Young adults engage some of these regions, including ventrolateral prefrontal and frontopolar cortex, more strongly when imagining the future (15, 16), which we have argued indicates that imagining novel future scenarios is a more demanding constructive process than simply reintegrating elements of past experience during memory retrieval (3, 16). Older adults did not show this effect, perhaps reflecting a change in the ability to ramp up activation in response to the constructive demands required by future simulation. Older adults also exhibited reduced activity in a number of regions for *both* the past and future tasks relative to younger adults. This pattern was evident in regions associated with episodic imagery and contextual detail, specifically, the hippocampus, parahippocampal gyrus and precuneus. Moreover, detail ratings in young adults correlated with the level of activity in these regions – an effect not seen in older adults. Instead older adults' detail ratings correlated with activity in lateral temporal regions. We also observed an enhanced recruitment of lateral temporal cortex in older adults during event elaboration (see also [14]). Taken together, we suggest these findings reflect the reduced episodic content (i.e., internal details) and increased conceptual and semantic information (i.e., external details) comprising the past and future events of older adults.

Concluding Comments

The studies reviewed here consistently show that aging is associated with parallel changes in remembering actual events that occurred in the past and simulating imaginary events that might occur in the future (or might have occurred in the past). Our findings fit well with the recently emerging literature discussed earlier that has revealed a variety of similarities at both cognitive and neural levels between remembering the past and imagining the future, and generally support the constructive episodic simulation hypothesis. However, many important questions and issues remain to be addressed.

As discussed earlier, imagining the future is thought to place greater demands on constructive processing than remembering the past (3, 16), and younger but not older adults showed activation increases related to these constructive demands. Consistent with these findings, Gallo and McDonough and their colleagues (17, 18) have provided behavioral evidence that a) constructing future simulations requires more cognitive effort than remembering past experiences in both young and old, and b) when attempting to distinguish between previously generated future simulations and previously generated autobiographical memories, older adults showed poorer memory for future simulations. Moreover, Gaesser et al. (8) found a modest age-deficit in imagination performance even after controlling for picture description and memory performance. Further research to pinpoint the source of these age differences is necessary.

Another important issue emerges from the aforementioned results comparing performance on the picture description task with memory and imagination tasks [8]. The fact that older adults showed largely parallel changes (reduced internal and increased external details) when describing a perceived scene, and when remembering a past event or imagining a future event, suggests that processes outside the domain of episodic memory contribute to age-related differences on the AI. From this perspective, a key task for future research is to distinguish among and further specify the non-episodic sources of age-related performance changes during memory and imagination.. For example, older adults sometimes generate more "off topic" speech than do younger adults (e.g., 19), perhaps resulting from age-related deficits in inhibitory control (20), which could similarly impact memory and imagination. In a related vein, older adults tend to be more focused on conveying the general significance and meaning of experiences than younger adults (e.g., 21, 22), possibly resulting in more external and fewer internal details during both memory and imagination. However, the precise relationship between inhibitory control, narrative discourse, and performance on the AI is poorly understood.

Consider also another possible interpretation of the age differences in picture description that we observed. Although the picture description task clearly does not require episodic memory, it may nonetheless recruit some of the same processes involved in constructing autobiographical memories and simulating future events, as subjects attempt to “tell the story” depicted in the picture they are viewing. While the instructions used in our picture description task indicated that participants should provide a literal description of picture contents without embellishment, informal examination of protocols produced during picture description indicates that they have a narrative structure that resembles protocols from the memory and imagination tasks. To the extent that subjects approach the task as one requiring a narrative, older adults might perform differently from younger adults for some of the same reasons as in the memory and imagination conditions. Available data do not speak to this possibility, but future studies should explore it.

A growing body of evidence indicates that simulating future events can serve important adaptive functions when people attempt to plan for upcoming events (for review and discussion, see [4]), suggesting that it will also be worth exploring how older adults use episodic memory and simulation in order to plan for the future, and how core network activity supports planning. For example, Spreng and Schacter [23] recently reported fMRI evidence concerning autobiographical planning in older and younger adults, using a task in which participants constructed plans to achieve real-life goals (e.g., exercise, travel, scheduling health care visits) during scanning. Both young and old participants activated core network regions during autobiographical planning, and younger adults deactivated the core network during a visuospatial planning task (the Tower of London), which recruits a distinct attentional network. Older adults, by contrast, failed to deactivate the core network during visuospatial planning, suggesting an age-related disruption in network dynamics. Further studies of planning, aging, and network interactions would be valuable.

We also think that work on future simulation in aging could be expanded to include counterfactual simulations of what could have happened in the past, that is, thoughts about what “might have been” (24). There is reason to believe that counterfactual simulations are common throughout the lifespan, especially when dealing with regrets and related phenomena that are highly relevant to older adults (25). Researchers have not yet applied the kinds of methods reviewed here for studying future simulations in the elderly to the study of counterfactual simulations of what might have been, but such studies would expand our understanding of the role of memory-based simulations on cognitive aging.

Although imagining future events can serve adaptive functions, future event simulation is also prone to errors and illusions (see [4]). For instance, when young adults repeatedly simulate emotionally positive or negative future events, there is in an increase in participants’ subjective sense of the plausibility of the simulated events, even though there is no corresponding change in objective circumstances that would warrant such an increase [26]. Nothing is known about whether older adults are equally, less, or possibly more susceptible to such effects. However, in light of evidence demonstrating age-related positivity biases (e.g. [27]), it would be interesting to determine whether repeatedly simulating future events differentially affects the subjective plausibility of positive versus negative events in older adults (for related evidence, see [17]). Similarly, recent evidence indicates that young adults tend to forget over time emotionally negative simulations to a greater degree than they forget positive or neutral simulations [28]. In light of work on age-related positivity bias, it would be worthwhile investigating whether older adults exhibit an exaggerated version of this effect. Evidence from a source memory paradigm (17) indicates that older adults do indeed show more source misattributions for simulations of negative rather than positive or neutral future events after a delay, though the effect does not appear to be exaggerated compared with young adults. Further work using a variety of paradigms will be needed to clarify the effect of emotion on future simulations in the elderly.

We noted earlier that while much research has examined remembering the past in older adults, little work has focused on imagining the future. We think that the studies reviewed here should be connected to other lines of research examining related kinds of future thinking in the elderly. For instance, Carstensen and her colleagues (29) have documented that future time perspective plays an important functional role in older adults: the perception that the end of life is approaching can lead to a shift in goals, such that social connection and emotion regulation are prioritized. It would be desirable to explore links between the age-related changes in imagining future events reviewed here and changes in goals related to temporal perspective. Similarly, financial planning is an important activity for the elderly that may engage the kinds of simulation processes we have discussed (30), and studies that explore the issue would be valuable. We are hopeful that the work we have discussed in this review can contribute to broadening our understanding of both the nature and functions of remembering the past and imagining the future in elderly individuals.

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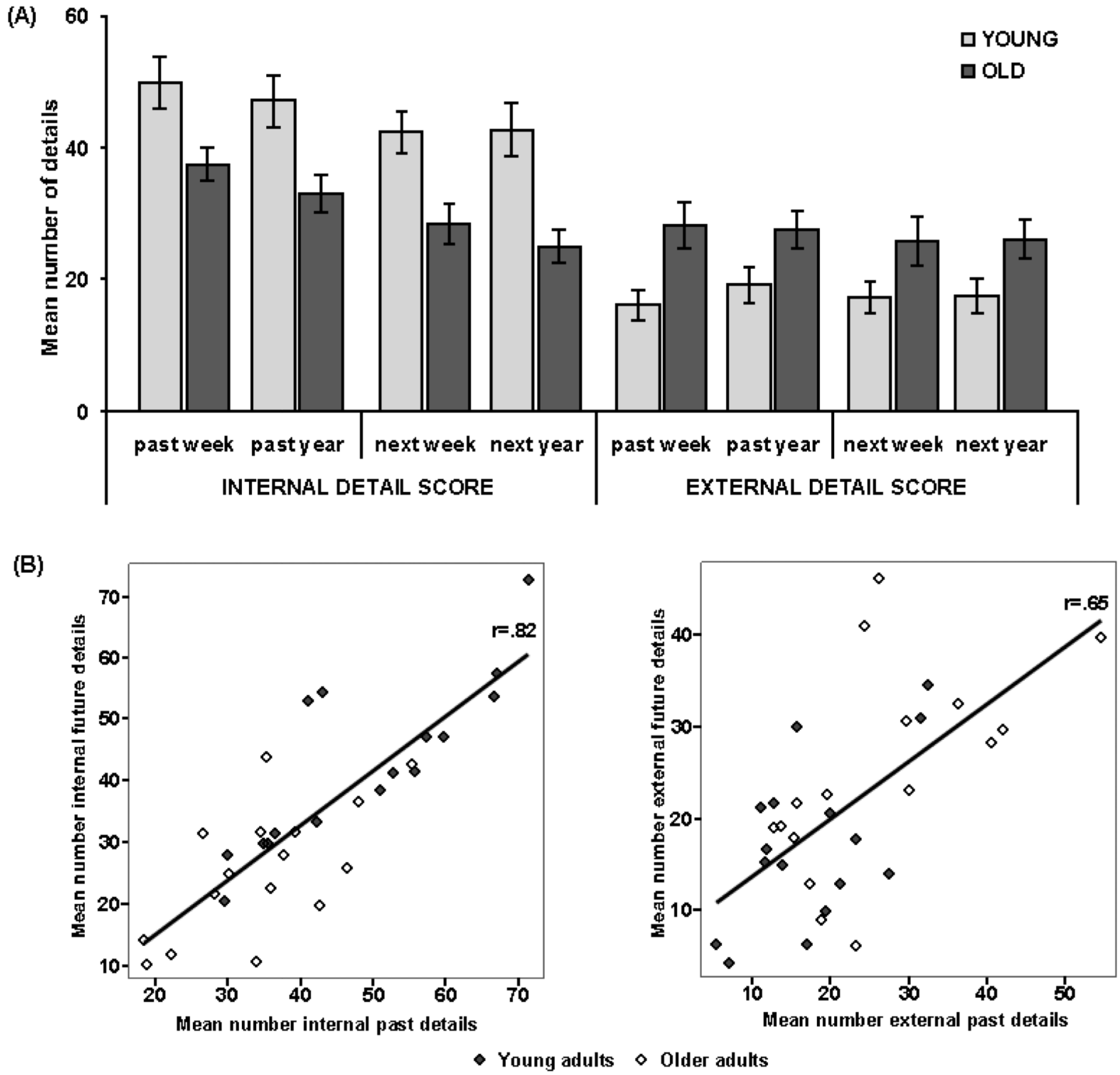

Figure 1.

Results from an experiment by Addis, Wong, & Schacter (2008) showing (A) the mean number of internal and external details generated by younger and older adults for past and future events as a function time period (error bars represent standard errors of the mean), and (B) correlations between the mean number of internal (left panel) and external (right panel) details for past and future events.

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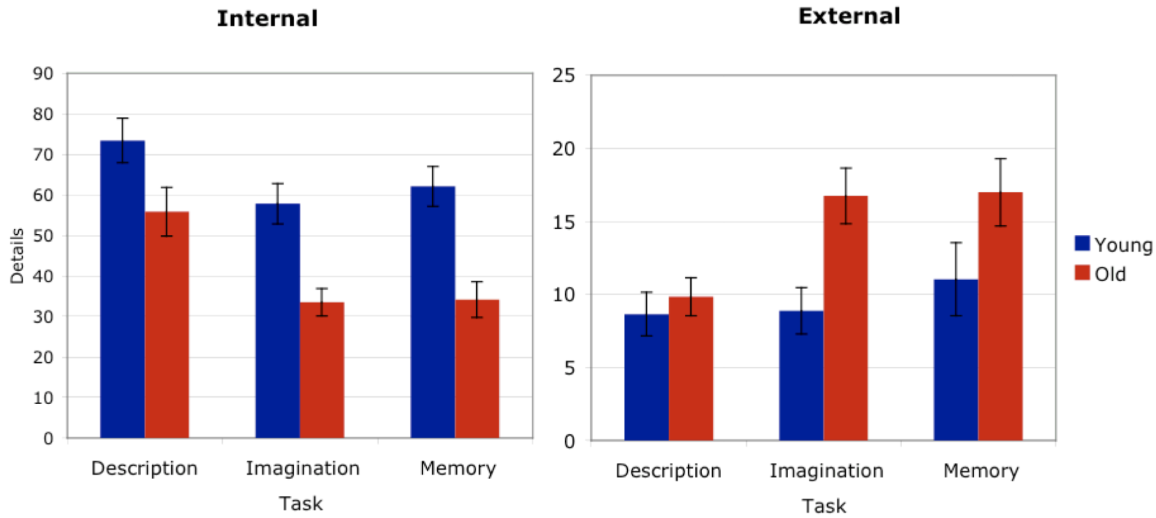

Figure 2.
Results from an experiment by Gaesser, Sacchetti, Addis, and Schacter (2011) depicting the mean number of internal and external details generated as a function of age group and task. Error bars represent standard errors of the means.