On the relationship between autobiographical episodic memory and spatial navigation

Carina L. Fan^{1,2}, Hervé Abdi³, and Brian Levine^{1,2}

¹Department of Psychology, University of Toronto

²Rotman Research Institute, Baycrest Health Sciences

³School of Behavioral and Brain Sciences, The University of Texas at Dallas

Corresponding authors:

Carina L. Fan

carina.fan@mail.utoronto.ca

(416) 785-2500 ex. 2826

Brian Levine

blevine@research.baycrest.org

(416) 785-2500 ex. 3593

Abstract

Influential research has focused on identifying the common neural and behavioural substrates underlying episodic memory (the recall 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 ($n = 7487$), 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 episodic autobiographical memory and spatial navigation correspond to distinct mental processes.

Keywords: autobiographical memory, episodic memory, navigation, visual imagery, individual differences

An influential body of animal and human research has investigated the overlapping neural and behavioural substrates of episodic memory (i.e., the recall of specific details from past experiences, 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., 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 an animal revisits a particular spatial location, and researchers have sought to extend these findings to primates (Rolls & Wirth, 2018) and humans (Ekstrom & Ranganath, 2018). Taken together, this body of work suggests 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. An implication of this 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; Palombo, Williams, Abdi, & Levine, 2013).

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 memory (memory for specific episodes from one's life), 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 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.

We examined how different forms of visual imagery—particularly object imagery (imagery for specific object features such as shape and colour) and spatial imagery (imagery for spatial relationships and transformations; Blajenkova, Kozhevnikov, & Motes, 2006;

Kozhevnikov, Kosslyn, & Shephard, 2005)—contribute differentially to episodic memory and spatial navigation abilities. Strong object imagers 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, strong spatial imagers 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. To test these predictions, we first assessed the relationship between spatial navigation and episodic memory abilities in healthy adults, and then we examined how object and spatial imagery corresponded to these abilities.

Methods

Participants

Participants were recruited online, and many came across our laboratory's research on severely deficient autobiographical memory (SDAM) through media exposure and an interest in their own memory abilities. 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 a key finding from this sample in a separate, previously collected dataset (see supplemental materials). 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 in possible.

Exclusions. 18,189 survey responses were 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 minutes, $n = 992$). Participants with fewer than 9 or greater than 26 years of education were excluded ($n = 656$), as well as participants under the age of 18 ($n = 3$).

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 they 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 ($n = 4055$).

After these preliminary cleaning steps, any participants who endorsed a history of major neurological conditions were excluded from the dataset (head injury with loss of consciousness >15 minutes, $n = 465$; 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 it 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 at <http://doi.org/10.17605/OSF.IO/JD4Q8>. Only the measures of interest to the current study will be described in more depth here.

To measure episodic autobiographical memory and spatial navigation abilities, we used the Survey of Autobiographical Memory (SAM; Palombo, Williams, Abdi, & Levine, 2013). The SAM is a validated 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 are 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 from 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 Object-Spatial Imagery Questionnaire (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. As such, we used a reduced set of items (7 object and 7 spatial), each of which load cleanly on only one imagery dimension (the specific selection criteria for these items is outside the scope of the current article and will be reported in a future publication, but see supplemental materials for the items used in this study). Items are 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 supplemental materials.

Statistical Analysis

Data were analyzed using *R* version 3.6.1. Principal components analysis was run using the *ExPosition* package (version 2.8.23; Beaton, Fatt, & Abdi, 2014), partial least squares correlation was run using the *TInPosition* package (version 0.13.6.1; Beaton et al., 2014), and effect sizes for linear models were obtained using the *lmsupport* package (version 2.9.13; Curtin, 2018). 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, by conducting a principal components analysis (PCA) on the 26 items of the SAM. PCA is a multivariate technique that represents a set of variables (in this case, questionnaire items) as a new set of orthogonal variables called principal components, or dimensions (Abdi & Williams, 2010). We used multiple correspondence analysis in the original report (Palombo et al., 2013) to better characterize the qualitative nature of Likert ratings (i.e., the difference between 1 and 2 on a 5-point scale is not necessarily identical to the difference between 2 and 3), but here we use PCA because it provides comparable results and is more intuitive to visualize and understand. We also conducted a PCA on the dataset reported on by Palombo et al. (2013) in order to validate this approach (see supplemental materials), and we found that this analysis replicated both the main conclusions from the multiple correspondence analysis in the 2013 sample, as well as the forthcoming conclusions from the present sample. 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.

The results of the PCA replicated the original validation of the SAM (Figure 1, bottom left and right): the first dimension, explaining 27.18% of the variance, reflected overall high memory abilities across the domains. The second dimension, explaining 12.94% of the variance, separated spatial items from items in the other three domains. We previously demonstrated that the episodic and semantic items from Dimension 1 can be dissociated as they differentially relate to sex, mood, and memory performance (Palombo et al., 2013; see also Sheldon, Farb, Palombo, & Levine, 2016). We therefore treated these sets of items as distinct in subsequent analyses. The

scree plot (Figure 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 supplemental materials). As reported in the supplemental materials, 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 an independent sample of participants. This replication was important, 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 an independent dataset comprised 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 on SAM scores in each of the four domains. 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 (Figure 2): 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. There was no notable difference between object and spatial imagery in predicting semantic memory abilities. These findings were unaffected by the inclusion of a measure of social desirability derived from the BFI (see supplemental materials).

While giving some compelling indications of the relationship between episodic and spatial memory and imagery, the above analyses are limited in that: a) domain scores are

averaged across items and do not tell us about the relations between specific items, and b) 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. One multivariate approach is to project the OSIQ items into the factor space of SAM (see supplemental materials); however, this is simply a visualization technique and does not simultaneously analyze items from both questionnaires. To address these limitations, we conducted a partial least squares (PLS) correlation 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 (Figure 3, right) indicated that, as predicted, spatial navigation abilities separated from other autobiographical memory abilities on the second dimension, and together with spatial imagery items. Object imagery items tended to cluster with episodic, future, 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 (supplemental materials).

The scree plot (Figure 3, left) indicated that the first two dimensions or latent variables explained most of the variance; as such, we examined the contributions of each questionnaire item to the first two latent variables (Figure 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 one semantic memory item 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 and the contributions of these two other memory items—a configuration providing evidence for a clear dissociation between episodic memory, future thinking, and object imagery on one hand, and spatial imagery and spatial navigation abilities on the other.

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 theoretical significance or importance.

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 on cognitive and neural levels, between the two functions (e.g., Buzsáki & Moser, 2013). There has been relatively little research in humans relating these capacities to other cognitive traits within an individual differences framework. We found that episodic autobiographical memory and spatial navigation abilities are distinct. 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, Hoyle, & Rubin, 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 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 patient work has corroborated this view, showing 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 findings are also consistent with relational theory, which posits that the hippocampus forms relational representations across modalities (Konkel & Cohen, 2009).

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 low-object imagers—individuals with 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; but 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. Our present findings support this contention: vivid object imagery was associated with rich self-reported episodic autobiographical memory, while spatial imagery tapped into the relatively independent construct of navigational ability. They 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 (Keogh & Pearson, 2018).

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, although our navigation measure corresponds to performance-based measures (Selarka et al., 2019). Moreover, our findings are in accord 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 (supplemental materials). 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, while 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.

In conclusion, we show here 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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Author Contributions

BL and HA developed the study concept and design. CLF performed the data analysis and interpretation under the supervision of BL and HA. CLF drafted the manuscript, and BL and HA provided critical revisions. All authors approved the final version of the manuscript for submission.

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 <http://doi.org/10.17605/OSF.IO/JD4Q8>.

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Tables

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	0.03	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	.01
Semantic	.06	0.16	0.01	16.00	< .001	.03	0.09	0.01	9.31	< .001	.01

Figures

Figure 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 supplemental materials for full item corresponding to each label.

Figure 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.

Figure 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 supplemental materials for full item corresponding to each

label.

Figure 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 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.