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The ability to recall scenes is a stable individual difference: Evidence from autobiographical remembering

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ABSTRACT

Four behavioral studies (*ns* ~ 200 to 400) extended neural studies of ventral stream damage and fMRI activation and behavioral studies of scene recall conducted on individual memories to individual differences in normal populations. Ratings of *scene* and *contents* were made on one set of autobiographical memories. Ratings of *reliving*, *vividness*, *belief*, *emotional intensity*, and *temporal specificity* were made on different memories. Thus, correlations between these ratings were due to variability in the participants, not the events remembered. *Scene* correlated more highly than *contents* with *reliving*, *vividness*, *belief*, and *emotional intensity* but not *temporal specificity*. *Scene* correlated more highly than other visual imagery tests with *reliving*, *vividness*, and *belief*. *Scene* correlated with individual differences tests of episodic memories and future events more highly than it did with tests of semantic memory and spatial navigation abilities. Moreover, *scene* had high test-retest correlations measured at periods of up to one month. The ability to recall scenes is a stable disposition, with both convergent and divergent validity, which predicts basic qualities of autobiographical memories. A Scene Recall Imagery Test is introduced.

1. Introduction

For autobiographical memory, a scene is the constructed retrieval, or the future imagination, of the layout of an event. Like any drawn scene, it must be from a fixed location, which provides the person retrieving it a perspective and thus, the sense of mentally viewing the scene again. Like any drawn scene, it has to be for one time, even though it could be a prototype scene integrated over many instances. Thus, as defined here, a scene requires a layout and a perspective, which combine to increase the autobiographical memory's sense of reliving, vividness, and belief that the event occurred as remembered.

A wide range of recent advances in neuropsychological, neuroimaging, and behavioral research indicates that scene construction is a fundamental cognitive process in the perception, encoding, and recall of autobiographical memories as well as the creation of future autobiographical events (e.g., Epstein & Kanwisher, 1998; Hassabis, Kumaran, Vann, & Maguire, 2007; Rubin, Deffler, & Umanath, 2019). Both neural damage and activation studies point to a system centered in the visual ventral stream from the visual cortex to the hippocampus (Rubin & Umanath, 2015). Behavioral data show that the degree to which individual memories consist of scenes correlates with the degree to which they are relived, vivid, and believed to be accurate, which are three classic properties of autobiographical memories (Rubin et al., 2019).

When the ratings of properties of different autobiographical memories are averaged to provide values for each individual, the properties correlate with standardized personality tests and measures of clinical disorder (e.g., Rubin, Dennis, & Beckham, 2011; Rubin, Schrauf, & Greenberg, 2003; Rubin & Siegler, 2004). The properties also correlate with themselves when measured on different events (Rubin, Schrauf, & Greenberg, 2004). Although these studies predate the formulation of scene recall, other measures used here, including measures of visual imagery, show such correlations. Together, these findings suggest that scene construction may be an individual differences variable with extreme levels occurring in neuropsychological damage and clinical syndromes including depression, schizophrenia, and dementia. In addition, individual difference in scene recall could inform events other than autobiographical memories (e.g., future events, fictional events, representations of other people's lives, and laboratory episodic memory). It also could inform development across the lifespan and the extent to which animals, children, and the cognitively impaired who cannot report on the reliving, vividness, and belief are having memories similar to autobiographical memories.

The ways scene construction varies across individuals in normal

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populations are examined in three studies. A fourth study describes the construction and evaluation of an individual differences measure of scene recall, the Scene Recall Imagery Test (*SRIT*).

1.1. Behavioral evidence for the importance of scenes in autobiographical memory

1.1.1. Autobiographical memory

Autobiographical memory is a term with multiple meanings in the psychological literature (Rubin, 1986, 1996). It can be considered a subset of event memory (Barsalou, 1988; Radvansky & Zacks, 2014; Rubin & Umanath, 2015; Zwaan & Radvansky, 1998), a broader classification that includes fictitious events, events not about the individual creating them, and events extended over long periods. It also can be considered as a frequent behavior of an intelligent, social species that depends on the recall of personally experienced events as well as socially and culturally shared non-experienced events, independent of their basis in fact, a behavior that is imparted to children in culturally specific ways (Nelson & Fivush, 2004). In the research that follows, autobiographical memory is defined as the collection of memories individuals report they have for specific events from their lives. A specific autobiographical memory is viewed as occurring at a particular time, even though it may have been constructed from schemas developed over many exposures.

Autobiographical memories, as defined here, are not constructed from an abstract, propositional cognitive structure or from any other unitary process or neural basis. Rather, sensory, language, emotion, and other systems, each of which uses fundamentally different structures and processes for fundamentally different kinds of information combine to encode, retain, and retrieve autobiographical memories. Each system has its own kinds of schemata and types of errors, which have been studied individually. Each system has a long intellectual and experimental history. Most systems date back as far as the recorded history of speculation about the mind (e.g., the five senses, narrative, and emotion; see Rubin, 2006 for a review). Each system can be supported by results from neuroanatomy, neuropsychology, neuroimaging, cognitive-experimental psychology, and individual differences research. Stability and change in autobiographical memories are due both to the schemata in each system (e.g., narrative schemata, visual schemata, auditory schemata) and to how they interact and constrain possible recalls (Greenberg & Rubin, 2003; Rubin, 2006, 2012, 2015). Some can be seen as part of scene construction, such as visual imagery and the core memory processes. Other processes, such as narrative and emotion, have less obvious contributions to scene construction (e.g., Habermas, 2018; Hirst & Echterhoff, 2012; McAdams & McLean, 2013; Talarico, LaBar, & Rubin, 2004).

1.1.2. The theoretical basis for the measures of autobiographical memories and scenes

Ratings of three phenomenological properties of autobiographical memories provide measures of the general quality of autobiographical memories. In contrast to the systems used in constructing autobiographical memories, the three phenomenological properties are assessed by ratings about the constructed memory. The three properties of a sense of *reliving*, *vividness*, and *belief*[1] in the accuracy of autobiographical memories have been key in understanding autobiographical memory, both historically and in current research (e.g., Brewer, 1986; Fitzgerald & Broadbridge, 2013; Johnson, Foley, Suengas, & Raye, 1988; Rubin, Schrauf, & Greenberg, 2003; Rubin & Siegler, 2004; Sutin & Robins, 2007). *Reliving* (e.g., autonoetic consciousness, mental time travel, recollection, remember versus know judgments) is a defining feature of episodic memory (Baddeley, 1992; Tulving, 1983, 2002). *Vividness* has been one factor in determining whether memories are based on actual events and thus whether they are relived and believed (Brewer, 1986, 1996). *Belief* in the occurrence and accuracy of events has long been an important feature in distinguishing autobiographical memories from other types of memory and imagination. Whether an event is believed is important in law, clinical syndromes, and reality monitoring (Brewer, 1996; De Brigard, 2017; Johnson et al., 1988).

The concepts of vividness and visual imagery are similar but distinct. Some populations are deficient in visual imagery. These include the congenitally blind, the color blind, and those who experience visual images only in dream, hypnogogic, or drug-induced states. Some situations are deficient in visual imagery. These include events that occurred when blindfolded or in total darkness. For both populations and situations, non-visual vivid memories are possible (Greenberg & Rubin, 2003; Rubin, Burt, & Fifield, 2003; Rubin & Umanath, 2015).

Ratings of two properties of scene construction provide a measure of the quality of a scene. The first property is that the *layout* of the scene as well as its *content* is important. The second is that the person remembering the scene has a fixed location, or *perspective*, relative to the scene. These features give the person remembering a sense of where he or she is in relation to the contents of the scene. In contrast to field (first person) versus observer (third person) perspective (Nigro & Neisser, 1983; Rice & Rubin, 2011), in which the location of the viewer is measured relative to encoding, here location is measured at retrieval. Although the layout versus content distinction is clear in the neural literature, the visual perspective at recall distinction is not always explicitly acknowledged. Nonetheless, together these features provide a sense of actually remembering the event that is lacking if the scene is not recalled.

1.1.3. The importance of scenes for individual autobiographical memories

The clearest evidence for the importance of scenes in the prediction properties of individual autobiographical memories comes from a recent paper (Rubin et al., 2019). In each of three studies, approximately 200 participants rated items measuring the *layout, perspective, content, reliving, vividness, belief*, and *emotion* in terms of *emotional intensity* of seven word-cued events. In two of these studies, there were also items measuring *temporal specificity* that were devised as contrasts to the measures of the spatial specificity present in scenes. However, unlike the studies conducted here, all ratings were based on the same memories. Thus, correlations could be influenced by both differences in the events rated and the participants rating them. In each of these three studies, as well as in a data set combining them, the scene variables were correlated with the three phenomenological measures of *reliving, vividness*, and *belief*. The correlations of *layout* and the combination of *layout* and *perspective* items were greater than were those of *content* and other measures for both simple correlations, multiple regressions, and structural equation models. In addition, the correlations of spatial specificity were greater than were those of *temporal specificity*.

1.2. Neural evidence for the importance of scenes in autobiographical memories

1.2.1. Hippocampal-based amnesia

There are differences among researchers on the general function of the hippocampus in retrieving autobiographical memories. There is evidence that autobiographical memories, no matter how old, depend on the hippocampus for retrieval (e.g., Nadel & Moscovitch, 1997; Winocur & Moscovitch, 2011), whereas other evidence supports the claim that older memories are independent of the hippocampus (Alvarez & Squire, 1994; Scoville & Milner, 1957; Squire, 1992). In contrast, Kopelman (2019), in his 2018 presidential address to the International Neuropsychological Society, takes a more nuanced view, which leads to no simple theoretical mechanism for the hippocampus in retrieval. The role of the hippocampus in scene construction, however,

[1] The measures that were rated and analyzed are placed in italics in the body of the paper to contrast them from the concepts that rely on these measures.

is clearer.

The strongest evidence for the role of the hippocampus in scene construction in autobiographical memory comes from neuropsychology. The ability to have autobiographical memories and the ability to imagine scenes are both lost with bilateral hippocampal damage (Andelman, Hoofien, Goldberg, Aizenstein, & Neufeld, 2010; Race, Keane, & Verfaellie, 2011; Robin, Rivest, Rosenbaum, & Moscovitch, 2019; Rosenbaum, Gilboa, Levine, Winocur, & Moscovitch, 2009; Tulving, 1985; for exceptions see Cooper, Vargha-Khadem, Gadian, & Maguire, 2011, and Squire et al., 2010).

In addition, there is a pattern of a loss of autobiographical memory and scene construction abilities with some preserved navigation ability, observed across etiologies and research groups. This pattern helps to distinguish scene construction from aspects of spatial ability. Consider observations from well-documented cases of amnesia. H. M. could draw a map of the interior of his childhood home that would allow him to navigate within his house, but H. M. did not show evidence of recalling scenes when questioned about his memories (Corkin, 2002). Similarly, K. C., Tulving's most studied amnesic who was tested more generally by the Toronto group (Rosenbaum et al., 2000) and E. P., an amnesic studied extensively by Squire's group (Teng & Squire, 1999), could both indicate the direction between familiar pre-amnesia landmarks but showed no evidence of recalling scenes. The same pattern held for T. T., a London taxi driver studied by the Maguire group (Maguire, Nannery, & Spiers, 2006).

In terms of hippocampal involvement, Maguire and colleagues are the closest in theoretical terms to the current view (e.g., Bonnici et al., 2012; Chadwick, Mullally, & Maguire, 2013; Hassabis & Maguire, 2007; Kumaran & Maguire, 2005; Maguire et al., 2006). They note that the hippocampus is involved in a range of cognitive functions including episodic memory, imagining, future thinking, and spatial navigation (e.g., Clark et al., 2019). These functions all involve scene construction; "the hippocampus is constructing scenes *all* the time" (Maguire & Mullally, 2013, p. 1185). Maguire and colleagues focus on the role of the hippocampus and expand the concept of scenes to include other functions. In contrast, in this paper, I isolate *perspective* and *layout* as the two key features of the recall of a *scene* and demonstrate that they are stable individual differences variables. To do this, I need to isolate *scene, perspective,* and *layout* as individual differences that are different from, but can affect, other functions. These functions include knowing the contents of scenes, episodic memory and autobiographical memory (as measured here by *reliving*, *vividness*, and *belief*), imagining fictitious events, future thinking, and spatial navigation. All of these are functions that Maguire and colleagues do not need to separate from their measures of hippocampal scene construction to support their theory.

Hassabis et al. (2007) investigated whether patients with hippocampal amnesia could imagine new scenes. They analyzed their five patients' and ten control subjects' verbal descriptions of constructed scenes. Patients were markedly impaired at imagining new experiences. In particular, "the patients' imagined experiences lacked spatial coherence, consisting instead of fragmented images in the absence of a holistic representation of the environmental setting" (p. 1726). To focus on the layout of scenes, I adapted their concept and measure of spatial coherence to form rating-scale measures of *coherence* and *fragmentation*. The resulting measures are described in detail in the methods section of Study 3.

1.2.2. Amnesia from damage earlier in the visual ventral stream

In a less common etiology, people with damage earlier in the visual ventral stream in areas that are needed to construct scenes have visual-memory-deficit amnesia (Greenberg, Eacott, Brechin, & Rubin, 2005; Greenberg & Rubin, 2003; Rubin & Greenberg, 1998). Visual-memory-deficit amnesia provides strong independent support for the role of scene construction in autobiographical memory because the damage often spares the patient's hippocampi, structures important to many processes besides scene construction. Behaviorally, visual memory deficit occurs when the patient can draw or copy something that is present but can neither identify it from visual input (i.e., visual agnosia) nor imagine or draw it from memory (Farah, 1984); this last criterion means the patient cannot imagine or recall scenes. In visual-memory-deficit amnesia, the loss of autobiographical memory for all pre-damage events produces an amnesia that can be as severe as amnesias caused by extensive medial temporal lobe damage. After a relatively short period, post-damage events can usually be encoded and recalled with their scenes constructed from other senses as they would be in other visually impaired individuals. The evidence for these claims comes from a review of existing cases (Rubin & Greenberg, 1998) and later testing of one of those cases (Greenberg et al., 2005). In the original review, all 11 patients who met the criteria for the visual memory deficit also had reports of amnesia. Five of the seven cases that reported on both pre- and post-damage amnesia found more pre-damage amnesia. Of these five cases, four reported no temporal gradient in the amnesia. Both of the last two observations are a contrast to what would be expected from amnesia caused by hippocampal damage, in which post-damage amnesia is more severe and memories for older events tend to be spared. Nonetheless, they are consistent with the inability to remember events that would have been recalled as scenes if the neural loss had not occurred (Rubin & Greenberg, 1998).

The claim that amnesia can be caused by a loss of scene construction cannot be made for any other process or system involved in constructing autobiographical memories, except for a more general loss of explicit memory associated with the hippocampus and surrounding structures. A loss of narrative reasoning associated with frontal lobe damage can result in confabulated autobiographical memories (Baddeley & Wilson, 1986). A loss of normal emotional functioning results in autobiographical memories with impaired emotions (Adolphs, Cahill, Schul, & Babinsky, 1997). Cortical damage to language and auditory areas produce impairments to language production and auditory imagery in autobiographical memory, respectively. However, these losses do not cause amnesia (Greenberg & Rubin, 2003). In contrast, a loss of scene construction leaves no autobiographical memory.

The role of hippocampal damage is different from the role of damage earlier in the visual system. With damage to the hippocampus, information cannot be integrated into new autobiographical memories; thus, post damage amnesia is severe. Pre-damage memories, especially older memories, are less affected and are often preserved without scenes. With damage earlier in the visual ventral stream, visual information is not available to construct scenes. For events that occurred after the damage, autobiographical memories can be formed with scenes constructed with information obtained from senses other than vision. For events that occurred before the damage, the visual information that was the most important information for the initial scene construction is lost. Without it, the scene cannot be constructed again. This functions much the way scene construction and other tasks that depend on visual information in the sighted are performed in the congenitally blind and in sighted individuals who are blindfolded or in the dark during the event. Non-visual information is used instead of the visual information (De Beni & Cornoldi, 1998; Greenberg et al., 2005; Kerr, 1983; Ogden, 1993; Rubin & Greenberg, 1998; Rubin & Umanath, 2015).

1.2.3. Neuroimaging evidence for the importance of scenes in autobiographical memories

Neuroimaging supports the neuropsychological findings that the visual ventral stream from the visual cortex to the hippocampus is centrally involved in both scene construction and autobiographical memory (e.g., Baldassano, Esteva, Fei-Fei, & Beck, 2016; Cabeza et al., 2004; Daselaar et al., 2008; Kanwisher & Dilks, 2014; see Rubin & Umanath, 2015 for a review). For instance, the parahippocampal place area is activated more by scenes than objects; for indoor scenes, activation occurs even if objects are removed, leaving just the walls and floor (Epstein & Kanwisher, 1998). The hippocampus and retrosplenial cortex are most active before the precuneus and visual cortex, showing temporal course of access and elaboration of autobiographical memories in the ventral stream (Daselaar et al., 2008). The parahippocampal cortex is active for objects that evoke a strong sense of the surrounding space compared to ones that do not (Maguire & Mullally, 2013; Mullally & Maguire, 2011). Moreover, most of these areas are more active for the recognition of autobiographical memories of photographs taken by a participant than photographs of the same general scene taken by a different participant and viewed only in the laboratory. These findings show the effect of the ventral stream on a richer autobiographical memory (Cabeza et al., 2004).

2. Goals and design of the current study

2.1. Empirical and analytic approach

The literature reviewed is consistent with the claim that people without significant neurological impairments vary in their ability to form scenes in ways that are correlated with their ability to recall autobiographical memories. Thus, scene recall is expected to vary not only across individual memories but also across individuals. This claim however remains an extrapolation from the neuropsychological findings and from the behavioral data, which focus on measures of scene construction and autobiographical memory within the same events. To test this extrapolation and some of its practical and theoretical implications, six empirically falsifiable hypotheses were made. They are presented in Table 1. Research relevant to the hypotheses is introduced in the individual studies. Because scene construction has not been investigated as an individual differences measure, the theoretical claims, though constrained by published studies, are novel. Therefore, throughout the paper, replications of the major claims are needed and are clearly noted along with any deviations from predicted results.

Four studies provide replicated tests of the hypotheses. Each has a different purpose and accumulates different knowledge. Moreover, in order not to fatigue participants, not all measures could appear in all studies. The items used to measure *scene* change slightly between the first three studies, which explores hypotheses and the fourth study, which evaluates an instrument to be used as a freestanding individual differences test. The fourth study also changes its statistical analyses to focus on measuring psychometric properties. To assess the stability of *scene* and *content* over a delay, the same participants were tested in the second and third studies.

In Study 1, 400 MTurk workers answered items about the *scene* and *content* in one set of memories and five properties of autobiographical memories of a different set of memories. In addition, there were two classic individual differences tests of visual imagery: the Vividness of Visual Imagery Questionnaire (*VVIQ*, Marks, 1973) and the Test of Visual Imagery Control (*TVIC*, Gordon, 1949) that were used by both Greenberg and Knowlton (2014) and Zeman, Beschin, Dewar, and Della Sala (2013). In Study 2, 341 Duke undergraduates rated the same measures, but without the *VVIQ* and *TVIC* visual imagery tests, to provide a replication of the basic findings. In Study 3, a subset of 197 of these undergraduates repeated the scene recall task after a delay between one week and two months to provide a measure of test-retest reliability. In addition, they also completed the *VVIQ*, *TVIC*, and three other visual imagery tests. To provide an assessment of how scene construction relates to other memory abilities, Study 3 included a standardized test of *episodic memory* ability, *semantic memory* ability, *spatial navigation* ability, and creating *future* event ability, the *SAM* (Palombo, Williams, Abdi, & Levine, 2013). It also included a test devised here to investigate whether *scene recall* plays a role in the Cognitive Interview (Geiselman, Fisher, MacKinnon, & Holland, 1986). In Study 4, the Scene Recall Imagery Test (*SRIT*), a simple, easy-to-administer measure of the ability to recall autobiographical memories as coherent scenes, was developed based on the results of the first three studies. The *SRIT* was administered to 300 MTurk workers, its psychometric properties were investigated, and it was correlated with individual differences tests drawn from the first three studies. These comparisons ensure that the *SRIT* retains the conceptual properties found in the earlier studies and provide an additional replication of their findings.

Throughout the studies, six hypotheses are used to make predictions. These hypotheses are in the form of *scene* measured on one set of autobiographical memories will correlate with other measures made on different memories (Hypothesis 1) or will correlate more highly with some of those measures more highly than with others (Hypothesis 2, 3, 4, and 5), or with itself at a later date (Hypothesis 6). Simple correlations are used for Hypotheses 1 and 6, multiple regressions for Hypotheses 2, 3, 4, and 5. Given the large sample size, statistical significance for Hypothesis 1 and 6 is required, but, in addition, substantial correlations are needed to convince the reader. Because it is hard to know a priori how large they should be, the multiple regressions comparing *scene* to the other measures is used as a proxy. Measures are not combined using structural equation models because the hypotheses needed to evaluate the theory are based on individual measures; differences among them provide insights for future work. When the psychometric properties of the SRIT are evaluated as an individual differences measure, the statistical analysis is changed from simple correlations and regressions to one more appropriate for that task.

Table 1
Six hypotheses.

The ability to recall scenes of autobiographical memories will correlate with
1. The reliving, vividness, and belief in the accuracy of autobiographical memories measured in a different set of memories.
2. Reliving, vividness, and belief more highly than does the ability to recall the contents of autobiographical memories.
3. Reliving, vividness, and belief more highly than with the emotional intensity and temporal specificity of autobiographical memories.
4. Other measures of visual ability and will do so in ways consistent with Hypotheses 1, 2, and 3.
5. The abilities to remember episodic memories more highly than it will with the abilities to access semantic memory and use spatial navigation but not more highly than future events.
6. Itself stably over time.

2.2. Six hypotheses

Hypothesis 1. *Scene recall* of autobiographical memories will correlate with the *reliving*, *vividness*, and *belief* in the accuracy of autobiographical memories measured in a different set of autobiographical memories. These three phenomenological properties are the classic, theoretically motivated measures of autobiographical memory ability that have been found to be stable over time and across memories (Rubin et al., 2004). Demonstrating that *scene recall* correlates with these measures when they are assessed in a different set of memories is needed to claim that *scene recall* is an individual differences ability and not just a property of the particular memories recalled.

Hypothesis 2. *Scene recall* ability will correlate with the *reliving*, *vividness*, and *belief* in the accuracy of autobiographical memories more highly than will the ability to recall the *content* of autobiographical memories. This prediction is not needed to claim that the ability to recall coherent scenes is an individual difference but rather to establish that the ability is not based on just remembering contents without remembering coherent scenes.

Hypothesis 3. *Scene recall* ability will correlate with *reliving, vividness*, and *belief* in the accuracy of autobiographical memories more highly than with measures of *emotional intensity* and *temporal specificity*. Like Hypothesis 2, Hypothesis 3 is an attempt to specify the role of *scene recall*. Both *emotional intensity* and *temporal specificity* are important psychological properties, which do not depend heavily on *scene recall* theoretically or in individual memories (Rubin et al., 2019; Rubin & Umanath, 2015). *Emotional intensity* is one of the most studied and clinically important properties of autobiographical memories. *Temporal specificity*, often combined with naming the location of an event, rather than *scene recall* is currently the standard empirical measure of the observed lack of memory specificity in studies of patients with neurological damage and clinical syndromes (Griffith et al., 2012; Kopelman, Wilson, & Baddeley, 1989; Kuyken & Dalgleish, 1995). However, *scene recall* has broader theoretical and empirical support than the within-one-day measure that is often used for *temporal specificity* (Rubin et al., 2019; Rubin & Umanath, 2015). Moreover, *temporal specificity* is included in the definition of episodic memories - and thus in definitions of autobiographical memories based on episodic memory - because episodic memory has to occur at a specific time and place, though no *scene recall* is required (Tulving, 1983). Thus, *temporal specificity* and *scene recall* are competing explanations of overgeneral memories and of autobiographical memories including their *reliving, vividness*, and *belief*.

Hypothesis 4. The *scene recall* ability of autobiographical memories will correlate with other measures of visual ability and will do so in ways consistent with Hypotheses 1, 2, and 3. This hypothesis is included because *scene recall* and construction are visual abilities, but ones with specific properties that differ from existing individual-difference measures of visual ability.

Hypothesis 5. *Scene recall* ability will correlate more highly with the ability to remember *episodic memory* than it will with measures of *semantic memory* and *spatial navigation ability*. However, *scene recall* will not correlate more highly with *episodic memory* than it does with the ability to construct *future* events. These predictions follow directly from the published theoretical formulations of scene construction (Rubin & Umanath, 2015). In addition, the prediction about future events is supported by the literature on future events that have behavioral and neural processes that are generally similar to those used in the recall of past events (for reviews, see D'Argembeau, 2012; Rubin, 2012, 2014; Schacter & Addis, 2007; 2009; Szpunar, 2010). An established individual differences test with scales for *episodic memory*, *semantic memory*, *spatial navigation*, and memory for *future* events is used to test this hypothesis (Palombo et al., 2013).

Hypothesis 6. *Scene recall* ability will correlate with itself stably over time. Such stability is needed for the claim that scene recall is a stable individual difference and not just a fluctuation that occurs within a single testing session. Here such measures are taken at a separation between one week and two months.

3. Study 1: 0074he first test of the hypotheses

Study 1 was an initial test of the first four hypotheses. In particular, it tested whether the *scene recall* ability correlates with the *reliving*, *vividness*, and *belief* in the accuracy of autobiographical memories measured in a different set of memories. It also tested whether *scene recall* ability correlates more highly with them than does the ability to recall *content*. In addition, Study 1 tested whether the ability to *scene recall* correlates more highly with these three phenomenological variables, which are key features of autobiographical memory, than with the two important but less conceptually central variables of *emotional intensity* and *temporal specificity*. Finally, Study 1 examined how well scene construction fits with two classic individual differences measures of visual ability.

3.1. Method

3.1.1. Participants

The 400 Amazon Mechanical Turk workers (192 female; mean age 35.34, *SD* 10.50, range 19 to 69) were each paid four dollars. In order to be included in the study, the participants had to complete the instruments, be native English speakers, record that they completed the study on a computer or tablet rather than a cell phone, and pass three attention checks. To help exclude 'robot' responses, participants also had to provide reasonable descriptions of the seven events used for the *scene recall* and *content* measures and four events used for the Autobiographical Memory Questionnaire (*AMQ*, Rubin, Schrauf, & Greenberg, 2003; Rubin et al., 2004). These responses tend to be simple associations to cues rather than events (e.g., "families are groups of people" to the request for an event with a family member). The attention checks used here and in Study 4 were mixed in with the regular items and were of the form "please answer two to this item."

Table 2
Individual scene and content items and cues.

Items used in Studies 1, 2, and 3

1. Perspective-a. While remembering the event, I can identify where I am in relation to the individual things that I am remembering.
2. Content-a. As I remember, I can identify the actions, objects, and/or people that are involved in the memory, though I may not be able to clearly say where they are in relation to each other.
3. Layout-a. While remembering the event, I can describe where the actions, objects, and people central to the event are located.
4. Content-b. While remembering, I can identify or name the setting where the memory occurred, although I might not be able to describe it clearly.
5. Layout-b. While remembering the event, I can describe the layout of the broader background setting in which the event is located.
6. Perspective-b. While remembering the event, I have the sense of seeing the event from my own eyes.

Items used in Study 4

1. Perspective-a. While remembering the event, I know where I am in relation to the individual things that I am remembering.
2. Layout-a. While remembering the event, I know where the actions, objects, and people are located.
3. Perspective b. While remembering the event, I have the sense of seeing the memory from my own eyes.
4. Layout b. While remembering the event, I can describe the layout of things in my memory relative to each other.

Event cues for all studies

1. Involving school or work
2. With a close friend
3. That changed your life
4. Involving travel or vacation
5. With a family member
6. Involving a mistake
7. Involving recreation, a hobby, or athletics

Notes. All items and cues listed in the order presented. All items were answered on a scale of 1 (not at all) to 7 (as if it were happening now), except item 6, which was answered on a scale of 1 (not at all) to 7 (as if I were seeing it now). The core perspective and core layout items are components of the core scene rating. Both perspective and layout items are components of the all scene rating. Both content items are components of the all contents rating. The copyright for the scale used in Study 4 is held by the author (©2019, Rubin). Permission is given to use the scale for research purposes.

3.1.2. Materials

Six items were repeated for each of the seven events to measure *scene* and *content*. The events were chosen to provide a broad sampling of memories from our participants' lives without any biases to particular time periods or quality of *scene recall*. The *AMQ* used three items to measure each of five properties of autobiographical memories, repeating these for four different events. The test items, rating scales, and event cues for these instruments are presented in Tables 2 and 3. The *VVIQ* has items divided into images. Participants are asked to imagine something (e.g., someone you know well, a sunrise, a store) and then rate how clear they can imagine and modify aspects of it. The responses are no image at all, you only "know" that you are thinking of the object (1), vague and dim (2), moderately clear and vivid (3), clear and reasonably vivid (4), and perfectly clear and as vivid as normal vision (5).

Table 3
Individual Autobiographical Memory Questionnaire (AMQ) items and cues used in all studies.

Items
1. Reliving 1. While remembering, it is as if I am reliving the event.
2. Belief 1. I believe the event in my memory really occurred in the way I remember it and that I have not imagined or fabricated anything that did not occur.
3. Emotion 1. While remembering the event, the emotions that I feel are extremely intense.
4. Vividness 1. My memory of the event is vivid.
5. Temporal 1. Was the memory for an event that occurred once and lasted less than a day or was the event extended in time for more than a day, possibly being made up of several related events. (reverse scored)
6. Reliving 2. While remembering, the event it is as if I am mentally traveling back to the time it occurred.
7. Belief 2. My memory of the event is an accurate reflection of the event as a neutral observer would report it and is not distorted by my beliefs, motives, and expectations.
8. Emotion 2. While remembering the event, I have a physical reaction (laughed, felt tense, sweaty, heart pounded).
9. Vividness 2. My memory event has lots of details.
10. Temporal 2. How long did the event last? (reverse scored)
11. Reliving 3. While remembering the event, it is as if I am experiencing the same general atmosphere again.
12. Belief 3. I would be confident enough in my memory of the event to testify in a court of law.
13. Emotion 3. While remembering the event, my emotions are negative or positive.
14. Vividness 3. My memory of the event is clear, not fuzzy or clouded.
15. Temporal 3. Could the event theoretically be dated to one specific day in your past, even though you might not be able to date it?

Event cues
1. Getting or losing a job.
2. Purchasing something important to you.
3. An important event at a religious or national holiday.
4. An important unexpected event.

Notes: All items and cues are listed in the order presented. AMQ items 1, 3, 4, 6, 8, 9, 11, and 14 are answered on a scale of 1 (not at all) to 7 (as if it were happening now). Item 2 has a scale of 1 (0% real) to 7 (100% real). Item 5 has a scale of 1 (definitely from a single event lasting less than a day), 3 (mostly from a single event lasting less than a day), 5 (mostly extended in time) to 7 (definitely extended in time). It was reverse scored. Item 7 has a scale of 1 (0% accurate) to 7 (100% accurate). Item 10 has a scale of 1 (less than ten minutes), 2 (between ten minutes and an hour), 3 (between an hour and a day), 4 (between a day and a week), 5 (between a week and a month), 6 (more than a month). It was reverse scored. Item 12 has a scale of 1 (not at all) to 7 (as much as any memory). Item 13 has a scale of 1 (extremely negative) to 4 (neutral) to 7 (extremely positive), which is transformed to a 3, 2, 1, 0, 1, 2, 3 to produce an intensity score. Item 15 has a scale of 1 (definitely not) 3 (probably not) 5 (probably) 7 (definitely). Each AMQ rating in the analyses is the combination of the three items listed here which share its name. The copyright for the scale is held by the author (©2019, Rubin). Permission is given to use the scale for research purposes.

The Test of Visual Imagery Control (*TVIC*, Gordon, 1949) uses 12 items grouped into scenes to measure the ease with which people can control or manipulate visual images. Participants are asked if they can visualize scenes and then modify them (e.g., imagine a car then change its color, then turn the car upside down, etc.). The responses are no (1), unsure (2), and yes (3).

3.1.3. Procedure

The study was administered through TurkPrime (Litman, Robinson, & Abberbock, 2016) to MTurk workers on the Qualtrics survey platform. Each participant was first asked to fill in a consent form and answer demographic questions. These were followed by the measurement of *scene* and *content* (see Table 2). The instructions for the scene items were to 'Please recall an autobiographical memory' followed by one of the seven events and the six items to be rated. Next, the properties of autobiographical memories of different events were measured using a version of the *AMQ* (see Table 3). The instructions for the *AMQ* were to 'Please consider the event you described as' followed by one of the four events and the 15 items to be rated. Thus, for each of the scene measures there were seven events with two items each (i.e., 14 items) that were averaged to provide the measure used in the analyses for each participant, whereas for the *AMQ* there were four events with three items each (i.e., 12 items) that were averaged to provide the measure used in the analyses. The session ended with the *VVIQ* and *TVIC*. The order was the same for all participants to avoid introducing additional variance that is not related to each individual, as is common in individual differences tests. For this and the remaining three studies, the procedures were self-paced and designed not to exceed 20 min because longer times can lead to poorer results as the participant become fatigued and increase the difficulty in recruiting participants (Buhrmester, Kwang, & Gosling, 2011).

3.2. Results and discussion

The means, standard deviations, and reliabilities for all measures are in Table 4. The means of all measures are not near the extremes of their range and have adequate standard deviations and reliabilities for the correlational analyses that follow. Correlational analyses were used throughout. Correlations of all measures with the *scene* and *content* measures are in Table 5 with multiple regressions comparing *scene* and *content* for these measures in Table 6. Table 7 contains the correlations of *scene* and the other two imagery measures with the *AMQ* ratings of five properties of autobiographical memory. The mean of the two *perspective* and two *layout* items correlated 0.85, $p < .0001$, supporting their combination to a single *scene* measure, as does the 0.94 α (Cronbach, 1951) of the combined four-item *scene* measure. *Scene* and *content* correlated 0.69, $p < .0001$, which is reasonable, as they are both measures of recalling properties of the images of the same events. *Scene* and *content* correlated with age 0.26 and 0.20, respectively (both $p < .0001$). Women had higher means than men on *scene* (5.73 versus 5.50, $t(398) = 2.46$, $p < .05$) and on *content* (5.78 versus 5.45, $t(398) = 3.38$, $p < .001$); however, the gender differences did not replicate in later studies.

Consistent with Hypothesis 1, correlations between *scene* and the three phenomenological measures of *reliving*, *vividness*, and *belief* are substantial (i.e., 0.64, 0.68, and 0.60). *Scene* and the phenomenological measures are based on different events. Thus, none of the relations can be attributed to the use of the same memories. To the best of my knowledge there are no individual differences measures other than *scene recall* that have correlations with these three phenomenological properties in this range.

Consistent with Hypothesis 2, the correlations of *scene* with the three phenomenological properties are higher in qualitative terms than are those of *content*, as shown by the correlations in Table 5. The multiple regressions in Table 6 provide a direct statistical comparison of *scene* and *content*. Thus, there is more to scene recall than just knowing the contents of the memory.

Consistent with Hypothesis 3, the correlation of *scene* with *emotion* and *temporal specificity* is lower than the correlation with *belief*, the lowest correlation of the three phenomenological measures, ($Z_H = 4.16$ and $9.74\, ps < 0.0001$, Hoerger, 2013). Thus, the correlations with *scene* point to its robust relation to phenomenological properties of autobiographical memory. The correlations also indicate that *scene* provides a measure of divergent validity. This is especially important for *temporal specificity*. *Temporal specificity* is a part of the definition of episodic memory having to occur once at a specific time and place, though, by definition, episodic memory need not come with the recall of a scene. *Temporal specificity* is also the primary measures of overgeneral memories, rather than the presence of scenes.

Consistent with Hypothesis 4, *scene* has higher correlations with the three phenomenological properties than with the two traditional measures of visual imagery, as seen in Table 5. Again, this difference does not extend to *emotion* and *temporal specificity*. Moreover, this is not because *scene* is a generally better measure of visual imagery; it does

Table 4
Means, standard deviations, and alphas for Studies 1 through 4.

Measures	Study 1			Study 2			Study 3			Study 4/SRIT		
	Mean	SD	α	Mean	SD	α	Mean	SD	α	Mean	SD	α
Scene & content												
Scene	5.62 (0.93)	0.94	5.45 (0.80)		0.92	5.27 (0.77)		0.91		5.77 (0.72)		0.94
Content	5.62(0.99)	0.91	5.50 (0.88)		0.89	5.41 (0.81)		0.86				
AMQ												
Reliving	0.12 (1.21)	0.92	4.50 (1.03)		0.86					5.36(1.02)	0.91	
Vividness	5.18(1.18)	0.91	4.20 (0.97)		0.83					5.37(0.97)	0.89	
Belief	5.65(1.07)	0.91	4.72 (1.05)		0.87					5.79(0.91)	0.90	
Emotion	4.52(1.17)	0.83	4.03 (0.82)		0.69					4.82(1.03)	0.80	
Temporal	5.21(0.89)	0.77	5.48 (0.81)		0.70					5.16(0.89)	0.77	
Imagery tests												
VVIQ	3.68(0.71)	0.92				3.64(0.64)		0.89	3.78(0.59)		0.89	
TVIC	2.62 (0.51)	0.92				2.68(0.36)		0.84				
SUIS						3.46(0.54)		0.68	3.60(0.57)		0.75	
Coherence						4.73(0.80)		0.70	5.04(0.81)		0.72	
Fragmentation						3.89(1.04)		0.69	3.45(1.28)		0.78	
Memory tests												
SAM episodic						3.09(0.58)		0.67	3.56(0.72)		0.82	
SAM semantic						3.34(0.65)		0.58	3.57(0.71)		0.68	
SAM spatial						3.28(0.82)		0.73	3.71(0.85)		0.80	
SAM future						3.70(0.63)		0.73	3.66(0.77)		0.83	
CITS						4.25(0.86)		0.73	4.48(0.96)		0.77	

Notes. The *N*s for Studies 1 to 4 are 400, 341, 197, and 300. α is Cronbach's Alpha (Cronbach, 1951). The VVIQ is the Vividness of Visual Imagery Questionnaire (Marks, 1973). The TVIC is the Test of Visual Imagery Control (Gordon, 1949). The SUIS is the Spontaneous Use of Imagery Scale (Kosslyn, Chabris, Shephard, & Thompson, 1998). The Coherence and Fragmentation Imagery Tests described in Section 5.1.2 are adaptations from the Spatial Coherence Index (Hassabis et al., 2007). The four scales of the SAM are from the Survey of Autobiographical Memory (Palombo et al., 2013) and the CITS is the Cognitive Interview Techniques Scale described in Section 5.1.2.

Table 5
Correlations for Studies 1 through 4 and memory data from earlier study.

	Scene				Content			Age	
	Study 1	Study 2/3	Study 4/SRIT	Memory	Study 1	Study 2/3	Memory	Study 1	Study 4/SRIT
Scene & content									
Scene								0.26***	0.11*
Content								0.20***	
AMQ									
Reliving	0.64***	0.48***	0.49***	0.62***	0.40***	0.32***	0.43***	0.04	0.04
Vividness	0.68***	.0.42***	0.57***	0.83***	0.43***	0.28***	0.57***	0.06	0.03
Belief	0.60***	0.43***	0.55***	0.59***	0.49***	0.31***	0.47***	0.11*	0.10
Emotion	0.42***	0.28***	0.32***	0.40***	0.23***	0.18***	0.28***	0.03	0.03
Temporal	0.02	0.22***	0.08	0.21**	0.16**	0.26***	0.30***	0.16**	0.09
Imagery tests									
VVIQ	0.56***	0.34***	0.49***		0.39***	0.17**		0.11*	0.10
TVIC	0.30***	0.06			0.25***	−0.05		0.06	
SUIS		0.26***	0.39***			0.12			0.05
Coherence		0.36***	0.47***			0.22**			−0.05
Fragmentation		−0.10	0.25***			0.01			0.01
Memory tests									
SAM episodic		0.34***	0.42***			0.29***			−0.03
SAM semantic		0.11	0.31***			0.22**			−0.15*
SAM spatial		0.01	0.24***			−0.04			0.04
SAM future		0.36***	0.34***			0.26***			−0.01
CITS		0.27***	0.43***			0.20**			−0.11*

Notes. The *N*s for Studies 1 and 4 are 400 and 300. For the Study2/3 column the AMQ variables are from Study 2, N = 341, and the remaining variables are from Study 3, N = 197. The Memory column is from Study 2 of Rubin et al. (2019); N = 203. The VVIQ is the Vividness of Visual Imagery Questionnaire (Marks, 1973). The TVIC is the Test of Visual Imagery Control (Gordon, 1949). The SUIS is the Spontaneous Use of Imagery Scale (Kosslyn et al., 1998). The Coherence and Fragmentation Imagery Tests described in Section 5.1.2 are adaptations from the Spatial Coherence Index (Hassabis et al., 2007). The four scales of the SAM are from the Survey of Autobiographical Memory (Palombo et al., 2013) and the CITS is the Cognitive Interview Techniques Scale described in Section 5.1.2.

* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 6
Multiple regressions using scene and content as independent variables for Studies 1, 2, and 3.

Measures	Study 1			Studies 2 & 3		
	Beta weights		R^2	Beta weights		R^2
	Scene	Content		Scene	Content	
AMQ						
Reliving	0.61***	−0.01	0.36	0.55***	−0.09	0.24
Vividness	0.67***	−0.01	0.43	0.48***	−0.08	0.18
Belief	0.49***	0.13*	0.34	0.43***	−0.01	0.18
Emotion	0.43***	−0.05	0.16	0.33***	−0.06	0.08
Temporal	−0.17*	0.27	0.04	0.06	0.21	0.07
Imagery tests						
VVIQ	0.44***	0.12*	0.28	0.53***	−0.23*	0.14
TVIC	0.15*	0.16*	0.08	0.26*	−0.26*	0.03
SUIS				0.41***	−0.20	0.08
Coherence				0.49***	−0.17	0.14
Fragmentation				0.24*	0.18	0.02
Memory tests						
SAM episodic				0.29*	0.06	0.12
SAM semantic				−0.16	0.34**	0.06
SAM spatial				0.12	−0.14	0.01
SAM future				0.39***	−0.04	0.13
CITS				0.27*	−0.00	0.07

Notes. The N for Studies 1 is 400. For the Study2/3 column the AMQ variables are from Study 2, N = 341, and the remaining variables are from Study 3, N = 197. The *N*s for Studies 1 to 4 are 400, 341, 197, and 300. The VVIQ is the Vividness of Visual Imagery Questionnaire (Marks, 1973). The TVIC is the Test of Visual Imagery Control (Gordon, 1949). The SUIS is the Spontaneous Use of Imagery Scale (Kosslyn et al., 1998). The Coherence and Fragmentation Imagery Tests described in Section 5.1.2 are adaptations from the Spatial Coherence Index (Hassabis et al., 2007). The four scales of the SAM are from the Survey of Autobiographical Memory (Palombo et al., 2013) and the CITS is the Cognitive Interview Techniques Scale described in Section 5.1.2.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

not correlate more highly with the other two measures of visual imagery than they correlate with each other. To probe Hypothesis 4 more directly, multiple regressions predicting the five *AMQ* variables were conducted using *scene* and the other two imagery measures. *Scene* was always the best predictor of the three phenomenological properties but not of *emotion* and *temporal specificity*. Because there were only three measures of visual imagery, all variables were entered into the regressions, which report standardized beta weights. The regressions are: *reliving* = 0.49*** *scene* + 0.34*** *VVIQ* − 0.13** *TVIC*, R^2 = 0.49; *vividness* = 0.53*** *scene* + 0.34*** *VVIQ* − 0.12** *TVIC*, R^2 = 0.54; *belief* = 0.47*** *scene* + 0.27*** *VVIQ* − 0.05 *TVIC*, R^2 = 0.40; *emotion* = 0.29*** *scene* + 0.29*** *VVIQ* − 0.11* *TVIC*, R^2 = 0.23; and *temporal specificity* = 0.05 *scene* − 0.15* *VVIQ* + 0.19*** *TVIC*, R^2 = 0.03.

Overall, Study 1 offers strong support for the first four hypotheses. Given the novelty of the findings, however, replication is needed. Moreover, there were only two standard measures of visual imagery and only one correlated with the autobiographical memory measures. Therefore, to be more fairly evaluated, Hypothesis 4 also requires additional imagery tests.

In addition, Table 5 contains a column labeled memory for both *scene* and *content* taken from the supplemental material of Study 2 of Rubin et al. (2019). In that study, 203 MTurk workers each produced and rated seven word-cued memories on variables that were similar to the ones reported here (specifically: *reliving, vividness, belief, emotional intensity, temporal specificity,* and *content*). However, unlike the current research, the correlations are all based on the same seven memories rather than correlations in which *scene* and *content* are taken from different memories. What is striking about these correlations is how similar they are to those of the current study and the other studies of this paper. This suggests that once averages are taken over seven memories, as they were in the column labeled memory, the averages mask any differences between the individual memories and depend strongly on individual differences.

The last two columns in Table 5 contain the correlations of the age of the participants with all of the other measures in Studies 1 and 4. These studies have similar age distributions, whereas Studies 2 and 3 test undergraduates and have a distribution that is too restricted to use

Table 7
Correlations of Autobiographical Memory Questionnaire with imagery tests.

	AMQ					Imagery tests				
	Reliving	vividness	belief	emotion	temporal	Scene	VVIQ	TVIC	SUIS	coherence
Study 1 (n = 400)										
Scene	0.655***	0.68***	0.60***	0.42***	0.02					
VVIQ	0.56***	0.58***	0.50***	0.41***	−0.04	0.56***				
TVIC	0.17***	0.19***	0.20***	0.10*	0.14**	0.30***	0.43***			
Study 3 (n = 197)										
Scene	0.39***	32***	0.35***	0.22**	0.11					
VVIQ	0.19**	0.19**	0.12	0.07	0.03	0.34***				
TVIC	−0.02	0.03	−0.02	−0.08	−0.02	0.06	0.46***			
SUIS	0.25***	0.24***	0.21**	0.12	−0.03	0.26***	0.43***	0.21**		
Coherence	0.22**	0.28***	0.19**	0.12	−0.01	0.36***	0.53***	31***	0.48***	
Fragment	−0.01	−0.05	−0.10	0.02	−0.04	0.10	−0.29***	−0.20**	−0.08	−0.29***
Study 4/SRIT (n = 300)										
Scene	0.49***	57***	0.55***	0.32***	0.08					
VVIQ	0.41***	0.44***	0.36***	0.33***	−0.01	0.49***				
SUIS	0.41***	0.40***	0.29***	0.37***	−0.01	0.39***		0.54***		
Coherence	0.42***	0.49***	0.41***	0.40***	−0.02	0.47***		0.52***	0.54***	
Fragment	−0.18*	−0.28***	−0.32***	−0.02	−0.26***	−0.25***		−0.19***	−0.11	−0.33***

Notes. The VVIQ is the Vividness of Visual Imagery Questionnaire (Marks, 1973). The TVIC is the Test of Visual Imagery Control (Gordon, 1949). The SUIS is the Spontaneous Use of Imagery Scale (Kosslyn et al., 1998). The Coherence and Fragmentation Imagery Tests described in Section 5.1.2 are adaptations from the Spatial Coherence Index (Hassabis et al., 2007).
* $p < .05$.
** $p < .01$.
*** $p < .001$.

for meaningful correlations with age. Unlike the *scene* and *content* columns, there were no hypotheses to guide the interpretation and so the results are exploratory. Nonetheless, all of the significant correlations with age Study 1 are either significant or have similar magnitude correlations in Study 4. Of note, in Study 1, *scene* and *content* have significant positive correlations with age, indicating that older participants tend to have higher values. A discussion follows Study 4, once the correlations from both studies are presented.

4. Study 2: a replication in a different population

Study 2 provides the first replication of the first three hypotheses and does so using a different population.

4.1. Method

4.1.1. Participants

Duke undergraduates enrolled in the study as part of a general screening given to all participants in the subject pool. Unlike Study 1, which used MTurk workers, this study did not include attention check questions to exclude participants. Fifty-eight subjects were excluded either for not completing the instruments or for repeating the identical value for each of the six *scene* and *content* items in most of the seven memories with only one item not being identical in the other memories. The remaining 341 Duke undergraduates (225 female; mean age of 18.87, range 18 to 23) were included.

4.1.2. Materials and procedure

The materials and procedure were similar to Study 1, except that the study used the SONA platform and included only the *scene*, *content* and *AMQ* items.

4.2. Results and discussion

Following the presentation of the basic results, the six hypotheses are addressed. The means, standard deviations, and reliabilities for all measures are in Table 4. Correlations of all measures with the *scene* and *content* measures are in Table 5 with multiple regressions comparing *scene* and *content* for these measures in Table 6. The mean of the two *perspective* and two *layout* items correlated 0.80, $p < .0001$, supporting their combination to a single *scene* measure, as does the 0.92 α (Cronbach, 1951) of the combined four-item *scene* measure. *Scene* and *content* correlated 0.75, $p < .0001$, which is reasonable, as they are both measures of recalling a good image of the same event even though they measure different properties as shown by the other analyses. Unlike Study 1, there were no significant gender differences in *scene* or *content*.

Consistent with Hypothesis 1 and replicating the results of Study 1, there are substantial correlations between the measure of *scene* and the three phenomenological measures of *reliving, vividness*, and *belief*. Consistent with Hypothesis 2 and replicating the results of Study 1, the correlations of *scene* with the three phenomenological properties and *emotion* are higher than those of *content* in the correlations of Table 5. The multiple regressions of Table 6 provide a direct statistical comparison of *scene* and *content*. Consistent with Hypothesis 3 and replicating the results of Study 1, the correlations of *scene* with *emotion* and *temporal specificity* are lower than with *vividness*, which is the lowest of the three phenomenological measures, ($Z_H = 3.09$ and $2.90\,ps < 0.01$, Hoerger, 2013). Thus, the correlations with *scene* again point to both its robust relation to phenomenological properties of autobiographical memory and to the specificity of that relation.

Study 2 provided a replication of the first three hypotheses in a different population. All the predictions were confirmed, leaving tests of Hypotheses 4, 5, and 6 for the next study.

5. Study 3: comparisons with tests of imagery and memory and a delayed test-retest reliability

Three hypotheses were tested in Study 3. Hypothesis 4 predicts that *scene* should correlate with other individual differences tests of visual imagery. It also predicts that *scene* should correlated more highly with the three phenomenological properties of *reliving, vividness*, and *belief* than the other tests, which do not depend as heavily on scene recall. And it predicts that *scene* should not correlate more highly with *emotion* and *temporal specificity* than the other tests, which do not depend as much on scene recall. Hypothesis 5 predicts that *scene* should correlate more highly with *episodic memory* than *semantic memory* and *spatial navigation*. To test Hypotheses 4 and 5, three imagery tests were added to the two from Study 1 along with a standardized individual differences test of *episodic memory, semantic memory, navigation*, and *future* events. Hypothesis 6 predicts that measures of *scene* will be stable over delays. This delayed test-retest reliability is needed to claim that *scene* is stable over time. In addition, a specially devised version of the cognitive interview, which is a commonly used oral procedure for eliciting more information about events, was administered to investigate whether it correlates with *scene*.

5.1. Method

5.1.1. Participants

A subset of 197 of the undergraduates who completed Study 2 (136 female; mean age of 18.79, range 18 to 22) also completed Study 3. An additional 15 undergraduates were excluded using the same criterion as Study 2.

5.1.2. Materials and procedure

The procedure was similar to that of Study 2 but with different measures except for *scene* and *content*, which were needed to examine the stability of these measures over time. A minimum delay of one week was imposed so that the stability of these measures could be investigated. The remaining instruments were the *VVIQ* and *TVIC* imagery tests used in Study 1; the Spontaneous Use of Imagery Scale (*SUIS*, Kosslyn et al., 1998; Nelis, Holmes, Griffith, & Raes, 2014); the *Coherence and Fragmentation Imagery Tests* (derived from Hassabis et al., 2007); the four scales of the Survey of Autobiographical Memory (*SAM*; Palombo et al., 2013) and the Cognitive Interview Techniques Scale (*CITS*), which was based on the cognitive interview (Geiselman et al., 1986, pp. 390–391).

The *SUIS* is a 12-item scale of the spontaneous use of mental imagery in daily life. Participants are asked to indicate the degree to which items are appropriate on a scale of never appropriate (1), appropriate about half of the time (2), always completely appropriate (5).

Statements include, “When I think about a series of errands I must do, I visualize the stores I will visit.”

The *Coherence and Fragmentation Imagery Tests* were derived from the Spatial Coherence Index. Hassabis et al. (2007) designed the Spatial Coherence Index for administration to individual participants after each had attempted to describe a specific newly constructed scene. Scoring involves counting the number of the 12 items of the Spatial Coherence Index that the participant indicates accurately describes his or her construction of their image. The dichotomous decisions are combined to form a scale. The index was adapted to allow direct comparison to the measures of the scene construction of autobiographical memories in the current studies. The goal was to retain a close conceptual relation to tests administered to amnesics, while changing the focus to assess memory for past autobiographical memories in a large sample of the general population. To do this, the request to develop a new scene was changed to making judgements in relation to autobiographical memories, the request to select items that applied was changed to making ratings, the tense was changed from past to present, and the one composite index became two scales. The rating scale used to capture the degree to which the item accurately described the construction was disagree (1), disagree somewhat (3), agree somewhat (5), and agree (7). These changes to the original Hassabis et al. (2007) Spatial Coherence Index were done to facilitate application of the original items in a survey environment. Intellectual credit for the basic test remains with the original authors who made their index available.

The SAM has four scales that measure properties related to autobiographical memory. In particular, the SAM measures *episodic and semantic memory*, consistent with Tulving's (1983) distinction and the coding in the Autobiographical Interview (Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). The *episodic* scale is based heavily on event details (e.g., I can recall objects that were in the environment, I can recall what I was wearing, I can recall which day of the week it was, p. 1537). The *semantic* scale focuses on learning and remembering facts, in isolation from specific events (e.g., I can learn and repeat facts easily, even if I don't remember where I learned them, After I have met someone once, I easily remember his or her name, p. 1537). The *spatial* scale includes items related to navigation rather than to the variables measured here for *scene* and *content* (e.g., my ability to navigate is better than most of my family/friends, I use specific landmarks for navigating, p. 1537). The *future* scale includes general autobiographical memory properties (e.g., when I imagine an event in the future: the event generates vivid mental images that are specific in time and place, I can picture people and what they look like, I can imagine how I may feel, p. 1537). Thus, except for occurring in the future rather than in the past, the *future* scale comes the closest of the four SAM scales to the conception of autobiographical memory on which the current research is based.

The Cognitive Interview Techniques Scale (*CITS*) was devised for the current study from a description of the cognitive interview (Geiselman et al., 1986). The cognitive interview was designed to increase the recall of eyewitnesses of crime scenes. It was selected for adaptation here because it increases recall in large part by having eyewitnesses reinstate and expand upon the crime scene. Each of the four principles was reworded for rating scales and made into two questions to increase the reliability of the scale. The first question asks participants what they could do and the second asks what they normally would do. The full test is shown in Table 8.

5.2. Results and discussion

The means, standard deviations, and reliabilities for all measures are in Table 4. Correlations of all measures with *scene* and *content* are in Table 5 with multiple regressions comparing *scene* and *content* for these measures in Table 6. Table 7 contains the correlations of *scene* and the other four imagery measures with the *AMQ* ratings of five properties of autobiographical memory. The mean of the two *perspective* and two *layout* items correlated 0.84, $p < .0001$, supporting their combination to a single scene measure, as does the 0.91 α (Cronbach, 1951) of the combined four-item scene measure. *Scene* and *content* correlated 0.79, $p < .0001$, which is reasonable, as they are both measures of recalling a good image of the same events even though they measure different properties as shown by the other analyses.

Hypothesis 4 is supported, replicating Study 1, and is extended to additional measures of imagery as shown by the correlations in Table 7. *Scene* correlated with other individual differences tests of visual imagery. However, *scene* was more highly correlated than the other imagery tests with the three phenomenological properties of *reliving, vividness*, and *belief*, though not necessarily with *emotion* and *temporal specificity*. In addition, the imagery and memory tests correlated more highly with *scene* than *content* as evident in the correlations in Table 5 and the multiple regressions in Table 6. To probe Hypothesis 4 more directly, multiple regressions predicting the five *AMQ* variables were conducted. Because there were six measures of visual imagery, only measures that entered and remained at the $p < .05$ level are reported. However, when all variables were entered into the regressions, little changed except that the standardized beta weights decreased as non-significant tests also accounted for variance. The regressions are *reliving* = 0.35*** *scene* + 0.16* *SUIS*, $R^2 = 0.18$; *vividness* = 0.25*** *scene* + 0.19* *coherence*, $R^2 = 0.13$; *belief* = 0.35*** *scene*, $R^2 = 0.13$; *emotion* = 0.22** *scene*, $R^2 = 0.05$; and *temporal specificity*, which had nothing enter at the $p < .05$ level. *Scene* always accounted for the most variance in these equations.

Hypothesis 5 is that *scene* should correlate more highly with *episodic* than with *semantic memory* and *spatial navigation*. This prediction is supported in qualitative terms by the correlations in Table 5. Direct tests indicated that the correlation of *scene* with *SAM episodic* is higher than it is with *SAM semantic* and *SAM spatial*, but not *SAM future* ($Z_H = 3.24$, $p = .0012$, $Z_H = 3.52$; $p = .0004$; and $Z_H = -0.31$ $p = .757$, Hoerger, 2013). In addition, there is a correlation of 0.27 between *scene* and the cognitive interview.

Hypothesis 6 concerned the stability of *scene* and *content* over time. The correlations of *scene* and *content* across the 197 participants who completed Studies 2 and 3 were 0.61 and 0.58, respectively (*ps* < 0.0001) with a mean delay of 16.44 days (SD = 10.24, median = 13). The participants were divided into four groups of approximately equal size based on their delay (43 with delays of 7 to 9 days, mean of 8.51 days; 55 with delays of 10 to 12 days, mean of 11.02; 47 with

Table 8
The Cognitive Interview Techniques Scale (CITS).

1. Could you recall the context surrounding an event you witnessed: what the surrounding environment looked like, such as rooms, the weather, any nearby people or objects, how you were feeling at the time and your reactions to the event?
2. Would you normally do this?
3. Could you recall everything about the event without holding back information because you are not quite sure that the information is important?
4. Would you normally do this?
5. Could you recall the events in different orders rather than just going through the event from beginning to end? For instance, starting with the thing that impressed you the most in the event and then go from there both forward and backward in time.
6. Would you normally do this?
7. Could you recall the event from different perspectives that you may have had or adopt the perspectives of others that were present during the event? For example, trying to place yourself in the role of a prominent character in the event and thinking about what he or she must have seen.
8. Would you normally do this?

Notes. The introduction to the test was "We are interested in aspects of how you recall events." Items 1, 3, 5, and 7 were answered on a scale of 1 (Not at all) to 7 (Very easily). Items 2, 4, 6, and 8 were answered on a scale of 1 (Never) to 7 (All the time). Modified from text in Geiselman et al., 1986.

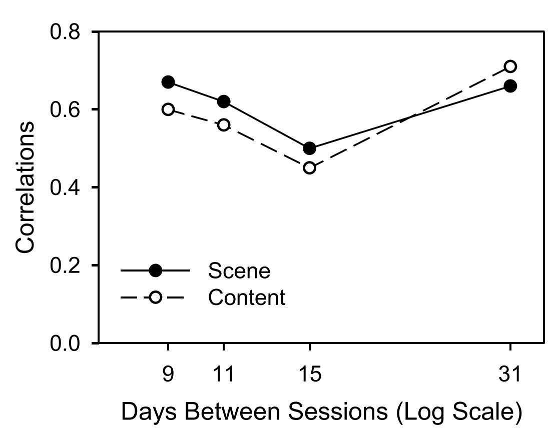

Fig. 1. The correlation of scene measured in Study 1 and Study 2 and content measured in Study 1 and Study 2 as a function of the time between the measurements. N = 197; n at the four delay periods = 43, 55, 47, and 52, respectively.

delays of 13 to 17 days, mean of 14.60 days; and 52 with delays of 18 to 59 days, mean of 30.96 days.). Correlations of *scene* and *content* calculated within each group are presented in Fig. 1. The values remain stable across time, arguing against much change in the correlations of these individual differences measures up to a month or two.

Study 3 replicated and extended Hypothesis 4. *Scene* correlated with new individual differences tests of visual imagery and correlated more highly with those tests than with the three phenomenological properties of *reliving, vividness*, and *belief*. *Scene* correlated more highly with *episodic* then *semantic memory* and *spatial navigation*, providing the first confirmation of Hypotheses 5. *Scene* was stable over delays of several weeks, providing the first confirmation of Hypotheses 6. In addition, *scene* correlated with the cognitive interview.

6. Study 4: development and test of the Scene Recall Imagery Test (*SRIT*)

An individual differences imagery test, the Scene Recall Imagery Test (*SRIT*), was created and tested in Study 4. Changes were made to make the items more clearly measure the core concept of coherent scene recall ability, as described in 6.1.2. In addition, the experimental format used in Studies 1 to 3 was changed to give the *SRIT* the format of other individual differences tests by not requiring memories to be recorded. In particular, the *SRIT* differs from Studies 1 to 3 in that it removes the *content* items, does not have participants recall and briefly describe all seven events, and changes the wording of some items. These changes could result in the *SRIT* no longer measuring what the scene measure did in Studies 1 to 3. To ensure that this did not occur, the *SRIT*'s correlations with the measures used earlier are analyzed.

6.1. Method

6.1.1. Participants

The 300 Amazon Mechanical Turk workers (129 female; mean age 37.04, *SD* 11.69, range 19 to 77) were each paid four dollars. In order to be included in the study, the participants had to complete the instruments, be native English speakers, pass three attention checks, provide reasonable descriptions of events, record that they completed the study on a computer or tablet, and spend at least 6 min on the task.

6.1.2. Materials and procedure

The procedure was similar to Study 1 but included all of the individual differences tests used in Studies 1 to 3 except for the TVIC test of visual imagery, which did not provide high correlations with *scene* in any of the earlier studies. As can be seen in Table 2, “know” replaced “can identify” and “can describe” in items 1 and 2 respectively and “the layout of things in my memory relative to each other” replaced “the layout of the broader background setting in which the event is located” in item 4. The order of the tests was the *SRIT*, *AMQ*, *Cognitive Interview*, the *Coherence* and *Fragmentation* Imagery Tests, *SUIS, VVIQ*, and *SAM*.

6.2. Results and discussion

6.2.1. Basic results and hypothesis predictions

The means, standard deviations, and reliabilities for all measures are in Table 4. Correlations of all measures with *scene* and *content* are in Table 5. The correlations are qualitatively higher in Studies 1 and 4 that test MTurk workers than for Studies 2 and 3, which test college students. This pattern has been noted more generally (Buhrmester et al., 2011) and may be increased by the use of TurkPrime, which tends to provide more conscientious participants (Litman et al., 2016). Table 7 contains the correlations of *scene* and the other four imagery measures with the *AMQ* ratings of five properties of autobiographical memory. Correlations among all measures, as well as the *perspective* and *layout* components of *scene*, are in Supplemental Table 1. The data from the 300 participants that produced these correlations are in Supplemental Table 2. There were no gender differences in the *SRIT* ($t(298) = 0.64$) and a small correlation with age of 0.11, $p < .05$.

In qualitative terms, means, standard deviations, reliabilities, correlations and regressions presented in the tables show a basic replication of the findings of the earlier studies. Overall, the correlations tend to be a bit lower than those of Study 1 and a bit higher than those of Studies 2 and 3, but have the same ranking of the magnitude of the individual correlations and thus the same pattern of conclusions with respect to the hypotheses.

Data were not collected to test Hypotheses 2 or 6. Consistent with Hypothesis 1 and replicating Studies 1 and 2, the correlations of *scene* with the three phenomenological measures of *reliving, vividness,* and *belief* are substantial (i.e., 0.49, 0.57, and 0.55). Consistent with Hypothesis 3 and replicating Studies 1 and 2, the correlations of *scene* with *emotion* and *temporal specificity* are lower than *reliving*, the lowest of the three phenomenological measures ($Z_H = 4.78$ and 5.12, $ps < 0.0001$, Hoerger, 2013).

Consistent with Hypothesis 4 and replicating Studies 1 and 3, as shown in Table 7, *scene* correlated with the other four measures of visual imagery. Moreover, it did so in qualitative ways consistent with Hypotheses 1 and 3, which predicted that it should correlate with the three phenomenological properties of *reliving, vividness* and *belief* and that these correlations should be higher than those with *emotional intensity* and *temporal specificity*. To probe the pattern of correlations claimed by Hypothesis 4 more directly, multiple regressions predicting the five *AMQ* variables were conducted using *scene* and the other four imagery measures. Because there were five measures of visual imagery, only measures that entered and remained at the $p < .05$ level are reported. However, when all variables entered into the regressions, little changed except that the standardized beta weights decreased as nonsignificant predictors accounted for some variance. The standardized regressions weights are: *reliving* = 0.34*** *scene* + 0.20*** *SUIS* + 0.15* *coherence*, $R^2 = 0.31$; *vividness* = 0.40*** *scene* + 0.12* *VVIQ* + 0.24*** *coherence*, $R^2 = 0.40$; *belief* = 0.44*** *scene* + 0.15** *coherence* - 0.17** *fragmentation*, $R^2 = 0.35$; *emotion* = 0.16** *scene* + 0.18** *SUIS* + 0.26*** *coherence* + 0.15* *fragmentation*, $R^2 = 0.22$; and *temporal specificity* = −0.12* *coherence* − 0.30*** *fragmentation*, $R^2 = 0.08$. *Scene* was always the best predictor of the three phenomenological properties of *reliving, vividness*, and *belief*, but not of *emotion* or *temporal specificity*.

Consistent with Hypothesis 5 and replicating Study 3, *scene* correlated more highly with *episodic* than with *semantic memory* and *spatial navigation*. This prediction is supported in qualitative terms by the correlations in Table 5. Direct tests indicated that the correlation of *scene* with *SAM episodic* is higher than it is with *SAM semantic* and *SAM spatial*, but not *SAM future* ($Z_H = 2.28$, $p = .022$, $Z_H = 3.16$; $p = .002$; and $Z_H = 0.161$, $p = .108$, Hoerger, 2013).

Thus, Study 4 provided support for all hypotheses except Hypothesis 2, which would have required a measure of *content*, and Hypothesis 6, which would have required two testing intervals.

The last column in Table 5 contain the correlations of the age of the participants with all of the other measures in Studies 4. Though there is some evidence that scenes can help older adults (Robin & Moscovitch, 2017), there were no hypotheses to guide the interpretation, so the results are exploratory. The similarity in the correlations that were prese)nt in Studies 1 and 4 makes these exploratory correlations reliable enough to warrant discussion. *Scene* in both studies and *content* in Study 1 have significant positive correlations with age. *Belief, temporal specificity*, and the *VVIQ* had significant correlations in Study 1 and correlations of similar magnitude in Study 4 that were non-significant, possibly due to less statistical power. In contrast to these correlations, which showed higher values with increasing age as did *scene* and *content*, the *SAM semantic* and the *CITS* had significant correlations in Study 4, showed decreasing values with increasing age. The effects of age should be studied in a larger sample with a more uniform distribution of ages. This would provide the power needed to see the effects of age, which are generally smaller than those of *scene*. It would also allow a plot of mean values for the measures included by decades that would allow the effects and any non-linear relations to be examined.

6.2.2. *The latent structure of the SRIT*

The *SRIT* has 28 items resulting from the four distinct rating scales shown in Table 2 that are each repeated for the seven events used in the earlier studies. Even though all 28 individual items correlated highly enough to yield a Cronbach's α of 0.94, in terms of theory, both the four rating scales and the seven events should each account for unique portions of the summed variance. The four rating scales were chosen to represent two different aspects of *scene*: *layout* and *perspective*. This choice was intended to offer some breadth to the concept of *scene* and to provide more variety in the questions in an attempt to reduce the likelihood that individuals would respond with the same value for all the rating scales in a single event. In addition, because remembering events takes more time than rating them, it is more efficient to obtain more than one or two estimates of the concept of *scene* for each event recalled. Seven event cues were chosen because this was likely to provide good stability based on Studies 1, 2, and 3. The test-retest reliability estimates confirmed this choice. In contrast to the four rating scales, the seven event cues were chosen to provide a broad sample of memories without any underlying dimensions. Thus, no systematic analysis of how the memories from the seven cues differed made theoretical sense.

The 378 correlations among the 28 means of the items (i.e., $28 * 27 / 2$) averaged 0.37 (calculated from the square root of the r^2, median 0.31), which is in the standard range for items in measures of individual differences. The correlations among the means of the four distinct rating scales of the *SRIT* range from 0.70 to 0.89 with a median of 0.77; the correlations between the means of the two *layout* and the two *perspective* items are 0.74 and 0.89, respectively; and the correlation between *layout* and *perspective* is 0.83 (all $ps < 0.0001$). Correlations among the four rating scales of the *SRIT* are generally higher within than between events.

Both the theoretical construction of the *SRIT* and the empirical pattern of correlations suggest that the structure should not lead to a single factor. Rather there should be a structure that allows for the estimation of how much of the total variance among the items is accounted for by both the four rating scales used to measure the concept of *scene* and the seven individual events. The structure should also provide assurance that none of the four distinct items or the two *layout* versus two *perspective* items, or any of the seven event cues, differed greatly enough from the others in their contributions to limit the overall usefulness of the *SRIT*. This latent structure was evaluated using confirmatory factor analysis of a bifactor measurement model (Reise, 2012). The model is shown graphically in Fig. 2. The values are in Table 9. The main conceptual difference between this analysis and the ones in the earlier studies is that the concepts shown

Table 9
Values for the parameters of the statistical analysis of the Scene Recall Imagery Test (SRIT).

Item		Event		Perspective/layout		Error
Perspective-a-1	=	0.391 * Event1	+	0.599 * Perspective	+	0.699
Layout-a-1	=	0.524 * Event1	+	0.627 * Layout	+	0.577
Perspective-b-1	=	0.492 * Event1	+	0.539 * Perspective	+	0.683
Layout-b-1	=	0.561 * Event1	+	0.587 * Layout	+	0.584
Perspective-a-2	=	0.531 * Event2	+	0.570 * Perspective	+	0.627
Layout-a-2	=	0.636 * Event2	+	0.590 * Layout	+	0.498
Perspective-a-2	=	0.377 * Event2	+	0.653 * Perspective	+	0.657
Layouts-b-2	=	0.569 * Event2	+	0.668 * Layout	+	0.480
Perspective-a-3	=	0.673 * Event3	+	0.404 * Perspective	+	0.620
Layout-a-3	=	0.749 * Event3	+	0.481 * Layout	+	0.456
Perspective-b-3	=	0.552 * Event3	+	0.567 * Perspective	+	0.612
Layout-b-3	=	0.722 * Event3	+	0.519 * Layout	+	0.457
Perspective-a-4	=	0.659 * Event4	+	0.588 * Perspective	+	0.468
Layout-a-4	=	0.692 * Event4	+	0.565 * Layout	+	0.449
Perspective-b-4	=	0.511 * Event4	+	0.623 * Perspective	+	0.592
Layout-b-4	=	0.651 * Event4	+	0.617 * Layout	+	0.442
Perspective-a-5	=	0.568 * Event5	+	0.649 * Perspective	+	0.507
Layout-a-5	=	0.587 * Event5	+	0.661 * Layout	+	0.467
Perspective-b-5	=	0.512 * Event5	+	0.630 * Perspective	+	0.584
Layout-b-5	=	0.608 * Event5	+	0.682 * Layout	+	0.408
Perspective-a-6	=	0.699 * Event6	+	0.500 * Perspective	+	0.510
Layout-a-6	=	0.697 * Event6	+	0.457 * Layout	+	0.553
Perspective-b-6	=	0.548 * Event6	+	0.563 * Perspective	+	0.618
Layout-b-6	=	0.685 * Event6	+	0.541 * Layout	+	0.488
Perspective-a-7	=	0.761 * Event7	+	0.486 * Perspective	+	0.431
Layout-a-7	=	0.728 * Event7	+	0.530 * Layout	+	0.435
Perspective-b-7	=	0.726 * Event7	+	0.489 * Perspective	+	0.484
Layout-b-7	=	0.758 * Event7	+	0.532 * Layout	+	0.376
Minimum		0.377		0.404		0.376
Maximum		0.761		0.682		0.699
Mean		0.622		0.573		0.534
SD		0.354		0.279		0.310
Variance		0.387		0.328		0.285

Note. Mean and SD calculated as √ of the squared values. The perspective and layout factors correlate $r = 0.863$. Table 2 provides the key to the numbering of the events.

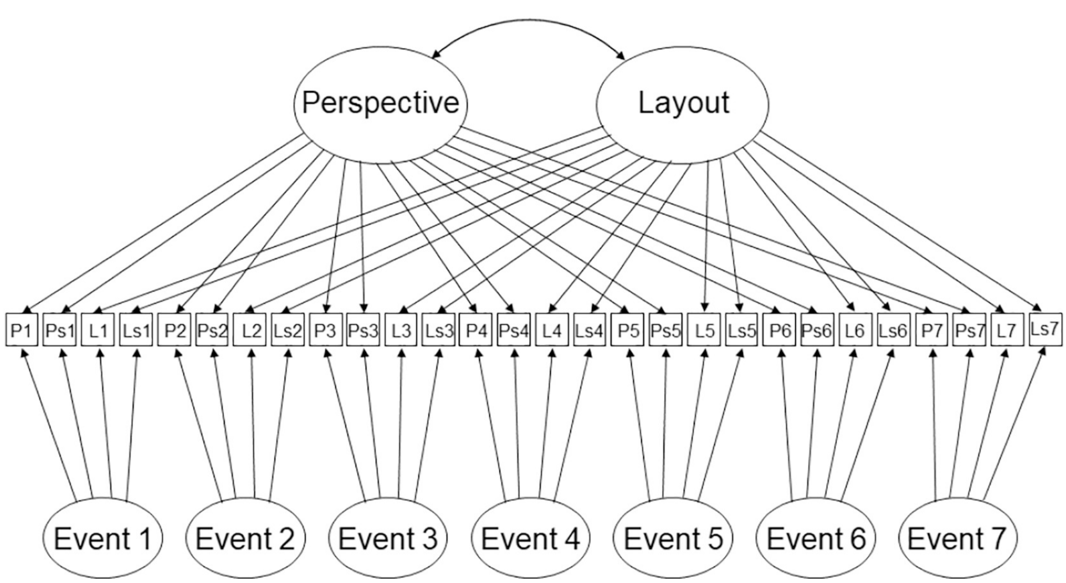

Fig. 2. Conceptual model for statistical analysis of the Scene Recall Imagery Test (SRIT). All values are given in Table 9.

in ellipses in Fig. 2 are unobserved latent variables (i.e., factors) that account for the correlations among the observed measures shown in the rectangles. That is, they are not sum scores of a small number of measures but unobserved, underlying factors that account for commonality between the observed variables. Each of the 28 item rows in Table 9 is an equation indicating the contribution of the item, the event, and the error not accounted for by either. The rows at the bottom indicate the average and standard deviations of the weights. The average of the squared weights is an approximate measure of variance accounted for by the items, the events, and the remaining error. As indicated, the items, the individual events, and the error account for approximately equal variance.

7. General discussion

7.1. Basic conclusions

Scene, as well as the other measures it was correlated with, had reasonable psychometric properties in a series of four studies. In addition, measures of scene recall were not highly correlated with gender or age. Gender differences in *scene* appeared in Study 1 but not in later studies indicating that gender differences were too small to appear reliably. In Studies 1 and 4, which tested MTurk workers with a wide range of ages, age correlated with *scene* 0.26 and 0.11, respectively.

Six hypotheses were formulated based on the existing literature. All were supported and all but one were replicated; some were replicated twice. Overall, the empirical work strongly supports the theoretical expectations.

In terms of the most basic prediction, which is Hypothesis 1, the three phenomenological properties of *reliving, vividness*, and *belief* that measure the quality of autobiographical remembering correlated consistently and substantially with *scene*. Measuring *vividness* separately from visual properties, and measuring *belief* based on what is remembered rather than on other factors is difficult, as are comparisons across studies. Nonetheless, among all the correlations of individual differences measures I can find, *scene* has the highest correlations with measures of *reliving*, *belief*, and *vividness*.

Hypothesis 2, which predicted that *scene* would correlate more highly than *content* with *reliving, vividness* and *belief*, was universally supported in terms of both simple correlations and multiple regressions. The difference between correlations with *scene* and *content* were especially clear in multiple regressions where *content* had a significant beta weight only for *belief* in Study 1. Hypothesis 3, which predicted lower correlations of *emotional intensity* and *temporal specificity* with *scene* than with the three phenomenological measures, was also repeatedly supported. Moreover, Hypotheses 1, 2, and 3 are consistent with what is observed in individual memories (Rubin et al., 2019), some of which are shown in Table 5 in the columns labeled memory for *scene* and *content* and described in detail at the end of Study 1. Thus, the effects obtained when measures were made within the same memories occur to a similar degree if the measures are taken in different memories. In qualitative terms, the pattern of correlations is similar enough for the various studies in Table 5 that, once averages are taken over seven memories, the averages depend strongly enough on individual differences among subjects to mask any differences in the individual memories.

The general predictions of Hypothesis 4 concerning other tests of visual imagery were also supported. The theoretical importance of the correlations with *emotional intensity* and *temporal specificity,* and the relation of *scene* to other measures of imagery ability, are discussed more fully in their own sections, which follow.

A standardized test (SAM, Palombo et al., 2013) allowed for the formulation and support of Hypothesis 5. *Scene* correlated with ratings of remembering *episodic memory* more highly than ratings of accessing *semantic memory* and the measure of *spatial navigation* but not more highly than ratings of *future* events. Episodic memory and future events both require scenes. The type of semantic memory and spatial navigation included in the SAM do not require scenes. This difference helps to define and confirm empirically the domains in which scene recall of autobiographical memories is important.

The stability of results over time in not always examined in the process of testing a new individual differences measure. Here, a time delay served to ensure that short-term fluctuations in scene use did not affect the measures of autobiographical memory and *scene* given in the same session. The confirmation of Hypothesis 6 by the high test-retest correlation with delays of a week or longer ensures that short-term fluctuation is not the cause of the stability.

Thus, there is strong support for the hypotheses formed to test theoretical ideas about the role of scene recall in autobiographical memory. The hypotheses all followed from theoretical statements and empirical work on scene construction in the neuropsychological and behavioral literature.

7.2. Specific issues

7.2.1. The place of the SRIT among other tests of imagery

A puzzle, which contributed to this project, is that standard individual differences tests of visual imagery that were not devised specifically to consider autobiographical memory do not typically correlate highly with reliving and other measures used in autobiographical memory tasks. However, ratings of the visual image of an autobiographical memory have been the best predictor of ratings of reliving in the same autobiographical memory (e.g., Rubin, Schrauf, & Greenberg, 2003). Thus, although there are many tests of visual imagery, finding a way to systematize them or even to obtain reliable correlations among them in different populations has not been easy (Carroll, 1993; Greenberg & Knowlton, 2014; Richardson, 1994).

One might reasonably ask why the *SRIT* is different. Unlike most tests, the *SRIT* was developed based on a specific behavioral function of imagery that had a known neural basis and clear neuropsychological evidence. That evidence included the observation that the loss of the ability to imagine scenes through either hippocampal damage or damage earlier in the ventral stream caused amnesia. Thus, reasonable hypotheses could be formulated on with what the *SRIT* should, and should not, be expected to correlate.

7.2.2. Temporal versus scene specificity and the concept of overgeneral memories

Autobiographical memory can be viewed either as dependent on scene construction as is done here or as similar to episodic memory (Tulving, 1983, 2002) and thus occurring at a specific time and place. Current measures of autobiographical memory specificity employ the latter, indicating whether an autobiographical memory is related to a specific event situated in time and space. In particular, they index temporal specificity and naming the location of an event rather than remembering a scene. This occurs even though the empirical evidence indicates that the dating of events is not an inherent part of autobiographical memories but rather a distinct process (Friedman, 1993, 2004, 2005; Thompson, Skowronski, Larsen, & Betz, 1996).

The most common methods in the cognitive and neuropsychological literature are the Autobiographical Interview (AI, Levine et al., 2002), the Autobiographical Memory Interview (AMI, Kopelman et al., 1989) and a method developed by Piolino, Desgranges, Benali, and Eustache (2002). These measures include a broad range of properties in addition to location, but they all require a specific event situated in time. Therefore, they should correlate highly with *temporal specificity*, though not necessarily with *scene*.

In the clinical literature, where habitually producing nonspecific memories is termed overgeneral memory, the Autobiographical Memory Test is the most commonly used test (AMT, Griffith et al., 2012; Kuyken & Dalgleish, 1995). Under the current clinical definition, only a lack of temporal specificity indicates overgeneral memory (Williams et al., 2007). However, current theories used to understand and treat overgeneral memories have a broader conception in which scene specificity is a component (Dalgleish & Werner-Seidler, 2014; Holmes, Blackwell, Burnett Heyes, Renner, & Raes, 2016; Slofstra, Nauta, Holmes, & Bockting, 2016; Williams et al., 2007). Thus, in spite of the emphasis on temporal specificity, current therapies that focus on increasing memory specificity may already target scene recall without measuring its effects.

The studies conducted here find that measures of *scene* correlate more highly with the phenomenological properties of *reliving, vividness*, and *belief* than does *temporal specificity* or *content*. This suggests that changing existing tests to include *scene* rather than, or in addition to, measures of temporal specificity and the names of locations might increase their utility.

7.2.3. The cognitive interview techniques scale

The attempt to devise and include the Cognitive Interview Techniques Scale (*CITS*) had less a priori support than the other measures, but it was included because of the importance of obtaining evidence in the legal system and debates that have followed about using techniques that increase visual images of events. The *CITS* correlated with *scene* and did so more highly than it did with *content*. These results are a first venture into a complex area and must be viewed with caution. More research is needed to investigate whether scene recall might affect the suggestibility of witnesses differently than other measures of visual imagery.

7.2.4. Theory building at the intersection of experimentation, individual differences and the neural and behavioral level of analysis

There have long been calls to integrate the experimental and individual differences approaches to understanding cognition, while at the same time noting the extreme difficulties in doing so (e.g., Boogert, Madden, Morand-Ferron, & Thornton, 2018; Cronbach, 1957; Engle & Martin, 2018; Logie, 2018; Underwood, 1975). The current research offered a modest attempt in what seemed near to ideal conditions. The experimental and individual differences contributions needed only minor modification to study the effects of scene recall on autobiographical memory. Moreover, those studying autobiographical memory behaviorally and with neuropsychological and neuroimaging methods are generally supportive of such integrations.

The neuropsychological and neuroimaging literatures used to formulate the current empirical research routinely integrate neural and behavioral observation and experimentation. For neuropsychology, the neural changes and the behavioral tests are often independent of each other. Thus, the neuropsychological damage may be seen as causing individual differences in behavior. The same is true for developmental studies. Although these studies are usually analyzed as single cases or grouped data using the logic of experimental studies, treating them behaviorally as continua is not a major conceptual change. Investigating correlations in performance and neural activation for the same task is becoming more common. Again, however, it would not be difficult to modify this to a procedure comparing different tasks in the same people.

Here it was possible to switch from prior research that measured the correlations among properties based on individual memories to correlations of properties based on different memories; that is, from a more traditional memory approach to a study of individual differences. In this way, the correlations obtained here could not be attributed to the properties of the memories but rather must be attributed to the participants. Thus, changing from an experimental to an individual differences study did not involve a major change in methods, although little of the empirical or theoretical literature on which the studies conducted was based on the recall of scenes as an individual difference in normal populations. Individuals were not randomly assigned to groups, which is one hallmark of an experiment. However, random assignment to groups also is not possible in most neuropsychological, clinical, or developmental studies. Nevertheless, by using repeated-measure designs, it could be easy to assign individuals randomly to experimental conditions that involve different kinds of and properties of memories (e.g., memories based on valence, emotional intensity, past versus future) or different memory cues, as was done here.

At a more abstract level, these studies are also an example of extending neural-level findings to behavior. For much of the intellectual history of psychological enquiry, conceptual nervous systems were invented from observations of behavior with great success as in Sherrington (1906) postulating a synapse from behavior before it could be observed, and without much success (for this view see, Skinner, 1974). Many historical explanations of amnesia can be seen as the application of behavioral theory to what was primarily the result of neural damage. In contrast, here the opposite direction of going from observations and experiments of individuals with known neural damage or known neural activation has been key to developing a behavioral theory and individual differences test.

7.2.5. Future directions and limitations

Scene recall in autobiographical memory is both a measure of *individual memories* and *individual difference* that correlates among the highest of any individual-differences measure with the sense of *reliving, vividness*, and *belief* of autobiographical memories. Scene recall is based on and supported by neuropsychology, neuroimaging, and behavioral findings (Rubin et al., 2019; Rubin & Umanath, 2015). In addition, many other factors contribute to constructing autobiographical memories. This is especially true when scene construction is considered for events that are not autobiographical memories (Radvansky & Zacks, 2014; Rubin, 2006; Rubin & Umanath, 2015) as is done next.

Individual differences in scene construction could be used to investigate classes of events other than autobiographical memories, such as future events, fictional events, and representations of other people's lives. They could also be used in studies of laboratory tasks of episodic memory that vary in the extent to which scenes are used and in investigating issues related to the remember versus know distinction. If scene construction is at the basis of such events and episodic memory, its measure as an individual difference should affect behavior, especially for people with limited scene construction ability.

The individual differences noted in scene construction, as well as those that can be noted in specific situations, could be used to examine changes in normal development and aging and in clinical populations. Similarly, it could be used to measure the extent to which autobiographical memory exists in animals, children, and cognitively impaired adults whose phenomenological reports of whether they are recollecting, and therefore having, an autobiographical memory either cannot be obtained or cannot be trusted. In both cases, scene construction would allow an independent measure that did not depend on a particular task.

Information is lacking on how scene construction as an individual differences measure interacts with other measures known to be important to the phenomenological reports and accuracy of autobiographical memories. These measures include emotional valence, narrative coherence within an event and within the life narrative, and expertise in the knowledge structures used to understand specific events. Moreover, research is needed on measures other than self reports.

Our results are for events averaged over cues that were not biased to any particular topic or emotional state. Thus, for instance, the effects of scene construction and how it interacts with narrative and emotional processes may be different for emotionally neutral past events involving a person's public life than they are for emotionally charged future events involving personal relationships. Such differences could be substantial. Similarly, both the positive and negative effects of scene construction should be explored. With increased scene construction, memories will support better narratives, richer images from which to find details, believable false memories, and more troubling negative events. For clinical syndromes, these memories will support intrusive memories, rumination, and worry.

7.3. Conclusion

Recent advances in neuropsychological, neuroimaging, and behavioral research indicates that scene construction is a fundamental cognitive process in the encoding and recall of autobiographical memories as well as in the creation of future autobiographical events. Both neural damage and activation studies point to a system centered in the visual ventral stream from the visual cortex to the hippocampus. Behavioral data show that the degree to which individual memories consist of scenes correlates with the degree to which they are relived, vivid, and believed to be accurate, which are three classic properties of autobiographical memories. This suggested the possibility that scene construction would be an individual differences variable in broadly sampled populations, that is, it could be measured in one set of memories and used to predict behavior in other tasks and memories.

Six hypotheses about an individual differences measure were formulated based on the existing literature. They were that *scene recall ability* would correlate with (1) the *reliving, vividness*, and *belief* in the accuracy of autobiographical memories measured in a different set of memories, and would do so more highly than did the ability to recall the (2) *content* and (3) the *emotional intensity* and *temporal specificity* of autobiographical memories. (4) Moreover, *scene recall* should correlate with other individual differences measures of visual ability and do so in ways consistent with Hypotheses 1, 2, and 3. (5) *Scene recall* should correlate with the abilities to remember *episodic memories* and *future events* more highly than it would with the abilities to accesses *semantic memory* and use *spatial navigation*. (6) Finally, *scene recall* should correlate with itself stably over time. All six hypotheses were supported and all but one were replicated; some were replicated twice. The empirical work strongly supports the theoretical expectations.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2019.104164.

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