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Article *in* Psychology and Aging · February 2017
DOI: 10.1037/pag0000162

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Psychology and Aging

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Online First Publication, February 23, 2017. http://dx.doi.org/10.1037/pag0000162

Psychology and Aging

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0882-7974/17/$12.00 http://dx.doi.org/10.1037/pag0000162

Familiar Real-World Spatial Cues Provide Memory Benefits in Older and Younger Adults

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Episodic memory, future thinking, and memory for scenes have all been proposed to rely on the hippocampus, and evidence suggests that these all decline in healthy aging. Despite this age-related memory decline, studies examining the effects of context reinstatement on episodic memory have demonstrated that reinstating elements of the encoding context of an event leads to better memory retrieval in both younger and older adults. The current study was designed to test whether more familiar, real-world contexts, such as locations that participants visited often, would improve the detail richness and vividness of memory for scenes, autobiographical events, and imagination of future events in young and older adults. The predicted age-related decline in internal details across all 3 conditions was accompanied by persistent effects of contextual familiarity, in which a more familiar spatial context led to increased detail and vividness of remembered scenes, autobiographical events, and, to some extent, imagined future events. This study demonstrates that autobiographical memory, imagination of the future, and scene memory are similarly affected by aging, and all benefit from being associated with more familiar (real-world) contexts, illustrating the stability of contextual reinstatement effects on memory throughout the life span.

Keywords: spatial context, scene memory, autobiographical memory, aging, imagination

Supplemental materials: http://dx.doi.org/10.1037/pag0000162.supp

In the past decade, a substantial body of research has emerged that indicates that the ability to recall the past and to imagine possible futures are related, in terms of both behavioral characteristics and neural substrates (Addis, Pan, Vu, Laiser, & Schacter, 2009; Addis, Wong, & Schacter, 2007; D'Argembeau & Van der Linden, 2004, 2006; Gamboz, Brandimonte, & De Vito, 2010; Hassabis, Kumaran, Vann, & Maguire, 2007; Robin & Moscovitch, 2014; Schacter, Addis, & Buckner, 2007; Spreng & Levine, 2006; Szpunar & McDermott, 2008; Szpunar, Watson, & McDermott, 2007). The link between these cognitive abilities persists in aging, as shown by similar age-related declines in episodic memory and future thinking in healthy older adults compared with younger populations (Addis, Musicaro, Pan, & Schacter, 2010; Addis, Wong, & Schacter, 2008; Gaesser, Sacchetti, Addis, & Schacter, 2011; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002; Schacter, Gaesser, & Addis, 2013). These changes have been shown to correlate with a decrease in hippocampal activity in older adults (Addis, Roberts, & Schacter, 2011; St. Jacques, Rubin, & Cabeza, 2012).

In contrast to these age-related memory decrements, studies examining the interaction of context and memory as a function of age have found that beneficial context reinstatement effects on memory are often equal or even more pronounced in older populations (Craik & Schloerscheidt, 2011; Naveh-Benjamin & Craik, 1995; Park, Puglisi, Smith, & Dudley, 1987). In studies such as these, when an item is learned in the presence of a given context, such as a picture of a scene, and that context is reinstated at retrieval, recognition memory for the associated item improves. The mechanism of this effect of context reinstatement on memory is not known, but has been hypothesized to rely on implicit forms of memory, because explicit memory for the individual items is impaired in older adults in these studies (Craik & Schloerscheidt, 2011; Naveh-Benjamin & Craik, 1995). This suggests a similar relationship as other previous studies that have proposed that nonhippocampal forms of memory, such as semantic memory or familiarity, can support episodic memory in instances of its decline related to aging or damage to the hippocampus (Bäckman, 1991; Kan, Alexander, & Verfaellie, 2009; Race, Palombo, Cadden, Burke, & Verfaellie, 2015).

The present study sought to test whether similar contextual benefits to memory carry over to real-world contexts and episodic memory. If more familiar contexts lead to more semantic or schematic memories associated with these locations, these forms of memory, which are thought to rely less on hippocampal func-

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This research was supported by a grant from the Canadian Institute of Health Research to Morris Moscovitch, and a postgraduate scholarship from the Natural Sciences and Engineering Research Council of Canada to Jessica Robin. Some of the data in this article were presented at the Cognitive Neuroscience Society Annual Meeting in 2013, and a version of this article was included as part of Jessica Robin's doctoral dissertation.

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tion, may serve to support episodic memory and other hippocampal memory processes. Previous studies have indicated that memory for very familiar locations or landmarks can be retained in individuals with amnesia relating to hippocampal damage (Rosenbaum et al., 2000), and other studies have shown that hippocampal activity decreases in response to navigation tasks as individuals became more familiar with the locations involved (Hirshhorn, Grady, Rosenbaum, Winocur, & Moscovitch, 2012). Thus, familiar contexts may facilitate memory in older adults by tapping into memory representations that rely both on hippocampal and extrahippocampal processes. If so, this possibility may have important implications for ways to preserve or improve memory in cases of episodic memory decline in older adults. Anecdotal evidence in support of this idea suggests that memory suffers when older adults move to new environments, because they must simultaneously encode the new environment while losing the contextual associations from previous environments, which may have helped with both memory encoding and retrieval.

In a previous study, we compared the effects of high- and low-familiarity contextual cues on memory for spatial scenes, autobiographical memories, and the ability to imagine future events in a sample of young adults (Robin & Moscovitch, 2014). More familiar contextual cues, in the form of real-world landmarks familiar to the participants, resulted in higher ratings of detail and vividness in all three conditions, and in a greater number of internal details reported for remembered scenes and events, even when nonspatial aspects of the events were considered, though not significantly for imagined future events. This study demonstrated that familiar spatial contexts had a supportive effect on spatial memory as well as on episodic memory and imagination, in which spatial context may play a determining role (Bird & Burgess, 2008; Byrne, Becker, & Burgess, 2007; Hassabis et al., 2007; Hassabis & Maguire, 2007, 2009; Maguire & Mullally, 2013; Mullally & Maguire, 2014; O'Keefe & Nadel, 1978).

Drawing on the findings that the ability to remember or imagine events in detail tends to decline in older age, but that contextual benefits are maintained or even increased in older participants, in the present study, we sought to compare the effects of contextual familiarity on remembered scenes, autobiographical events, and imagined future events in younger and older adults. By using similar spatial contextual cues across all three conditions, we matched the tasks as closely as possible in order to test whether there are parallel declines in these three abilities related to aging. In addition, by cuing the scenes, memories, and future events with landmarks varying in familiarity, we tested whether one's familiarity with the spatial context affected the quality of the representation based on that cue, as has been shown to be the case in younger adults (Robin & Moscovitch, 2014).

Two previous studies have employed similar methodologies to study memory, future thinking, and aspects of scene perception or imagination in older adults. In one study, older and younger adults provided descriptions of autobiographical memories and imagined future events based on pictures of activities (Gaesser et al., 2011). In another condition in that study, participants were asked to describe the picture cues in detail. Older adults were found to provide fewer internal (specific, relevant) details than did younger adults in all three conditions. In a second study, older and younger adults were prompted with verbal descriptions of atemporal scenes, future events, and a navigational narrative, and asked to imagine these and describe them in detail (Rendell et al., 2012). Again, older adults were found to perform worse than younger adults on all three conditions, as determined by a composite measure of performance reflecting content, self-ratings, and independent ratings of quality.

The present study builds on these previous reports, and extends them in novel directions, in a few ways. First, although both of the previous studies included a condition involving scene description (either from a presented image or from an imagined navigational narrative), neither directly tested memory for scenes. Research on spatial memory and aging has indicated an age-related decline in highly detailed forms of spatial memory that involve scene representations, whereas other types of spatial memory are spared. One study found that older adults perform similar to, or better than, younger adults on tests of navigation and schematic spatial memory measures such as distance or direction judgments between well-known locations (Rosenbaum, Winocur, Binns, & Moscovitch, 2012). Older adults, however, report lower subjective vividness and detail when performing spatial memory tasks, and performed worse than younger adults on tests of landmark recognition, requiring memory for detailed scenes. Though less severe, this pattern of intact and impaired function mirrors that observed in patients with hippocampal damage (Rosenbaum, Gao, Richards, Black, & Moscovitch, 2005; Rosenbaum et al., 2000). Another study found that when older adults described navigating along a route, the number of details provided correlated with spatial and nonspatial tests of hippocampal function, including the number of details provided in the autobiographical interview (AI; Levine et al., 2002), but not with schematic map-like knowledge of the area (Hirshhorn, Newman, & Moscovitch, 2011). Together, these studies support the existence of an age-related decline in highly detailed spatial representations and suggest that this is related to autobiographical memory. Based on these studies, we predict that older adults will show similar age-related impairments in the amount of detail provided in the autobiographical memory and scene memory conditions.

Second, and most importantly, the present study introduces the novel factor of context familiarity. Increased detail and vividness in imagined and remembered events as a result of increased spatial contextual familiarity has been well-documented in studies of younger adults (Arnold, McDermott, & Szpunar, 2011; D'Argembeau & Van der Linden, 2012; Robin & Moscovitch, 2014; Robin, Wynn, & Moscovitch, 2016; Szpunar & McDermott, 2008). These findings have been interpreted as evidence of the contextual dependence of both memory and imagination, and in particular, as showing that the spatial context of an event acts as a scaffold on which to construct the details of the event, whether remembered or imagined (Hassabis & Maguire, 2007; Maguire & Mullally, 2013; Robin & Moscovitch, 2014; Robin et al., 2016). Given that other studies have reported equivalent, or even increased, context effects in older individuals (Craik & Schloerscheidt, 2011; Naveh-Benjamin & Craik, 1995; Park et al., 1987), it is important to test whether more familiar contexts can aid scene memory, autobiographical memory, and imagination in older adults, despite the expected age-related declines in these abilities. If they can, this demonstration will provide novel evidence of how impoverished episodic memory and prospection in older adults may be improved by the presence of familiar spatial contexts, and yield insight into how the relationships between spatial context, memory, and imagination persist throughout the life span.

Method

Participants

Twenty-six young adults and 22 older adults participated in the experiment either for course credit or for monetary compensation. Eight (five young, three older) participants were excluded due to completing an insufficient number of trials (i.e., not recalling or imagining anything on more than half the trials in a given condition), one (young) due to not having lived in Toronto, Canada, for a year, one (young) due to not being a native English speaker, one (older) due to very low scores on the neuropsychological tests, and one (young) due to experimenter error. The final group consisted of 18 young adults (two male; $M_{age} = 22.5$, $SD = 3.94$; range = 18–30) and 18 older adults (three male; $M_{age} = 77.83$, $SD = 4.90$; range = 70–87). All participants stated that they frequently visit the downtown area of Toronto (at least several times per month), and had lived in Toronto for at least 1 year ($M_{young} = 12.47$, $SD = 8.86$; $M_{old} = 55.72$, $SD = 18.74$), ensuring that they had a variety of memories involving the landmarks featured in the study. The older group had lived in Toronto for significantly more years than the younger group, $t(34) = -8.85$, $p < .001$, $r = .84$. Young and older adults did not differ in terms of years of education ($M_{young} = 15.61$, $SD = 2.68$; $M_{old} = 15.67$, $SD = 2.57$), $t(34) = -.06$, $p = .950$. All participants were native or fluent speakers of English, had normal or corrected-to-normal vision and hearing, and had no history of neurological illness or injury. All participants provided informed consent prior to participating in the experiment. This study received approval from the University of Toronto Office of Research Ethics.

Neuropsychological Measures

Young and older adults performed similarly on measures of verbal fluency, $t(34) = 1.32$, $p = .195$, digit span, $t(34) = 1.52$, $p = .139$, immediate memory, $t(34) = .85$, $p = .404$, and delayed memory, $t(34) = 1.36$, $p = .182$. Younger adults performed significantly better on tests of spatial memory both at immediate test, $t(34) = -3.94$, $p < .001$, $r = .56$, and delayed test, $t(34) = -2.17$, $p = .037$, $r = .35$. Younger adults were faster on tests of executive function, Trails A, $t(34) = -4.72$, $p < .001$, $r = .63$, and B, $t(34) = -3.51$, $p = .001$, $r = .52$, but the Trails B to Trails A ratio (B/A) did not differ between groups, $t(34) = .170$, $p = .87$. Older adults performed significantly better on a vocabulary test, $t(34) = -5.31$, $p < .001$, $r = .67$. Although the overall lower performance of the older adults on measures of spatial memory is consistent with the decreased details provided in the memory conditions, there were no within-age-group correlations between the neuropsychological measures and the number of details provided in any of the memory conditions (all ps $> .05$). Table 1 provides a summary of performance on neuropsychological measures.

Procedure

Prestudy questionnaire. At least 24 hr prior to the study, participants completed an online questionnaire to assess their familiarity with a variety of well-known Toronto buildings and landmarks. The questionnaire provided a list of 120 landmarks located mostly in downtown Toronto, including 60 from the original Toronto Public Places Test (Rosenbaum, Ziegler, Winocur, Grady, & Moscovitch, 2004) as well as 60 additional landmarks (for a full list of landmarks, see Table S1 in the online supplemental materials). Participants were asked to estimate the number of times they had visited each of the landmarks (response options: *never*, *1–2 times*, *3–5 times*, *6–10 times*, *more than 10 times*), with "visit" entailing both walking by the landmark or entering the building or location in question. Participants were told to select "never" if they were unsure of whether they had visited the landmark or were unfamiliar with the landmark name.

Table 1
Mean (and Standard Deviation) of Performance on Each Neuropsychological Measure by Age Group

Neuropsychological measure	Older adults	Younger adults
Verbal Associative Fluency	64.44 (13.50)	71.28 (17.26)
Digit span	16.39 (3.03)	18.39 (4.70)
WMS-R III/IV Logical Memory I (Immediate)	45.06 (10.50)	47.89 (6.99)
WMS-R III/IV Logical Memory II (Delay)	30.28 (8.59)	33.56 (5.34)
Spatial Memory—Immediate	97.69 (61.77)*	33.11 (31.93)*
Spatial Memory—Delay	63.11 (76.65)*	19.29 (38.02)*
Trail Making A	38.94 (10.21)*	24.5 (8.00)*
Trail Making B	93.11 (29.96)*	59.39 (27.63)*
Trails B/A Ratio	2.51 (1.23)	2.46 (.77)
Shipley Vocabulary Test	36.67 (2.11)*	31.17 (3.85)*

Note. For Verbal Associative Fluency, score represents the sum of the number of words produced in response to three letter cues (C, F, L) and one category cue (animals); for Digit Span, score is the sum of the maximum forward and backward span scores achieved; for WMS-R III/IV Logical Memory I, score is the sum of story items immediately remembered (maximum 75), and for WMS-R III/IV Logical Memory II, score is the sum of story items remembered after a 15-min delay (maximum = 50); for Spatial Memory, the score is the average distance of the selected location from the target locations (in virtual units); for Trail Making A & B, the score is the number of seconds required to complete the task without error; for the Shipley Vocabulary Test, the score represents the number of words for which a synonym was correctly identified (maximum = 40). Measures on which older adults and younger adults performed significantly differently are indicated by asterisks. WMS-R III = Wechsler Memory Scale Revised/III.

As in previous studies (Robin & Moscovitch, 2014; Robin et al., 2016), landmarks visited between one and five times were considered “low familiarity” and landmarks visited more than 10 times were considered “high familiarity.” Based on each participant’s questionnaire responses, a set of 21 low-familiarity landmarks and at least 21 high-familiarity landmarks was selected and used as stimuli in their unique version of the experiment.

Study procedure. The experiment included three conditions: scene memory, autobiographical memory, and imagination of the future (for a schematic of the study procedure, see Figure 1). Each condition consisted of 14 trials (seven using high-familiarity landmarks as cues, and seven using low-familiarity landmarks as cues). Each landmark was randomly assigned to one of the conditions, and was only used once in the study. The study was blocked by condition in order to minimize any confusion between the tasks, and the order of the conditions was counterbalanced across participants to eliminate any order effects. Before starting each condition, participants were shown an example of the trial type by the experimenter, and then they completed two practice trials.

Scene condition. In the scene condition, participants were asked to picture the landmark named on the screen and mentally reconstruct the area surrounding it in as much detail as possible. They were instructed to avoid recalling any specific events or people that they associated with that landmark, focusing on the visuospatial representation of the location only. Each trial began with a prompt instructing participants to “picture the scene around. . .,” and then the name of a landmark appeared on the screen. Participants were instructed to press the space bar as soon as an image of the scene was in mind. The landmark remained on the screen for a maximum of 20 s. Following this retrieval phase was a mental elaboration phase for 30 s, for participants to visualize the scene and to retrieve as many details as possible. The participant was then presented with three rating scales and was asked to assess the memory in terms of amount of detail (1 = *not very detailed* to 5 = *very detailed*; or 0 = *no event*); vividness (1 = *not very vivid* to 5 = *very vivid*; or 0 = *no event*); the most recent time that they visited that landmark (*never*, *<1 month ago*, *1–6 months ago*, *6–12 months ago*, *>1 year ago*, *>5 years ago*). Between each trial there was a 3-s fixation cross.

Autobiographical memory condition. In the memory condition, participants were asked to recall past personal episodes occurring at or around landmarks. Participants were instructed that they should recall events both specific in time and in place (i.e., no longer than 1 day in duration and occurring in close proximity to the landmark in question). The trials followed the same procedure as the scene condition. The only differences were that participants

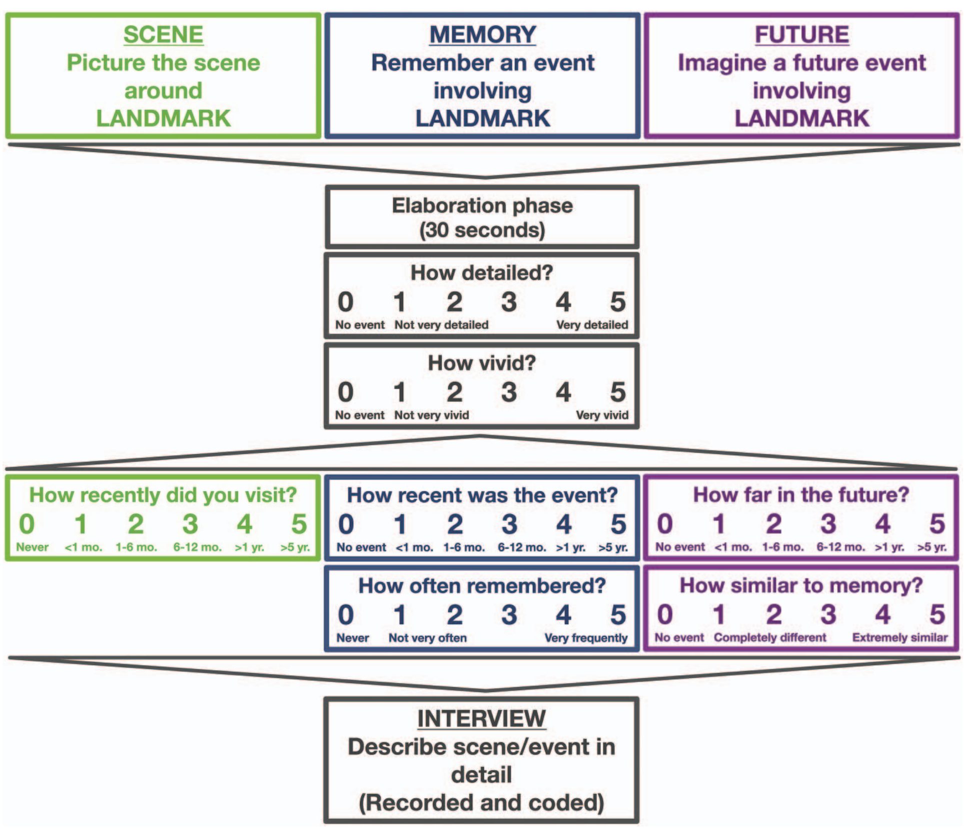

Figure 1. Schematic of the study procedure. In each condition, participants were prompted to picture a scene, remember an event, or imagine a future event based on a landmark cue. Once retrieved, participants were prompted to mentally elaborate on the scene or event in as much detail as possible. Next, participants rated the scenes and events based on their detail and vividness. Subsequent rating scales varied by condition (see color coding in figure). After each condition, participants were asked to describe a subset of the scenes and events aloud. See the online article for the color version of this figure.

were asked to indicate length of time since the event actually occurred (*0 = no event*, *<1 month*, *1–6 months*, *6–12 months*, *>1 year*, *>5 years*) and the amount of rehearsal of the memory (0 = *never* to 5 = *very frequently*) during the rating scales portion.

Future condition. In the future condition, participants were asked to conjure a plausible future event involving themselves and the landmark presented on the screen. As in the autobiographical memory condition, they were instructed to imagine events specific in time and place, and that were distinct from any past memories involving the landmark in question. In addition, it was noted that each imagined event should differ in content from one another and not simply be the same event occurring in different settings. The procedures were identical to the previous conditions, except that participants were asked to indicate how far in the future the imagined event took place (*no event*, *<1 month*, *1–6 months*, *6–12 months*, *>1 year*, *>5 years*) instead of recency, and how similar the imagined event was to a past memory on a rating scale ranging from 1 = *completely different* to 5 = *extremely similar*.

In all three conditions, if participants failed to press the spacebar indicating a memory, scene, or imagined event was in mind, or chose *0 = no event* for any of the rating scales, that trial was discarded from the analysis. Participants who indicated this for more than half of the trials in any condition were excluded from analyses. Of the retained participants, younger participants completed 92.5% of trials (mean number of trials by condition: scene = 12.9/14; memory = 12.5/14; future = 13.5/14), and older participants completed 90.3% of trials (mean number of trials by condition: scene = 13.2/14; memory = 12.6/14; future = 12.2/14).

Poststudy interviews. Following each condition, a short interview was performed with each participant in order to obtain an objective measure of detail in conjunction with the participants' subjective ratings. In the interview, two high-familiarity and two low-familiarity landmarks were randomly selected from the previous experimental condition and participants were asked to describe in detail the memory, scene, or imagined event that they conjured based on that landmark. The interview techniques were based on the AI (Levine et al., 2002), in which participants were first asked to freely recall and describe the scene or event, followed by some general probing (e.g., "Are there any other details that come to mind?"). There was no specific probing for particular types of details. The participants were asked to describe the scenes and events in as much detail as possible, and were advised that they could opt to skip a certain landmark if they had failed to conjure a scene, memory, or imaginary event associated with that landmark during the experiment, or did not wish to describe the associated event or scene for any reason.

The interviews were recorded using a digital voice recorder, and the sound files were transferred to a computer and transcribed by a research assistant, and later verified by a second transcriber. Transcribed interviews were then scored for the number of relevant details in each memory, imagined event, or scene. The number of relevant details was counted for each interview, while the coder remained blind to whether the landmark was of high or low familiarity to the participant. A second coder scored 20% of the interviews from each age group and all three conditions, and interrater reliability was found to be high for both internal (r = .949) and external details (r = .943).

For memories and imagined events, detail scoring was based on guidelines from the AI, in which relevant (or "internal") details are defined as those that are directly related to the event being recounted, whereas external details consisted of semantic or other extraneous information (Levine et al., 2002). Following this procedure, the main event in each description was identified and the interview was segmented into details. A detail was defined as a unique occurrence, observation, or thought, typically expressed as a grammatical clause (i.e., "I met my friend Joanna"; Levine et al., 2002). Additional information in the clause would count as additional details. For example, "I met my friend Joanna at St. Lawrence Market last Friday" contains three details: an event (meeting a friend), a location (St. Lawrence Market), and a time (last Friday). Internal details were those that directly related to the main event being described, including any actions or events that occurred; the time, the place, or the people involved; and sensory perceptions, thoughts, or feelings felt or expressed at the time. Importantly, spatial details about the landmarks were excluded in the memory and future conditions in order to examine the effects of cue familiarity on nonspatial aspects of the events.

All other details, including unrelated events, general background or semantic information, reflections or judgments of the memories or future events, and repetitions or similar statements were considered "external" details, consistent with coding guidelines and previous studies (Levine et al., 2002; Robin & Moscovitch, 2014). External details are those irrelevant to the event being described, or those that are considered nonepisodic in nature, reflecting semantic information or information related to recurring events (e.g., "we often play tennis") rather than specific event details unique to the episode. Imagined future events were coded according to the same guidelines as memories, except that uncertain statements using terms such as "probably" or "hopefully" were taken as factual statements, due to the fact that people tend to describe imagined events in more uncertain terms than actual memories.

The number of details in each scene description was coded according to separate guidelines. For scenes, only visual or spatial information about the landmark and its surrounding area was considered as a relevant detail. Descriptions of the building itself, colors, textures, placement of windows, signs or doors, and similar descriptions of the area or buildings surrounding the landmark were counted as details. Event-specific information, general knowledge, or other semantic information were considered external details in this case.

Neuropsychological tests. Following the completion of all experimental conditions and interviews, participants completed a set of neuropsychological tests to evaluate general cognitive function. The tests included the Verbal Associative Fluency Test, the Wechsler Memory Scale Revised/III/IV: Logical Passages/Memory I (immediate) and II (delay), the digit span test, a computerized test of spatial memory based on the table-top spatial memory test (Smith & Milner, 1981), the Trail Making Task A & B, and the Shipley Vocabulary Test (Shipley, 1940). In the spatial memory test, eight objects were presented on a 4 × 6 grid for 10 s. Then, the objects reappeared on the side of the screen and participants were asked to replace the objects back in their locations in the grid. This procedure was repeated three times, with the objects in the same locations throughout. Then, after a 10-min delay, participants were asked to again replace the objects in their locations in the grid, without an immediately preceding study phase. Accuracy was measured by calculating the average distance between the chosen location and the target location (for which a correct response would have a distance of zero). This was assessed across the three immediate trials and separately for the delayed memory test.

Results

Detail and Vividness Ratings

To assess the effects of age and cue familiarity on the subjective ratings of detail for the scenes, memories, and imagined events, we conducted a 2 × 2 × 3 mixed factorial ANOVA with one between-subjects factor (Age: young, old), two within-subjects factors (Familiarity [high, low] and Condition [scene, memory, future]; see Figure 2). For detail ratings, we found a large significant main effect of Familiarity, $F(1, 34) = 202.96$, $p < .001$, $\eta^2 = .86$, indicating that more familiar cues produced higher ratings of detail. There was also a significant Familiarity × Condition interaction, $F(2, 68) = 12.34$, $p < .001$, $\eta^2 = .27$. Post hoc paired t tests collapsing across age group confirmed that the more familiar cues led to higher ratings of detail in all three conditions (scene: $t[35] = 10.51$, $p < .001$, $r = .87$; memory: $t[35] = 6.97$, $p < .001$, $r = .76$; future: $t[35] = 6.74$, $p < .001$, $r = .75$), although this effect was strongest in the scene condition. There were no significant main effects of Condition, $F(2, 68) = 1.69$, $p = .193$, or Age, $F(1, 34) = .91$, $p = .346$, and no other significant interactions: Familiarity × Age, $F(1, 34) < 1$, $p = .193$; Condition × Age, $F(2, 68) < 1$, $p = .490$; Familiarity × Condition × Age, $F(2, 68) = 2.08$, $p = .133$. Because subjective ratings of detail and vividness were very highly correlated in both young adults, $r(18) = .85$, $p < .001$, and older adults, $r(18) = .97$, $p < .001$, we only describe analyses for detail ratings, but identical patterns were found for vividness ratings (see Figure 3).

Internal Details

The number of internal details reported was examined according to the factors of Age, Familiarity, and Condition using a 2 × 2 × 3 mixed factorial ANOVA. This analysis revealed main effects of Age, $F(1, 34) = 9.88$, $p = .003$, $\eta^2 = .23$, Condition, $F(2, 68) = 7.39$, $p = .001$, $\eta^2 = .18$, and Familiarity, $F(1, 34) = 25.77$, $p < .001$, $\eta^2 = .43$. The significant main effect of Age reflected the

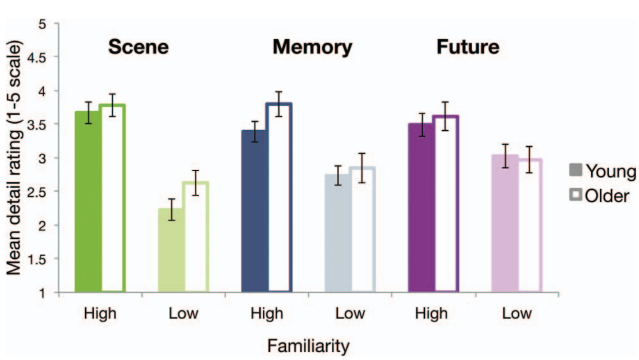

Figure 2. Average detail ratings for remembered scenes, remembered events, and imagined future events, across young and older adults, and high- and low-familiarity spatial cues. Error bars represent standard error of the mean. See the online article for the color version of this figure.

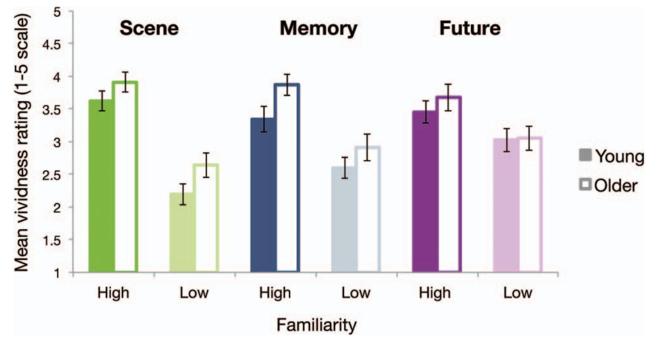

Figure 3. Average vividness ratings for remembered scenes, remembered events, and imagined future events, across young and older adults, and high- and low-familiarity spatial cues. Error bars represent standard error of the mean. See the online article for the color version of this figure.

expected pattern of younger adults producing more internal details than did older adults (see Figure 4). The main effect of Familiarity replicated the findings from subjective ratings of increased detail for more familiar cues. There was also a significant Familiarity × Condition interaction, $F(2, 68) = 4.00$, $p = .023$, $\eta^2 = .11$. Post hoc paired t tests collapsing across age group confirmed that the more familiar cues led to a higher number of internal details in all three conditions (scene, $t[35] = 5.47$, $p < .001$, $r = .68$; memory, $t[35] = 2.70$, $p = .011$, $r = .42$; future, $t[35] = 2.54$, $p = .016$, $r = .39$), though this effect was strongest in the scene condition and marginal in the future condition when using an alpha level of .016, Bonferroni-corrected for multiple comparisons. No other interactions reached significance: Familiarity × Age, $F(1, 34) < 1$, $p = .906$; Condition × Age, $F(2, 68) = 2.54$, $p = .087$; Familiarity × Condition × Age, $F(2, 68) < 1$, $p = .563$.

Spatial details were excluded from the memory and future conditions to ensure that the cue familiarity effects were not driven simply by the presence of more spatial information in the events associated with more familiar locations. When these spatial details were analyzed for the memory and future conditions, it was found that, overall, very few spatial details were produced in these conditions ($M = 1.59$, $SD = 3.09$). A 2 × 2 × 2 mixed factorial ANOVA found no significant effect of Age, $F(1, 34) < 1$, $p =$

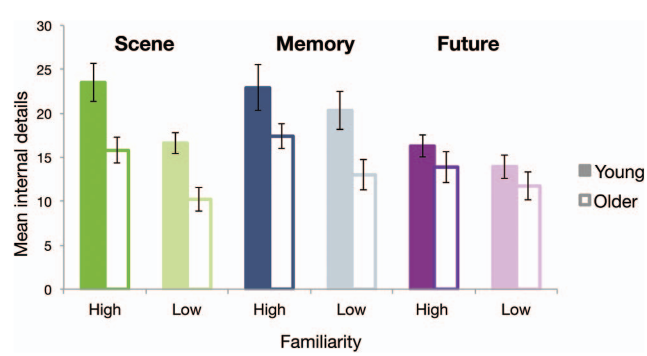

Figure 4. Average number of internal details provided for remembered scenes, remembered events, and imagined future events, across young and older adults, and high- and low-familiarity spatial cues. Error bars represent standard error of the mean. See the online article for the color version of this figure.

.662, or Familiarity, $F(1, 34) < 1$, $p = .880$, on the number of spatial details, and a marginal effect of Condition, $F(1, 34) = 4.24$, $p = .047$, $\eta^2 = .11$. This effect of condition was driven by significantly more spatial details in the memory condition (M = 2.22, SD = 3.74) than in the future condition (M = .958, SD = 1.37), $p = .014$.

External Details

When the number of external details was examined using 2 × 2 × 3 mixed factorial ANOVA, significant main effects of Age, $F(1, 34) = 21.67$, $p < .001$, $\eta^2 = .39$, and Familiarity, $F(1, 34) = 9.63$, $p = .004$, $\eta^2 = .22$, were found, and a marginal main effect of Condition, $F(2, 68) = 3.06$, $p = .053$, $\eta^2 = .08$. The significant main effect of age reflected the expected pattern of younger adults producing fewer external details than older adults, as shown in Figure 5. There were significant Familiarity × Age, $F(1, 34) = 12.31$, $p = .001$, $\eta^2 = .27$, and Familiarity × Condition, $F(2, 68) = 5.09$, $p = .009$, $\eta^2 = .13$, interactions, but there were no significant interactions for Condition × Age, $F(2, 68) < 1$, p = .41, and Familiarity × Condition × Age, $F(2, 68) = 1.06$, $p = .35$. Post hoc paired t tests collapsing across condition showed that the more familiar cues led to a higher number of external details than the low-familiarity cues across all conditions for the older group, $t(53) = 3.72$, $p < .001$, $r = .46$, but not the younger group, $t(53) = -.43$, $p = .67$. Post hoc paired t tests collapsing across age group confirmed that the more familiar cues led to a higher number of external details in the memory condition, $t(35) = 3.28$, p = .002, $r = .48$, but not in the scene condition, $t(35) = -.16$, p = .88, or in the future condition, $t(35) = 2.08$, $p = .045$, $r = .33$, when using a Bonferroni-corrected alpha value of .01.

Temporal Proximity Ratings

Temporal proximity (i.e., recency of landmark visit, recency of memory, time period of future event) ratings were analyzed using 2 × 2 mixed factorial ANOVAs with factors of Age and Familiarity separately for each condition because different measures were collected for each task. These ratings could not be included as covariates in the previous analyses of detail, because the specific measures collected differed according to each condition, and were collected for each familiarity condition rather than one overall measure per participant. For the scene condition, the recency of the last visit to the landmark differed according to factors of Age, $F(1, 34) = 37.98$, $p < .001$, $\eta^2 = .53$, and Familiarity, $F(1, 34) = 22.38$, $p < .001$, $\eta^2 = .40$. There was also a significant Age × Familiarity interaction on the recency of the last visit to the landmark, $F(1, 34) = 7.33$, $p = .011$, $\eta^2 = .18$. Post hoc paired t tests revealed that more familiar landmarks were visited significantly more recently than less familiar landmarks by the younger adults, $t(17) = 7.42$, $p < .001$, $r = .87$, but this was not the case for the older adults, $t(17) = 1.17$, $p = .258$. On average, younger adults visited the landmarks more recently than did older adults ($M_{young} = 2.31$, $M_{old} = 3.57$).

For the memory condition, the recency of the memory differed according to Age, $F(1, 34) = 26.02$, $p < .001$, $\eta^2 = .43$, and Familiarity, $F(1, 34) = 7.70$, $p = .009$, $\eta^2 = .19$, but there was no significant interaction between the two factors, $F(1, 34) = 1.25$, $p = .271$. Memories cued by more familiar landmarks had occurred more recently than those cued by less familiar landmarks ($M_{high} = 3.55$, $M_{low} = 3.92$). Older adults tended to recall memories that occurred longer ago than younger adults ($M_{young} = 3.26$, $M_{old} = 4.22$).

For the future condition, participants rated how far in the future their imagined event took place. This rating did not differ according to Age, $F(1, 34) = 1.08$, $p = .31$, or Familiarity, $F(1, 34) < 1$, $p = .95$, and there was no significant interaction between the two factors, $F(1, 34) < 1$, $p = .64$. Overall, imagined events tended to take place sometime in the next year, but not in the next month ($M = 2.84$). For analyses of other subjective ratings, refer to the online supplemental materials.

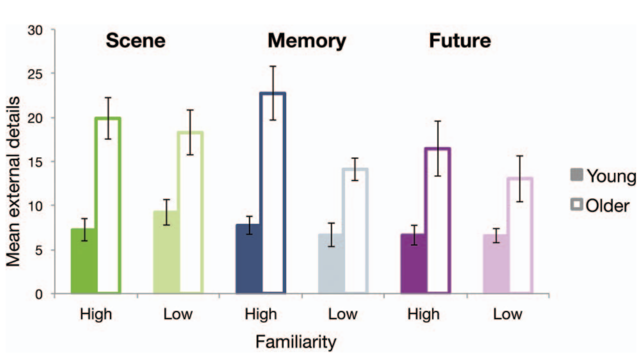

Figure 5. Average number of external details provided for remembered scenes, remembered events, and imagined future events, across young and older adults, and high- and low-familiarity spatial cues. Error bars represent standard error of the mean. See the online article for the color version of this figure.

Discussion

This study demonstrates the pervasive effects in younger and older adults of spatial context familiarity on real-world memory quality. Across young and older adults, more familiar spatial contextual cues led to more detailed representations not only of the scenes evoked by the cues but also of remembered and, to some extent, imagined events associated with the cues, even when only nonspatial details were considered. These effects were evident in terms of self-ratings of detail and vividness, and more objective measures of detail, based on the coded verbal descriptions of the scenes and events. The effect of cue familiarity was strongest in the scene condition, carrying over to the remembered events in terms of objective and subjective measures of detail and the imagined future event condition in terms of subjective detail, and marginally for objective detail.

Importantly, the effect of cue familiarity was observed despite an age-related decline in internal details. There was a consistent decline in the number of internal details provided by older adults in all three conditions: remembered scenes, remembered events, and imagined future events. This finding replicates previous reports demonstrating that older adults produce decreased internal details for remembered and imagined events (Addis et al., 2010, 2008; Gaesser et al., 2011; Rendell et al., 2012; Romero & Moscovitch, 2012), and provides a novel demonstration that it is also true of remembered scenes. The decline in internal details did not vary according to condition or according to the familiarity of the cue. This objective detail measure differed from the subjective ratings of detail and vividness, which were equivalent in young and older adults, consistent with previous studies reporting age-related memory decline for objective measures of memory richness and detail, but not subjective ratings (St. Jacques et al., 2012; St-Laurent, Abdi, Burianová, & Grady, 2011).

Previous studies of episodic memory and imagination in healthy aging have hypothesized that age-related decreases in internal details are related to a reduced ability to form or retrieve coherent relations, owing to a decline in hippocampal function with age (Addis et al., 2010, 2008; Romero & Moscovitch, 2012). Alternatively, the scene construction theory (Hassabis & Maguire, 2007; Maguire & Mullally, 2013; Mullally & Maguire, 2014) might ascribe these changes to the fact that the ability to represent scenes relies on the hippocampus, and all three of these conditions involve representations based on constructing scenes from memory. These results are consistent with both hypotheses, given that mentally constructing spatial scenes requires forming representations rich in relations and has been shown to be impaired in cases of hippocampal damage (Hassabis et al., 2007).

Thus, although a common reliance in both age groups on underlying processes or neural structures may account for the decline seen across all three conditions, the facilitation relating to spatial context familiarity in both groups suggests a shared reliance on spatial contextual representations that persists throughout the life span in healthy participants. This interpretation is consistent with previous research showing that context reinstatement effects are stable or even increase in aging, despite overall declines in episodic memory (Craik & Schloerscheidt, 2011; Naveh-Benjamin & Craik, 1995), and extends these findings by showing that they additionally apply to real-world scene memory, autobiographical memory, and future thinking.

Notably, the cue familiarity effect was the weakest in the future imagination condition, as demonstrated by the significant interaction between familiarity and condition, and post hoc comparisons revealing only a marginal effect of familiarity on internal details across both age groups. This finding is consistent with findings in young adults, in which cue familiarity had no significant effect on internal details for imagined events, but did for remembered events and scenes (Robin & Moscovitch, 2014). In both the present and previous studies, self-ratings of detail and vividness were significantly higher for the imagined events based on more familiar cues, perhaps indicating that the more familiar context increased the subjective richness of the imagined event without affecting the content itself, as measured by the number of details described. Accordingly, imagined events may be less tightly linked to their associated contextual representations, perhaps because the events were not actually experienced in those locations, unlike in the case of memories. The finding that the memory condition had significantly more spatial details than the future condition (though still very few) may support this interpretation. In addition, in both studies, the future condition was also the one with the fewest details reported overall, which may contribute to the attenuated contextual familiarity effects observed.

The pattern of external detail production differed from that of internal details. As expected, older adults produced more external details than the younger adults across all conditions. This replicates numerous studies of memory and imagination (Addis et al., 2010, 2008; Gaesser et al., 2011; Levine et al., 2002), and shows that this pattern extends to scene memory as well. Interestingly, for older adults, more familiar spatial cues also led to the production of more external details, especially in the memory condition. In contrast, this pattern was not shown in younger adults. The increase in external details in the older adults may indicate that the more familiar cues serve to activate diverse knowledge relating to the landmark, including semantic or unrelated information, and not only the specific details relevant to performing the memory and imagination task. The high-familiarity cues in this study would presumably have more associations than the less familiar cues in both hippocampally related episodic memory and nonhippocampally related semantic memory, consistent with the notion that more general schematic or semantic representations, represented extrahippocampally, can be used to support episodic memory (Kan et al., 2009; Race et al., 2015) and imagination (Irish, Addis, Hodges, & Piguet, 2012). As episodic memory declines in older adults, there may be an increased reliance on nonepisodic contextual support (Craik & Schloerscheidt, 2011), and the nonepisodic details that accompany a high-familiarity cue may be used to compensate for the decreased specificity of the events or scenes. Although younger adults may also have access to more external details for the high-familiarity cues, they may not need to rely on these because their episodic memories are more detail-rich or easier to access, or perhaps they can more effectively inhibit the unrelated information (Radvansky, Zacks, & Hasher, 2005).

Although this study replicates previous findings that older adults describe remembered and imagined events in less detail than younger adults (Gaesser et al., 2011; Rendell et al., 2012), Rendell and colleagues (2012) additionally reported that older adults were especially impaired at imagining future events compared with atemporal scenes, and attributed this difference to the additional demand for autonoetic consciousness in that condition. The present study did not find a selective age-related deficit in the conditions requiring autonoetic consciousness (i.e., autobiographical memory and future imagining) compared with the scene memory condition. Thus, we suggest that the differences found by Rendell and colleagues likely cannot be attributed solely to greater impairment in autonoetic consciousness in older adults. An alternative possibility is that the atemporal scene condition in Rendell et al.'s study, which used general cues (e.g., "a sandy beach"), may have been able to be supported by semantic memory representations more so than the conditions requiring specific events. In contrast, the present study used real-world cues from previously visited locations, which may have made greater demands on detailed spatial representations mediated by the hippocampus, comparable with those used to describe autobiographical events (Hirshhorn et al., 2011; Rosenbaum et al., 2012; Winocur & Moscovitch, 2011; Winocur, Moscovitch, Rosenbaum, & Sekeres, 2010). This interpretation would explain why there was no interaction between age and condition in the present study.

It is important to note that the additional ratings collected in the study revealed that that recency of memories also varied in response to cue familiarity. As expected, in the scene and memory conditions, more familiar landmarks were rated as visited more recently and cued more recently occurring memories, respectively. There was no effect of cue familiarity on the time that the future events were imagined to take place, but based on the other conditions, it is likely that the more familiar landmarks would also have been visited more recently, though this measure was not collected. These findings are not surprising, as it is likely that a more familiar landmark has been visited more recently if it has been visited more times overall. For this reason, it is difficult to tease apart the effects of familiarity from recency in this paradigm, and it is possible that the familiarity effects described above are related to having visited the landmarks more recently as well as more often. Furthermore, although participants were instructed to judge familiarity based on number of visits, other factors, including recency and even scene vividness, may have contributed to judgments of landmark familiarity. Although it is difficult to control these factors in real-world memory paradigms such as this one, future studies using different paradigms could compare cue familiarity and recency to examine their possibly independent contributions to detail richness of memory and imagination.

In conclusion, the present study provides a novel demonstration that familiarity with a spatial contextual cue affects scene memory, episodic memory, and future thinking over the life span. Despite overall age-related decline in the specificity and detail richness of memory for scenes, events, and imagination of future events, a more familiar spatial context provides an equivalent benefit to all three in both age groups. This finding supports the notion that the quality of spatial memory, autobiographical memory, and imagination depends, at least somewhat, on the associated spatial contextual representation, and that this is stable throughout the life span. This study demonstrates how scene memory, episodic memory, and imagination of the future are all similarly affected by ageing, with decreases in the number of specific details reported for all three types of representations in the older group. More broadly, this study indicates that familiar spaces or locations can serve as powerful memory triggers, and perhaps even enhance encoding of new memories in older individuals, both of which can be used to create memory aids and implement interventions in aging populations.

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Received November 18, 2015
Revision received January 5, 2017
Accepted January 10, 2017 ■