



On the relationship between trait autobiographical episodic memory and spatial navigation

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Abstract

Influential research has focused on identifying the common neural and behavioural substrates underlying episodic memory (the re-experiencing of specific details from past experiences) and spatial cognition, with some theories proposing that these are supported by the same mechanisms. However, the similarities and differences between these two forms of memory in humans require further specification. We used an individual-differences approach based on self-reported survey data collected in a large online study ($n = 7,487$), focusing on autobiographical episodic memory and spatial navigation and their relationship to object and spatial imagery abilities. Multivariate analyses replicated prior findings that autobiographical episodic memory abilities dissociated from spatial navigational abilities. Considering imagery, episodic autobiographical memory overlapped with imagery of objects, whereas spatial navigation overlapped with a tendency to focus on spatial schematics and manipulation. These results suggest that trait episodic autobiographical memory and spatial navigation correspond to distinct mental processes.

Keywords Autobiographical memory · Episodic memory · Navigation · Visual imagery · Individual differences

Introduction

An influential body of animal and human research has investigated the overlapping neural and behavioural substrates of episodic memory (i.e., the recall and re-experiencing of details from past events with a specific spatiotemporal context; Tulving, 1972, 2002) and spatial cognition. This work began with Tolman's (1948) conceptualization of a cognitive map, used in spatial navigation and in guiding cognitive behaviour more broadly. Theoretical and experimental work in this field

has proliferated in the past decade, particularly in trying to reconcile the role of the hippocampus in both memory and spatial cognition (Buzsáki & Moser, 2013; Collin, Milivojevic, & Doeller, 2017; Ekstrom & Ranganath, 2018; Schiller et al., 2015). These studies seek to provide an integrative framework for how the hippocampus's critical roles in both spatial and episodic memory can be explained using the same fundamental processes.

Cognitive map theory posits that the brain builds a unified representation of the spatial environment in order to navigate, and that this process is also used to support memory and guide future action in other cognitive domains (e.g., Behrens et al., 2018; Ekstrom & Ranganath, 2018; Schiller et al., 2015). This work mostly stemmed from rodent research, especially from the discovery of place cells in the rodent hippocampus (O'Keefe & Nadel, 1978). These cells are active when a rodent revisits a particular spatial location, and researchers have extended these findings to other mammals (e.g., Poulter, Hartley, & Lever, 2018), including monkeys (e.g., Rolls & Wirth, 2018) and humans (e.g., Bellmund, Gärdenfors, Moser, & Doeller, 2018). With respect to human episodic memory, cognitive map theory proposes that we form a map-like representation of memories in time and space, and that the processes supporting navigation through physical space also support navigation through our episodic memories (Epstein, Patai, Julian, & Spiers, 2017). An implication of this

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view might be that strong navigation abilities correspond to better episodic memory. While little research exists to address this possibility, some evidence suggests that this is not the case (Berntsen, Hoyle, & Rubin, 2019; Clark et al., 2019).

A related stream of research has investigated the overlap between spatial processing and episodic memory by focusing on scene construction (Hassabis & Maguire, 2007; Rubin & Umanath, 2015). Unlike the foundational studies on cognitive map theory, scene construction and related theories have focused on human episodic memory, particularly autobiographical episodic memory, or memory for specific episodes from one's life (as opposed to episodic memory for laboratory stimuli), and the use of visual processes to construct detailed recollections. According to scene construction theory, an image of the spatial context or location serves as a scaffold for elaboration with additional details. It follows that individuals who are able to form strong and vivid mental images of scenes should have a corresponding benefit in recollecting past autobiographical episodes (Conway, 2005; Greenberg & Knowlton, 2014).

These two influential bodies of research emphasize different aspects of spatial memory: map-like spatial representations versus memory for contexts and scenes. Studying individual differences in these abilities can provide a theoretical framework in which to understand the relative contributions of different aspects of spatial processing to memory retrieval (Underwood, 1975), but there has been relatively little research on the relationship between spatial and episodic autobiographical memory abilities across individuals (for an exception, see Clark et al., 2019). In the present report, we use an individual-differences approach among healthy adults to evaluate the relationships between spatial cognition and episodic autobiographical memory. We sought to assess these relationships at the trait level using self-reported capacities for episodic autobiographical memory and spatial navigation in naturalistic contexts.

Trait-based, individual-differences measures of memory provide an important distinction and complement to both performance- and laboratory-based measures. First, there is a distinction between trait- and performance-based measures of autobiographical memory. Trait-level autobiographical memory abilities reflect general tendencies in how individuals recall memories (Palombo, Sheldon, & Levine, 2018; Sheldon, Farb, Palombo, & Levine, 2016); this is in contrast to performance-based measures of autobiographical memory that involve the recall and description of a select few, often well-rehearsed, events (e.g., Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). As such, individuals with low trait-level autobiographical episodic memory abilities may tend not to retrieve details when recalling memories in everyday life yet still may generate many seemingly episodic details when recalling a particular event during an autobiographical memory task (Palombo, Alain, Söderlund, Khuu, & Levine,

2015), because the memory selected for the task was one of the few that did incorporate some episodic re-experiencing for the individual, or because the memory was well rehearsed and the individual “knows” the details without re-experiencing them, or some combination of the two. This could account for the relative lack of association between trait and performance measures of autobiographical memory (Clark & Maguire, 2020; Palombo, Williams, Abdi, & Levine, 2013), although when a sample is carefully selected to cover a broad range of trait mnemonic abilities, then an association between trait- and performance-based measures does emerge (Armson, Diamond, Levesque, Ryan, & Levine, 2020).

Second, there is a distinction between measures of autobiographical episodic memory, which involve the rich recollection of personal past episodes, and traditional laboratory-based episodic memory measures, which often involve the recollection of lists of simple stimuli such as words or pictures (Gilboa, 2004; McDermott, Szpunar, & Christ, 2009). Furthermore, there is inter-individual variability in baseline naturalistic memory abilities that many studies fail to consider and integrate when examining cognitive processes by relying on group differences (Goodhew & Edwards, 2019). Thus, our approach to assessing the relationship between naturalistic episodic autobiographical memory and spatial cognition abilities from an individual-differences perspective provides a novel framework in which to address the question of their relationship.

This study builds upon earlier research using the Survey of Autobiographical Memory (SAM; Palombo et al., 2013), an instrument that we developed to measure self-reported episodic autobiographical, semantic, spatial, and future thinking abilities. In a sample of 598 university students, our data-driven analyses demonstrated that episodic autobiographical memory and navigation abilities as measured by the SAM were orthogonal – an effect that was unexpected given the above-described body of research on memory and navigation. In the present study, our first aim was to replicate this finding in separate samples. Our second aim was to examine how individual differences in visual imagery – particularly object imagery (imagery for specific object features such as shape and colour) and spatial imagery (imagery for spatial relationships and transformations) as measured by the Object-Spatial Imagery Questionnaire (OSIQ; Blajenkova, Kozhevnikov, & Motes, 2006) – contribute differentially to episodic memory and spatial navigation abilities. Individuals scoring high on the object subscale of the OSIQ can form detailed mental images of scene components, and according to scene construction theory, these individuals should have strong episodic autobiographical memory abilities. On the other hand, individuals scoring high on the spatial subscale of the OSIQ can easily form schematic representations such as blueprints of environments, and according to cognitive map theory, these individuals should have strong episodic autobiographical memory abilities.

Methods

Participants

Participants were drawn from responses to an online survey that we created as a platform for research participation in response to media reports on our work on severely deficient autobiographical memory (SDAM; Palombo et al., 2015). The present study includes records collected from April 2015 to October 2019, after which recruitment declined and additional records did not substantively add to our dataset. While not random, given its large number of respondents this sample nonetheless provides information concerning the dimensional structure of episodic memory and spatial navigation abilities and their relationship to visual imagery. Extensive cleaning of the dataset was conducted to assess the cognitive and neurological health of this sample. To evaluate the generalizability of our results, we replicated key findings from this sample in two separate previously collected datasets (see [Online Supplemental Materials](#) [OSM]). Participants who completed this short study as well as a longer follow-up online study were compensated with a \$10 gift card. We did not specify an a priori target sample size; rather, we left our online survey open and aimed to collect as many responses as possible.

Exclusions Of the 18,189 survey responses recorded, 3,241 responses were blank in the fields of interest (i.e., only had data such as location coordinates, but not for our questionnaires), indicating either non-human responses or human respondents looking for compensation without actually completing the questionnaires, and were thus removed from the dataset. For multiple survey responses listed with the same email address, only the first response was kept (260 emails were associated with two or more responses). In addition, responses were removed if they were completed in an implausibly short length of time (i.e., less than 3 min, $n = 992$). Participants with fewer than 9 years or greater than 26 years of education were excluded ($n = 656$), as were participants under the age of 18 years ($n = 3$).

We included two “catch” questions as part of the online survey to ensure participants were paying attention and were human (rather than “bots”), in which participants were asked to select a specific point on a Likert scale (e.g., “For this question, please select ‘Totally agree’.”). We also included a text catch in which participants had to answer “What is 3 plus seven” in a text box. Responses that failed one or more of the catch questions were excluded from analyses ($n = 4,055$).

After these preliminary cleaning steps, participants who endorsed a history of major neurological conditions were excluded from the dataset (head injury with loss of consciousness >15 min, $n = 465$; stroke, $n = 35$; dementia, $n = 20$; epilepsy, $n = 155$; brain surgery, $n = 50$; cancer, $n = 156$; psychotic disorder requiring hospitalization, $n = 147$; learning

disorder, $n = 637$; alcohol/drug abuse, $n = 777$), as were participants who reported a significant decline in cognition over the past few years that affects everyday function ($n = 502$). Furthermore, participants who scored 20 or higher on the Patient Health Questionnaire depression module (PHQ9; Kroenke, Spitzer, & Williams, 2001), indicating severe depression, were excluded ($n = 532$). All participants who met these exclusionary criteria but otherwise provided valid data were nonetheless compensated for their participation, reducing the likelihood of under-reporting health conditions in order to receive compensation.

After all exclusions, our sample comprised 7,487 adults aged 18–85 years ($M = 40.00$, $SD = 14.23$). On average, the sample had 16.92 years of education ($SD = 3.15$), and included 4,954 females, 2,451 males, and 82 individuals who indicated “Prefer not to answer” with respect to gender.

Measures

Our complete online survey materials can be found on the Open Science Framework (OSF) at <https://doi.org/10.17605/OSF.IO/JD4Q8>. The survey took 10–15 min to complete and was hosted on Qualtrics. Only the measures of interest for the current study are described in more depth here.

To measure episodic autobiographical memory and spatial navigation abilities, we used the Survey of Autobiographical Memory (SAM; Palombo et al., 2013). The SAM is a validated (Petrican, Palombo, Sheldon, & Levine, 2020; Sheldon et al., 2016) self-report questionnaire designed to assess trait-level autobiographical memory abilities in four domains: episodic, spatial, semantic, and future. The spatial items on the SAM largely assess navigation abilities (as opposed to other spatial processes such as scene construction; Selarka, Rosenbaum, Lapp, & Levine, 2019). Items were rated on a Likert scale from 1 (strongly disagree) to 5 (agree strongly). Total scores on each of the four memory domains can be derived using a weighting algorithm on the raw item ratings, developed during the original validation of the SAM, but in the present study we calculated domain scores by averaging the raw scores across items, to preserve the scale of measurement for purposes of comparison with our other key questionnaire of interest.

Imagery ability was assessed using the OSIQ (Blajenkova et al., 2006). The OSIQ measures two domains of imagery: (1) object imagery, or the ability to vividly imagine specific features such as colour and shape; and (2) spatial imagery, or the ability to imagine spatial relations and transformations. However, not all the items on this questionnaire load cleanly on one or the other domain; several have factor loadings that are equal in magnitude but opposite in direction on both domains, a pattern indicating that they are not measuring *either* object or spatial imagery but rather tapping into both. Our participants completed the full questionnaire, but we used a

reduced set of items (seven object and seven spatial). These items were selected on the basis of a principal components analysis (PCA) that identified the items that loaded cleanly onto two orthogonal dimensions (Eslami, Fan, Levine, & Abdi, 2020). Items were rated on a Likert scale from 1 (totally disagree) to 5 (totally agree). Object and spatial imagery scores were each calculated by taking the average of all the items in that domain.

Finally, we included measures of personality (Big Five Inventory; John, Donahue, & Kentle, 1991; John, Naumann, & Soto, 2008) and depression (PHQ9; Kroenke et al., 2001) in order to rule out alternative explanations for the anticipated relationships between the SAM and OSIQ. Analyses of these measures can be found in the OSM.

Statistical analysis

Although we previously used multiple correspondence analysis to take into account the qualitative nature of Likert ratings in developing and validating the scale (Palombo et al., 2013), we use PCA here because it is more intuitive to visualize and understand. PCA is generally conducted on standardized scores, but since all the variables in this analysis were already on the same scale, we conducted the analysis on mean-centred but unstandardized scores. All analyses were conducted using R version 4.0.2. PCA was run using the *ExPosition* package (version 2.8.23; Beaton, Fatt, & Abdi, 2014). To address the relationship between the SAM and OSIQ, we first ran linear models with effect sizes obtained using the *lmsupport* package (version 2.9.13; Curtin, 2018). We next ran a partial least squares correlation (PLSC) using the *TInPosition* package (version 0.13.6.1; Beaton et al., 2014). While inferential statistics can be obtained (e.g., via bootstrapping methods) for both PCA and PLSC, we focused here on interpreting visualizations and on the magnitude of contributions, because our large sample size leads to highly precise estimates and thus very low *p*-values for almost every effect investigated, regardless of its size, theoretical significance, or importance. Our complete analysis scripts and output can be found at our OSF link.

Results

We first examined the factor structure of the SAM to replicate the finding in the original validation report that episodic autobiographical memory and spatial navigation abilities were independent (Palombo et al., 2013). To begin with, we conducted a PCA on the dataset reported on by Palombo et al. (2013; originally analyzed using multiple correspondence analysis) in order to validate this approach. As expected, this analysis replicated the main conclusions from the multiple correspondence analysis (see OSM).

We then conducted a PCA on the SAM in the present, larger data set (Fig. 1, bottom left and right). The scree plot (Fig. 1, top left) suggested five significant dimensions, but we focus on the first two dimensions here (visualizations of Dimensions 3–5 can be found in the OSM). The first dimension, explaining 27.18% of the variance, reflected overall high memory abilities across the domains. We previously demonstrated that the episodic and semantic items from Dimension 1 can be dissociated as they differentially relate to gender, mood, and memory performance (Palombo et al., 2013; see also Armson et al., 2020; Berntsen et al., 2019; Coutanche, Koch, & Paulus, 2020; Sheldon et al., 2016). We therefore treated these sets of items as distinct in subsequent analyses. The second dimension, explaining 12.94% of the variance, separated spatial items from items in the other three domains. As reported in the OSM, this factor structure was unrelated to gender, personality dimensions as measured by the BFI, or depressive symptoms as measured by the PHQ9, and it replicated in two independent samples of participants. This replication speaks to the overall stability of the SAM's factor structure, given that our sample was biased towards individuals with an interest in their own memories; the fact that the factor structure of the SAM held in two large independent datasets composed of participants not recruited on the basis of memory abilities supports the validity of the present findings.

Next, we assessed the relationship between the SAM and OSIQ, using both univariate and multivariate analyses. We first used linear regression to determine the differential contributions of OSIQ object versus spatial scores to SAM scores in each of the four domains, although we note that these analyses are limited in that: (1) domain scores are averaged across items and do not tell us about the relations between specific items, and (2) the four memory domains must be assessed in four separate models and do not allow for comparison of the relationship between the OSIQ and SAM domains in a single analysis. However, the regressions provide an intuitive way to understand the relationships between each domain, and we follow them up with multivariate visualizations and analyses that illustrate the same patterns of results at the item level.

The results from the four regressions are shown in Table 1. To correct for multiple comparisons the α level was set at 0.0125 (i.e., Bonferroni adjustment: .05/4). Given the size of our sample, all of the regression results were statistically significant; as such, we looked to the magnitude of partial η^2 to interpret the size of each effect. Critically, object and spatial imagery did not contribute equally to each of the four memory domains (Fig. 2): for episodic memory and future thinking, object imagery had a substantially larger effect size than spatial imagery did in predicting memory scores. The reverse was true for spatial navigation abilities: spatial imagery had a larger effect than did object imagery. There was no notable difference between object and spatial imagery in predicting semantic memory abilities. These findings were replicated in an

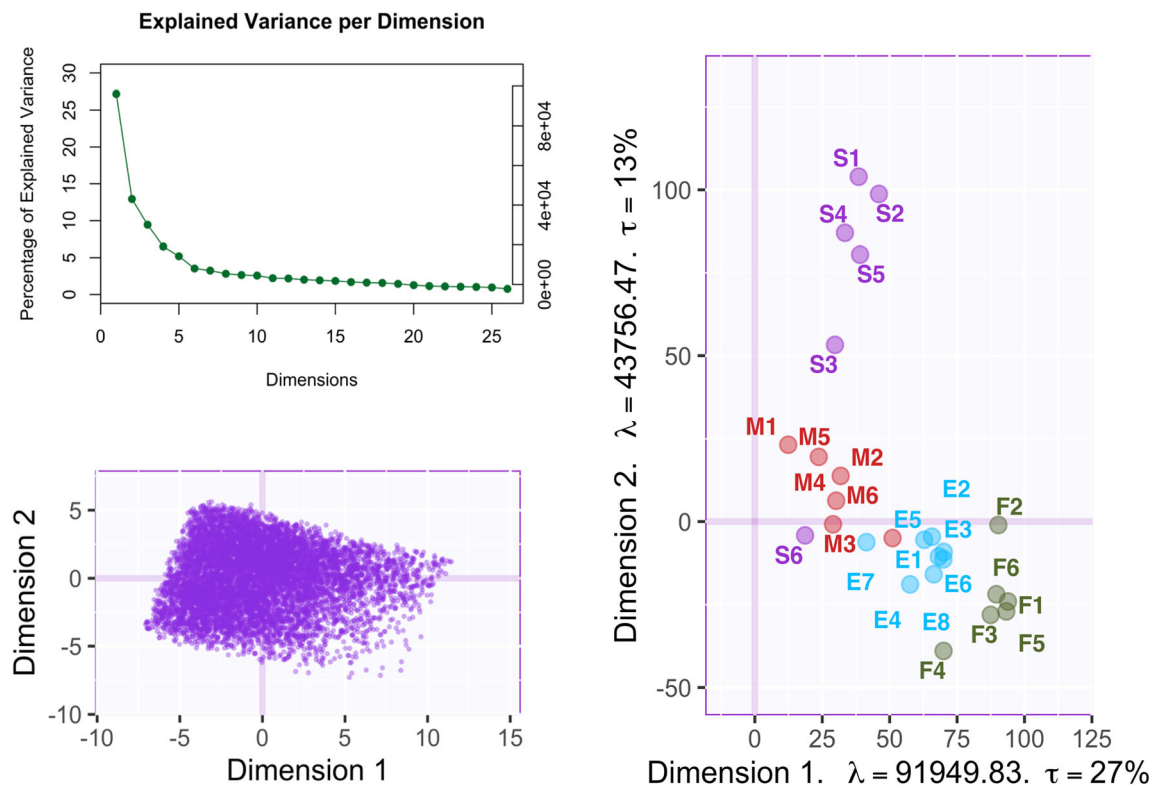


Fig. 1 Results of a principal components analysis on the Survey of Autobiographical Memory (SAM). **Top left:** Scree plot. **Bottom left:** Loadings of each subject on the first two dimensions. **Right:** Loadings of each SAM item on the first two dimensions. The horizontal axis on the latter two plots represents the first dimension, and reflects an overall high memory ability across domains. The vertical axis represents the second

dimension, and separates spatial navigation abilities from episodic and semantic memory as well as future thinking. Each point represents one SAM item (**right**) or one subject (**bottom left**), and letters in the item plot (**right**) represent the SAM domain: E = episodic, S = spatial, F = future, M = semantic. See OSM for full items corresponding to each label

independent sample and unaffected by the inclusion of a measure of social desirability derived from the BFI (see OSM).

While these univariate results give compelling indications about the relationship between episodic and spatial memory and imagery, our multivariate analyses incorporated the various factor scores in a single model and provided better visualization of the data. One multivariate approach is to project the OSIQ items into the factor space of SAM (see OSM); however, this simple visualization technique does not simultaneously analyze items from both questionnaires. To explicitly analyze the information common to the SAM and OSIQ,

we conducted a partial least squares correlation (PLSC) analysis on the items of the SAM and OSIQ. This analysis derives latent variables (LVs) that describe the shared variance between two sets of data, in this case the SAM items and the OSIQ items (Abdi & Williams, 2013).

Visual inspection of the questionnaire items in the first two dimensions resulting from this analysis (Fig. 3, right) indicated that, as predicted, spatial navigation abilities separated from other autobiographical memory abilities on the second dimension, but clustered together with spatial imagery items. Object imagery items tended to cluster with episodic, future,

Table 1. Regression results for models of each Survey of Autobiographical Memory (SAM) domain score (rows) predicted by object and spatial imagery scores

| | Model R^2 | Object | | | | | Spatial | | | | |
|----------|-------------|---------|------|-------|--------|----------|---------|------|-------|--------|----------|
| | | β | SE | t | P | η^2 | β | SE | t | p | η^2 |
| Episodic | .33 | 0.52 | 0.01 | 57.26 | < .001 | .30 | 0.06 | 0.01 | 6.25 | < .001 | .005 |
| Spatial | .19 | 0.09 | 0.01 | 8.55 | < .001 | .01 | 0.41 | 0.01 | 38.16 | < .001 | .16 |
| Future | .53 | 0.84 | 0.01 | 84.17 | < .001 | .49 | 0.13 | 0.01 | 12.51 | < .001 | .02 |
| Semantic | .06 | 0.16 | 0.01 | 16.00 | < .001 | .03 | 0.09 | 0.01 | 9.31 | < .001 | .01 |

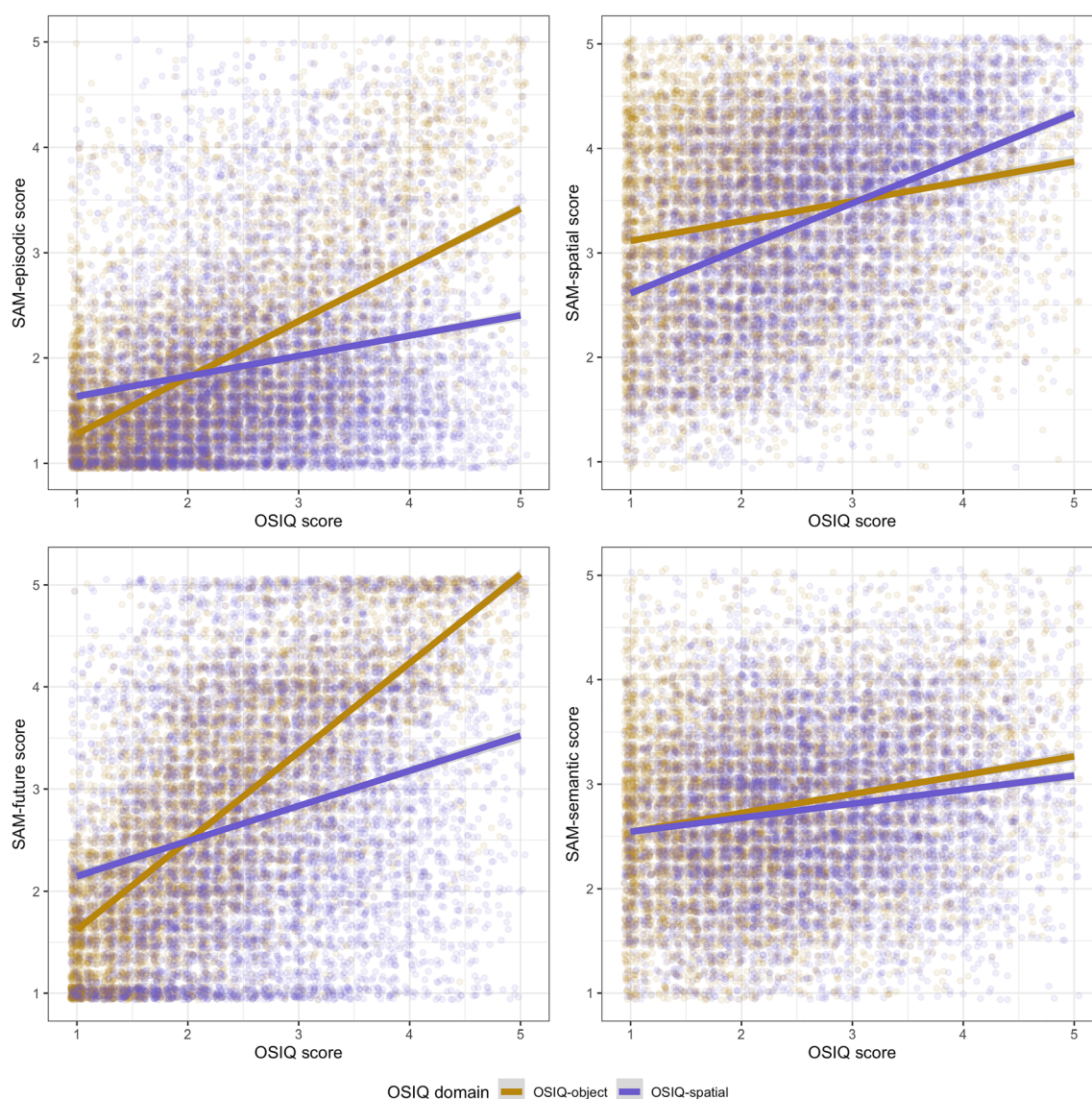


Fig. 2 Scatterplots of regression analyses predicting domain scores on the Survey of Autobiographical Memory (SAM) with object and spatial imagery scores on the Object-Spatial Imagery Questionnaire (OSIQ). Points have been jittered to allow for better visualization of the spread of data

and semantic memory on the vertical dimension. These relationships were also apparent from the heat map of Pearson correlation coefficients between each of the items of the SAM and OSIQ (see OSM).

The scree plot (Fig. 3, left) indicated that the first two dimensions explained most of the variance decomposed by the PLSC (Dimension 1, 89.27%; Dimension 2, 9.85%); as such, we examined the contributions of each questionnaire item to the first two sets of latent variables (Fig. 4). LV1 reflected object imagery items, along with episodic autobiographical memory and future-thinking items. LV2 reflected spatial imagery items and spatial navigation items, although two semantic memory items also loaded just above average in the same direction as the spatial items and one future item loaded just above average in the opposite direction. However, the contributions of the spatial

navigation items clearly exceeded the average contribution as well as the contributions of these three other memory items – a configuration providing evidence for a clear dissociation between episodic memory, future thinking, and object imagery on the one hand, and spatial imagery and spatial navigation abilities on the other hand. We also conducted a PLSC on the SAM and OSIQ in an independent sample and replicated these results (see OSM).

Discussion

Researchers have recently increased their efforts to unify episodic memory and spatial cognition in a single theoretical framework that can account for the many similarities, both

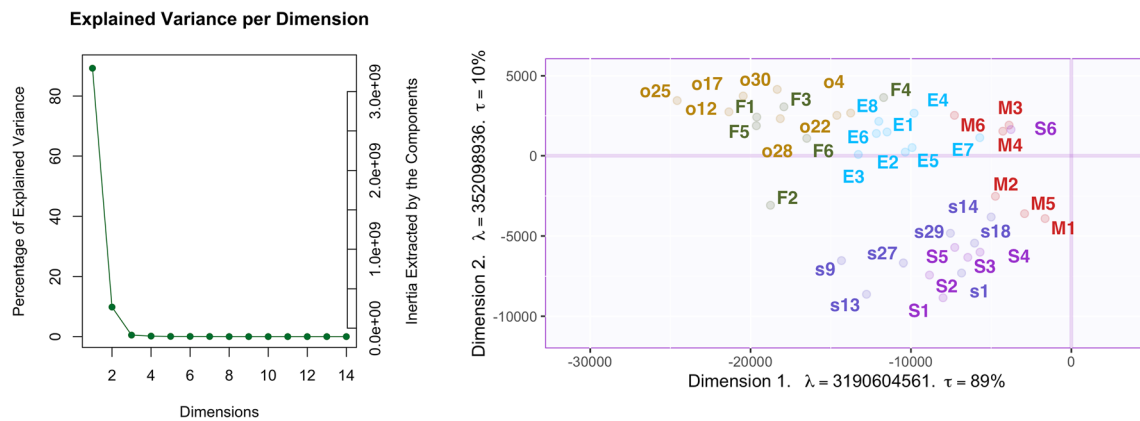


Fig. 3 Results of a partial least squares correlation analysis on the Survey of Autobiographical Memory (SAM) and Object-Spatial Imagery Questionnaire (OSIQ). **Left:** Scree plot. **Right:** Loadings of the SAM and OSIQ items in the partial least squares analysis. The horizontal axis represents the first dimension, and reflects an overall high memory and imagery ability across domains. The vertical axis represents the second

dimension, and separates spatial navigation and spatial imagery abilities from episodic, future, and semantic memory, as well as object imagery. Each point represents one SAM or OSIQ item. Uppercase letters represent SAM domains: E = episodic, S = spatial, F = future, M = semantic. Lowercase letters represent OSIQ domains: o = object, s = spatial. See OSM for full item corresponding to each label

on cognitive and neural levels, between the two systems (e.g., Buzsáki & Moser, 2013). There has been relatively little research in humans relating episodic and spatial memory

abilities to other cognitive traits within an individual-differences framework. We found that episodic autobiographical memory and spatial navigation abilities are distinct, and

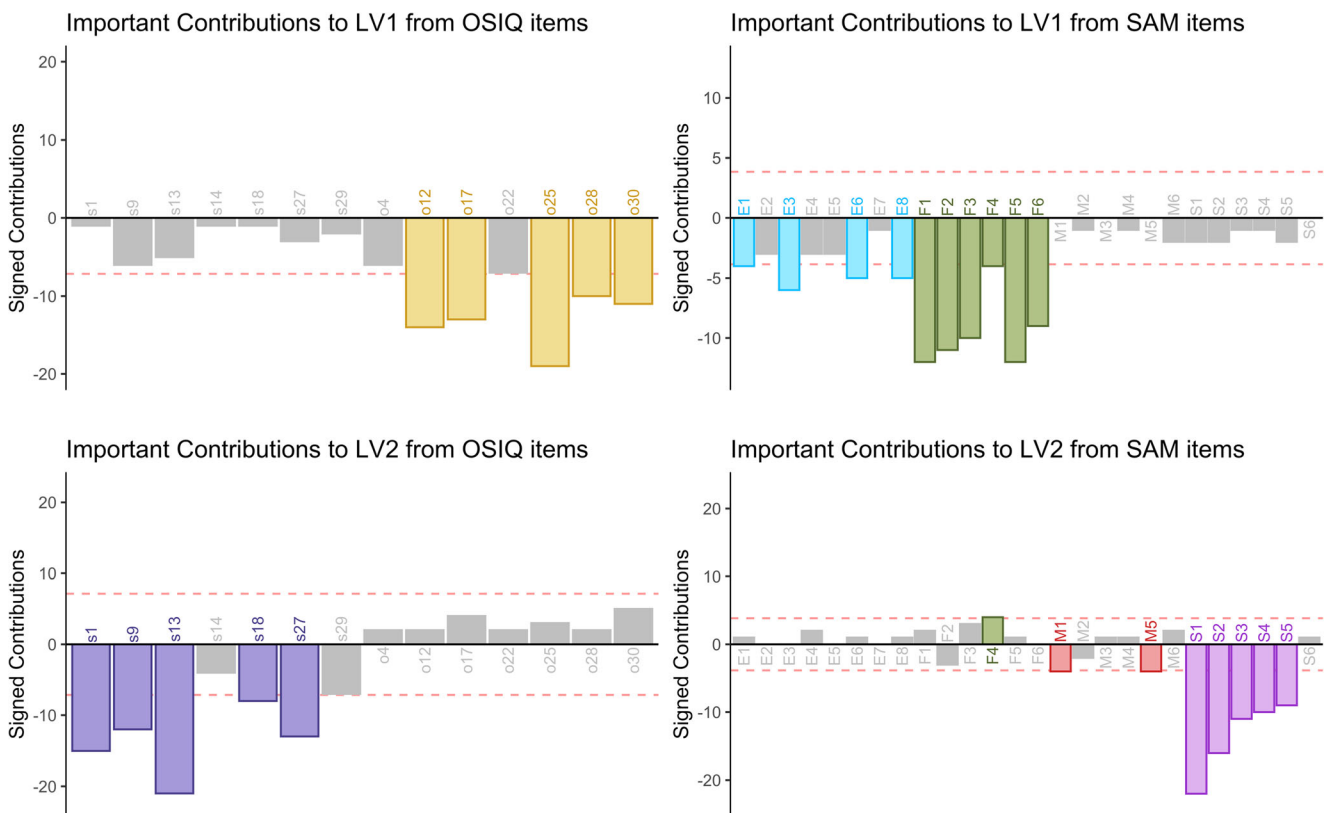


Fig. 4 Contributions of each item on the Survey of Autobiographical Memory (SAM) and Object-Spatial Imagery Questionnaire (OSIQ) to each of the first two latent variables resulting from a partial least squares correlation analyses between the two questionnaires. The dotted line in each plot indicates the absolute value of the average contribution;

coloured bars indicate contributions of items that exceed this average in magnitude. Each bar represents one SAM or OSIQ item. Uppercase letters represent SAM domains: E = episodic, S = spatial, F = future, M = semantic. Lowercase letters represent OSIQ domains: o = object, s = spatial

that the relationships of these abilities to forms of visual mental imagery shed new light on the differential processes underlying episodic memory and spatial processing.

We first replicated findings from previous reports using the SAM (Palombo et al., 2013) showing that self-reported spatial navigation ability is independent from episodic and semantic memory and future autobiographical thinking when analyzed in a multidimensional space (see also Berntsen et al., 2019). While there is shared variance in overall spatial navigation and memory abilities, as evidenced by the first dimension in the PCA and PLSC analyses (likely owing to the positive manifold; Spearman, 1925), spatial navigation is orthogonal to episodic memory and future thinking in the second dimension. This finding aligns with previous work showing that SAM-spatial (but not SAM-episodic) scores relate to navigation performance (Clark et al., 2019; Selarka et al., 2019), but it stands in contrast to the body of work emphasizing the overlap between the processes driving spatial navigation and episodic memory, as in cognitive map theory, where spatial navigation and episodic memory are viewed as different instantiations of the same underlying process.

One reason for this discrepancy could be the rodent-based research methods and history that cognitive map theory is built upon. This theoretical framework stemmed largely from work investigating the role of the hippocampus – a structure well accepted to be crucial in both navigating spatial environments and constructing detailed episodes from past experiences (e.g., Burgess, Maguire, & O’Keefe, 2002). The discovery in the rodent hippocampus of place cells, which fire when the animal revisits a particular spatial location, was seminal in setting the groundwork in this area, and researchers have been eager to extend these findings to learn more about human navigation and memory. However, further study found that while hippocampal neurons in rodents respond mainly to the place where the animal is located, analogous hippocampal neurons in primates – sensitive to foveation and a highly developed visual system – respond to where a monkey is looking (Rolls & Wirth, 2018). It is possible that the hippocampal system began as a navigational system, as in rodents, but through evolution developed representations for more complex spatial and temporal information, forming the basis of episodic memory (O’Keefe, Burgess, Donnett, Jeffery, & Maguire, 1998) – but the extent to which rich episodic memory retrieval in humans depends on navigational processes remains in question.

An alternative to cognitive map theory views scene construction as the key component linking spatial and episodic memory and aligns with the idea that the human hippocampal system has developed to emphasize visual processing (rather than mental maps) to reconstruct memories of past events (Hassabis & Maguire, 2007; Rubin & Umanath, 2015). Recent work has corroborated this view, showing that navigation and non-spatial episodic memory can be dissociated in healthy adults (Ngo, Weisberg, Newcombe, & Olson, 2016).

Furthermore, patient work shows that scene memory and episodic memory are similarly supported by the medial temporal lobes, whereas more schematic forms of spatial memory, such as navigation, are independent (Robin, Rivest, Rosenbaum, & Moscovitch, 2019). Accordingly, we found that the ability to form vivid mental images of specific objects and scenes corresponded to episodic memory ability. The ability to imagine schematics and spatial relationships between items, on the other hand, corresponded more closely with spatial navigation ability and demonstrated dissociations from object imagery and episodic memory. This finding suggests that the importance of spatial processing in episodic memory retrieval may not be in the mapping process, but in the construction of a spatial context to which further event details can be added (Hassabis & Maguire, 2007).

Our results contribute to the body of work investigating the relationship between visual imagery and autobiographical memory. Previous studies have yielded mixed results. Vannucci, Pelagatti, Chiorri, and Mazzoni (2016) showed that – compared to those reporting low object imagery – individuals reporting strong object imagery were faster to generate autobiographical memories in response to cue phrases and reported more sensory and perceptual details and associated visual images in their memories; however, Sheldon, Amaral, and Levine (2017) found that interfering with visual imagery processes impeded recall of event details (particularly spatial ones) more for individuals high in spatial imagery, while its impact did not differ for individuals with differing object imagery abilities. Aydin (2018) found that object imagery was related to phenomenological characteristics such as the level of sensory and perceptual details retrieved in relation to past experiences, whereas spatial imagery predicted the level of episodic specificity of past events. Clark et al. (2019) reported that navigation performance dissociated from autobiographical memory retrieval and scene construction, and they speculated that navigation reflects schematic spatial imagery, whereas autobiographical memory draws upon vivid imagery for objects and scenes. They also suggested that a dissociation of function along the long axis of the hippocampus underlies this effect, such that navigation and spatial imagery rely on posterior subregions, whereas episodic memory and object imagery rely on anterior subregions. This could also be a potential neural substrate of our finding that vivid object imagery was associated with rich self-reported episodic autobiographical memory, while spatial imagery tapped into the relatively independent construct of navigational ability.

Our findings also align with evidence from individuals with aphantasia, who report having no phenomenological experience of visual mental imagery and have correspondingly low OSIQ-object scores, yet have OSIQ-spatial scores matching those of controls (Dawes, Keogh, Andrillon, & Pearson, 2020; Keogh & Pearson, 2018). Like individuals with SDAM, those with aphantasia report a lack of subjective

reliving when they remember past experiences (Greenberg & Knowlton, 2014; Zeman, Dewar, & Della Sala, 2015, 2016), a pattern indicating that intact spatial imagery is not sufficient for episodic autobiographical memory recall.

While we focused here on interpreting the relationship between self-reported episodic memory and spatial navigational abilities, it is worth noting that future autobiographical thinking was also highly related to episodic memory and seemed even more strongly dissociated from spatial navigation abilities (Addis & Schacter, 2012). The future subscale of the SAM largely assessed individuals' ability to imagine specific future events, and may have thus acted as an indirect measure of detailed object imagery. Future work may be better able to dissociate detailed imagery for future scenes versus the imagination of a series of events unfolding in the future, and address how these forms of future thinking relate to episodic memory and spatial navigation.

A limitation to these findings is the use of self-report as opposed to performance-based measures. In particular, there is evidence that self-reported autobiographical memory abilities do not always correspond to performance on autobiographical memory tests (Clark & Maguire, 2020; but see Armson et al., 2020); this dissociation could be due to measurement differences across tests of trait (i.e., lifetime) abilities versus tests of recall for single events, which can be accomplished with non-episodic processes or, depending on how events are cued, may not reflect one's propensity to episodically re-experience events in general (Palombo et al., 2015; see also Fan, Romero, & Levine, 2020). As for navigation, there is a closer coupling between trait- and performance-based measures (Selarka et al., 2019), possibly because objective feedback is more readily available for navigation (i.e., whether or not one has arrived at the destination) than for autobiographical memory, particularly the subjective aspect of re-experiencing, for which there is often no objective criterion. Moreover, our findings concur with those reported in relation to spatial navigation performance (Clark et al., 2019), and we conducted detailed control analyses to rule out several alternative explanations, such as an overall social desirability bias in self-report (see OSM). Nonetheless, further work augmenting findings from trait measures with performance measures will help clarify the nature of these relationships.

Another caveat to our interpretation is that our measure of navigation ability focused on navigating familiar environments, whereas the cognitive map theory literature largely studies new-route learning; and the OSIQ-object scale focuses on measuring imagery vividness, whereas scene construction theory also emphasizes the coherent integration of scene components. While the current findings cannot speak to these aspects of the distinction between cognitive map and scene construction theory, they provide a novel piece in this puzzle by focusing on individual differences in memory and spatial abilities as lifelong traits, rather than as measured by task

performance. Finally, although our sample was not random, as indicated earlier, its large size and our supplemental control analyses render it no less generalizable to the healthy adult population than are conventional small samples of college undergraduates. We also replicated our key findings in two large, independently collected datasets that were recruited from the community, rather than from a population of individuals interested in their own memory abilities, further supporting the generalizability of the results reported here.

In conclusion, we show that episodic memory and spatial navigation are independent constructs at the trait level, and that these forms of memory correspond to different forms of mental imagery. Our data suggest that the importance of spatial processing in episodic memory may not be in the formation of a spatial map, but rather in the retrieval of a spatial context or scene. While research investigating and emphasizing the importance of "space" in episodic memory has proliferated, independent streams of work have focused on different meanings of the term. Space undoubtedly plays a critical part in episodic memory at both the cognitive and neural levels, but further clarity is needed when assessing which aspects of spatial memory are driving this overlap.

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Open practices statement The studies reported in this article were not formally preregistered. The data have not been made available on a permanent third-party archive because our Institutional Review Board ruled that we could not post the data; requests for the data can be sent via email to the corresponding author. The complete questionnaires and our analysis scripts are available online at <https://doi.org/10.17605/OSF.IO/JD4Q8>.

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view might be that strong navigation abilities correspond to better episodic memory. While little research exists to address this possibility, some evidence suggests that this is not the case (Berntsen, Hoyle, & Rubin, 2019; Clark et al., 2019).

A related stream of research has investigated the overlap between spatial processing and episodic memory by focusing on scene construction (Hassabis & Maguire, 2007; Rubin & Umanath, 2015). Unlike the foundational studies on cognitive map theory, scene construction and related theories have focused on human episodic memory, particularly autobiographical episodic memory, or memory for specific episodes from one's life (as opposed to episodic memory for laboratory stimuli), and the use of visual processes to construct detailed recollections. According to scene construction theory, an image of the spatial context or location serves as a scaffold for elaboration with additional details. It follows that individuals who are able to form strong and vivid mental images of scenes should have a corresponding benefit in recollecting past autobiographical episodes (Conway, 2005; Greenberg & Knowlton, 2014).

These two influential bodies of research emphasize different aspects of spatial memory: map-like spatial representations versus memory for contexts and scenes. Studying individual differences in these abilities can provide a theoretical framework in which to understand the relative contributions of different aspects of spatial processing to memory retrieval (Underwood, 1975), but there has been relatively little research on the relationship between spatial and episodic autobiographical memory abilities across individuals (for an exception, see Clark et al., 2019). In the present report, we use an individual-differences approach among healthy adults to evaluate the relationships between spatial cognition and episodic autobiographical memory. We sought to assess these relationships at the trait level using self-reported capacities for episodic autobiographical memory and spatial navigation in naturalistic contexts.

Trait-based, individual-differences measures of memory provide an important distinction and complement to both performance- and laboratory-based measures. First, there is a distinction between trait- and performance-based measures of autobiographical memory. Trait-level autobiographical memory abilities reflect general tendencies in how individuals recall memories (Palombo, Sheldon, & Levine, 2018; Sheldon, Farb, Palombo, & Levine, 2016); this is in contrast to performance-based measures of autobiographical memory that involve the recall and description of a select few, often well-rehearsed, events (e.g., Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). As such, individuals with low trait-level autobiographical episodic memory abilities may tend not to retrieve details when recalling memories in everyday life yet still may generate many seemingly episodic details when recalling a particular event during an autobiographical memory task (Palombo, Alain, Söderlund, Khuu, & Levine,

2015), because the memory selected for the task was one of the few that did incorporate some episodic re-experiencing for the individual, or because the memory was well rehearsed and the individual “knows” the details without re-experiencing them, or some combination of the two. This could account for the relative lack of association between trait and performance measures of autobiographical memory (Clark & Maguire, 2020; Palombo, Williams, Abdi, & Levine, 2013), although when a sample is carefully selected to cover a broad range of trait mnemonic abilities, then an association between trait- and performance-based measures does emerge (Armson, Diamond, Levesque, Ryan, & Levine, 2020).

Second, there is a distinction between measures of autobiographical episodic memory, which involve the rich recollection of personal past episodes, and traditional laboratory-based episodic memory measures, which often involve the recollection of lists of simple stimuli such as words or pictures (Gilboa, 2004; McDermott, Szpunar, & Christ, 2009). Furthermore, there is inter-individual variability in baseline naturalistic memory abilities that many studies fail to consider and integrate when examining cognitive processes by relying on group differences (Goodhew & Edwards, 2019). Thus, our approach to assessing the relationship between naturalistic episodic autobiographical memory and spatial cognition abilities from an individual-differences perspective provides a novel framework in which to address the question of their relationship.

This study builds upon earlier research using the Survey of Autobiographical Memory (SAM; Palombo et al., 2013), an instrument that we developed to measure self-reported episodic autobiographical, semantic, spatial, and future thinking abilities. In a sample of 598 university students, our data-driven analyses demonstrated that episodic autobiographical memory and navigation abilities as measured by the SAM were orthogonal – an effect that was unexpected given the above-described body of research on memory and navigation. In the present study, our first aim was to replicate this finding in separate samples. Our second aim was to examine how individual differences in visual imagery – particularly object imagery (imagery for specific object features such as shape and colour) and spatial imagery (imagery for spatial relationships and transformations) as measured by the Object-Spatial Imagery Questionnaire (OSIQ; Blajenkova, Kozhevnikov, & Motes, 2006) – contribute differentially to episodic memory and spatial navigation abilities. Individuals scoring high on the object subscale of the OSIQ can form detailed mental images of scene components, and according to scene construction theory, these individuals should have strong episodic autobiographical memory abilities. On the other hand, individuals scoring high on the spatial subscale of the OSIQ can easily form schematic representations such as blueprints of environments, and according to cognitive map theory, these individuals should have strong episodic autobiographical memory abilities.

On the relationship between trait episodic autobiographical memory and spatial navigation

Supplemental Material

Carina Fan, Hervé Abdi, and Brian Levine

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1 Factor structure of the SAM

1.1 Additional visualizations

As reported in the main text, we conducted a principal components analysis (PCA) on the Survey of Autobiographical Memory (SAM) to assess the factor structure of the questionnaire. We focused on interpreting the first two dimensions resulting from this analysis in the main text, but visual examination of the scree plot (elbow test; Figure 1a in main text) indicated that the first five dimensions explained meaningful amounts of variance. As such, we visualize and report dimensions 3–5 here (Figure 1). Dimension 3 explained 9.41% of the variance, dimension 4 explained 6.45%, and dimension 5 explained 5.15%.

1.2 Replication in two independent samples

As reported in the main text, our large online sample could be biased, as most participants came across the study through an interest in their own memory function. As such, we wanted to show that the same factor structure held in independent samples of participants recruited from the community. We used two datasets collected in our laboratory for projects unrelated to the dataset reported on in the main text. Importantly, these samples were recruited from the community, rather than from a sample of individuals interested in their own memory function. We conducted a PCA on the SAM in each of these two samples. The first sample was collected for the original validation report of the SAM (Palombo, Williams, Abdi, & Levine, 2013). The second sample was collected to pre-screen participants for a project assessing individual differences in autobiographical memory and eye movements (Armson, Diamond, Levesque, Ryan, & Levine, 2019).

1.2.1 2013 dataset

In the original validation report of the SAM (Palombo et al., 2013), we used multiple correspondence analysis (MCA) to investigate the factor structure of the questionnaire. Here, we returned to those original data ($n = 598$; further characterization of this sample can be found in the 2013 report) and conducted a PCA on them, for two reasons: 1) to confirm that MCA and PCA yield comparable results, and 2) to replicate the factor structure reported in the main text of the present report.

This PCA revealed a first dimension that accounted for 26.19% of the variance, and a second dimension accounting for 10.03%, comparable to the analysis reported in the main text. Figure 2 illustrates the scree plot, as well as the item and subject plots for the first 4 dimensions of this analysis. Of importance, the first dimension again appears to reflect general memory abilities whereas the second dimension separates spatial navigation from the other memory domains, replicating the findings reported in the original 2013 report and the main text, and supporting our use of PCA to analyze and interpret the data from the present study.

1.2.2 2019 dataset

We also conducted a PCA on the SAM in a sample of 535 participants (383 female, 146 male, 6 who preferred not to answer), a subset of which was recruited for further testing for an independent project (Armson et al., 2019). These participants' ages ranged from 18 to 72 ($M = 26.57$, $SD = 8.91$) and they had an average of 16.95 years of education ($SD = 2.67$). They were screened for a history of major neurological conditions, as in the main sample. They completed a short battery of measures online, including the Survey of Autobiographical Memory (SAM) and Object-Spatial Imagery Questionnaire (OSIQ). We utilized this sample to replicate the key analyses on our primary sample reported here and in the main text.

This PCA revealed a first dimension that accounted for 34.87% of the variance, and a second dimension accounting for 10.01%, comparable to the analysis reported in the main text. Figure 3 illustrates the scree plot, as well as the item and subject plots for the first 4 dimensions of this analysis. The first dimension again appears to reflect general memory abilities whereas the second dimension separates spatial navigation from the other memory domains, replicating the findings reported above and in the main text.

Note that while the directionality of the dimensions may appear reversed in these replications (i.e., items that load negatively on one dimension may appear to load positively when the analysis is replicated), this is arbitrary in PCA and does not change the interpretation of the overall factor structure.

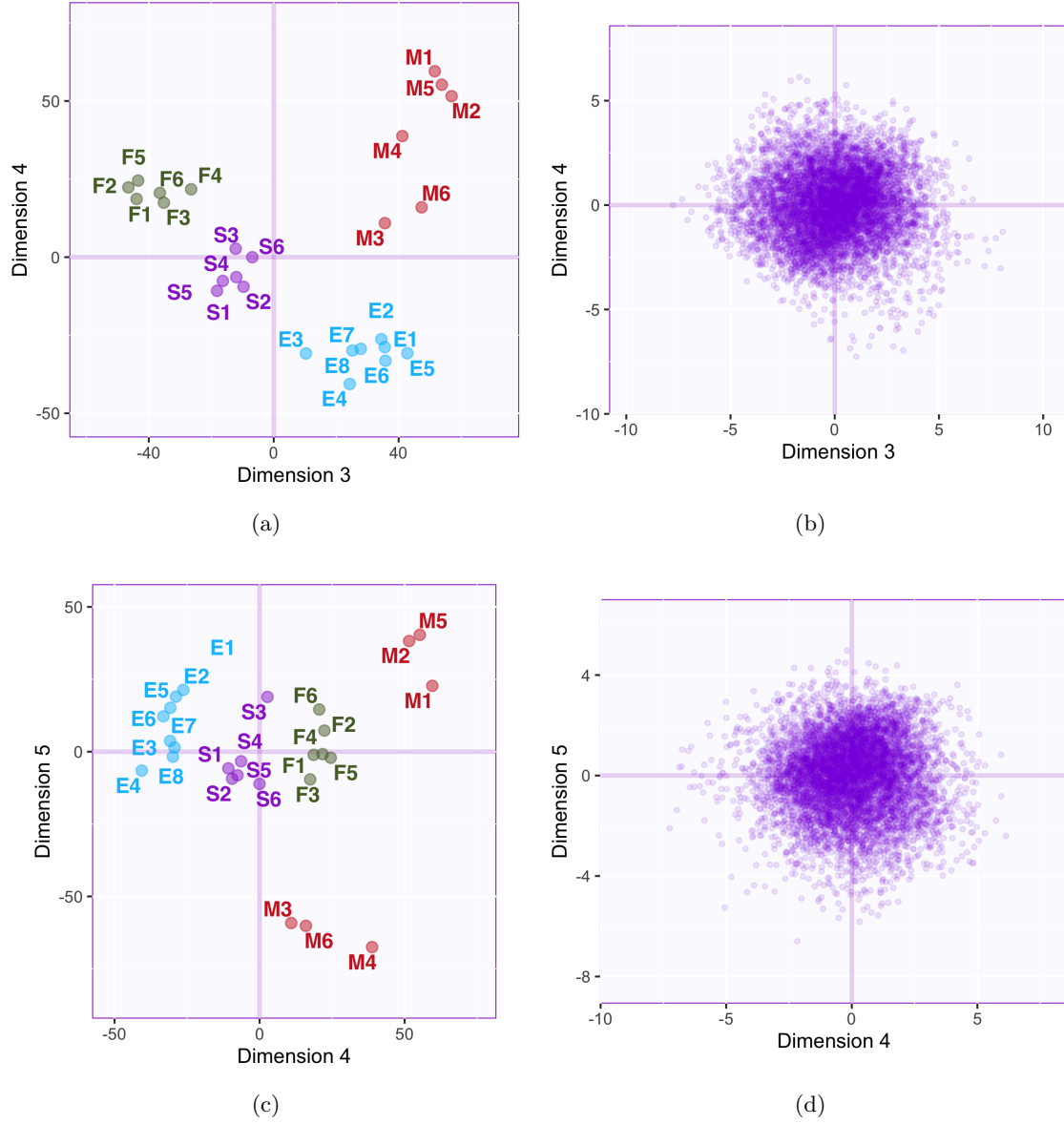
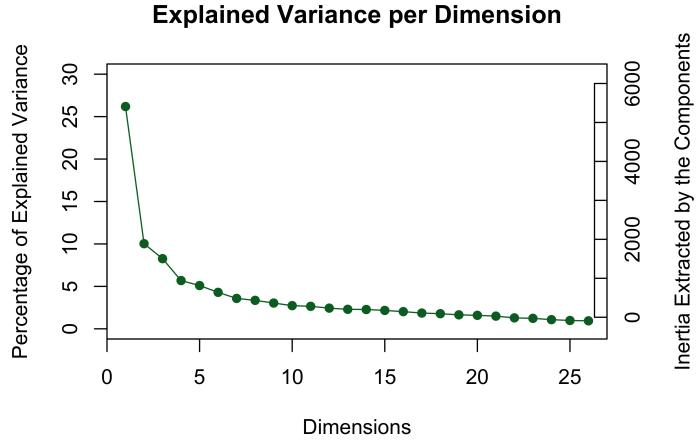
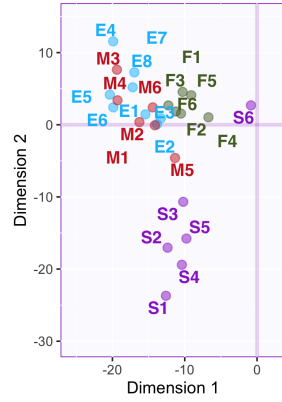


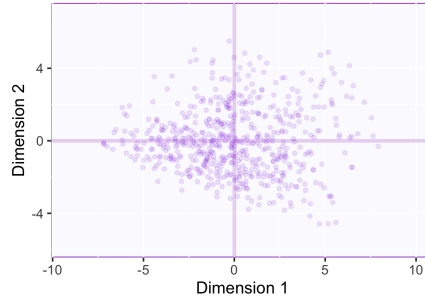
Figure 1: Results of a principal components analysis on the Survey of Autobiographical Memory (SAM). Panels **a** and **c** show item loadings, where each point represents one SAM item, and letters represent the SAM domain (E = episodic, S = spatial, F = future, M = semantic; see appendix for full item corresponding to each label). Panels **b** and **d** show subject loadings, where each point represents one subject.



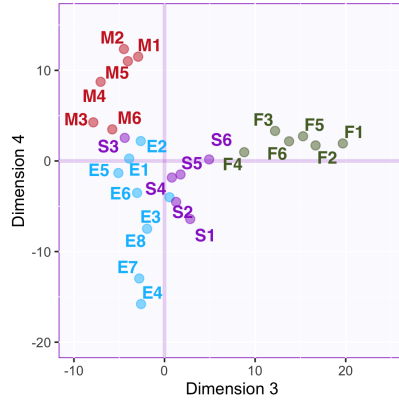
(a)



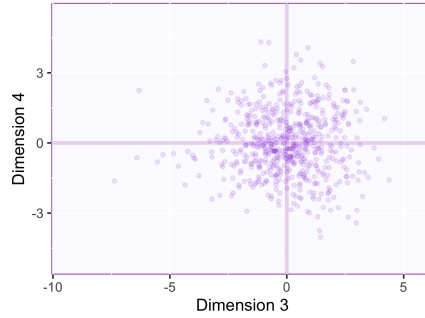
(b)



(c)

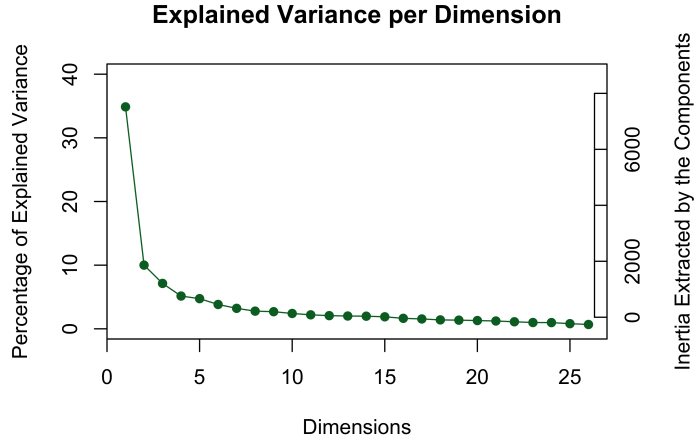


(d)

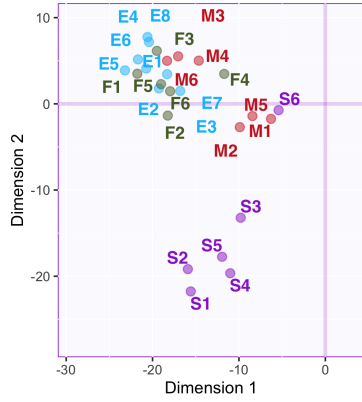


(e)

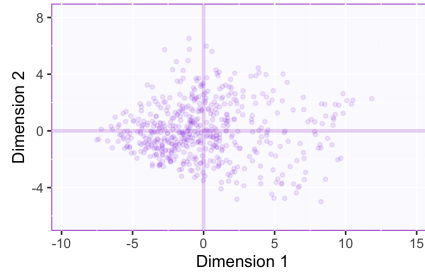
Figure 2: Results of a principal components analysis on the Survey of Autobiographical Memory (SAM) in an independent sample (2013 dataset). Panel a shows the scree plot. Panels b and d show item loadings, where each point represents one SAM item, and letters represent the SAM domain (E = episodic, S = spatial, F = future, M = semantic; see appendix for full item corresponding to each label). Panels c and e show subject loadings, where each point represents one subject.



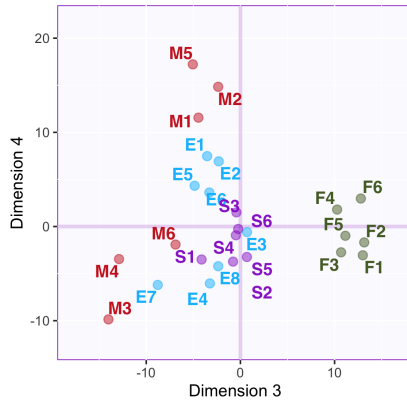
(a)



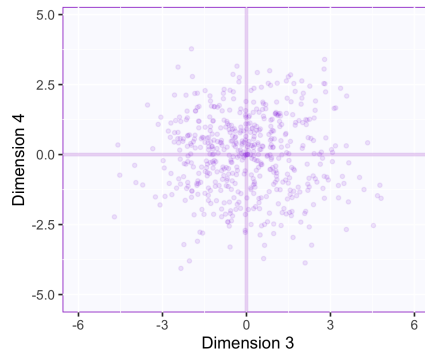
(b)



(c)



(d)



(e)

Figure 3: Results of a principal components analysis on the Survey of Autobiographical Memory (SAM) in an independent sample (2019 dataset). Panel a shows the scree plot. Panels b and d show item loadings, where each point represents one SAM item, and letters represent the SAM domain (E = episodic, S = spatial, F = future, M = semantic; see appendix for full item corresponding to each label). Panels c and e show subject loadings, where each point represents one subject.

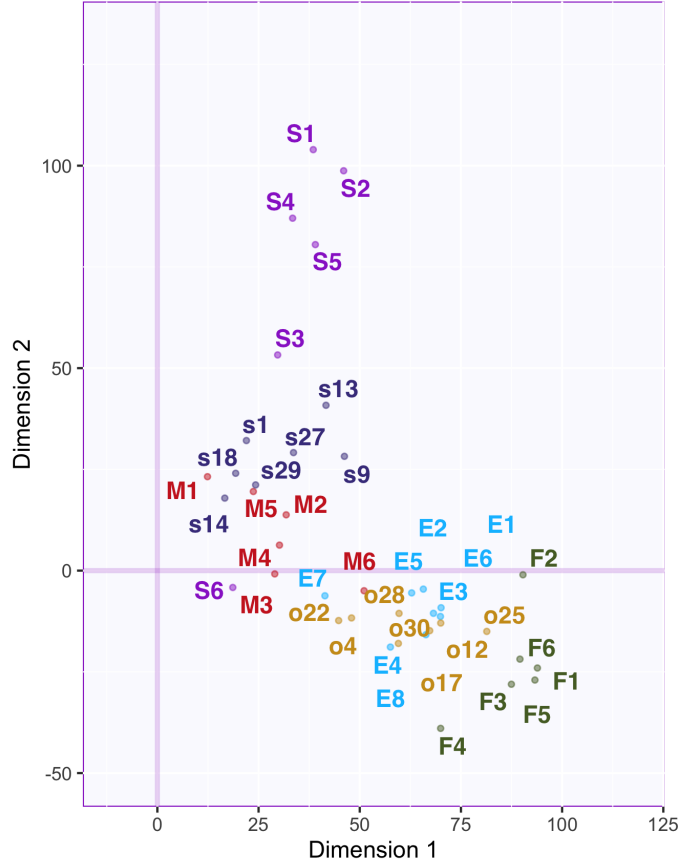


Figure 4: Projection of the Object-Spatial Imagery Questionnaire (OSIQ) items into the factor space defined by a principal components analysis on the Survey of Autobiographical Memory (SAM). Each point represents one SAM or OSIQ item. Uppercase letters represent SAM domains: E = episodic, S = spatial, F = future, M = semantic. Lowercase letters represent OSIQ domains: o = object, s = spatial. See appendix for full item corresponding to each label.

2 Relationship between SAM and OSIQ

2.1 Additional visualizations

In order to visualize the multivariate relationship between the SAM and OSIQ, we examined where the OSIQ items fell in the factor space of the SAM. This visualization method holds constant the dimensions resulting from the PCA on the SAM, and projects the OSIQ items into this space without having those items influence the analysis itself. The resulting figure (Figure 4) shows that object imagery items largely overlap with SAM-episodic items, whereas spatial imagery items overlap somewhat with SAM-semantic items but tend towards SAM-spatial items.

In the main text, we conducted a partial least squares correlation (PLSC) on the SAM and OSIQ. Because this is a correlation-based method, we also examined the matrix of Pearson correlation coefficients between each of the items on both questionnaires in order to get a general sense of the existing relationships in the data (Figure 5).

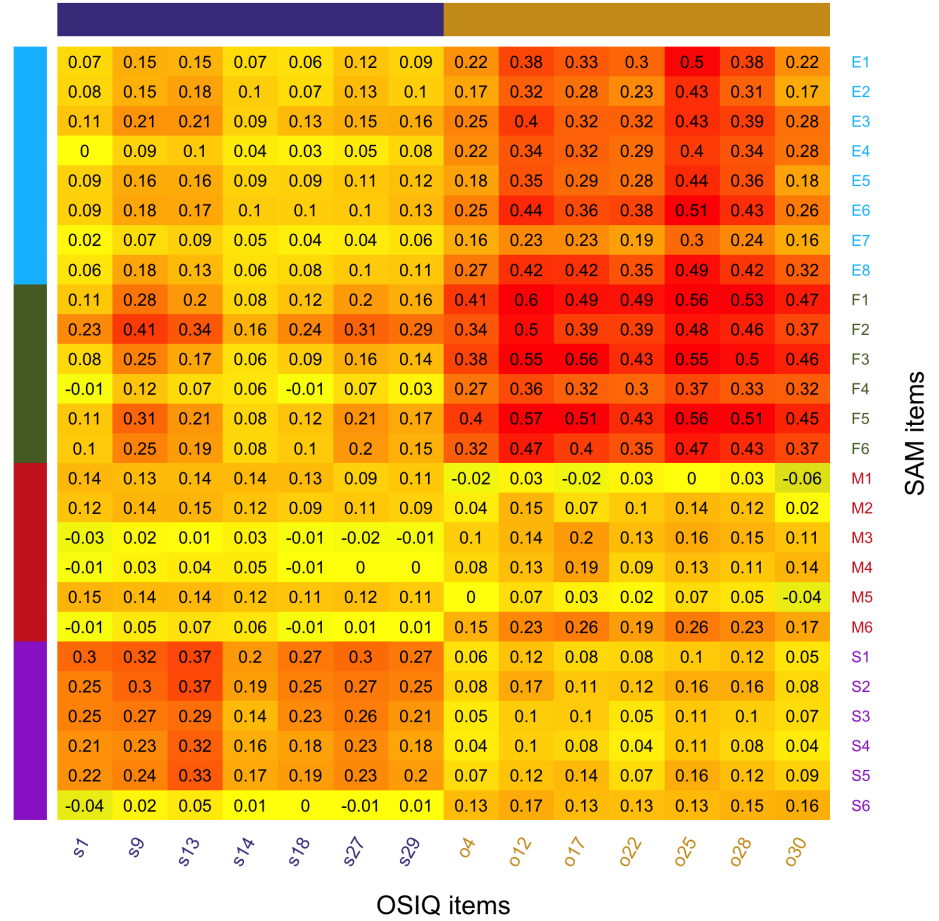
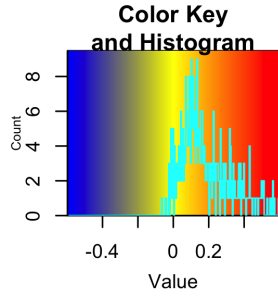


Figure 5: Correlation heat map on items from the Survey of Autobiographical Memory (SAM) and Object-Spatial Imagery Questionnaire (OSIQ). Each cell is labelled with the Pearson correlation coefficient. Warmer cell colours reflect more positive correlations, and cooler cell colours reflect more negative correlations (see key at top left). Coloured bars on the top and left correspond to SAM and OSIQ domains. Uppercase letters represent SAM domains: E = episodic, S = spatial, F = future, M = semantic. Lowercase letters represent OSIQ domains: o = object, s = spatial. See appendix for full item corresponding to each label.

2.2 Replication in an independent sample (2019 dataset)

Again, the large sample reported on in the main text could be biased due to the way many participants were recruited (via media exposure and an interest in their own memory abilities). We replicated the key analyses reported in the main text and above relating the SAM to the OSIQ in a separate dataset (used to pre-screen participants for Armson et al., 2019).

2.2.1 Univariate analysis (linear regression)

We first used linear regression to determine the differential contributions of OSIQ object versus spatial scores to SAM scores in each of the four domains in this separate dataset. The results from the four regressions are shown in Table 1. We looked to the magnitude of partial η^2 to interpret the size of each effect. The key result we replicated was that object and spatial imagery did not contribute equally to each of the four memory domains (Figure 6): for episodic memory and future thinking, object imagery had a substantially larger effect size than spatial imagery in predicting memory scores. The reverse was true for spatial navigation abilities: spatial imagery had a larger effect than object imagery.

Table 1

Regression results for models of each Survey of Autobiographical Memory (SAM) domain score (rows) predicted by object and spatial imagery scores

| | Object | | | | | | Spatial | | | | |
|----------|-------------|---------|------|-------|-------|----------|---------|------|-------|-------|----------|
| | Model R^2 | β | SE | t | p | η^2 | β | SE | t | p | η^2 |
| Episodic | .43 | 0.66 | 0.04 | 18.38 | <.001 | 0.39 | 0.09 | 0.04 | 2.22 | .03 | 0.01 |
| Spatial | .26 | 0.17 | 0.04 | 4.49 | <.001 | 0.04 | 0.46 | 0.04 | 10.87 | <.001 | 0.18 |
| Future | .50 | 0.71 | 0.03 | 21.00 | <.001 | 0.45 | 0.10 | 0.04 | 2.72 | .007 | 0.01 |
| Semantic | .20 | 0.35 | 0.03 | 10.26 | <.001 | 0.17 | 0.07 | 0.04 | 1.83 | .07 | 0.01 |

2.2.2 Multivariate analysis: PLSC

We then used a partial least squares correlation (PLSC) to assess the relationship between the SAM and OSIQ domains with a single multivariate model (Figure 7). The key result we replicated was that spatial navigation abilities separated from other autobiographical memory abilities on the second dimension, but clustered together with spatial imagery items. Object imagery items tended to cluster with episodic, future, and semantic memory on the vertical dimension. Dimension 1 largely reflected object imagery items and episodic autobiographical memory and future thinking items and explained 93.35% of the variance. Dimension 2 largely reflected spatial imagery items and spatial navigation items and explained 5.58% of the variance..

3 Gender differences

We conducted exploratory analyses to assess whether the factor structure of the SAM differed between genders, and whether gender influenced the relationship between the SAM and OSIQ. Given that only a small proportion of our sample indicated “Prefer not to answer” with respect to gender ($n = 82$), and because we had no insight into the reason for them choosing this option, we excluded these individuals from this section of the analysis and only included individuals who reported being either female or male.

Figure 8 shows the results of PCA in each gender. Visual inspection indicates that they are not appreciably different from each nor from the combined PCA reported in the main text, suggesting that there are no large gender differences in the relationship between self-reported episodic memory and spatial navigation abilities.

We also included gender as a covariate in the regressions of the OSIQ on each of the SAM domains. Results with Type III Sums of Squares from these four models are shown in Tables 2 (main effects) and 3 (interactions). Compared to OSIQ scores, gender did not contribute greatly to SAM scores (as assessed

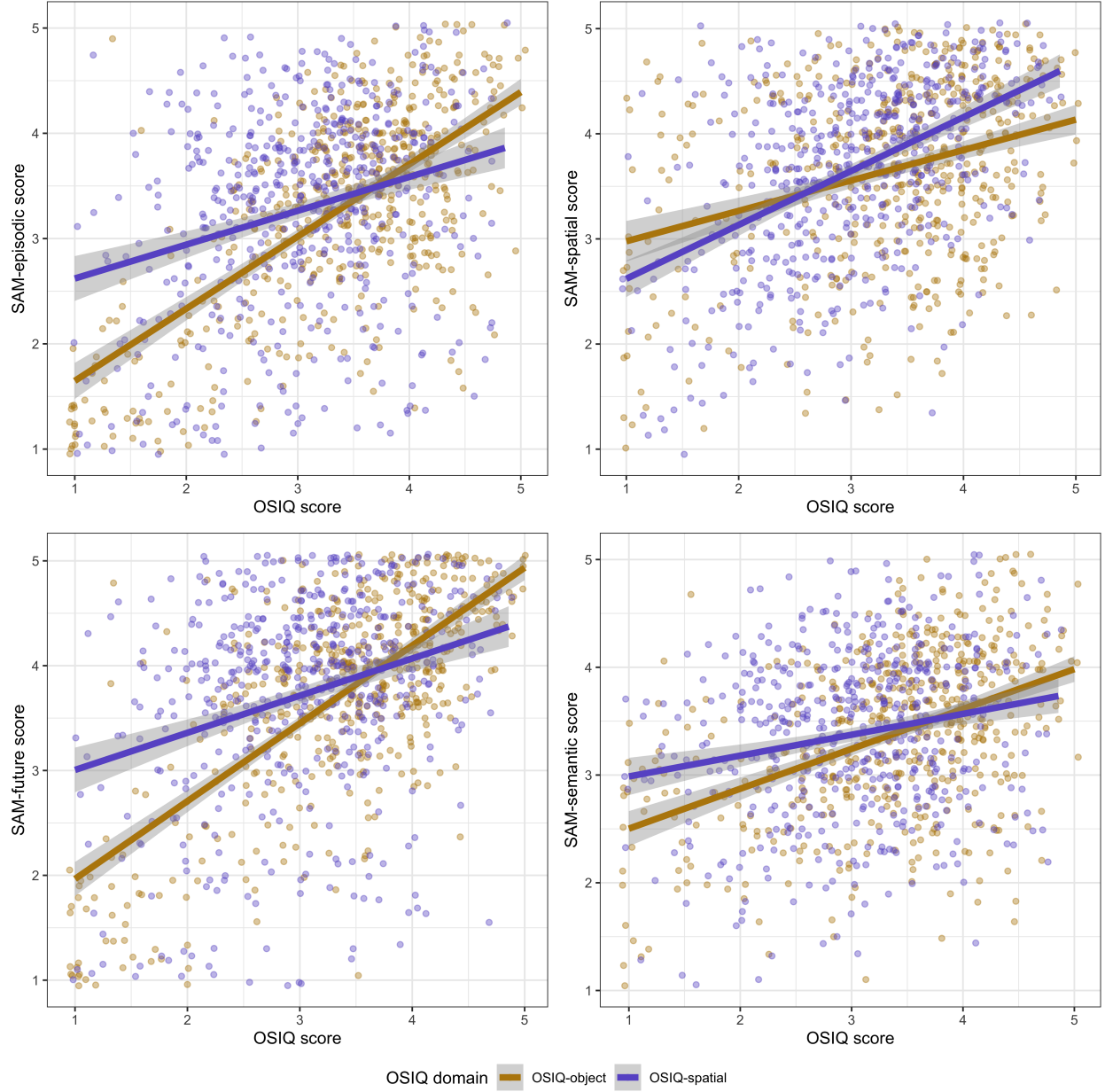


Figure 6: Scatterplots of regression analyses predicting domain scores on the Survey of Autobiographical Memory (SAM) with object and spatial imagery scores on the Object-Spatial Imagery Questionnaire (OSIQ) in an independent sample (2019 dataset). Points have been jittered to allow for better visualization of the spread of data.

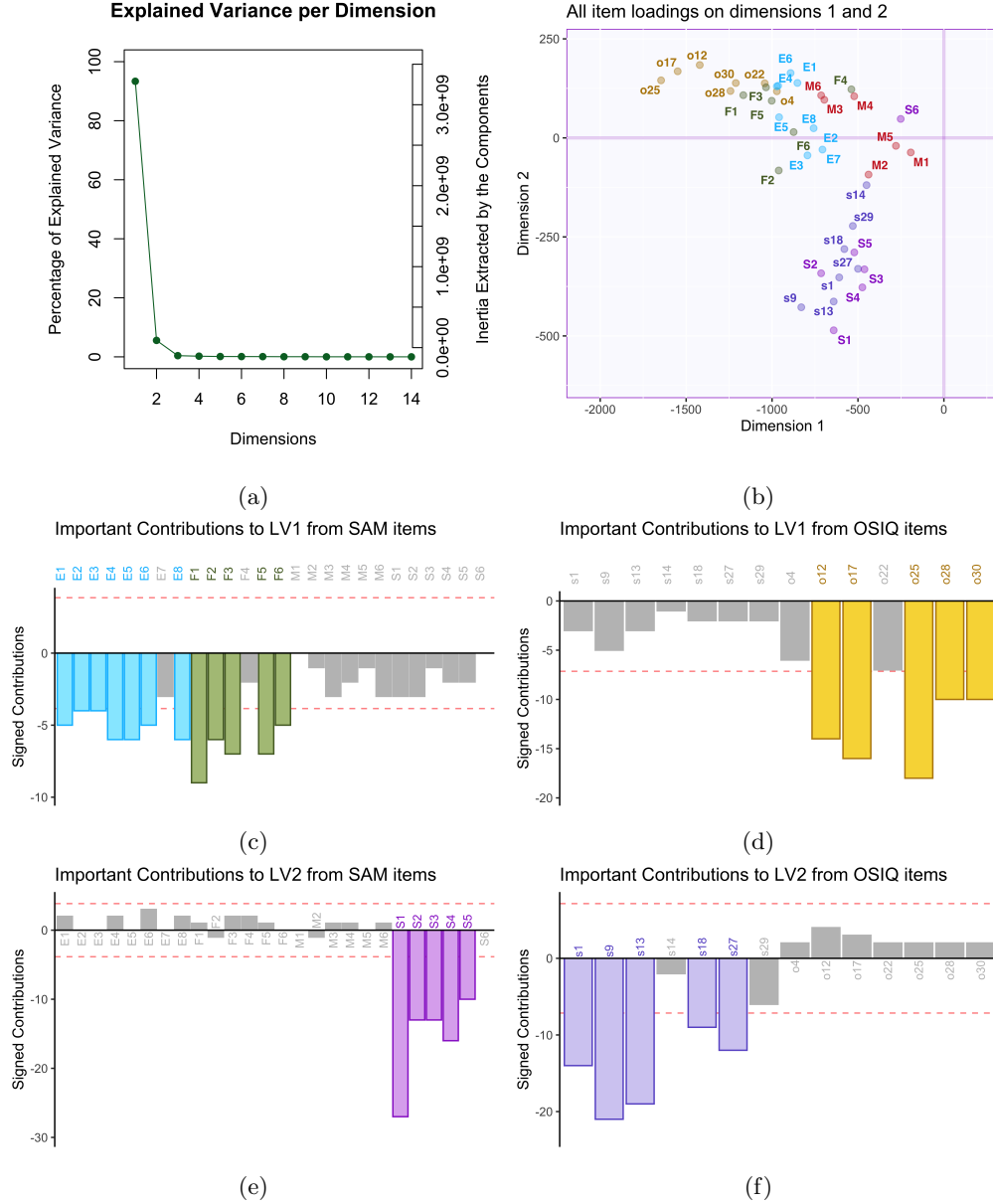


Figure 7: Results of a partial least squares correlation analysis on the Survey of Autobiographical Memory (SAM) and Object-Spatial Imagery Questionnaire (OSIQ) in an independent sample (2019 dataset). Panel **a** shows the scree plot. Panel **b** shows loadings of the SAM and OSIQ items in the partial least squares analysis. The horizontal axis represents the first dimension, and reflects an overall high memory and imagery ability across domains. The vertical axis represents the second dimension, and separates spatial navigation and spatial imagery abilities from episodic, future, and semantic memory, as well as object imagery. Each point represents one SAM or OSIQ item. Panels **c**, **d**, **e**, and **f** show contributions of each SAM and OSIQ item to each of the first two latent variables. The dotted line in each plot indicates the average contribution; coloured bars indicate contributions of items that exceed this average in magnitude. Each bar represents one SAM or OSIQ item. In all panels, uppercase letters represent SAM domains: E = episodic, S = spatial, F = future, M = semantic. Lowercase letters represent OSIQ domains: o = object, s = spatial. See appendix for full item corresponding to each label.

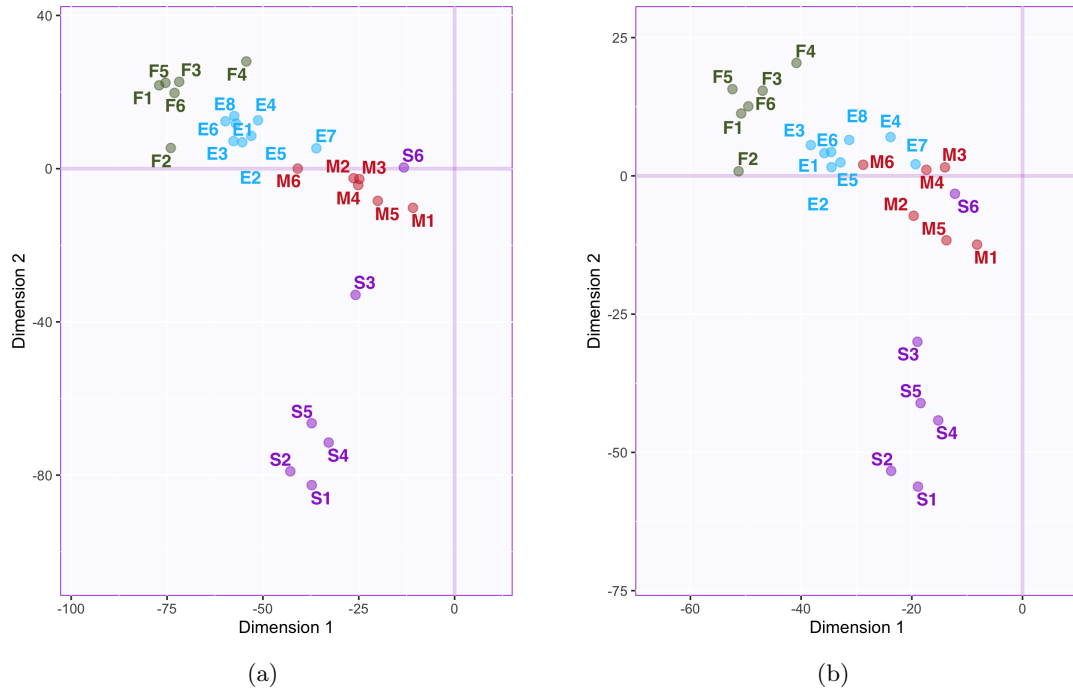


Figure 8: Item loadings from principal components analyses on the Survey of Autobiographical Memory (SAM) split by gender. Panel a shows females and panel b shows males. Each point represents one SAM item, and letters represent the SAM domain: E = episodic, S = spatial, F = future, M = semantic. See appendix for full item corresponding to each label).

by effect size), nor did the inclusion of gender change the the interpretation of the relationship between the SAM and OSIQ domains as reported in the main text.

As noted in the main text, our sample size is very large and will thus lead to very small p-values regardless of the practical significance of any observed effects, and the effect sizes here are very small even for statistically significant effects. Furthermore, demand characteristics of our survey could potentially lead to gender differences in self-reported abilities. More rigorous research is required to draw conclusions about gender differences (or lack thereof) in autobiographical memory, spatial navigation, and mental imagery.

Table 2

Main effects of object and spatial imagery and gender on each Survey of Autobiographical Memory (SAM) domain

| | Object | | | | | Spatial | | | | | Gender | | | |
|----------|-------------|------|---------|-------|----------|---------|--------|-------|----------|------|--------|-------|----------|--|
| | Model R^2 | df | F | p | η^2 | df | F | p | η^2 | df | F | p | η^2 | |
| Episodic | .34 | 1 | 2277.69 | <.001 | 0.24 | 1 | 48.38 | <.001 | 0.007 | 1 | 5.86 | .02 | 0.0008 | |
| Spatial | .21 | 1 | 128.79 | <.001 | 0.02 | 1 | 765.93 | <.001 | 0.09 | 1 | 49.71 | <.001 | 0.007 | |
| Future | .53 | 1 | 4634.71 | <.001 | 0.39 | 1 | 94.29 | <.001 | 0.01 | 1 | 10.28 | 0.001 | 0.002 | |
| Semantic | .06 | 1 | 219.04 | <.001 | 0.03 | 1 | 35.18 | <.001 | 0.005 | 1 | 3.33 | .07 | 0.004 | |

Table 3

Interactions between gender and object and spatial imagery on each Survey of Autobiographical Memory (SAM) domain

| | Gender \times Object | | | | | Gender \times Spatial | | | |
|----------|------------------------|------|-------|-------|----------|-------------------------|------|-----|----------|
| | Model R^2 | df | F | p | η^2 | df | F | p | η^2 |
| Episodic | .34 | 1 | 5.09 | .02 | 0.0007 | 1 | 4.30 | .04 | 0.0006 |
| Spatial | .21 | 1 | 14.01 | <.001 | 0.002 | 1 | 1.72 | .19 | 0.0002 |
| Future | .53 | 1 | 0.08 | 0.78 | <.0001 | 1 | 2.90 | .09 | 0.0005 |
| Semantic | .06 | 1 | 2.33 | 0.13 | 0.0003 | 1 | 0.12 | .72 | <.0001 |

Table 4

*Regression results for models of each Survey of Autobiographical Memory (SAM) domain score (rows)
predicted by object and spatial imagery scores and halo scores*

| | | Object | | | | | Spatial | | | | | Halo | | | | |
|----------|-------------|---------|------|-------|-------|----------|---------|------|-------|-------|----------|---------|------|-------|-------|----------|
| | Model R^2 | β | SE | t | p | η^2 | β | SE | t | p | η^2 | β | SE | t | p | η^2 |
| Episodic | .34 | 0.52 | 0.01 | 56.99 | <.001 | 0.30 | 0.05 | 0.01 | 4.91 | <.001 | 0.003 | 0.05 | 0.01 | 7.05 | <.001 | 0.01 |
| Spatial | .22 | 0.08 | 0.01 | 7.92 | <.001 | 0.01 | 0.38 | 0.01 | 35.56 | <.001 | 0.14 | 0.10 | 0.01 | 13.93 | <.001 | 0.03 |
| Future | .53 | 0.84 | 0.01 | 83.94 | <.001 | 0.48 | 0.12 | 0.01 | 11.77 | <.001 | 0.02 | 0.02 | 0.01 | 3.10 | .002 | 0.001 |
| Semantic | .07 | 0.15 | 0.01 | 15.57 | <.001 | 0.03 | 0.08 | 0.01 | 7.48 | <.001 | 0.01 | 0.07 | 0.01 | 9.79 | <.001 | 0.01 |

4 Personality effects

It is possible that the dispositional tendency for individuals to attribute socially desirable characteristics to themselves (halo effect; Anusic, Schimmack, Pinkus, & Lockwood, 2009) may have influenced our results. Though it is unlikely that such an effect would lead to the dissociation between episodic and spatial memory that we observed, we investigated this possibility by calculating a “halo” score using the Big Five Inventory (BFI; John, Donahue, & Kentle, 1991; John, Naumann, & Soto, 2008): we took the average of each individual’s standardized scores on openness, extraversion, conscientiousness, and agreeableness, and then subtracted the standardized score on neuroticism. We then examined the relationship of this halo score to each of our measures.

4.1 Regressions of OSIQ on SAM

We first included halo scores as a covariate in the regressions of the OSIQ on each of the SAM domains. Table 4 contains the full regression results. Compared to OSIQ scores, halo scores did not contribute greatly to SAM scores (as assessed by effect size), nor did the inclusion of halo scores change the interpretation of the relationship between the SAM and OSIQ domains as reported in the main text.

4.2 BFI and SAM

We next assessed whether personality traits more broadly related to the SAM in a manner that could explain the observed relationship between the SAM and OSIQ. To this end, we conducted multivariate analyses on the SAM and BFI in the same manner that we investigated the SAM and OSIQ in the main text.

First, we visualized the five BFI domains—extraversion, neuroticism, openness, agreeableness, and conscientiousness—in terms of the SAM dimensions by projecting the BFI items into the factor space defined by the PCA on the SAM. Figure 9 shows that the BFI items cluster near the origin of this factor space, suggesting that these items do not map onto the dimensional structure of the SAM in any meaningful way.

To corroborate this interpretation, we conducted a partial least squares correlation (PLSC) on the SAM and BFI, and plot the first two dimensions resulting from this analysis in Figure 10. In this shared factor space, there appears to be little meaningful dissociation between the domains on either questionnaire, apart from neuroticism loading on the opposite end of the first horizontal dimension (which is to be expected, given that it is the only negatively valenced domain).

In sum, personality traits do not seem to explain the observed dissociation between spatial and episodic memory, nor do they contribute to the relationship between imagery and memory.

5 Depression effects

Finally, we wanted to ensure that depressive symptoms were not driving or biasing our interpretations, given depression’s influence on cognition (Gotlib & Joormann, 2010). Although we excluded participants with severe depression, as measured by the depression module of the Patient Health Questionnaire (PHQ9; Kroenke, Spitzer, & Williams, 2001), it is possible that subclinical depressive symptoms influenced our results. As such, we conducted multivariate analyses of the PHQ9 and SAM.

First, we projected the PHQ9 items into the factor space defined by the PCA on the SAM. Figure 11 indicates that the PHQ items largely fall near the origin, indicating that they do not map onto the dimensional structure of the SAM in a meaningful way.

To corroborate this interpretation, we conducted a partial least squares correlation (PLSC) on the SAM and PHQ, and plot the first two dimensions resulting from this analysis in Figure 12. The first, horizontal dimension appears to separate SAM items from PHQ items, indicating that strong self-reported memory abilities are negatively associated with high depression scores. Importantly, however, there is little dissociation amongst the SAM domains, and certainly no corresponding dissociation in the PHQ items.

In sum, depression does not seem to explain the observed dissociation between spatial and episodic memory.

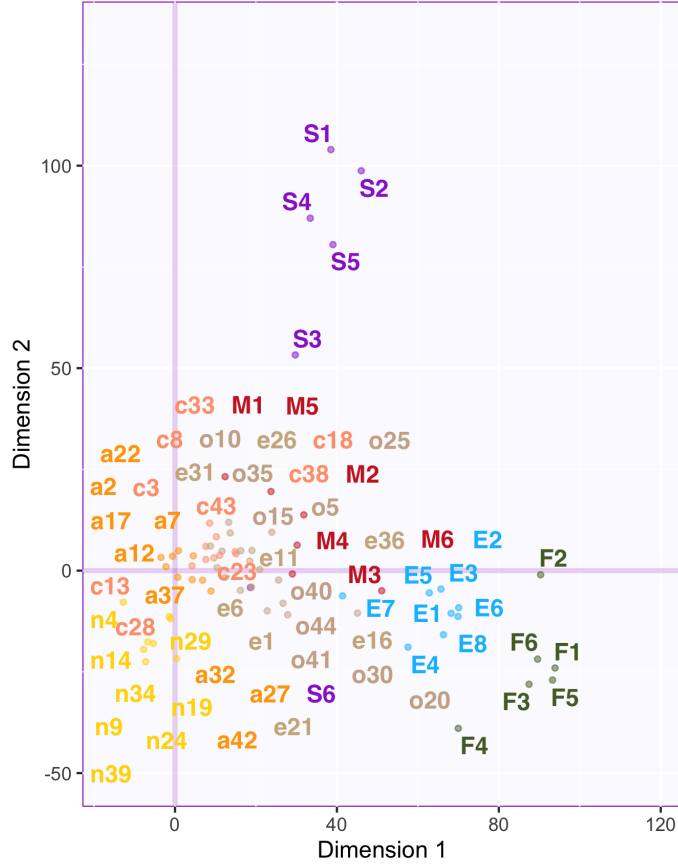


Figure 9: Projection of the Big Five Inventory (BFI) items into the factor space defined by a principal components analysis on the Survey of Autobiographical Memory (SAM). Each point represents one SAM or BFI item. Uppercase letters represent SAM domains: E = episodic, S = spatial, F = future, M = semantic. Lowercase letters represent BFI domains: a = agreeableness, c = conscientiousness, e = extraversion, n = neuroticism, o = openness. See appendix for full item corresponding to each label for the SAM. Item numbers for the BFI correspond to the published version of the questionnaire.

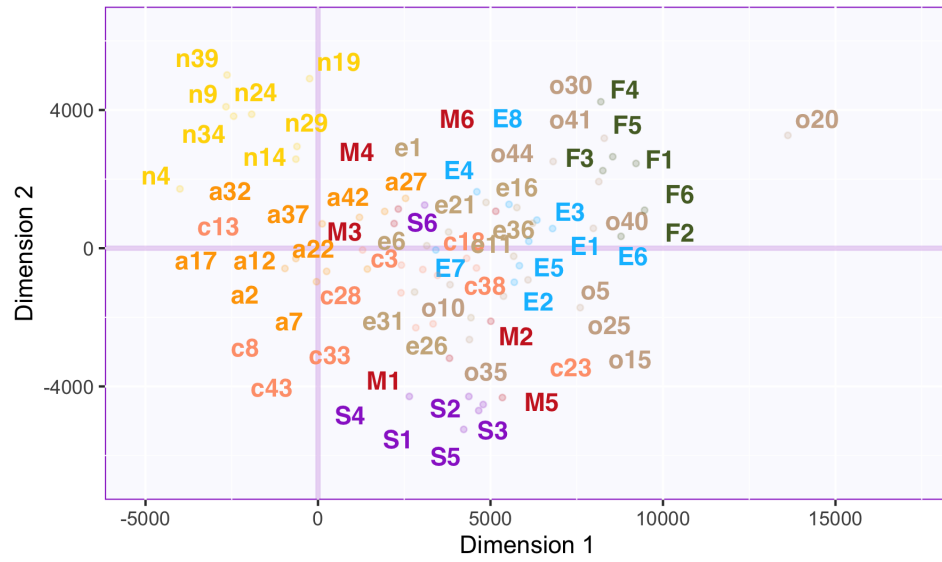


Figure 10: Results of a partial least squares correlation analysis on the Survey of Autobiographical Memory (SAM) and Big Five Inventory (BFI). Each point represents one SAM or BFI item. Uppercase letters represent SAM domains: E = episodic, S = spatial, F = future, M = semantic. Lowercase letters represent BFI domains: a = agreeableness, c = conscientiousness, e = extraversion, n = neuroticism, o = openness. See appendix for full item corresponding to each label for the SAM. Item numbers for the BFI correspond to the published version of the questionnaire.

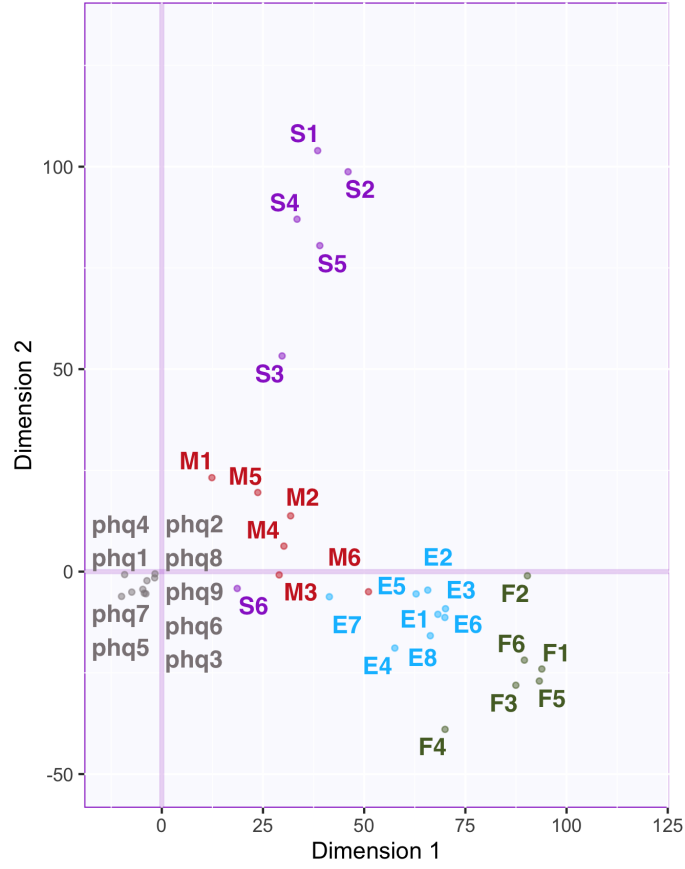


Figure 11: Projection of the Patient Health Questionnaire (PHQ9) items into the factor space defined by a principal components analysis on the Survey of Autobiographical Memory (SAM). Each point represents one SAM or PHQ item. Uppercase letters represent SAM domains: E = episodic, S = spatial, F = future, M = semantic. See appendix for full item corresponding to each label for the SAM. Item numbers for the PHQ9 correspond to the published version of the questionnaire.

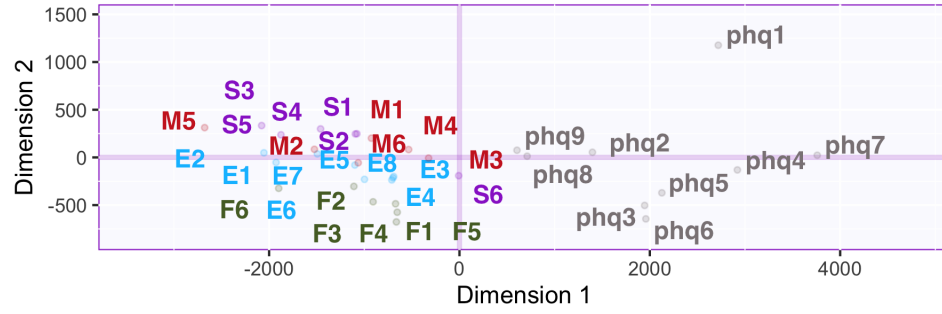


Figure 12: Results of a partial least squares correlation analysis on the Survey of Autobiographical Memory (SAM) and Patient Health Questionnaire (PHQ9). Each point represents one SAM or PHQ item. Uppercase letters represent SAM domains: E = episodic, S = spatial, F = future, M = semantic. See appendix for full item corresponding to each label for the SAM. Item numbers for the PHQ9 correspond to the published version of the questionnaire.

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Appendices

A Questionnaire items

Here we include the full list of items used from the Survey of Autobiographical Memory (SAM) and Object–Spatial Imagery Questionnaire (OSIQ), along with the corresponding label for each item used in figures both here and in the main text.

Table 5

SAM items and corresponding labels in figures

| Item label in figures | Domain | Item |
|--------------------------|----------|---|
| E1 | Episodic | Specific events are difficult for me to recall (R) |
| E2 | Episodic | When I remember events, I have a hard time determining the order of details in the event (R) |
| E3 | Episodic | When I remember events, in general I can recall objects that were in the environment |
| E4 | Episodic | When I remember events, in general I can recall what I was wearing |
| E5 | Episodic | I am highly confident in my ability to remember past events |
| E6 | Episodic | When I remember events, I remember a lot of details |
| E7 | Episodic | When I remember events, in general I can recall which day of the week it was |
| E8 | Episodic | When I remember events, in general I can recall people, what they looked like, or what they were wearing |
| M1 | Semantic | I can learn and repeat facts easily, even if I don't remember where I learned them |
| M2 | Semantic | After I have read a novel or newspaper, I forget the facts after a few days (R) |
| M3 | Semantic | After I have met someone once, I easily remember his or her name |
| M4 | Semantic | I can easily remember the names of famous people (sports figures, politicians, celebrities) |
| M5 | Semantic | I have a hard time remembering information I have learned at school or work (R) |
| M6 | Semantic | I am very good at remembering information about people that I know (e.g., the names of a co-worker's children, their personalities, places friends have visited etc.) |
| S1 | Spatial | In general, my ability to navigate is better than most of my family/friends |
| S2 | Spatial | After I have visited an area, it is easy for me to find my way around the second time I visit |
| S3 | Spatial | I have a hard time judging the distance (e.g., in meters or kilometers) between familiar landmarks (R) |
| S4 | Spatial | I get lost easily, even in familiar areas (R) |
| S5 | Spatial | If my route to work or school was blocked, I could easily find the next fastest way to get there |
| S6 | Spatial | I use specific landmarks for navigating |
| F1 | Future | When I imagine an event in the future, the event generates vivid mental images that are specific in time and place |
| F2 | Future | When I imagine an event in the future, I can picture the spatial layout |
| F3 | Future | When I imagine an event in the future, I can picture people and what they look like |
| F4 | Future | When I imagine an event in the future, I can imagine how I may feel |
| F5 | Future | When I imagine an event in the future, I can picture images (e.g., people, objects, etc.) |
| F6 | Future | I have a difficult time imagining specific events in the future (R) |

Note. (R) indicates a reverse-coded item.

Table 6

OSIQ items and corresponding labels in figures

| Item label in figures | Domain | Item |
|--------------------------|---------|---|
| o4 | Object | My images are very colourful and bright. |
| o12 | Object | My images are very vivid and photographic. |
| o17 | Object | When I imagine the face of a friend, I have a perfectly clear and bright image. |
| o22 | Object | Sometimes my images are so vivid and persistent that it is difficult to ignore them. |
| o25 | Object | I can close my eyes and easily picture a scene that I have experienced. |
| o28 | Object | My visual images are in my head all the time. They are just right there. |
| o30 | Object | When I hear a radio announcer or a DJ I've never actually seen, I usually find myself picturing what he or she might look like. |
| s1 | Spatial | I was very good in 3-D geometry as a student. |
| s9 | Spatial | I can easily imagine and mentally rotate 3-dimensional geometric figures. |
| s13 | Spatial | I can easily sketch a blueprint for a building that I am familiar with. |
| s14 | Spatial | I am a good Tetris player. |
| s18 | Spatial | I have excellent abilities in technical graphics. |
| s27 | Spatial | I find it difficult to imagine how a 3-dimensional geometric figure would exactly look like when rotated. (R) |
| s29 | Spatial | My graphic abilities would make a career in architecture relatively easy for me. |

Note. (R) indicates a reverse-coded item.