Cognition 190 (2019) 81–92

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/cognit

Original Articles

Spontaneous memory retrieval varies based on familiarity with a spatial context

Jessica Robin[a,b,*], Luisa Garzon[b], Morris Moscovitch[a,b,c]

[a] Rotman Research Institute, Baycrest Health Sciences, 3560 Bathurst Street, Toronto, ON M6A 2E1, Canada
[b] Department of Psychology, University of Toronto, 100 St. George Street, Toronto, ON M5S 3G3, Canada
[c] Department of Psychology, Baycrest Health Sciences, 3560 Bathurst Street, Toronto, ON M6A 2E1, Canada

ARTICLE INFO

Keywords:
Involuntary memory
Autobiographical memory
Semantic memory
Episodic memory
Spatial context

ABSTRACT

Spatial context can serve as a powerful cue for episodic memory. In daily life, we encounter locations varying in familiarity that may trigger different forms of memory retrieval. While previous research on autobiographical memory suggests that more familiar landmarks cue more detailed memories, theories such as cue overload predict that less familiar cues will more reliably trigger specific memory retrieval. It is therefore possible that more and less familiar cues will differentially elicit more generalized and specific memories, respectively. In this series of studies, we develop a novel paradigm for eliciting spontaneous memory retrieval based on real-world spatial contexts varying in familiarity. We found evidence that more familiar contexts generally lead to higher rates of spontaneous memory retrieval for semantic and generalized memories, but that episodic memories are more frequently retrieved for less familiar cues. These patterns demonstrate how related memories lead to the formation of more generalized representations over time, while memories with fewer associates remain episodic. We discuss these findings in relation to those obtained in a version of the study in which participants were instructed to retrieve thoughts. Together these findings provide novel insight into the dynamics of context familiarity and memory retrieval in a naturalistic autobiographical memory paradigm.

1. Introduction

Spatial context is a ubiquitous feature of episodic memory. In everyday life, spatial context is often complex, dynamic, and serves as a potent cue for memory retrieval. For example, walking by a movie theatre may remind you of the last movie you saw there, make you think of what movies are currently playing, or trigger thoughts about when you might go there next. While the role of spatial context in memory retrieval has been extensively studied in the laboratory (Smith & Vela, 2001), only a handful of studies examine the influence of complex, naturalistic contextual cues on real-world memories. In the present study, we used a novel, naturalistic paradigm to examine the relationship between the familiarity of real-world spatial contexts and the frequency and types of memories retrieved based on those contexts.

Studies examining the role of contextual familiarity on memory and imagination have consistently found that more familiar contexts facilitate aspects of memory retrieval and event imagination (Arnold, McDermott, & Szpunar, 2011; D'Argembeau, Ortoleva, Jumentier, & Van der Linden, 2010; de Vito, Gamboz, & Brandimonte, 2012; McLelland, Devitt, Schacter, & Addis, 2015; Robin & Moscovitch, 2014, 2017b; Robin, Wynn, & Moscovitch, 2016; Szpunar & McDermott, 2008). Remembered and imagined events set in more familiar contexts are more detail-rich and more vividly experienced than those in less familiar, or unfamiliar, contexts (Arnold et al., 2011; D'Argembeau & Van der Linden, 2012; de Vito et al., 2012; McLelland et al., 2015; Robin & Moscovitch, 2014, 2017b; Robin et al., 2016; Szpunar & McDermott, 2008). These effects have been hypothesized to relate to the role of spatial context serving as a scaffold for episodic memory and imagination, wherein a stronger scaffold provides support for more detailed and vivid events (Hassabis & Maguire, 2007, 2009; Nadel, 1991; O'Keefe & Nadel, 1978; Robin & Moscovitch, 2014, 2017b; Robin et al., 2016). These effects are also consistent with the encoding specificity principle, which predicts that a greater match between a cue and a stored memory will increase the probability of retrieval success (Tulving & Thomson, 1973; Wiseman & Tulving, 1976). Thus, a more familiar context may have a richer representation in memory, which provides a better match to a cue and elicits more robust memory recall or event imagination.

Familiar spatial contexts may serve as particularly effective cues for triggering spontaneous memory retrieval, but this relationship has yet

* Corresponding author at: Baycrest Health Sciences, 3560 Bathurst Street, Toronto, ON M6A 2E1, Canada.
E-mail address: jrobin@research.baycrest.org (J. Robin).

https://doi.org/10.1016/j.cognition.2019.04.018
Received 18 September 2018; Received in revised form 17 April 2019; Accepted 20 April 2019
Available online 28 April 2019
0010-0277/

to be explored directly. Spontaneous memories, or more specifically, involuntary autobiographical memories (IAMs) are memories of personal events that come to mind with no deliberate attempt at retrieval, and are a frequent occurrence in daily life (Berntsen, 1998, 2007, 2010; Rasmussen & Berntsen, 2011). Early studies of IAMs relied on diary procedures, but more recent research has developed ways of measuring and eliciting IAMs in the laboratory to explore which factors modulate the retrieval of spontaneous memory (Barzykowski & Niedźwieńska, 2016; Barzykowski & Staugaard, 2017; Berntsen, Staugaard, & Sørensen, 2013; Mace, 2005; Mace, 2006; Schlagman & Kvavilashvili, 2008; Vannucci, Batool, Pelagatti, & Mazzoni, 2014). This research has demonstrated that factors such as instructions, attention, priming and cue types can all affect the frequency and characteristics of involuntary memories. In particular, distinctive external cues, peripheral to an event, are thought to elicit spontaneous autobiographical memories more reliably, which tend to be clearer and more vivid than voluntarily retrieved memories (Barzykowski & Niedźwieńska, 2016; Berntsen, 2007; Berntsen & Hall, 2004; Schlagman, Schulz, & Kvavilashvili, 2006; Wagenaar, 1986). Thus, studying spontaneous memories elicited by spatial context may provide insight into how spatial context supports episodic memory and serves as a frequent cue for involuntary autobiographical memory retrieval. Given past findings that spatial context is especially effective in retrieving memories for events voluntarily, we predicted that it may play a similar role in involuntary retrieval.

Previous research documenting the cue overload or fan effect (Anderson & Reder, 1999; Watkins & Watkins, 1975) predicts that "the probability of recalling an item declines with the number of items subsumed by its functional retrieval cue" (Watkins & Watkins, 1975). Thus, a more familiar context, with numerous associations stored in memory, would be predicted to be a *less* effective memory cue, as a result of the interference between its associated memories or, alternatively, as a result of diminished distinctiveness of the cue and/or related memories (Hunt & Smith, 1996; Mäntylä & Nilsson, 1988; Moscovitch & Craik, 1976; Talmi & Moscovitch, 2004; Wagenaar, 1986). A study of involuntary memory retrieval found evidence consistent with this prediction, with cues having fewer associations being more likely to elicit spontaneous retrieval of these associations (Berntsen et al., 2013). In this series of experiments, participants learned associations between sound cues and pictures in the lab, in which each of the sound cues and pictures were either unique or repeated. Later, participants completed an involuntary retrieval task in which sound cues were played in the context of another task, but participants were asked to report if any pictures spontaneously came to mind. The highest instance of spontaneous retrieval of the associated pictures occurred in the condition with a one-to-one (rather than one-to-many) correspondence between sound and picture. It was also found that memories retrieved in the condition with repeated cues and scenes were rated to be less specific and clear than those in the condition with unique cues and scenes.

Thus, previous studies relating to the cue overload theory suggest that fewer associations to a cue will more reliably lead to recall of a specific memory, which would predict that *less familiar* contexts may be better cues for specific episodic memories. In contrast, the autobiographical memory studies reviewed above suggest that *more familiar* cues facilitate voluntary memory retrieval and imagination, leading to more detailed and vivid memories. Another possibility is that more and less familiar contexts may cue different types of memories. Less familiar cues may elicit specific, episodic memories, while more familiar cues may result in the retrieval of more general or semanticized representations. As cues become more familiar and gain more associated memories, there may be a trade-off between the retrieval of specific episodic memories and more generalized forms of memory, representing semanticization of associations to the cues or the formation of schemas related to those episodes. Previous studies that restrict retrieval to one type of memory, such as autobiographical episodes or semantic information are not able to simultaneously measure different memory types and how these relate to different cues. In order to test how familiarity with a spatial context affects the frequency and type of memory retrieval, we designed a novel paradigm to elicit spontaneous real-world memories and other types of thoughts in response to spatial contextual cues varying in familiarity.

In this novel paradigm, across three experiments, participants were shown a series of pictures of well-known landmarks in Toronto. In Experiment 1 participants were asked to study each scene and later were asked to answer a question about a visual detail of the scene. Participants were asked to indicate if they noticed any thoughts that came to mind while viewing the scene, and to categorize these thoughts based on their content. The visual memory question served as a cover task so that memory retrieval was spontaneous and not directed. In Experiment 2, we replicated the same procedure but participants were additionally asked to provide verbal descriptions of the thoughts that came to mind, which were coded and analysed. This addition was made in order to provide a more objective characterization of the types of thoughts reported by the participants.

In order to determine if the effects observed in Experiments 1 and 2 were related to the spontaneous nature of the memory retrieval, in Experiment 3, participants were not asked a visual memory question and were simply instructed to study the scene and report if it reminded them of anything. While autobiographical memory retrieval was still not specifically cued, the retrieval of memories and thoughts related to the picture was overtly prompted in this experiment, allowing us to determine if the relationship between context familiarity and memory retrieval varied based on retrieval mode (Rugg & Wilding, 2000; Tulving, 1983a; Tulving, 1983b). In all three experiments, participants completed a second section in which they viewed all the landmarks again and indicated if they recognized them based on real-world experience and made familiarity judgments if they did. This procedure allowed us to assess the occurrence of various thought types, including memories, in response to real-world spatial contextual cues based on their familiarity.

We predicted that spatial contexts would reliably elicit spontaneous autobiographical memories, as well as other types of related thoughts such as semantic memories and thoughts about the future. We predicted that more familiar spatial contexts would result in higher rates of related thoughts, consistent with previous studies of spatial context and autobiographical memory. However, if the cue overload effect applies to real-world episodic memory, the occurrence of specific episodic memories would be expected to be higher in response to spatial locations that have been visited fewer times. In contrast, memories retrieved in response to highly familiar cues would be predicted to reflect more generalized representations (Berntsen & Hall, 2004). This study extends and bridges existing literatures by providing insight into the dynamics of real-world memory retrieval and into how familiarity with a spatial context affects retrieval. Our findings have theoretical implications regarding the cue overload and fan effects, and help to elucidate how episodic memories may be maintained as episodes or transformed into more generalized representations.

2. Methods

2.1. Experiment 1

2.1.1. Participants

Thirty young adults (22 female, 8 male; mean age = 20.67 years, SD = 3.49, range: 18–30) were recruited through advertisement (and received $10 CAD/hour as compensation) or through undergraduate courses (and received course credit) at the Department of Psychology, University of Toronto. Participants had completed an average of 14.07 years of formal education (SD = 2.39), were native or fluent English speakers, had normal or corrected-to-normal vision and hearing, and had no history of psychological or neurological disorders. All participants had lived in Toronto for at least one year (mean = 12.48, SD = 8.81), in order to ensure that they had potentially had experience with the various landmarks featured in the study, and had a variety of old and new memories associated with them. All participants provided informed consent prior to participating in the experiment, in accordance with the University of Toronto Office of Research Ethics.

2.1.2. Materials

The experiment was programmed and run with E-Prime 2.0 (Psychology Software Tools, Inc.). The experiment was run on a computer with a 17–in (43.18 cm) CRT monitor set at 1024 × 768 resolution. One hundred and five landmarks were chosen based on the Toronto Public Places Test, and other related studies using Toronto landmarks (Robin & Moscovitch, 2014, 2017b; Robin et al., 2016; Rosenbaum, Ziegler, Winocur, Grady, & Moscovitch, 2004). For each landmark, images were obtained from Google StreetView of the exterior of the building and its immediate surroundings. Two views of each landmark were collected. A pilot study was conducted to determine the most recognizable view, and that image was selected for use in the present study. Images were resized to 700 × 400 pixels. Images filled the screen in the scene study phase and were displayed at 75% size for the recognition phase. Participants viewed the screen from a distance of approximately 80 cm.

2.1.3. Procedure

The experiment consisted of two phases: a scene study phase and a recognition phase. The scene study phase consisted of 105 trials, each including a picture of a scene from Toronto presented in a continuous randomized order. Between each trial, a 2-second fixation cross was displayed. Participants were instructed that they would be presented with scenes and were instructed to passively view the scene for the 10-second trial. Participants were told that they would be asked questions about the scenes later in the experiment.

Crucially, participants were not given explicit instructions to report on the occurrence of memories, but were asked to press the space bar on the keyboard when they noticed “any particular thoughts” that came to mind while looking at the scene. If the participant pressed the space bar, the trial continued uninterrupted, but was followed by a screen prompting participants to classify what thoughts came to mind. Categories included: 1 – knowledge about the location (semantic), 2 – memory about being in that location (memory), 3 – thoughts about being there in the future (future), 4 – some combination of 1, 2 and/or 3 (mix), 5 – unrelated memories or thoughts (unrelated), 6 – other unrelated thoughts (other). Categories 5 and 6 both referred to unrelated thoughts and were grouped together for all analyses. These categories were presented and explained to participants, with examples, during the practice session. Following the thought categorization, or immediately following the scene if no thoughts were reported, participants were asked a question about a visual feature of the scene (e.g. how many windows were in the scene?). There was a pool of 15 possible visual questions, of which one was randomly selected on each trial. The visual memory question served as the cover task to have participants believe that this was a visual attention and memory experiment, and the main focus was not the spontaneously reported thoughts. The structure of one trial in which the space bar was pressed is shown in Fig. 1A.

After the scene study phase, participants completed the scene recognition phase of the experiment. In the scene recognition phase, all 105 scenes were displayed again in a random order and participants were asked to make a recognition judgment (yes or no) for each scene. Participants were asked if they recognized the scene based only on their personal experiences outside the laboratory setting (i.e. not from having seen these scenes during the scene study phase). If they indicated that they did not recognize the landmark, the trial ended and proceeded to the next scene. If participants indicated that they did recognize the scene, they were asked to rate the landmark according to its familiarity (1–5 scale, corresponding to “not very familiar” to “extremely familiar”), and to estimate how many times they had previously visited it (response options: never, 1–2 times, 3–5 times, 6–10 times, more than 10 times, more than 50 times). If they said they recognized the landmark but then chose “never” for the number of visits that landmark was omitted from the analyses, since we were interested in personally familiar landmarks. Participants also made a recency judgment, indicating the time of their most recent visit to landmark (response options: never, within the past week, within the past month, within the past year, within the past 5 years, more than 5 years ago). Between each trial, a 2-second fixation cross was displayed. The structure of one trial in which the landmark was recognized is shown in Fig. 1B.

Prior to each section, participants were given verbal instructions and detailed explanations of the different response options by the experimenter. Participants completed three practice trials in the presence of the experimenter to ensure that they understood the procedure. The scenes that were used for these trials were from the Greater Toronto Area (GTA), and were not included as stimuli in the subsequent trials. In both phases of the experiment, participants were given the opportunity for a short break after every 30 trials. The entire session lasted approximately 60–90 min depending on the number of thoughts generated, and the number of landmarks that were recognized. After the study, participants were asked about what they thought the study hypotheses were. Most participants stated that they thought the experiment was examining visual memory for scenes, and no participants anticipated that the study was examining the rates and types of spontaneous thoughts based on the familiarity of the landmarks.

2.2. Experiment 2

2.2.1. Participants

Forty-one young adults were recruited through advertisement or through undergraduate courses for this version of the experiment. Four participants were excluded due to computer errors, resulting in 37 participants (26 female, 11 male; mean age = 20.81 years, SD = 2.85, range: 18–30). Participants had completed an average of 14.68 years of formal education (SD = 1.53), were native or fluent English speakers, had normal or corrected-to-normal vision and hearing, and had no history of psychological or neurological disorders. All participants had lived in Toronto for at least one year (mean = 11.26, SD = 7.84). All participants provided informed consent prior to participating in the experiment, in accordance with the University of Toronto Office of Research Ethics.

2.2.2. Procedure

Experiment 2 followed the same procedure as Experiment 1 with the addition of describing thoughts out loud. Following a scene study trial in which the space bar was pressed to indicate a thought, participants were asked to briefly describe the thought that came to mind into a microphone, and their descriptions were recorded. Descriptions were recorded for a maximum of 30-seconds per trial. Participants then proceeded with the trial, completing the thought categorization and visual memory question before continuing to the next trial. If the space bar was not pressed, no recording was made.

Descriptions were transcribed and coded according to the types of thoughts included. A coding scheme was developed based on reading a subset of the transcripts and classifying the types of categories that were included. The coding categories determined were similar to the categories provided to participants in the study, but were more specific, to better capture the types of thoughts observed in the study. The coding categories included: landmark identification (ID; naming the building or location shown in the scene, such as, “that’s Dundas Square”), description of knowledge about the landmark (DK; any semantic information relating to the landmark or scene, such as, “that’s where they have ballet performances”), personal semantic memories relating to the landmark (PS; statements reflecting autobiographical memory, but not

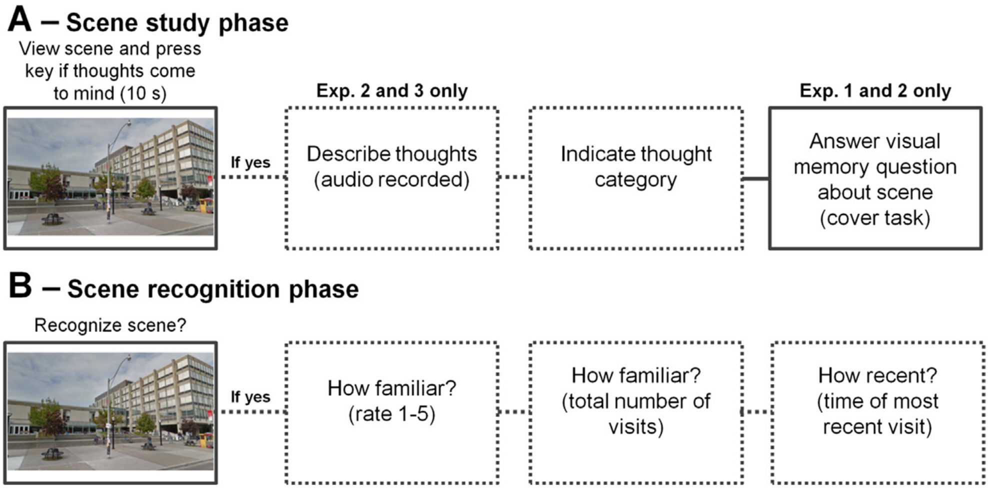

Fig. 1. Summary of experimental methods. (A) In the scene study phase, participants viewed images of landmarks and were instructed to study them, reporting if any thoughts came to mind. If so, participants indicated the category of the thoughts (Semantic memory, Autobiographical memory, Future thoughts, Mix, Unrelated/Other). In Experiments 1 and 2, participants then answered a visual memory question about the scene, which served as the cover task. In Experiment 3, there was no cover task or visual memory question. In Experiments 2 and 3, participants described their thoughts out loud prior to categorizing them, and descriptions were recorded and coded. (B) In the scene recognition phase, participants viewed landmark images again and indicated if they recognized the landmark based on experiences before the study. If so, they indicated how familiar they were with the landmark with a subjective rating and by estimating the number of times they had visited it, and how recently they had visited the landmark.

specific to a single episode, such as, "I pass by there on my way to school"), specific memories relating to the landmark (SM; statements describing specific, personal events at that location, such as, "I went there to see a movie last week"), unrelated specific memories that did not take place at or near the landmark (UM; specific, personal events not at that location), future thoughts (F; statements describing going there in the future, such as, "I have an exam there next week"); picture descriptions (PD; statements commenting on visual aspects of the picture, such as, "there's a red car parked in front"); and other or unrelated thoughts (O; any other information that does not fit in the previous categories, such as, "I can't remember where this is"). Each trial was coded according to what categories it included, and could include more than one of the above categories. Coding for Experiment 2 and 3 was done by two trained raters. A third independent rater coded 20% of the transcripts, and achieved good agreement with the raters (agreement = 90%; Cohen's $\kappa = 0.69$, $p < 0.001$).

This version of the experiment lasted approximately 90–120 min depending on the number of thoughts generated, and the number of landmarks that were recognized. After the study, participants were asked about what they thought the study hypotheses were. Most participants stated that the experiment was examining visual memory for scenes, and no participants anticipated that the study was examining the rates and types of spontaneous thoughts based on the familiarity of the landmarks.

2.3. Experiment 3

2.3.1. Participants

Thirty-five young adults were recruited through advertisement or through undergraduate courses for this version of the experiment. Four participants were excluded due to computer errors, resulting in 31 participants (28 female, 3 male; mean age = 20.48 years, SD = 3.51, range: 18–32). Participants had completed an average of 13.77 years of formal education (SD = 1.99), were native or fluent English speakers, had normal or corrected-to-normal vision and hearing, and had no history of psychological or neurological disorders. All participants had lived in Toronto for at least one year (mean = 8.47, SD = 8.43). All participants provided informed consent prior to participating in the experiment, in accordance with the University of Toronto Office of Research Ethics.

2.3.2. Procedure

Experiment 3 followed the same procedure as Experiment 2, but with the omission of the visual memory cover task. In this experiment, participants were instructed that the focus of the study was on what types of thoughts come to mind when viewing scenes, thus rendering retrieval more directed compared to the previous two experiments. Participants were instructed to view each scene for 10 s and to press the space bar if any thoughts came to mind. If they pressed the space bar, they were prompted to provide short descriptions of the thoughts and categorize them, as in Experiment 2. No visual memory question was posed following the thought categorization. This version of the experiment lasted approximately 90–120 min depending on the number of thoughts generated and the number of landmarks that were recognized.

2.4. Statistical analyses

Data from the three experiments were analysed using mixed ANOVAs with between-subjects factors of Experiment (E1, E2, E3) and within-subjects factors of Familiarity or Recency. ANOVAs were corrected for sphericity violations using the Greenhouse-Geisser correction, when applicable. In these cases, corrected degrees of freedom are reported. Effect sizes are reported via generalized eta-squared (η^2_G). Least-squared means (predicted marginal means) were calculated based on the factors in the ANOVA models and used to compute post-hoc tests of significant effects. Post-hoc tests were conducted using Bonferroni-corrected t-tests or tests of linear contrasts to model linear effects based on increasing levels of familiarity. Data from the three separate experiments were modelled together using omnibus ANOVAs in order to test for effects or interactions relating to the experiment version. Post-hoc tests were conducted, when applicable, on each experiment separately in order to test for the presence and replicability of effects across the three versions of the experiment. Raw data are available on the Open Science Framework, DOI: 10.17605/OSF.IO/C7KVB (Robin, Garzon, & Moscovitch, 2019).

We note that sample size varied across the three versions of the experiment (E1: n = 30; E2: n = 37; E3: n = 31). Our target number of participants for each experiment was 30, based on sample sizes commonly used in previous involuntary memory studies (Barzykowski & Niedźwieńska, 2016, 2018, Barzykowski & Staugaard, 2016, 2017; Berntsen et al., 2013; Mace, McQueen, Hayslett, Staley, & Welch, 2019; Schlagman, Kvavilashvili, & Schulz, 2008). Experiment 2 included more participants (n = 37), which was motivation, in part, for including a factor of Experiment in all analyses, to test if there were significant differences between experiment versions that could be attributable to sample size differences. Due to the open-ended nature of the tasks in these experiments, the number of participants contributing to each analysis varied based on the number of participants who had usable data in all bins, particularly for the familiarity analyses. Data analysis was conducted after subject recruitment was finished, so we could not control how many subjects were included in these analyses. As a result, we have noted how many participants were included in each analysis throughout the results section.

3. Results

3.1. Rates of thoughts by landmark familiarity

In these three experiments, participants reported the incidence and types of thoughts that came to mind while they viewed landmarks varying in personal familiarity. Thoughts could include memories, semantic information, thoughts about the future, and any other or unrelated content that came to mind. We first compared the proportion of trials in which any thought was reported, according to whether the landmark was later recognized or not. A 3 × 2 mixed ANOVA with a between-subjects factor of Experiment (E1, E2, E3) and a within-subjects factor of Landmark Recognition (Recognized, Not recognized) revealed a strong significant main effect of Landmark Recognition $F(1, 95) = 355.24$, $p < 0.0001$, $\eta^2_G = 0.503$, and a significant main effect of Experiment $F(2, 95) = 3.61$, $p = 0.03$, $\eta^2_G = 0.052$, with no significant interaction, $F(2, 95) = 0.87$, $p = 0.42$. The main effect of Landmark Recognition reflected significantly higher proportions of trials with thoughts reported when the landmark was recognized (E1: 75.18% of trials, SD = 31.72%; E2: 67.68% of trials, SD = 30.58%; E3: 83.33% of trials, SD = 14.26%) compared to not recognized (E1: 19.72% of trials, SD = 20.82%; E2: 20.86% of trials, SD = 22.52%; E3: 32.91% of trials, SD = 28.58%; see Fig. 2). Bonferroni-corrected comparisons between experiment versions revealed that Experiment 2 had significantly lower proportions of trials with thoughts than Experiment 3, $t(95) = 2.58$, $p = 0.03$, but Experiments 1 and 2, $t(95) = -0.78$, $p > 0.99$, and Experiments 1 and 3, $t(95) = -1.87$, $p = 0.19$, did not differ.

We next examined the influence of landmark familiarity on the overall incidence of thoughts. For the landmarks that were recognized, we compared the proportion of trials in which thoughts were reported, according to the familiarity of the landmark (Fig. 3). We chose to focus on landmark familiarity as determined by number of visits to the landmark, since this was a more objective measure, was more related to personal experience, and was consistent with how familiarity has been defined in previous studies (Robin & Moscovitch, 2014, 2017b; Robin et al., 2016). A 3 × 5 mixed ANOVA with a between-subjects factor of Experiment (E1, E2, E3) and a within-subjects factors of Landmark

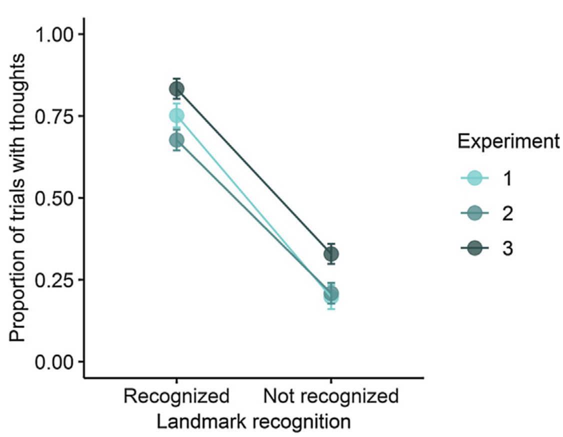

Fig. 2. Proportion of trials with spontaneous thoughts reported (all categories), based on whether the landmark was subsequently recognized or not recognized. Note that proportion of trials with thoughts is calculated separately for recognized and unrecognized landmarks, and thus, these do not sum to 1.

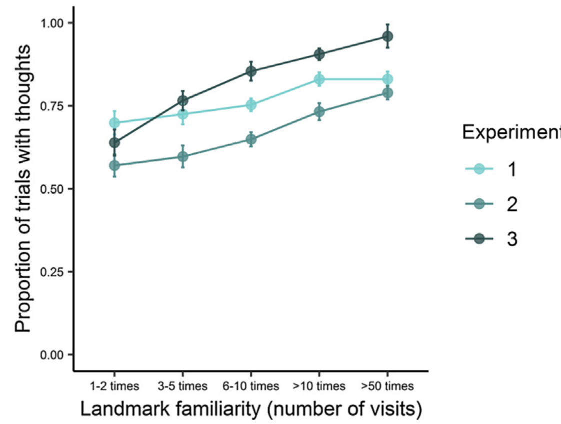

Fig. 3. Proportion of trials with spontaneous thoughts reported (all categories) based on the familiarity of the landmark. This analysis includes only trials in which the landmark was later recognized. Familiarity was defined as the estimated number of previous visits to the landmark.

Familiarity reflecting the estimated number of visits to the landmark (1–2 times, 3–5 times, 6–10 times, > 10 times, > 50 times) revealed a significant effect of Landmark Familiarity on the proportion of trials with thoughts reported, when considering all thought types, $F(2.99, 236.57) = 29.86$, $p < 0.0001$, $\eta^2_G = 0.068$. There was a marginal effect of Experiment, $F(2, 79) = 2.50$, $p = 0.09$, $\eta^2_G = 0.049$, and no significant interaction, $F(5.98, 236.57) = 1.76$, $p = 0.11$. Linear contrasts confirmed that the main effect of Landmark Familiarity reflected an increasing linear trend in all three experiment versions (E1: $t(316) = 3.75$, $p = 0.0006$; E2: $t(316) = 6.98$, $p < 0.0001$; E3: $t(316) = 8.43$, $p < 0.0001$). Note that subjects that did not have observations in every familiarity bin were removed from this analysis (resulting sample sizes: E1: n = 23; E2: n = 33; E3: n = 26). For analyses of thought rates and thought types according to the recency of the landmark instead of its familiarity, see Supplementary Material – Figs. S2 and S3.

3.2. Types of thoughts reported

While the analyses above included all types of thoughts, participants further categorized their thoughts according to the type of content that each thought included. In order to understand the prevalence of each type of thought, we next examined the distribution of the types of thoughts that were reported in each experiment for the trials in which participants recognized the landmarks (Fig. 4). A 3 × 5 mixed ANOVA with a between subjects factor of Experiment (E1, E2, E3) and a within-subjects factor of Thought Type showed a significant effect of Thought Type on the proportion of trials with that thought reported, $F(1.75, 160.98) = 65.34$, $p < 0.0001$, $\eta^2_G = 0.41$, but no significant effect of Experiment, $F(2, 92) = 2.18$, $p = 0.12$, or interaction between Experiment and Thought Type, $F(3.50, 160.98) = 1.76$, $p = 0.15$. Across all three experiments, the most frequently chosen category was Mix, reflecting some combination of semantic information, autobiographical memories and thoughts of visiting a location in the future (E1: 41.58% of trials, SD = 31.22%; E2: 55.95% of trials, SD = 31.91%; E3: 44.57% of trials, SD = 29.67%). The next most frequent category was Autobiographical Memory (E1: 31.34% of trials, SD = 26.59%; E2: 20.85% of trials, SD = 20.64%; E3: 22.58% of trials, SD = 18.93%), followed by Semantic Information (E1: 19.11% of trials, SD = 21.75%; E2: 12.85% of trials, SD = 12.85%; E3: 15.02% of trials, SD = 16.24%). Other/Unrelated information (E1: 4.25% of trials, SD = 7.05%; E2: 7.08% of trials, SD = 9.52%; E3: 7.54% of trials, SD = 7.76%) and Future Thoughts (E1: 3.71% of trials, SD = 7.14%; E2: 3.26% of trials, SD = 4.63%; E3: 3.77% of trials, SD = 6.25%) were reported less frequently. After excluding participants who did not report thoughts on

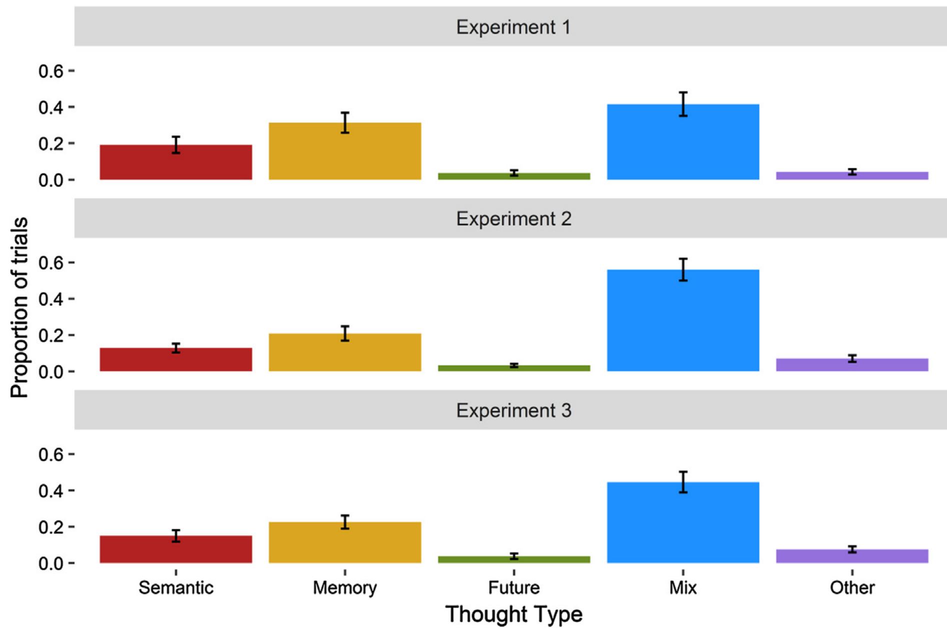

Fig. 4. Distribution of thought types reported for trials in which thoughts were reported and landmarks were recognized in Experiments 1, 2, and 3. Mix refers to a combination of semantic information, personal memories and future thoughts.

any trials in which they recognized landmarks, resulting sample sizes for this analysis were: E1: n = 29; E2: n = 35; E3: n = 31. For the distribution of thought types for unrecognized landmarks, see Supplementary Material – Fig. S1.

3.3. Rates of self-reported thought types by landmark familiarity

Our target question for the study was whether different types of thoughts would have the same relationship with the familiarity of the landmark. The analyses in Section 3.1 and Fig. 3 show that, overall, the incidences of thoughts increase with familiarity, but we hypothesized that this might not be the case for all types of thoughts, with a specific focus on episodic memories. To understand the influence of landmark familiarity on each category of thought, we tested the relationship between landmark familiarity and each thought type. For each participant, we determined the number of trials with thoughts reported for each familiarity bin. Then, for each thought type, we calculated the proportion of trials in which that thought type was reported (Fig. 5). For each thought type, we conducted a 3 × 5 mixed ANOVA with a between-subjects factor of Experiment (E1, E2, E3) and a within-subjects factors of Landmark Familiarity, followed by follow-up linear contrasts (Bonferroni-corrected for multiple comparisons) if the effects of familiarity were significant, to test the effects of familiarity in each version of the experiment. Note that not all subjects had trials with thoughts for landmarks in every familiarity bin, so these analyses included fewer participants (E1: n = 20; E2: n = 26; E3: n = 25).

For Semantic Information, an ANOVA revealed a significant main effect of Landmark Familiarity, $F(3.38, 230.42) = 3.02$, $p = 0.03$, $\eta^2_G = 0.022$, with no effect of Experiment, $F(2, 68) = 0.56$, $p = 0.57$, or interaction, $F(6.78, 230.42) = 1.62$, $p = 0.13$. Follow-up linear contrasts demonstrated a negative relationship between increasing familiarity and the incidence of semantic thoughts in E1, $t(272) = -2.48$, $p = 0.042$, and in E2, $t(272) = -3.41$, $p = 0.002$, but not in E3, $t(272) = 0.64$, $p > 0.99$.

For Autobiographical Memory, an ANOVA revealed a significant main effect of Landmark Familiarity, $F(3.21, 218.5) = 7.13$, $p < 0.0001$, $\eta^2_G = 0.038$, with a marginal effect of Experiment, $F(2, 68) = 2.61$, $p = 0.08$, and no significant interaction, $F(6.42, 218.5) = 1.19$, $p = 0.31$. Follow-up linear contrasts demonstrated a negative relationship between increasing familiarity and the incidence of autobiographical memories in E1, $t(272) = -4.15$, $p < 0.0001$, and in E3, $t(272) = -3.82$, $p = 0.0006$, but not in E2, $t(272) = -0.89$, $p > 0.99$.

For Future Thoughts, an ANOVA revealed no effects of Landmark Familiarity, $F(3.14, 213.69) = 1.61$, $p = 0.19$, Experiment, $F(2, 68) = 0.53$, $p = 0.59$, and no significant interaction, $F(6.28, 213.69) = 1.08$, $p = 0.37$.

For the Mix category, an ANOVA revealed a significant main effect of Landmark Familiarity, $F(3.15, 214.77) = 25.99$, $p < 0.0001$, $\eta^2_G = 0.092$, with no effect of Experiment, $F(2, 68) = 1.23$, $p = 0.29$, or interaction, $F(6.31, 214.77) = 1.43$, $p = 0.20$. Follow-up linear contrasts demonstrated a strong positive relationship between increasing familiarity and the incidence of mixed thoughts, including semantic information, autobiographical memories and/or future thoughts, in all three experiment versions, E1: $t(272) = 7.69$, $p < 0.0001$, E2: $t(272) = 5.58$, $p < 0.0001$, E3: $t(272) = 4.16$, $p < 0.0001$.

For thoughts that were classified as Other or Unrelated, an ANOVA revealed a significant main effect of Landmark Familiarity, $F(2.49, 169.43) = 6.32$, $p = 0.001$, $\eta^2_G = 0.049$, with no effect of Experiment, $F(2, 68) = 0.68$, $p = 0.51$, or interaction, $F(4.98, 169.43) = 0.83$, $p = 0.53$. Follow-up linear contrasts demonstrated a negative relationship between increasing familiarity and the incidence of unrelated or other thoughts, in all three experiments, E1: $t(272) = -2.41$, $p = 0.050$, E2: $t(272) = -3.52$, $p = 0.0015$, E3: $t(272) = -2.58$, $p = 0.030$.

3.4. Rates of coded thought types by landmark familiarity

In order to more objectively categorize participants' thought types and better understand the contents of the 'Mix' thought types, we recorded short descriptions of the participants' thoughts in Experiments 2 and 3 and coded these according to what types of information were included (for a breakdown of the thought types in the 'Mix' trials see Supplementary Material – Fig. S4). Coding categories included: identification of the landmark; providing descriptions/knowledge pertaining to the landmark location; personal semantic memories, reflecting autobiographical memory not specific to a single episode; specific episodic memories referring to single events; unrelated memories not occurring at that landmark; future thoughts; picture

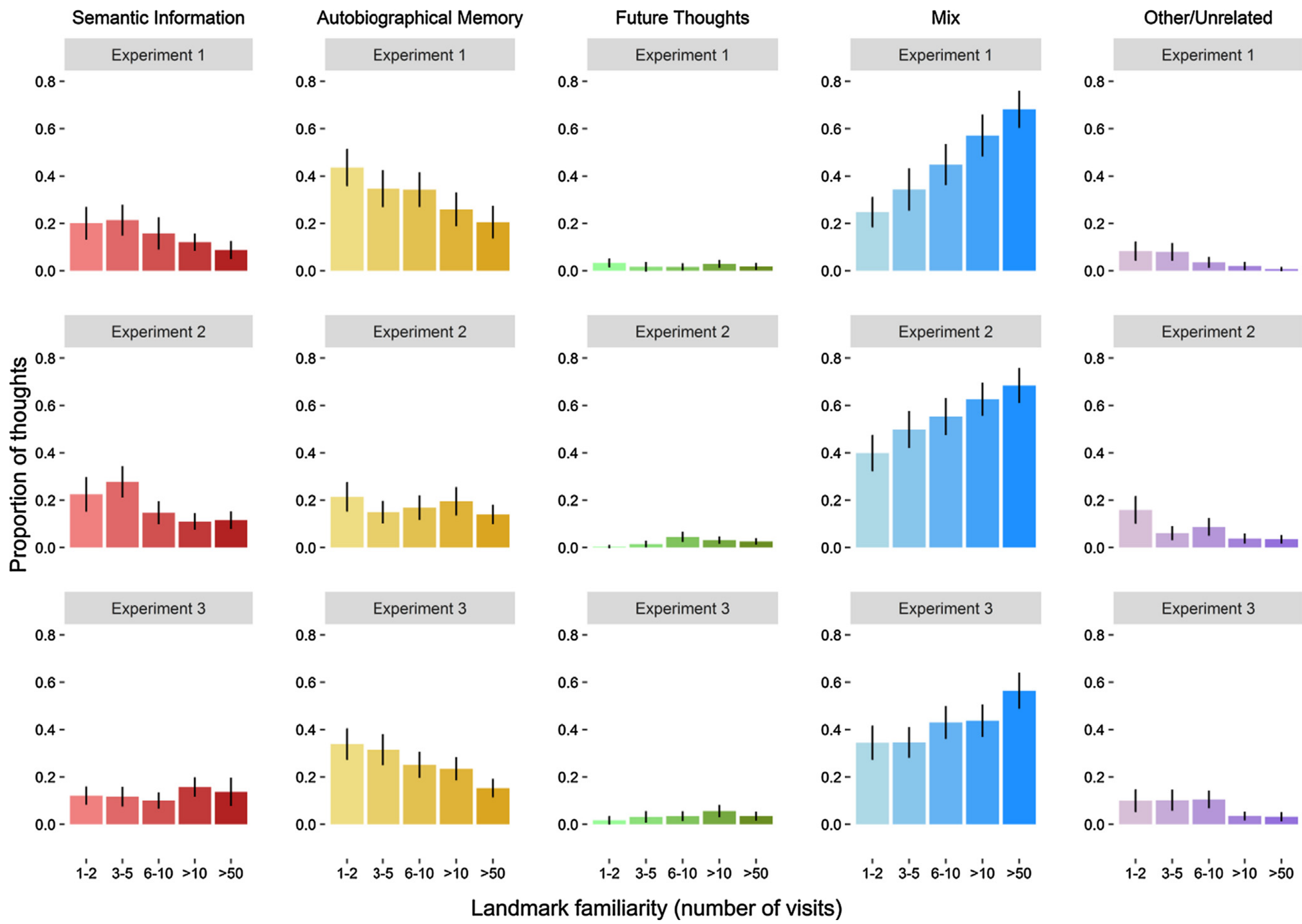

Fig. 5. Proportion of trials with each thought type reported, based on the familiarity of the landmark. While the Mix category demonstrated a positive linear relationship with familiarity, there was evidence for negative relationships between familiarity of the landmark and the incidences of semantic, autobiographical and unrelated thoughts.

descriptions; and other/unrelated thoughts. With the trials coded according to these more precise categories, we could again examine the effect of familiarity on each type of thought content (Fig. 6). For each participant, we determined the number of trials in each familiarity bin that had any type of thought reported, and then calculated the proportion of thoughts of each coding category for those trials. We then compared the effects of experiment version and of landmark familiarity on each thought type using 2 (Experiment) × 5 (Familiarity) mixed ANOVAs, with subsequent linear contrasts (Bonferroni-corrected for multiple comparisons) to test increasing and decreasing relationships with familiarity. We did not include Future Thoughts and Unrelated Memories in these analyses due to the very low instances of these types of thoughts. As with the analyses in the previous section, we included only subjects who reported trials with thoughts for landmarks in every familiarity bin (E2: n = 26; E3: n = 25).

For landmark identification, an ANOVA revealed a significant main effect of Landmark Familiarity, $F(3.35, 164.13) = 14.61$, $p < 0.0001$, $\eta^2_G = 0.13$. There was no significant effect of Experiment, $F(1, 49) = 1.26$, $p = 0.26$, or interaction, $F(3.35, 164.13) = 1.19$, $p = 0.32$. Linear contrasts revealed a significant positive relationship between Landmark Familiarity and verbal landmark identification, in both experiments, E2: $t(196) = 4.80$, $p < 0.0001$, E3: $t(196) = 5.63$, $p < 0.0001$.

For description and knowledge about the landmark, there was a significant main effect of Landmark Familiarity, $F(3.48, 170.65) = 4.89$, $p = 0.0016$, $\eta^2_G = 0.037$. There was no significant effect of Experiment, $F(1, 49) = 1.05$, $p = 0.31$, or interaction, $F(3.48, 170.65) = 0.44$, $p = 0.75$. Linear contrasts found no relationship between Landmark Familiarity and descriptions and knowledge about the landmark in either experiment, E2: $t(196) = 1.48$, $p = 0.42$, E3: $t(196) = 1.47$, $p = 0.43$. Visual inspection of the data suggested that an inverted quadratic model may better describe the data (modelled with the coefficients: −2, 1, 0, 1, −2), which was found to be the case in both experiments, E2: $t(212) = -5.15$, $p < 0.0001$, E3: $t(196) = 3.42$, $p = 0.0016$.

For personal semantic memories relating to the landmark, there was a significant main effect of Landmark Familiarity, $F(3.60, 176.64) = 8.87$, $p < 0.0001$, $\eta^2_G = 0.094$. There was no significant effect of Experiment, $F(1, 49) = 1.39$, $p = 0.24$, or interaction, $F(3.60, 176.64) = 0.07$, $p = 0.98$. Linear contrasts revealed a significant positive relationship between Landmark Familiarity and rate of reporting personal semantic memories in both experiments, E2: $t(196) = 4.25$, $p < 0.0001$, E3: $t(196) = 3.89$, $p = 0.0002$.

For specific episodic memories relating to the landmark, there was a significant main effect of Landmark Familiarity, $F(2.99, 146.77) = 3.58$, $p = 0.015$, $\eta^2_G = 0.04$. There was no significant effect of Experiment, $F(1, 49) = 0.05$, $p = 0.82$, or interaction, $F(2.99, 146.77) = 0.88$, $p = 0.45$. Linear contrasts revealed a significant negative relationship between Landmark Familiarity and the incidence of specific episodic memories in Experiment 3, E3: $t(196) = -2.82$, $p = 0.01$, and a negative relationship in Experiment 2 that did not reach significance after correcting for multiple comparisons, E2: $t(196) = -1.97$, $p = 0.10$.

For instances of picture description, there was a significant main effect of Landmark Familiarity, $F(2.94, 144.05) = 3.70$, $p = 0.014$, $\eta^2_G = 0.04$. There was no significant effect of Experiment, F(1,

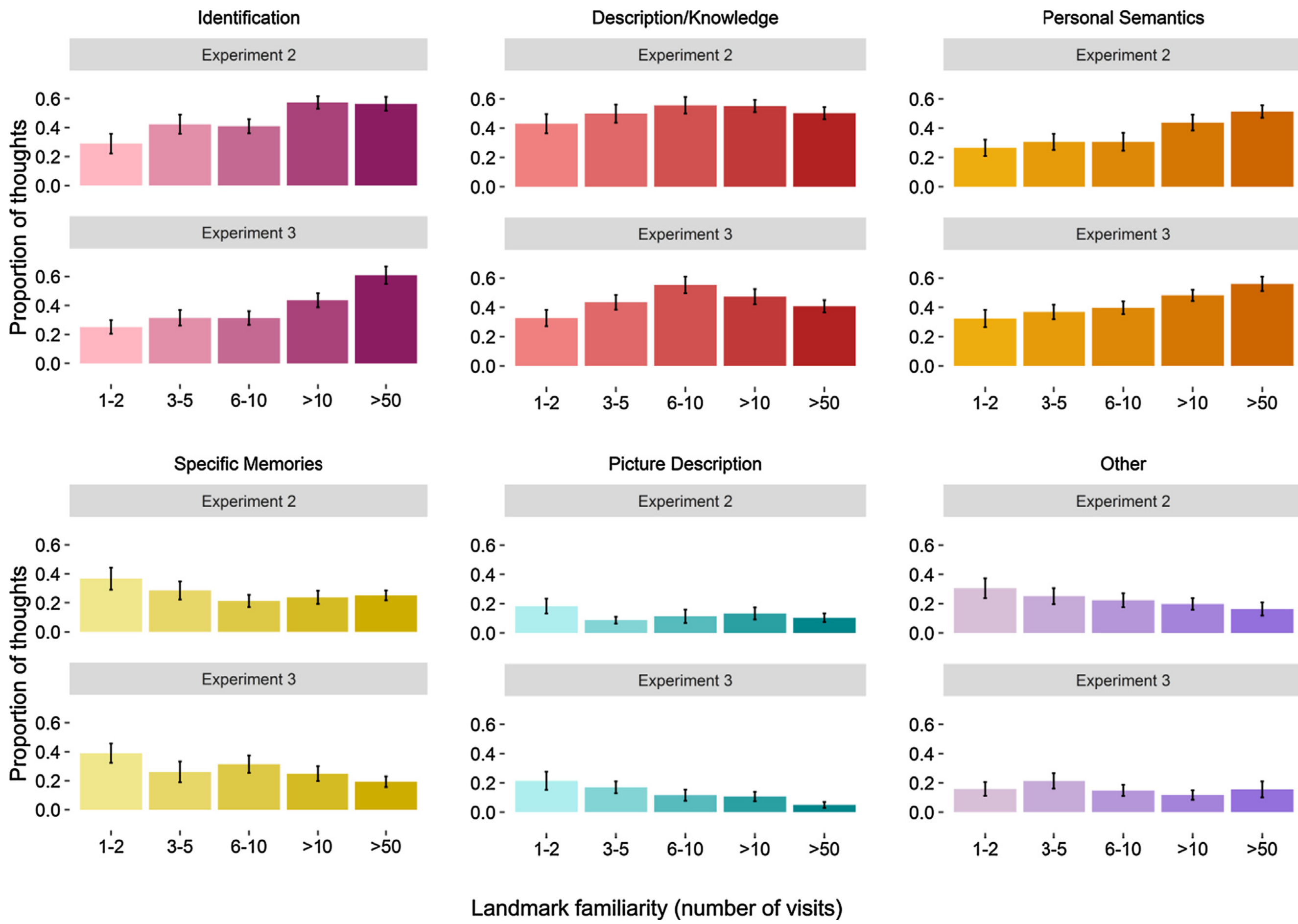

Fig. 6. Proportion of trials with each coding category identified in verbal descriptions, based on the familiarity of the landmark for Experiments 2 and 3. There was evidence for positive linear relationships between landmark familiarity and landmark identification and personal semantic memories. In contrast, there was a negative linear relationship between specific memories and landmark familiarity.

49) = 0.05, p = 0.83, or interaction, F(2.94, 144.05) = 1.30, p = 0.27. Linear contrasts revealed a significant negative relationship between Landmark Familiarity and incidence of picture description in E3: t(196) = −3.76, p = 0.0004, but not in E2: t(196) = −1.11, p = 0.54.

For thoughts that did not fall into any of the other categories, which included off-topic or meta-cognitive statements, there was no effect of Landmark Familiarity, F(3.54, 173.4) = 1.84, p = 0.13, no significant effect of Experiment, F(1, 49) = 1.84, p = 0.18, and no interaction, F(3.54, 173.4) = 0.92, p = 0.44.

4. Discussion

We found that spatial contexts reliably cued spontaneous memory retrieval, primarily cueing forms of semantic and episodic memory, with lower rates of future thoughts or unrelated information. Across all three experiments, we observed a higher incidence of thoughts reported in response to recognized landmarks than unrecognized landmarks, as expected. Within the recognized landmarks, the overall rate of thoughts increased with increasing familiarity of the landmark across all three experiments. In contrast, when subcategories of thoughts were examined based on participants' reports, we found that the rates of purely semantic thoughts and autobiographical memories decreased with increasing familiarity in two of the three experiments. In contrast, there was a robust increase in "mixed" thoughts with increasing familiarity, indicating that more familiar landmarks were eliciting combinations of semantic information, autobiographical memories and thoughts of the future. Thus, it was possible that semantic thoughts and autobiographical memories were not in fact decreasing with increased landmark familiarity, but instead were occurring more often in conjunction with one another for the more familiar landmarks, resulting in a combination of episodic and semantic material and in choosing the "mixed" thought category.

In order to investigate the nature of thoughts reported in more detail, in Experiments 2 and 3, we collected verbal descriptions of the thoughts triggered by the landmarks and coded these based on their content. These analyses revealed that when participants chose the "mixed" thought category, they frequently described a combination of identification of the landmark, semantic information about the landmark and personal semantic memories, which likely reflected generalized representations based on multiple autobiographical memories (Renoult, Davidson, Palombo, Moscovitch, & Levine, 2012; see Fig. S4). When thought types coded from the verbal descriptions were analyzed based on the familiarity of the landmarks, we found that landmark identification and personal semantic memories increased with increasing familiarity. In contrast, specific episodic memories again showed decreasing linear trends with increasing familiarity, suggesting that more familiar landmarks are less likely to trigger the retrieval of a specific episode. In both Experiment 2 and 3, the highest rate of specific episodic memories occurred for the least familiar landmarks, those that had been visited only once or twice. This finding is consistent with the cue overload effect (Berntsen et al., 2013; Watkins & Watkins, 1975), which predicts that more associations to a cue result in lower rates of memory retrieval, either as a result of interference among the items or of loss of distinctiveness between the cue its associated targets (Moscovitch & Craik, 1976). This pattern of results is specific to episodic memory, however, while the incidence of more generalized forms of memories, including semantic information and personal semantics, increased with increasing familiarity of a spatial context.

The results from the present study provide novel insights into the retrieval dynamics of real-world memories in response to spatial cues varying in familiarity. Overall, increased familiarity of a spatial context results in increased retrieval of information related to the landmark, consistent with previous studies reporting that more familiar contexts enhance memory and imagination (Arnold et al., 2011; D'Argembeau & Van der Linden, 2012; de Vito et al., 2012; McLelland et al., 2015; Robin & Moscovitch, 2014, 2017b; Robin et al., 2016; Szpunar & McDermott, 2008). When, however, the types of thoughts are parsed in more detail, more generalized forms of memory, including semantic information and personal semantics, are found to increase with the familiarity of the landmark, while specific episodic memories occur most frequently for landmarks only visited once or twice. These results expand upon previous autobiographical memory studies that limit participants to only reporting episodic memories, to show how different types of memories are spontaneously elicited by different cue types. This pattern of results may depend, however, on whether retrieval is involuntary and may differ if search is targeted toward recovering an episodic memory. We consider these alternatives later in the discussion.

This study adds to existing involuntary memory literature showing how factors such as priming, attention, cue types and retrieval instructions can affect the frequency and quality of spontaneous memory retrieval (Barzykowski & Niedźwieńska, 2016, 2018; Berntsen et al., 2013; Mace, 2005; Mace, 2004; Mace et al., 2019; Schlagman & Kvavilashvili, 2008; Vannucci, Batool, Pelagatti, & Mazzoni, 2014) by highlighting cue familiarity as another important contributing factor. Future work is needed to determine how these different factors may interact in the generation of spontaneous memories. Our novel paradigm, while sharing some similarities to other laboratory-based spontaneous memory paradigms (Barzykowski & Niedźwieńska, 2018; Mace et al., 2019; Schlagman & Kvavilashvili, 2008), offers a new method for eliciting spontaneous memories in the lab that does not rely on verbal stimuli. By using images of real-world scenes, this paradigm capitalizes on previous findings showing that external cues, such as features of one's spatial environment, are reliable triggers for spontaneous memories (Berntsen, 1998, 2007), and may more closely mirror every day experiences of spontaneous memory retrieval. It must be noted, however, that the cover task in this experiment was more directly related to the spontaneous memory task since they both involved the same scene cues, unlike other laboratory tasks that use unrelated vigilance tasks with intermittent word cues to prompt memory retrieval (Schlagman & Kvavilashvili, 2008). Therefore, the viewing of scenes may have primed participants to think of familiar locations and their related thoughts and memories, and made memories more accessible. It is also difficult to know what aspect of the scenes prompted spontaneous thoughts (i.e. particular visual details, semantic knowledge, etc.). Nonetheless, we think that this paradigm contributes to the involuntary memory literature by offering a novel, imagery-based way of eliciting spontaneous thoughts and memories.

The patterns of memory retrieval we observed in this study may indicate how memories are transformed as we accumulate related representations that are linked to a common context. For landmarks that had been visited only once or twice, the episodic memories based on these visits were maintained as specific, isolated episodes, distinct from one another. When viewing the spatial context associated with these memories, an episode was more frequently retrieved, consistent with predictions based on cue overload or fan effect theories, since there is little to interfere with these memories or diminish their distinctiveness (Anderson & Reder, 1999; Berntsen et al., 2013; Radvansky, O'Rear, & Fisher, 2017; Watkins & Watkins, 1975). The spatial imagery of the context serves as a strong cue, initiating recall for the other elements of the episode. Interestingly, less familiar scenes were also more likely to elicit picture descriptions and unrelated thoughts, demonstrating that episodic memories are not retrieved on all trials, and that less familiar cues are also most likely to elicit thoughts unrelated to memory.

For more familiar landmarks that had been visited more frequently, we observed lower incidences of retrieving a specific episodic memory, but higher rates of reporting more generalized memories, including personal semantics and other semantic information. These findings are consistent with predictions that increased familiarity of a cue results in the retrieval of generalized memories (Berntsen & Hall, 2004). The finding of fewer specific memories for more familiar cues seems to also be consistent with previous findings that repeated cues were very unlikely to generate the retrieval of unique associated scenes in a previous involuntary memory study (Berntsen et al., 2013). That study also found that repeated cues were likely to generate retrieval of multiple repeated scenes, but only in a voluntary retrieval condition, reflecting generalized memories that are more available to voluntary retrieval processes. As multiple memories associated with a given context accumulate, we hypothesize that more general representations are formed based on commonalities across the memories (Renoult et al., 2012; Richards et al., 2014), accompanied by a loss of distinctiveness.

One exception to the pattern of increased generalized memories with increasing landmark familiarity was found for descriptions or knowledge relating to the landmark. In both Experiment 2 and 3, this category was found to show an inverted U-shaped trend, with the highest rate occurring for landmarks that had been visited 6–10 times. This result was unexpected, and it is not clear why this type of memory would increase and then decrease as familiarity increased. One possibility could be that as landmarks become very familiar, personal semantics overtake general semantic information, resulting in the decrease for the highest levels of familiarity, but further research is needed to replicate and explore this pattern.

We hypothesize that spontaneous retrieval of episodic memories would rely on the hippocampus, known to be involved in automatic retrieval of episodic memories, as well as the perception and memory of complex scenes (Hodgetts, Shine, Lawrence, Downing, & Graham, 2016; Lee et al., 2005a, 2005b; Moscovitch, 2008; Moscovitch, Cabeza, Winocur, & Nadel, 2016; Scoville & Milner, 1957; Zeidman & Maguire, 2016; Zeidman, Mullally, & Maguire, 2015). More semantic/schematic forms of memory are not thought to rely on the hippocampus, being mediated instead by the neocortex, including lateral temporal and medial frontal regions (Gilboa & Marlatte, 2017; Moscovitch et al., 2016; Renoult et al., 2012; Robin & Moscovitch, 2017a; Sekeres, Winocur, & Moscovitch, 2018; Sekeres et al., 2018). Similarly, very familiar spatial environments have also been shown to no longer depend on the hippocampus, compared to less familiar spatial environments which activate the hippocampus during learning and memory (Hirshhorn, Grady, Rosenbaum, Winocur, & Moscovitch, 2012; Maguire, Nannery, & Spiers, 2006; Rosenbaum et al., 2000; Rosenbaum, Winocur, Grady, Ziegler, & Moscovitch, 2007; Teng & Squire, 1999). Thus, it may be the case that less familiar landmarks trigger hippocampally-dependent memory representations, which are more directly linked to specific episodic memories involving those locations. In contrast, a more familiar location would activate neocortical spatial memories and trigger more generalized forms of schematic or semantic memory relating to the landmark. These predictions require further investigation using neuroimaging methods. Spontaneous memory can be difficult to study in neuroimaging contexts, owing to its unpredictable and variable occurrence, but previous studies suggest that involuntary autobiographical memory involves many of the same neural structures as voluntarily-retrieved episodic memory and spatial imagery, including the medial temporal lobes and hippocampus, posterior cingulate cortex and precuneus (Hall, Gjedde, & Kupers, 2008; Hall et al., 2014; Kompus, Eichele, Hugdahl, & Nyberg, 2011).

Another question we sought to answer in these studies was whether the retrieval patterns associated with spatial context familiarity were dependent on directedness of memory retrieval associated with the adoption of a retrieval mode. Experiments 1 and 2 were designed to test the spontaneous retrieval of thoughts, with participants studying the scenes and answering a question about visual aspects of the scene as a cover task. Participants were questioned during debriefing about the goals of the experiment and none reported guessing that the hypotheses related to the relationship between landmark familiarity and memory retrieval, suggesting that memory retrieval was not directed or effortful. In contrast, in Experiment 3, participants were directly instructed to study the scenes and report any thoughts that came to mind, although there were no specific instructions about the types of thoughts or memories to retrieve. This change in instructions resulted in a higher rate of thoughts reported in Experiment 3, which was statistically different from Experiment 2, but not Experiment 1. The increase in thoughts suggests that participants may have been more explicitly attempting to retrieve thoughts in this version of the experiment, or may have been less distracted by the absence of a cover task, resulting in more spontaneous thoughts.

While this instruction change resulted in a modest increase in the overall thoughts reported, the rates of each category of thought did not differ across the different experiments. In analyses of the familiarity effects, experiment version never interacted with the effects of familiarity. We interpret these findings to indicate that the effects of context familiarity were robust to differences in retrieval modes. This interpretation is consistent with theoretical views that voluntary and involuntary memories are based on the same underlying episodic memory system (Berntsen, 2010), but inconsistent with predictions that spontaneous memories tend to be more episodic, while voluntary retrieval results in more general memories (Berntsen, 1998, 2010). We acknowledge that the differences in our spontaneous and directed retrieval versions of the experiment were subtle. It may have been that in Experiment 3, retrieval was still somewhat spontaneous, since participants were prompted to report any types of thoughts that came to mind, and not to search specifically for memories related to the landmarks. Despite the different retrieval instructions in Experiment 3, our findings regarding the types of memories and their relationship with cue familiarity were mostly consistent across all three experiments, suggesting that the relationship between context familiarity and memory retrieval does not depend on retrieval mode.

This pattern of results, however, is not entirely consistent with that obtained in previous studies that also used landmarks as cues, but in which retrieval was targeted to recover episodic autobiographical memories associated with those landmarks (Robin & Moscovitch, 2014, 2017b). Under those conditions, the speed with which memories were recovered and the number of episodic details were positively related to the familiarity of the landmarks. We turn to trace transformation theory to reconcile these seemingly inconsistent findings (Sekeres et al., 2018; Sekeres et al., 2018; Winocur & Moscovitch, 2011). According to trace transformation theory, many detailed episodic memories which are dependent on the hippocampus are transformed with time and experience to more generalized memories, such as gist, semantics and schemas, which are more dependent on the neocortex. Detailed episodic memories and generalized memories can therefore co-exist with one another, but rely on different neural structures (Moscovitch et al., 2016; Winocur & Moscovitch, 2011). Which type of memory is recovered depends, in part, on the nature of the cue and on task demands. When retrieval is not under tight control, in cases of involuntary retrieval, or voluntary, but not very specific, retrieval (Moscovitch, 1992; Moscovitch et al., 2016), then the congruency of the memory with the cue dictates the type of memory that will be retrieved. A highly familiar location cue is likely to have a more generalized representation and is therefore likely to elicit semantic or schematic memories more than episodic ones, whereas the reverse holds for the more “episodic” unfamiliar cues. The more distinct representations associated with less familiar cues are more likely to elicit specific episodes in memory since no generalized representations have been formed. Detailed episodic memories, however, are still available such that when retrieval is voluntary and targeted to recover episodic memories, control processes can overcome these congruency effects and enable the recovery of episodic memories that were previously masked. Now, highly familiar cues can be used to recover, and possibly reconstruct, episodic memories more rapidly and with greater detail and vividness, than can less familiar cues, effectively reversing the fan effect seen when memory retrieval is not directed.

Future work combining voluntary and involuntary retrieval in the same experiment is needed to directly test the speculative mechanisms described above. In Experiment 3, retrieval was more overtly directed, but was still open-ended, prompting the retrieval of any type of thought relating to the scenes displayed in the study, in order to remain comparable to the methods in Experiments 1 and 2. In future work, a modified design targeting only personal memories may be better able to compare the mechanisms of voluntary and involuntary episodic memory retrieval. This design would also avoid the reliance on participants to accurately classify their thoughts throughout the experiment, or on experimenter coding of reported thoughts, which were necessary in this study to define the various thought types. It is important to note, however, that previous studies have found that modification of the instructions in involuntary memory studies to direct participants to focus only on personal memories changes the number of memories reported (Barzykowski & Niedźwieńska, 2016; Vannucci et al., 2014), so it may be difficult to compare the results from such a study to those in the present report. For example, in our previous studies of directed episodic memory retrieval, we found that more familiar spatial contextual cues led to faster retrieval of memories, and the retrieval of more detailed and vivid episodes (Robin & Moscovitch, 2014, 2017b).

4.1. Conclusions

In summary, in this paper we present the results from three experiments using a novel paradigm for examining spontaneous real-world memory retrieval in response to naturalistic spatial contextual cues. This study is unique in that it examines the spontaneous retrieval of autobiographical memory in response to real-world cues in the laboratory, in contrast to naturalistic diary studies (Berntsen, 2010; Rasmussen & Berntsen, 2011; Rasmussen, Johannessen, & Berntsen, 2014; Rasmussen, Ramsgaard, & Berntsen, 2015; Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009; Schlagman et al., 2006) or laboratory tasks using simplified stimuli (Barzykowski & Niedźwieńska, 2018; Mace et al., 2019; Mazzoni, Vannucci, & Batool, 2014; Schlagman & Kvavilashvili, 2008). By virtue of their rich imagery and close ties to episodic memory, familiar spatial contexts may serve as an important trigger for spontaneous autobiographical memories. Our study is the first to examine this relationship in a systematically controlled way. We found that spatial contextual cues reliably elicit semantic and episodic forms of memory retrieval. Overall, there was an increase in thoughts in response to more familiar landmarks. Parsing the types of memories in more detail revealed an intriguing pattern of results, demonstrating increasing rates of semantic memory and personal semantics for more familiar cues, but decreasing rates of specific episodic memories, consistent with predictions based on the cue overload principle. Our findings suggest that multiple memories associated with a familiar context may be transformed into more generalized representations that are more readily retrieved than the individual episodes on which they are based. In contrast, specific episodes that have fewer associations in memory are more likely to be preserved as singular events. Which type of memory is recovered also depends on the control processes exerted at retrieval. These results provide novel insights into the retrieval dynamics of different types of memory and potential connections to the differing neural bases of episodic and semantic memories.

Acknowledgments

We gratefully acknowledge Sara Pishdadian and Rania Mansour for help with data collection and Anna Waisman for help with transcription and coding. This research was supported by a grant from the Canadian

Institutes of Health Research to Morris Moscovitch [grant number MOP 49566], and postgraduate scholarships from the Natural Sciences and Engineering Research Council of Canada and the Ontario Graduate Scholarship to Jessica Robin.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2019.04.018.

References

Anderson, J. R., & Reder, L. M. (1999). The fan effect: New results and new theories. *Journal of Experimental Psychology: General, 128*(2), 186–197. https://doi.org/10.1037//0096-3445.128.2.186.

Arnold, K. M., McDermott, K. B., & Szpunar, K. K. (2011). Imagining the near and far future: The role of location familiarity. *Memory & Cognition, 39*(6), 954–967. https://doi.org/10.3758/s13421-011-0076-1.

Barzykowski, K., & Niedźwieńska, A. (2016). The effects of instruction on the frequency and characteristics of involuntary autobiographical memories. *Plos One, 11*(6), e0157121. https://doi.org/10.1371/journal.pone.0157121.

Barzykowski, K., & Niedźwieńska, A. (2018). Priming involuntary autobiographical memories in the lab. *Memory, 26*(2), 277–289. https://doi.org/10.1080/09658211.2017.1353102.

Barzykowski, K., & Staugaard, S. R. (2016). Does retrieval intentionality really matter? Similarities and differences between involuntary memories and directly and generatively retrieved voluntary memories. *British Journal of Psychology, 107*(3), 519–536. https://doi.org/10.1111/bjop.12160.

Barzykowski, K., & Staugaard, S. R. (2017). How intention and monitoring your thoughts influence characteristics of autobiographical memories. *British Journal of Psychology, 1–20*. https://doi.org/10.1111/bjop.12259.

Berntsen, D. (1998). Voluntary and involuntary access to autobiographical memory. *Memory, 6*(2), 113–141. https://doi.org/10.1080/741942071.

Berntsen, D. (2007). Involuntary autobiographical memories: Speculations, findings, and an attempt to integrate them. *Involuntary Memory* (pp. 20–49). Oxford, UK: Blackwell Publishing Ltd. https://doi.org/10.1002/9780470774069.ch2.

Berntsen, D. (2010). The unbidden past: Involuntary autobiographical memories as a basic mode of remembering. *Current Directions in Psychological Science, 19*(3), 138–142. https://doi.org/10.1177/0963721410370301.

Berntsen, D., & Hall, N. M. (2004). The episodic nature of involuntary autobiographical memories. *Memory & Cognition, 32*(5), 789–803. https://doi.org/10.3758/BF03195869.

Berntsen, D., Staugaard, S. R., & Sørensen, L. M. T. (2013). Why am I remembering this now? Predicting the occurrence of involuntary (spontaneous) episodic memories. *Journal of Experimental Psychology: General, 142*(2), 426–444. https://doi.org/10.1037/a0029128.

D'Argembeau, A., Ortoleva, C., Jumentier, S., & Van der Linden, M. (2010). Component processes underlying future thinking. *Memory & Cognition, 38*(6), 809–819. https://doi.org/10.3758/MC.38.6.809.

D'Argembeau, A., & Van der Linden, M. (2012). Predicting the phenomenology of episodic future thoughts. *Consciousness and Cognition, 21*(3), 1198–1206. https://doi.org/10.1016/j.concog.2012.05.004.

de Vito, S., Gamboz, N., & Brandimonte, M. A. (2012). What differentiates episodic future thinking from complex scene imagery? *Consciousness and Cognition, 21*(2), 813–823. https://doi.org/10.1016/j.concog.2012.01.013.

Gilboa, A., & Marlatte, H. (2017). Neurobiology of schemas and schema-mediated memory. *Trends in Cognitive Sciences, 21*(8), 618–631. https://doi.org/10.1016/j.tics.2017.04.013.

Hall, N. M., Gjedde, A., & Kupers, R. (2008). Neural mechanisms of voluntary and involuntary recall: A PET study. *Behavioural Brain Research, 186*(2), 261–272. https://doi.org/10.1016/j.bbr.2007.08.026.

Hall, S. A., Rubin, D. C., Miles, A., Davis, S. W., Wing, E. A., Cabeza, R., & Berntsen, D. (2014). The neural basis of involuntary episodic memories. *Journal of Cognitive Neuroscience, 26*(10), 2385–2399. https://doi.org/10.1162/jocn_a_00633.

Hassabis, D., & Maguire, E. A. (2007). Deconstructing episodic memory with construction. *Trends in Cognitive Sciences, 11*(7), 299–306. https://doi.org/10.1016/j.tics.2007.05.001.

Hassabis, D., & Maguire, E. A. (2009). The construction system of the brain. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 364*(1521), 1263–1271. https://doi.org/10.1098/rstb.2008.0296.

Hirshhorn, M., Grady, C., Rosenbaum, R. S., Winocur, G., & Moscovitch, M. (2012). The hippocampus is involved in mental navigation for a recently learned, but not a highly familiar environment: A longitudinal fMRI study. *Hippocampus, 22*(4), 842–852. https://doi.org/10.1002/hipo.20944.

Hodgetts, C. J., Shine, J. P., Lawrence, A. D., Downing, P. E., & Graham, K. S. (2016). Evidencing a place for the hippocampus within the core scene processing network. *Human Brain Mapping, 37*(11), 3779–3794. https://doi.org/10.1002/hbm.23275.

Hunt, R. R., & Smith, R. E. (1996). Accessing the particular from the general: The power of distinctiveness in the context of organization. *Memory and Cognition, 24*(2), 217–225. https://doi.org/10.3758/BF03200882.

Kompus, K., Eichele, T., Hugdahl, K., & Nyberg, L. (2011). Multimodal imaging of incidental retrieval: The low route to memory. *Journal of Cognitive Neuroscience, 23*(4), 947–960. https://doi.org/10.1162/jocn.2010.21494.

Lee, A. C. H., Buckley, M. J., Pegman, S. J., Spiers, H., Scahill, V. L., Gaffan, D., ... Graham, K. S. (2005a). Specialization in the medial temporal lobe for processing of objects and scenes. *Hippocampus, 15*(6), 782–797. https://doi.org/10.1002/hipo.20101.

Lee, A. C. H., Bussey, T. J., Murray, E. A., Saksida, L. M., Epstein, R. A., Kapur, N., ... Graham, K. S. (2005b). Perceptual deficits in amnesia: Challenging the medial temporal lobe "mnemonic" view. *Neuropsychologia, 43*(1), 1–11. https://doi.org/10.1016/j.neuropsychologia.2004.07.017.

Mace, J. (2005). Priming involuntary autobiographical memories. *Memory, 13*(8), 874–884. https://doi.org/10.1080/09658210444000485.

Mace, J. H. (2004). Involuntary autobiographical memories are highly dependent on abstract cuing: The proustian view is incorrect. *Applied Cognitive Psychology, 18*(7), 893–899. https://doi.org/10.1002/acp.1020.

Mace, J. H. (2006). Episodic remembering creates access to involuntary conscious memory: Demonstrating involuntary recall on a voluntary recall task. *Memory, 14*(8), 917–924. https://doi.org/10.1080/09658210600759766.

Mace, J. H., McQueen, M. L., Hayslett, K. E., Staley, B. J. A., & Welch, T. J. (2019). Semantic memories prime autobiographical memories: General implications and implications for everyday autobiographical remembering. *Memory and Cognition, 47*(2), 299–312. https://doi.org/10.3758/s13421-018-0866-9.

Maguire, E. A., Nannery, R., & Spiers, H. J. (2006). Navigation around London by a taxi driver with bilateral hippocampal lesions. *Brain, 129*(11), 2894–2907. https://doi.org/10.1093/brain/awl286.

Mäntylä, T., & Nilsson, L. G. (1988). Cue distinctiveness and forgetting: Effectiveness of self-generated retrieval cues in delayed recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*(3), 502–509. https://doi.org/10.1037/0278-7393.14.3.502.

Mazzoni, G., Vannucci, M., & Batool, I. (2014). Manipulating cues in involuntary autobiographical memory: Verbal cues are more effective than pictorial cues. *Memory & Cognition, 42*(7), 1076–1085. https://doi.org/10.3758/s13421-014-0420-3.

McLelland, V. C., Devitt, A. L., Schacter, D. L., & Addis, D. R. (2015). Making the future memorable: The phenomenology of remembered future events. *Memory, 23*(8), 1255–1263. https://doi.org/10.1080/09658211.2014.972960.

Moscovitch, M. (1992). Memory and working-with-memory: A component process model based on modules and central systems. *Journal of Cognitive Neuroscience, 4*(3), 257–267. https://doi.org/10.1162/jocn.1992.4.3.257.

Moscovitch, M. (2008). The hippocampus as a "stupid", domain-specific module: Implications for theories of recent and remote memory, and of imagination. *Canadian Journal of Experimental Psychology = Revue Canadienne de Psychologie Expérimentale, 62*(1), 62–79. https://doi.org/10.1037/1196-1961.62.1.62.

Moscovitch, M., Cabeza, R., Winocur, G., & Nadel, L. (2016). Episodic memory and beyond: The hippocampus and neocortex in transformation. *Annual Review of Psychology, 67*(1), 105–134. https://doi.org/10.1146/annurev-psych-113011-143733.

Moscovitch, M., & Craik, F. I. M. (1976). Depth of processing, retrieval cues, and uniqueness of encoding as factors in recall. *Journal of Verbal Learning and Verbal Behavior, 15*(4), 447–458. https://doi.org/10.1016/S0022-5371(76)90040-2.

Nadel, L. (1991). The hippocampus and space revisited. *Hippocampus, 1*(3), 221–229. https://doi.org/10.1002/hipo.450010302.

O'Keefe, J., & Nadel, L. (1978). *The Hippocampus as a Cognitive Map.* Oxford: Oxford University Press.

Radvansky, G. A., O'Rear, A. E., & Fisher, J. S. (2017). Event models and the fan effect. *Memory & Cognition, 45*(6), 1028–1044. https://doi.org/10.3758/s13421-017-0713-4.

Rasmussen, A. S., & Berntsen, D. (2011). The unpredictable past: Spontaneous autobiographical memories outnumber autobiographical memories retrieved strategically. *Consciousness and Cognition, 20*(4), 1842–1846. https://doi.org/10.1016/j.concog.2011.07.010.

Rasmussen, A. S., Johannessen, K. B., & Berntsen, D. (2014). Ways of sampling voluntary and involuntary autobiographical memories in daily life. *Consciousness and Cognition, 30C*, 156–168. https://doi.org/10.1016/j.concog.2014.09.008.

Rasmussen, A. S., Ramsgaard, S. B., & Berntsen, D. (2015). Frequency and functions of involuntary and voluntary autobiographical memories across the day. *Psychology of Consciousness: Theory, Research, and Practice, 2*(2), 185–205. https://doi.org/10.1037/cns0000042.

Renoult, L., Davidson, P. S. R., Palombo, D. J., Moscovitch, M., & Levine, B. (2012). Personal semantics: At the crossroads of semantic and episodic memory. *Trends in Cognitive Sciences, 16*(11), 550–558. https://doi.org/10.1016/j.tics.2012.09.003.

Richards, B. A., Xia, F., Santoro, A., Husse, J., Woodin, M. A., Josselyn, S. A., & Frankland, P. W. (2014). Patterns across multiple memories are identified over time. *Nature Neuroscience, 17*(7), 981–986. https://doi.org/10.1038/nn.3736.

Robin, J., Garzon, L., & Moscovitch, M. (2019). Spontaneous memory retrieval varies based on familiarity with a spatial context. *Open Science Framework.*. https://doi.org/10.17605/OSF.IO/C7KVB.

Robin, J., & Moscovitch, M. (2014). The effects of spatial contextual familiarity on remembered scenes, episodic memories, and imagined future events. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*(2), 459–475. https://doi.org/10.1037/a0034886.

Robin, J., & Moscovitch, M. (2017a). Details, gist and schema: Hippocampal–neocortical interactions underlying recent and remote episodic and spatial memory. *Current Opinion in Behavioral Sciences, 17*, 114–123. https://doi.org/10.1016/j.cobeha.2017.07.016.

Robin, J., & Moscovitch, M. (2017b). Familiar real-world spatial cues provide memory benefits in older and younger adults. *Psychology and Aging, 32*(3), 210–219. https://doi.org/10.1037/pag0000162.

Robin, J., Wynn, J., & Moscovitch, M. (2016). The spatial scaffold: The effects of spatial context on memory for events. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*(2), 308–315. https://doi.org/10.1037/xlm0000167.

Rosenbaum, R. S., Priselac, S., Köhler, S., Black, S. E., Gao, F., Nadel, L., & Moscovitch, M. (2000). Remote spatial memory in an amnesic person with extensive bilateral hippocampal lesions. *Nature Neuroscience, 3*(10), 1044–1048. https://doi.org/10.1038/79867.

Rosenbaum, R. S., Ziegler, M., Winocur, G., Grady, C. L., & Moscovitch, M. (2004). "I have often walked down this street before": fMRI studies on the hippocampus and other structures during mental navigation of an old environment. *Hippocampus, 14*(7), 826–835. https://doi.org/10.1002/hipo.10218.

Rosenbaum, R., Winocur, G., Grady, C. L., Ziegler, M., & Moscovitch, M. (2007). Memory for familiar environments learned in the remote past: fMRI studies of healthy people and an amnesic person with extensive bilateral hippocampal lesions. *Hippocampus, 1251*, 1241–1251. https://doi.org/10.1002/hipo.

Rugg, M. D., & Wilding, E. L. (2000). Retrieval processing and episodic memory. *Trends in Cognitive Sciences, 4*(3), 108–115. https://doi.org/10.1016/S1364-6613(00)01445-5.

Schlagman, S., Kliegel, M., Schulz, J., & Kvavilashvili, L. (2009). Differential effects of age on involuntary and voluntary autobiographical memory. *Psychology and Aging, 24*(2), 397–411. https://doi.org/10.1037/a0015785.

Schlagman, S., & Kvavilashvili, L. (2008). Involuntary autobiographical memories in and outside the laboratory: How different are they from voluntary autobiographical memories? *Memory & Cognition, 36*(5), 920–932. https://doi.org/10.3758/MC.36.5.920.

Schlagman, S., Kvavilashvili, L., & Schulz, J. (2008). Effects of age on involuntary autobiographical memories. *Involuntary Memory* (pp. 87–112). Oxford, UK: Blackwell Publishing Ltd. https://doi.org/10.1002/9780470774069.ch5.

Schlagman, S., Schulz, J., & Kvavilashvili, L. (2006). A content analysis of involuntary autobiographical memories: Examining the positivity effect in old age. *Memory, 14*(2), 161–175. https://doi.org/10.1080/09658210544000024.

Scoville, W., & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. *Journal of Neurology, Neurosurgery & Psychiatry, 20*(11), 11–21.

Sekeres, M. J., Winocur, G., & Moscovitch, M. (2018). The hippocampus and related neocortical structures in memory transformation. *Neuroscience Letters, 680*, 39–53. https://doi.org/10.1016/j.neulet.2018.05.006.

Sekeres, M. J., Winocur, G., Moscovitch, M., Anderson, J. A. E., Pishdadian, S., Wojtowicz, J. M., ... Grady, C. (2018). Changes in patterns of neural activity underlie a time-dependent transformation of memory in rats and humans. *Hippocampus, 28*(10), 745–764. https://doi.org/10.1002/hipo.23009.

Smith, S. M., & Vela, E. (2001). Environmental context-dependent memory: A review and meta-analysis. *Psychonomic Bulletin & Review, 8*(2), 203–220. https://doi.org/10.3758/BF03196157.

Szpunar, K. K., & McDermott, K. B. (2008). Episodic future thought and its relation to remembering: Evidence from ratings of subjective experience. *Consciousness and Cognition, 17*(1), 330–334. https://doi.org/10.1016/j.concog.2007.04.006.

Talmi, D., & Moscovitch, M. (2004). Can semantic relatedness explain the enhanced memory for emotional words? *Memory and Cognition, 32*(5), 742–751.

Teng, E., & Squire, L. R. (1999). Memory for places learned long ago is intact after hippocampal damage. *Nature, 400*(6745), 675–677. https://doi.org/10.1038/23276.

Tulving, E. (1983a). Ecphoric processes in episodic memory. *Philosophical Transactions of the Royal Society B: Biological Sciences, 302*(1110), 361–371. https://doi.org/10.1098/rstb.1983.0060.

Tulving, E. (1983b). *Elements of episodic memory.* Oxford University Press.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80*(5), 352–373. https://doi.org/10.1037/h0020071.

Vannucci, M., Batool, I., Pelagatti, C., & Mazzoni, G. (2014). Modifying the frequency and characteristics of involuntary autobiographical memories. *PLoS ONE, 9*(4), https://doi.org/10.1371/journal.pone.0089582.

Wagenaar, W. A. (1986). My memory: A study of autobiographical memory over six years. *Cognitive Psychology, 18*(2), 225–252. https://doi.org/10.1016/0010-0285(86)90013-7.

Watkins, O., & Watkins, M. (1975). Buildup of proactive inhibition as a cue-overload effect. *Journal of Experimental Psychology: Human Learning and Memory, 104*(4), 442–452.

Winocur, G., & Moscovitch, M. (2011). Memory transformation and systems consolidation. *Journal of the International Neuropsychological Society, 17*(05), 766–780. https://doi.org/10.1017/S1355617711000683.

Wiseman, S., & Tulving, E. (1976). Encoding specificity: Relation between recall superiority and recognition failure. *Journal of Experimental Psychology: Human Learning & Memory, 2*(4), 349–361. https://doi.org/10.1037/0278-7393.2.4.349.

Zeidman, P., & Maguire, E. A. (2016). Anterior hippocampus: The anatomy of perception, imagination and episodic memory. *Nature Reviews Neuroscience, 17*(3), 173–182. https://doi.org/10.1038/nrn.2015.24.

Zeidman, P., Mullally, S. L., & Maguire, E. A. (2015). Constructing, perceiving, and maintaining scenes: Hippocampal activity and connectivity. *Cerebral Cortex, 25*(10), 3836–3855. https://doi.org/10.1093/cercor/bhu266.