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The cognitive tools that support mentally constructing event and scene representations

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ABSTRACT
Constructing mental representations is critical for many cognitive tasks, yet it is unclear if forming different representations relies on distinct cognitive processes. We tested how episodic memory contributes to constructing scene and event-based mental scenarios as well as the effects of two types of imagery ability (object and spatial imagery) on this contribution. Forty participants were given a series of scenario cues that were classified as scenes (e.g., a beach) or events (e.g., a family meal) by independent raters. To these cues, the participants described the details of the associated mental representation. They also rated the representation for vividness, sense of presence, and if forming the representation stimulated the retrieval of an autobiographical memory. The resulting descriptions were then scored for number of contained episodic and non-episodic details. We found participants generated more details – particularly episodic – for event than scene representations. Interestingly, episodic detail generation was predicted by subjective ratings for the scene and not event representations. Other rating differences were that scenes were experienced with a greater sense of presence and events were more likely to trigger autobiographical memory retrieval. Finally, we found dissociation in how object and spatial imagery ability related to event representations. For these representations, generating episodic and non-episodic details related to object and spatial imagery, respectively. These findings indicate how the nature of a representation directs contributions from episodic memory and are affected by imagery ability.

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Mental representations; episodic memory; imagery ability; individual differences

Many cognitive tasks require forming detailed mental representations, including remembering past experiences and planning future events (Suddendorf, Addis, & Corballis, 2009; Szpunar, Addis, McLelland, & Schacter, 2013). Although there is a wealth of research indicating that episodic memory processes mediated by the medial temporal lobes (MTL) are needed to relate together associated details of a mental representation (Moscovitch, Cabeza, Winocur, & Nadel, 2016; Mullally, Vargha-Khadem, & Maguire, 2014; Rubin & Umanath, 2014; Sheldon & Levine, 2016), the nature of this processing support is not entirely clear. One body of work suggests that episodic memory processes specifically support relating spatial elements of mental representations (Hassabis, Kumaran, Vann, & Maguire, 2007; Hassabis & Maguire, 2009; Maguire & Hassabis, 2011; Maguire, Intraub, & Mullally, 2016; Maguire & Mullally, 2013; Mullally et al., 2014), while another line of research focuses on how episodic memory contributes to broadly forming event representations (Addis, Sacchetti, Ally, Budson, & Schacter, 2009; Addis & Schacter, 2008, 2011; Eichenbaum, 2004, 2016; Schacter & Addis, 2007; Schacter et al., 2012). Motivated by these views, one aim of the current study was to contrast how episodic memory processes are recruited when forming spatial and event mental representations and how this recruitment affects the experience of a formed mental representation.

Another aim of the current study was to examine the role of imagery in forming these mental representations. We tested specific hypotheses concerning the contribution of visual imagery processes in using episodic memory for constructing them (Keogh, Pearson, & Baker, 2011; Kosslyn, Ganis, & Thompson, 2001). Since there is a great deal of individual variability in how people use imagery for cognitive tasks (Blajenkova, Kozhevnikov, & Motes, 2006; Brewer & Pani, 1996; D'Argembeau & Van der Linden, 2006; Vannucci, Pelagatti, Chiorri, & Mazzoni, 2015), we investigated the link between imagery ability and episodic memory use for forming mental representations with an individual differences approach.

Event versus scene mental representations

There are two main views for how MTL episodic memory processes support forming mental representations. One view, the scene construction theory (Hassabis et al., 2007; Hassabis & Maguire, 2009; Maguire et al., 2016; Maguire & Hassabis, 2011; Maguire & Mullally, 2013; Mullally et al.,

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2014), posits that the hippocampus - a structure within the MTL - is specialised for processing spatial information; a view that extends from cognitive map theory and the discovery of place cells within the hippocampus (O'Keefe, 1991; O'Keefe & Dostrovsky, 1971). This theory suggests that when thinking about complex scenarios, such as past experiences, hippocampal processes construct the spatial context of that experience. This mental scene acts as a "scaffold" to gather additional details related to the constructed mental representation of the experience (Maguire & Mullally, 2013). This implies that (hippocampally-mediated) episodic memory processes play a central role in thinking about events inasmuch as the imagined event depends on a centralised coherent spatial context. In fact, some versions of this view propose that these episodic memory processes may not be needed at all for recalling non-spatial event details of mental representations (e.g., Hassabis et al., 2007; Nyberg, Kim, Habib, Levine, & Tulving, 2010).

Another view is that hippocampal episodic memory processes are not exclusive to constructing spatial relations, but are instrumental in relating together all forms of information for a mental representation (Eichenbaum, 2016; Olsen, Moses, Riggs, & Ryan, 2012). Under this view, relating spatial elements of representations is just one example of how the relational processes that define episodic memory are used for creating mental simulations. For example, the constructive episodic simulation hypothesis (Addis, Pan, Vu, Laiser, & Schacter, 2009; Addis & Schacter, 2008; Madore, Gaesser, & Schacter, 2014) proposes that episodic memory processes support tasks like autobiographical memory retrieval and future event imagination by binding together multiple types of details of an experience in mind. These processes can be used to build event simulations, not just scene-based imaginations, by recombining different types of details accumulated from past events, a useful characteristic for several complex cognitive tasks (Madore, Addis, & Schacter, 2015; Madore & Schacter, 2014; Sheldon, McAndrews, & Moscovitch, 2011; Sheldon, Romero, & Moscovitch, 2013).

Inspired by these different views of hippocampal process contributions to forming mental representations, we sought to determine if distinct episodic memory contributions for forming spatial and event mental representations are present behaviourally. We propose that spatial processing is a particular manifestation of episodic memory such that it supports imagining a defined spatial context and thus will influence forming scene-based mental representations. Given that spatial processing is inherently perceptual, these scene representations will be built with more specific detail (i.e., more perceptual specificity) which will enhance how vividly a person experiences the mental representation. In contrast, we propose that event representations require other manifestations of episodic memory to gather additional/supplementary details that encompass an event (e.g., temporal sequence information; general schematic knowledge), and thus these representations will be generated and experienced in a different manner than scene representations. In support of this proposed distinction, one of our recent studies showed that autobiographical memories recalled via a spatial or an event guided route led to qualitatively different recollections, particularly in the use of episodic memory processes (Sheldon & Chu, 2016). In addition, another research group found dissociable patterns of neural activity when forming mental representations of future events and novel scenes (Palombo, Hayes, Peterson, Keane, & Verfaellie, 2016), indicating that there are different mechanisms at play for event and scene mental construction.

Individual differences in imagery

Visual imagery is an important component for forming past and future event mental representations (Greenberg, Eacott, Brechin, & Rubin, 2005; Greenberg & Rubin, 2003; Rubin & Umanath, 2014). In support of this idea, investigations have found that damage or deterioration to regions of the brain that are critical for visual perception and imagery result in a parallel loss of autobiographical memory (Gardini et al., 2011; Greenberg et al., 2005; Ogden, 1993). There are also case reports of individuals with congenital visual imagery deficits that suggest that these individuals also have deficits in forming detailed representations of past experiences (Zeman et al., 2010; Zeman, Dewar, & Della Sala, 2015).

There is a lack of research that has explicitly examined the impact of imagery ability on constructing mental representations in healthy populations. Some noteworthy exceptions include studies that reported a link between the ability to recall visual images with forming clear and coherent autobiographical memories (Brewer & Pani, 1996; D'Argembeau & Van der Linden, 2006) and another study that found that individuals who don't use imagery processing when remembering the past report a reduced sense of reliving recalled events (Greenberg & Knowlton, 2014).

Some other investigations in this area note that imagery ability is not a unitary construct (Kosslyn et al., 2001; Kosslyn, Thompson, Sukel, & Alpert, 2005; Thompson, Slotnick, Burrage, & Kosslyn, 2009). One distinction is between object and spatial imagery ability (Blajenkova et al., 2006). Object imagery refers to the ability to formulate a mental image in rich visual detail, bringing to mind specific perceptual features of objects (e.g., forming a mental representation of a red rose from a garden). Spatial imagery, on the other hand, refers to the ability to imagine spatial relations between items in one's mind eye (e.g. the landscape of the garden itself; Blajenkova et al., 2006).

There are some indications that object and spatial imagery differently relate to how an individual uses episodic memory (and other processes) to construct mnemonic representations. A recent study found that individuals high in object imagery ability were faster at responding to autobiographical memory cues than those low in object imagery ability and that the high object imagers reported experiencing memories with more detail (Vannucci et al., 2015). In one of our recent studies, we found that differences in spatial imagery ability determined the effect of presenting an imagery interference stimulus as individuals recalled details from studied videos depicting real-world events (Sheldon, Amaral, & Levine, 2016). Together, these studies provide evidence that spatial and object imagery contribute to distinct aspects of autobiographical memory, and likely, to forming mental representations more broadly.

One specific hypothesis is that spatial imagery ability is related to the ability to form a "scaffold" to create a mental representation. In our previous study (Sheldon, Amaral, et al., 2016), presenting imagery interference stimuli as participants remembered details from studied videos selectively affected the ability to retrieve higher-level details (e.g., details concerning how an event unfolded over time or large-scale spatial details) and not item-specific elements (e.g., specific perceptual features) for high spatial imagers. We took this as evidence that spatial imagery is related to using imagery-based processes for recalling gist or broad aspects of a complex event, but not the specific episodic details. From this finding, we further speculated that spatial imagery may not completely overlap with episodic memory ability – the ability to use a variety of relational processes to construct detailed mental representations. That is, forming relations among gist-based elements within a mental representation is needed to craft a mental scaffold and is linked to spatial imagery and this scaffold can promote the use of episodic memory processes to relate detailed elements to the representation (for a related, more neurocognitive view, see Konkel & Cohen, 2009).

If spatial imagery is linked to forming broader connections when constructing a mental scenario, how does object imagery relate to forming a mental representation? The results of Vannucci et al.'s (2015) study address this question. Again, this study found that object imagery ability was linked to recalling sensory and perceptual (i.e., fine-grained) details of recalled experiences. Previous work has shown that recruiting fine-grained details via episodic memory determines how mental representations are experienced, especially the vividness of a mental recollection (e.g., Gilboa, Winocur, Grady, Hevenor, & Moscovitch, 2004; Greenberg & Knowlton, 2014; Greenberg & Rubin, 2003; Palombo, Alain, Söderlund, Khuu, & Levine, 2015; St-Laurent, Abdi, & Buchsbaum, 2015), thus we hypothesize that object imagery ability is an important trait-level determiner for the detailed creation and phenomenological experience of a mental representation.

Current study

The first aim of the present experiment was to directly contrast the cognitive processes involved in forming event and spatial mental representations. To this end, participants generated detailed descriptions of imagined scenarios to cues that represented either an activity/event or a location/scene. Instead of relying on our own judgment of what constituted an event versus a scene, we collected independent online ratings for each of these scenario cues to classify them as events or scenes. We then scored the descriptions generated to the event and scene cues to assess the contributions of episodic and non-episodic memory processes using a well-used scoring technique (Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). Finally, we had participants provide ratings of their experience of the imagined scenarios on a series of scales to assess how the scenarios that were classified as events and scenes were experienced and how these experience measures related to episodic memory use.

The second aim of our study was to assess the relationship of spatial and object imagery abilities with forming event and scene mental representations. We measured imagery ability using a well-validated self-report questionnaire, the Object Spatial Imagery Questionnaire (OSIQ; Blajenkova et al., 2006) and related the resulting scores to the measures noted above. In doing so, we tested two predictions. First, if spatial imagery helps form broad relations that guide creating mental representations, then scores on this imagery scale should relate to the recruitment of non-episodic details when describing imagined scenarios. Second, if object imagery helps recruit fine-grained (episodic) details for mental representations, then scores on this imagery scale should relate to the recruitment of episodic details when describing imagined scenarios.

Methods and materials

Participants. Forty (29 female) healthy young adult participants were recruited via online classified advertisements posted on McGill University websites. The participants were free of neurological conditions and psychiatric illness, were between the ages of 19 and 31 years (M = 21.00 years, SD = 2.80) and had an average of 15 years of education (SD = 2.26). Two participants were excluded from the reported analyses, one due to incomplete data collection, and one was an outlier (defined by detail generation output that was greater than three standard deviations about the mean). All participants gave informed consent in a manner approved by McGill University and were compensated for their time.

Stimuli. The cues were taken from the Hassabis et al. (2007) stimuli set. This set is composed of six written statements depicting real-world event or scene scenarios (e.g., "you are standing on a white sand beach in a beautiful tropical bay"; "a future and plausible wedding reception you will attend"; Table 1).

Experimental Procedure. Figure 1 illustrates the general experimental procedure. Over six trials, participants were randomly presented with the scenarios (cues)

Table 1. The scenario cues used in the present study, the associated classification and the average 'activity-place' rating score given by a group of independent raters. An 'activity-place' rating close to 0 represents cues defined as a place (scene) and a rating close to 100 represents cues defined as an activity (event). For these average ratings, standard errors are shown in parentheses.

Cue	Type	Rating (0 to 100)
A future and plausible family holiday meal	Event	86.4 (1.65)
A future and plausible wedding reception that you will attend	Event	73.5 (2.61)
Standing by a small stream somewhere deep in a forest	Scene	27.0 (2.76)
Lying on a white sand beach in a beautiful tropical bay	Scene	22.2 (2.66)
A future and plausible visit to the barbershop or salon	Mix	61.8 (3.34)
Standing in the main hall of a museum containing many exhibits	Mix	29.3 (3.17)

on a computer screen via an E-prime programme. Upon presentation of a cue, participants were given ten seconds to silently think of the associated scenario (i.e., construct a vivid mental image of the situation represented by the cue). Participants were instructed not to think of a previously experienced event, but to imagine a novel situation. Following this ten-second period, participants were given up to five minutes to describe out loud the scenario they imagined in as much detail as possible. After reaching a natural end to their description, the experimenter would ask for more details in the form of a general probe ("Can you think of any more details or can you see anything else in the scenario?"). Each trial concluded after the participant rated the experience of imagining the scenario on three five-point rating scales:

1. Vividness of the imagined scenario (0 – not really seeing anything in mind to 5 – picturing an extremely salient/detailed image in mind)
2. Sense of presence in the scenario (0 – not feeling present in the imagined scenario to 5 – feeling strongly present in the imagined scenario)
3. The similarity of a past personal experience to the imagined scenario (0 – not at all to 5 – very strongly).

Scoring Procedure. Each scenario description was audio-recorded, transcribed, and then scored with an adapted version of the Autobiographical Interview scoring protocol (Levine et al., 2002) that has been used successfully in several previous studies (e.g., Addis et al., 2008; Sheldon & Chu, 2016; Sheldon et al., 2011, 2015). This procedure segments narratives into details or distinct pieces of information and then classifies each detail as either internal or external. Internal details are pieces of information that pertain to the main scenario being described, are specific to the spatial and temporal context of the cued scenario, and measure the use of episodic memory processes. External details represent the use of non-episodic memory processes, including those that support retrieving semantic or schematic-like representations, and include information that is not specific the context of the cue. Two raters scored all of the descriptions and correlation scores for the two raters on randomly selected scenes and event descriptions ($N = 12$) was sufficiently high for internal details ($r = 0.93$), external ($r = 0.97$) and total details ($r = 0.87$).

Imagery ability measure. All participants completed the OSIQ (Blajenkova et al., 2006). This questionnaire consists of 30 items in which participants endorse statements on a five-point disagree/agree scale to measure two subtypes of imagery ability – object and spatial imagery. An object imagery score and a spatial imagery score are each estimated by the average of 15 unique questions.

Cue classification ratings. To determine which of the given scenarios reflected imagined event or scenes in an objective manner, we collected ratings for each scenario cue using Amazon's Mechanical Turk online rating platform. 100 raters were presented with the six cues in random order and judged whether the cue best represented an "activity" (event) or a "place" (scene) by

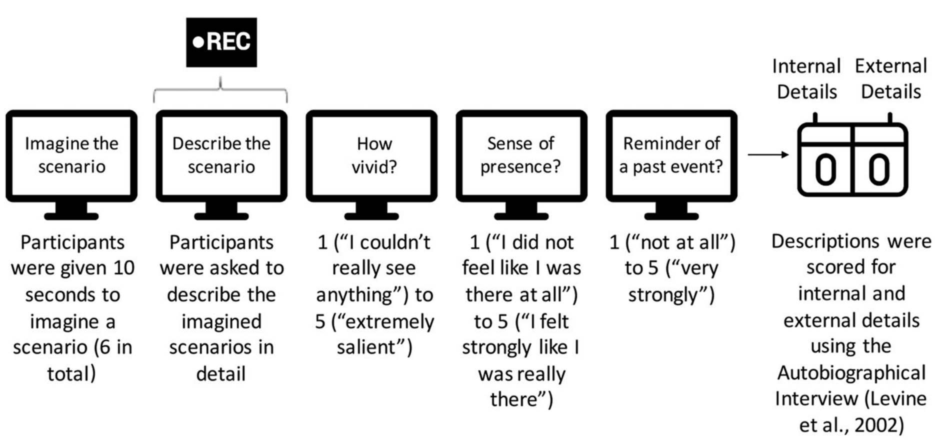

Figure 1. A schematic of the experimental design used in the current study.

selecting a number from a scale that ranged from 0 to 100. For this survey, we defined activities (events) as events that happen in our lives and that can occur in many locations and places (scenes) as descriptions of specific locations or spatial contexts. "Activity" and "place" were used as anchors for the scale (either 0 or 100) and whether they appeared as the 0 or 100-point anchor was counterbalanced across participants. For analyzing the data, we converted all ratings so that scores closest to 0 represented cues that best defined a "place" and scores closest to 100 represented cues that best defined an "activity." (N.B. for an additional study, we also collected ratings of frequency, imageability and uniqueness ratings for each cue).

Description classification ratings. Our experimental procedure did not specifically instruct participants to generate event versus scene cues, thus we had two trained raters read each participant's description - without knowledge of the associated cue - and classify the descriptions as scenes or events. For each description, the raters first indicated if the description best represented an activity or place. Next, they judged on a 100-point scale the proportion of the details in the descriptions that pertained to an activity (0 – no activity details were present; 100 – only activity details were included in the description) and the proportion of details that pertained to location details using a similar 100-point scale.

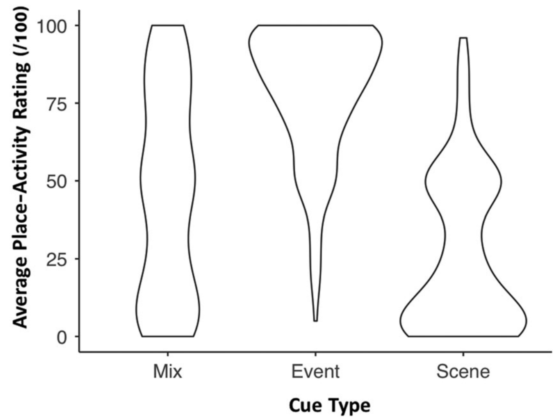

Figure 2. The distribution of rating scores for the cue categories collected from online MTurk raters. Lower scores on the place-activity rating scale indicates the cue was rated as representing a scene (place) and higher scores indicates the cue was rated as representing an event. The width of the plot indicates a higher probability of a rating.

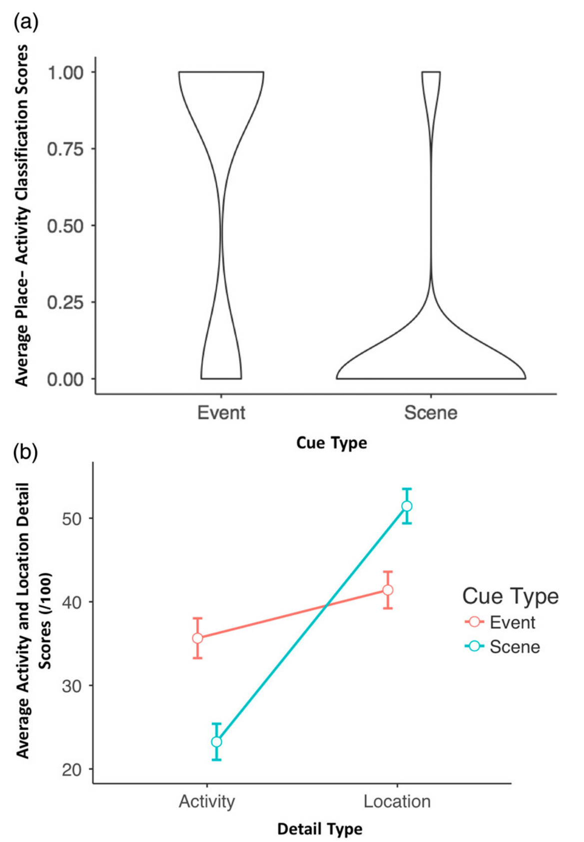

Figure 3. (a) The distribution of the classification of participant scene and event cue descriptions as places (0) or activities (1) as judged by two unbiased raters. (b) The average activity and location detail rating scores of participants' scene and event cue descriptions as judged by two unbiased raters. Standard error bars are shown.

Results

Cue classification ratings. After implementing a 95 confidence limit (i.e., applying a trim proportion value of 0.05 to the sample), we used the average MTurk online rating scores to select the two cues that were most consistently defined as events (activities), the two most consistently defined scenes (places), and then discarded the two cues that were intermediate or a "mix" between these two classifications (Table 1; see Figure 2 for an illustration of the density of place-activity ratings scores for each of these cue categories).

Description classification ratings. As illustrated in Figure 3a, the two blind raters who judged all of the participants' scenario descriptions could accurately discriminate those generated to cues classified via the online ratings as event and scenes (0 – scene and 1 – event). 80% of the descriptions made in response to cues classified as scenes were judged as representing a scene whereas 74% of the responses to cues classified as events were judged as representing events/activities. A chi-square analysis confirmed that these percentages were different (X^2 (1,162) = 60.2, $p < .001$).

The two blind raters also estimated the proportion of the details in the descriptions that were activity and location details. Treating the ratings as repeated measures and each rating as an independent factor, an ANOVA revealed a significant interaction between cue type and rating ($F(1,160) = 22.0$, $p < .001$, $\eta_p^2 = .12$). Post-hoc comparisons indicated that activity ratings were significantly higher for descriptions made in response to event cues than scene cues ($p < .001$) and location ratings were significantly higher for descriptions made in response to scene versus event cues ($p = .008$). There was a greater rating of location than activity details for scene cues ($p < .001$), but there was no difference between the ratings of activity and location details for event cues ($p = .33$; Figure 3b). The resulting distinctions of the activity and location detail ratings within each cue category suggests that scene descriptions incorporated more spatial details than activity details but event descriptions did not contain a preferential amount of activity nor spatial details.

Event and scene descriptions. Using the event and scene cues from the above cue classification analysis, we ran a repeated measures ANOVA with cue type condition (event versus scene) and detail type (internal versus external) as within-subjects factors on the average number of details generated for each participant. There was a main effect of condition ($F(1,37) = 13.47$, $p < .001$, $\eta_p^2 = .27$) and detail ($F(1,37) = 133.23$, $p < .001$, $\eta_p^2 = .78$), as well as an interaction between the two factors ($F(1,37) = 4.74$, $p = .04$, $\eta_p^2 = .12$). Focusing on the effects of condition, more details were generated for events (mean = 15.82, $SE = 1.37$) than scenes (mean = 13.22, $SE = 1.19$; $p = .001$). This difference was more prominent for internal (event: mean = 26.20, $SE = 2.26$; scene: mean = 22.29, $SE = 1.93$; $t(37) = 3.28$, $p = .002$) than external details (event: mean = 5.43, $SE = .73$; scene: mean = 4.15, $SE = 0.66$; $t(37) = 2.35$, $p = .02$).

We ran a MANOVA with cue type condition as a factor (event versus scene) and ratings of vividness, sense of presence, and use of a past event as variables of interest. This revealed an overall significant effect of condition ($F(1,35) = 3.71$, $p = .02$, $\eta_p^2 = .24$). Follow-up univariate tests indicated that the vividness ratings did not significantly differ between the conditions ($F(1,37) = .05$, $p = .82$, $\eta_p^2 = .001$), but ratings of sense of presence ($F(1,37) = 4.05$, $p = .05$, $\eta_p^2 = .10$) and use of a past event ($F(1,37) = 4.44$, $p = .004$, $\eta_p^2 = .11$) did differ between conditions. Imagining scenes was associated with a higher rating of sense of presence (mean = 3.5, $SE = .1$) than events (mean = 3.2, $SE = .1$). In contrast, imagining events was associated with a higher endorsement of recalling a past event (mean = 3.0, $SE = .2$) compared to scenes (mean = 2.6, $SE = .2$).

Finally, we looked at how the number of internal details – a measure of episodic memory – could be predicted by these subjective ratings by running linear regressions separately for events and scenes descriptions. The model for the event descriptions was not significant ($F(1,34) = 1.19$, $p = .33$); however the model for the scene descriptions was significant ($F(1,34) = 4.18$, $p = .01$, $R^2 = .27$). Vividness ($beta = .37$, $t(37) = 2.03$, $p = .05$) and the use of a past event ($beta = .41$, $t(37) = 2.41$, $p = .02$), but not sense of presence ($beta = .28$, $t(37) = -1.46$, $p = .15$), significantly predicted the number of internal details used to describe scenes.

Individual differences in imagery ability. We established object and spatial imagery scores using the procedures associated with the OSIQ (Blajenkova et al., 2006). The mean object imagery score was 3.5 ($SE = .1$) and the mean spatial imagery score was 3.0 ($SE = .1$), which align with what has been previously reported (Blajenkova et al., 2006). Also similar to previous studies, object and spatial imagery scores in our sample did not correlate ($r = -.12$, $p = .46$).

With thes scores, we performed two sets of correlational analyses. One examined the link between imagery ability and detail generation and the other examined the link with the subjective ratings. These correlations were planned a priori thus did not require correction for multiple comparisons. For our first analysis, we ran a series of Pearson correlations between object and spatial imagery scores and the average number of internal and external details used in the descriptions for events and scenes. We found the ability to generate internal details was related to object imagery scores, but the ability to generate external details was related to spatial imagery scores only for event descriptions (Table 2).

For our second analysis, we calculated Pearson correlations between object and spatial imagery scores and the average subjective rating scores for each cue type, which are listed in Table 3. Of note, object imagery scores significantly and positively related to the experience of constructing both events and scenes, particularly, how vividly these events were experienced. Sense of presence correlated with object imagery ability scores for event descriptions (Table 3).

Discussion

In this study, we report evidence that dissociable processes support constructing and experiencing event- and scene-based mental representations. In a within-subjects design, participants described imagined scenarios to cues that were classified as either an event (e.g., a family meal) or a scene (i.e., spatial context, e.g., a beach). We assessed the use of episodic memory processes in forming these scenarios by scoring the resulting descriptions for the number of episodic (internal) details, but also scored for the number of non-episodic (external) details (Levine et al., 2002). To measure how these representations were experienced, participants rated how vividly they imagined each scenario as well as their sense of presence in the associated image and indicated whether the image stimulated the retrieval of a past personal experience. Our first finding was that more details were used to describe event compared to scene

Table 2. Pearson correlation co-efficients between the average number of details generated with object and spatial imagery ability scores as determined by the OSIQ.

	Object Imagery	Spatial Imagery
Event Descriptions		
Internal details	0.32*	0.04
External details	−0.07	0.33*
Scene Descriptions		
Internal details	0.11	0.24
External details	0.18	−0.11

*$p < .05$.

Table 3. Pearson correlation co-efficients between the average subjective ratings for generating event and scene representations with spatial imagery ability scores as determined by the OSIQ.

	Object Imagery	Spatial Imagery
Event Descriptions		
Vividness	0.48**	−0.18
Sense of Presence	0.42**	−0.05
Use of Past Event	0.35*	0.27
Scene Descriptions		
Vividness	0.48**	−0.03
Sense of Presence	0.26	0.13
Use of Past Event	0.35*	0.33*

*$p < .05$, **$p < .01$.

representations, a finding that was particularly prominent for internal details. Second, participants were more likely to recall a past event when constructing event compared to scene images but generated scene representations with a greater sense of presence than event representations. We also found vividness ratings and the use of a past event could predict internal detail generation (i.e., episodic content) for scene but not event representations. These patterns are evidence that the recruitment of episodic memory – as indicated by internal detail generation – make different contributions to forming distinct mental representations and this is linked to one's mental experience of the representation. In addition to these results, we found that individual differences in distinct forms of imagery ability – spatial and object imagery – were linked to the likelihood of generating external and internal details but only for event representations. This suggests that different forms of imagery contribute to different aspects of forming mental representations, and specifically, event scenarios are more heavily affected by imagery ability fluctuations. We discuss the implications of both sets of findings below.

Dissociable cognitive processes support forming event and scene representations

Overall, our findings suggest that there are distinct cognitive mechanisms that support forming event and scene representations, which fits with some recent autobiographical memory research that reports processing differences between event-based and spatial-based memory retrieval (Sheldon & Chu, 2016). When remembering autobiographical experiences was triggered by an event cue (e.g., a family meal), recall was more conceptual in nature and recruited a greater diversity of information than when remembering was triggered by a scene cue (e.g., a coffee shop), for which recall tended to be more perceptual and experiential in nature (Sheldon & Chu, 2016). Likewise, we found imagining event representations was associated with generating a greater diversity of details (i.e., both episodic and non-episodic details), but producing specific episodic content was related to imagining scene representations, which were experienced with a greater sense of presence than events. This means that mental representations are more diverse in content when they are thought of as events yet more episodically experiential when they are thought of as scenes.

In one respect, our findings align well with the constructive episodic simulation hypothesis (Addis, Pan, et al., 2009; Addis & Schacter, 2008; Madore et al., 2014). This hypothesis suggests that (hippocampal) episodic memory processes are important for relating both spatial and non-spatial details of mental scenarios (Addis, Sacchetti, et al., 2009; Addis & Schacter, 2008, 2011; Eichenbaum, 2004, 2016; Schacter & Addis, 2007; Schacter et al., 2012). Extending from this theory, the differences we report suggest that different aspects of episodic memory play a stronger or weaker role in forming mental representations that will depend on what details are being used to form it.

In another respect, our findings align with the scene construction theory (Hassabis et al., 2007; Hassabis & Maguire, 2009; Maguire & Hassabis, 2011; Maguire et al., 2016; Maguire & Mullally, 2013; Mullally et al., 2014). We found that unbiased raters judged the descriptions of imagined scenarios in response to scene cues as including mostly spatial location details but judged the descriptions made to events cues as including a similar amount of activity (event) and location (spatial) details. This finding showcases the natural importance of spatial processes – or least establishing a mental "location" – for forming both types of mental representations, corresponding to scene construction theory. It also reinforces the notion that imagined events may be more broadly defined in terms of content than imagined scenes.

We offer a more cooperative interpretation of our results rather than interpreting our findings as support for only one of these theories. We propose that episodic memory processes can contribute to different aspects of event and scene representations (for related thoughts, see Roberts, Schacter, & Addis, 2017). Specifically, we suggest that event representations recruit episodic memory to support knowledge-guided construction – thus recruiting diverse memory elements related to conceptual knowledge – whereas scene representations relate more strongly to experiential information, thus these are built with a more perceptually-based route to construction (Sheldon & Levine, 2016). Although speculative, data from our study supports this idea. First, event representations stimulated a greater generation of internal and external details compared to scene representations. External details include recalling general knowledge and facts, which suggests that these imaginations are tapping into a more expansive range of one's knowledge than scenes. Also, we found that event representations were more likely to remind a participant of a past event, suggesting a role of prior knowledge or experience when mentally constructing events. Scene representations were associated with a greater sense of presence than event representations, indicating that participants were more immersed in these simulations. Moreover, the ability to generate episodic content for scene representations (i.e., internal details) was predicted by vividness and the use of a past event, which suggests that episodic memory processes are playing some role in the experience of these imaginations, particularly because vividness is a strong indicator of immersing oneself into the sensory-perceptual details of a generated scenario (Wheeler, Petersen, & Buckner, 2000).

The event/scene difference in the predictive power for generating episodic details of the subjective ratings is a good indicator that episodic memory processes are differently related to the experience and likely formation of event and scene representations. A similar dissociation has been reported in neuroimaging studies that have provided evidence for two MTL networks that support memory retrieval (Ranganath & Ritchey, 2012; Ritchey, Libby, & Ranganath, 2015; Sheldon, McAndrews, Pruessner, & Moscovitch, 2016). Specifically, these studies find evidence for an anterior MTL memory system that forms past event representations with existing semantic or conceptual information and a posterior MTL memory system that supports contextually-guided (perceptual) retrieval and helps bind together elements of a memory to a specific location or scene (also see, Giovanello, Schnyer, & Verfaellie, 2009).

More generally, our findings are also relevant for models of autobiographical knowledge organisation. The self-memory system model posits that such knowledge is organised in a hierarchy, from general event information to specific episodic and context-specific content (Conway, 2000; Conway & Pleydell-Pearce, 2000; Tulving, 2002). At the top of this hierarchy is knowledge organised around lifetime periods, which is both thematic and conceptual knowledge of a period in our lives (e.g., "when I completed my undergraduate degree"). General event knowledge makes up the middle of this hierarchy (e.g., "romantic relationships"), and event-specific knowledge – sensory and perceptual details associated with a single past event – are at the bottom. Considering the immense overlap between accessing autobiographical memories and forming new mental scenarios (Moscovitch et al., 2016; Schacter et al., 2012; Sheldon & Levine, 2016; Szpunar et al., 2013), we speculate that mental representations that include more diverse details (e.g., event representations) would require access to autobiographical knowledge from the top of this hierarchy, whereas one can access information more directly from the bottom of the hierarchy – going directly to contextual-perceptual (spatial) details – when forming scene representations. In other words, event and scene representations require accessing autobiographical information in fundamentally different ways, which is reflected in how episodic memory is used.

The role of object and spatial imagery ability

In addition to dissociating processing support for event and scene mental representations, we also found support for our hypotheses regarding how different forms of imagery guide constructing mental representations. First, object imagery ability, the likelihood that an individual recalls rich perceptual details when forming mental scenarios, was particularly associated with the experiential aspect of the tested mental tasks. We found that object but not spatial imagery positively correlated with ratings of vividness for both event and scene simulations. While object imagery correlated with the ability to generate episodic details for event representations, there was no relation for generating these details for scene representations. This finding supports some work that has linked memory specificity –recalling episodic details – and imagery (Brewer, 1996; Rubin, Schrauf, & Greenberg, 2003) but specifies that this is for recalling events and for object-based imagery. We were surprised to find this link specific to events, but one possibility is the use of such imagery processes is necessary for forming scene representations, which are more perceptual in nature, but enhance the episodic content of event representations.

Unlike object imagery, spatial imagery ability distinctly related to the generation of external details while imagining events, but not scenes. External details measure the recruitment of extraneous and more conceptual information related to the central node of a mental representation, and as such, they may serve as a marker of recalling higher-order or scenario-peripheral elements. These elements may act as "scaffolding" for generating the main details of the mental representations (for a similiar view, see Irish, Addis, Hodges, & Piguet, 2012). Thus, we propose that spatial imagery, as measured at the level of the individual, is a metric for the ability (or tendency) to form a blueprint of an imagined event that can then guide more specific imagery-based processes (the use of which is measured by object imagery scores) to fill in the details of a mentally represented event (for example, see Robin, Wynn, & Moscovitch, 2016). This idea fits with the previous finding that spatial imagery is related to retrieving broad level details from complex scenarios (Sheldon, Amaral, et al., 2016) and that object imagery is related to recalling specific details from remembered events (Vannucci et al., 2015).

To further comment on the link between spatial imagery ability and generating external details for event representations, it is worth noting that such non-episodic details are not all spatial in nature. Thus, it could be that trait-level spatial imagery ability is capturing not a tendency for spatial processing per se, but rather for coarse-grained imagery processes that include, but may not be limited to, imagining broad spatial relations. This follows with another view that coarse-grained imagery likely does not rely on the same processes as fine-grained imagery processes that may be captured by object imagery (Pearson & Kosslyn, 2015; Pearson, Naselaris, Holmes, & Kosslyn, 2015). Thus, we suggest that there are dissociable forms of imagery processing for event-based mental representations, which are more diverse than scene-based mental representations.

Limitations and conclusions

As with any study, our study has a few limitations. In our experimental design, we included six cues, however, two of these cues did not represent events or scenes and were discarded from analysis. Having these cues in the experiment may have altered the way participants performed the task. We also note that the supplementary cue ratings we collected via MTurk indicated that scene cues were rated as more vivid, frequent, and unique than event cues, which may have impacted our pattern of results. Despite these limitations, our findings are a strong step towards understanding the processing support for complex tasks that require mentally generating events and scenes, and supplement a growing body of literature suggesting that trait-level imagery differences affect the way individuals approach tasks that require mental representations – from remembering the past to imagining the future. Thus, we advocate for the incorporation of individual approaches and abilities to complex cognitive tasks when investigating the underlying cognitive mechanisms.

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