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Individual differences in visual imagery determine how event information is remembered

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ABSTRACT

Individuals differ in how they mentally imagine past events. When reminiscing about a past experience, some individuals remember the event accompanied by rich visual images, while others will remember it with few of these images. In spite of the implications that these differences in the use of imagery have to the understanding of human memory, few studies have taken them into consideration. We examined how imagery interference affecting event memory retrieval was differently modulated by spatial and object imagery ability. We presented participants with a series of video-clips depicting complex events. Participants subsequently answered true/false questions related to event, spatial, or feature details contained in the videos, while simultaneously viewing stimuli that interfered with visual imagery processes (dynamic visual noise; DVN) or a control grey screen. The impact of DVN on memory accuracy was related to individual differences in spatial imagery ability. Individuals high in spatial imagery were less accurate at recalling details from the videos when simultaneously viewing the DVN stimuli compared to those low in spatial imagery ability. This finding held for questions related to the event and spatial details but not feature details. This study advocates for the inclusion of individual differences when studying memory processes.

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Episodic memory; imagery; individual differences

Individuals differ in the way they remember the past. For some individuals, remembering a dinner party from last month brings to mind rich visual images of that meal, the arrangement of the furniture in the dining room, and the people who attended the party. Constructing this image helps create a rich recollection of that event, fitting with the proposal that visual imagery is a cornerstone of autobiographical memory (Greenberg & Knowlton, 2014; Greenberg & Rubin, 2003; Rubin & Umanath, 2015). In fact, the notion that visual imagery and memory are related dates back to William James (1890). At that time, James's contemporary, Francis Galton, suggested that the relationship between imagery and remembering might not be so straightforward. He noted that "[there are] different degrees of vividness with which different persons have the faculty of recalling familiar scenes under the form of mental pictures" (Galton, 1880, p. 306). This suggests that when some individuals are remembering a dinner party, they do so without forming a rich mental image of the event. If remembering can occur with or without imagery, then what is the nature of the relationship between these two processes? The current study addressed this question.

Autobiographical memory and visual imagery

Visual imagery is considered an essential element of autobiographical memory by assisting in the mental reconstruction of a remembered event (for a recent discussion, please see Rubin & Umanath, 2015). Support for the role of imagery in memory has been reported in several areas of research. For example, early behavioural work found that remembering autobiographical events is often accompanied by associated visual images (Brewer, 1986; Rubin, 2005). Neuropsychological investigations have reported that damage to or deterioration of brain areas that support visual perception (primarily the occipital and parietal cortical regions) leads to a loss of both visual imagery and autobiographical memory (Gardini et al., 2011; Greenberg, Eacott, Brechin, & Rubin, 2005; Ogden, 1993). A recent study reported that individuals with a lifetime reduction of visual imagery were likely to have corresponding deficits in autobiographical remembering (Zeman et al., 2010; Zeman, Dewar, & Della Sala, 2015). In a similar vein, work from our laboratory found that individuals with severely deficient autobiographical memory (SDAM; Palombo et al., 2015) reported having poor visual imagery. Neuroimaging studies have also linked imagery

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processing to memory by illustrating that cortical regions involved in visual perceptual processing figure prominently during autobiographical memory retrieval (Cabeza et al., 2004; Daselaar et al., 2008; Sheldon & Levine, 2013; Svoboda, McKinnon, & Levine, 2006). Moreover, manipulations of mental imagery can improve autobiographical memory recall as well as the ability to generate plausible future events (Ernst et al., 2015; Madore, Gaesser, & Schacter, 2014; Madore & Schacter, 2014). In sum, there are good indicators in the literature that imagery and event memory are related.

Individual differences in imagery and autobiographical memory

Imagery abilities clearly differ across individuals. Despite evidence for a strong role of imagery in remembering, how such individual variations relate to memory performance has not been adequately investigated. Only a handful of studies have examined the impact of individual differences in imagery on the phenomenological characteristics of autobiographical remembering. These reports have indicated that being able to recall rich visual images relates to the clarity of event recall (D'Argembeau & Van der Linden, 2006) as well as the overall ability to recall the past (Brewer & Pani, 1996). A more recent study reported that healthy individuals with significantly reduced visual imagery had a reduced sense of reliving when remembering past events, yet seemingly contrary results were observed when the relation between autobiographical memory recall and mental imagery was probed in a larger group of individuals (Greenberg & Knowlton, 2014).

The scarcity of studies on the impact of imagery differences to memory may be related to how imagery has been conceptualised and measured. Visual imagery is often considered unitary, yet it is clear that there are different forms (Kosslyn, Ganis, & Thompson, 2001; Kosslyn, Thompson, Sukel, & Alpert, 2005; Thompson, Slotnick, Burrage, & Kosslyn, 2009). A particularly useful distinction is between object and spatial imagery. Object imagery refers to the ability to image visual details, features, or objects (e.g., the vibrant red rose in a garden), whereas spatial imagery refers to the ability to imagine spatial relations (e.g., the landscape of the garden itself; (Blajenkova, Kozhevnikov, & Motes, 2006)). It is likely that these distinct forms of imagery have different relationships to autobiographical memory.

We propose that spatial imagery figures prominently in the ability to remember autobiographical events. Spatial relational processes are considered crucial in recalling complex events (Burgess, Becker, King, & O'Keefe, 2001). Accordingly, the neural structures critical for constructing spatial relations are also important for vividly remembering the past and constructing imagined scenarios (scene construction theory; Bird & Burgess, 2008; Hassabis, Kumaran, & Maguire, 2007; Hassabis & Maguire, 2007; Hassabis et al., 2014; Mullally & Maguire, 2013; Whitlock, Sutherland, Witter, Moser, & Moser, 2008). Yet, there is recent evidence in support of a strong relation between object imagery and autobiographical memory (Vannucci, Pelagatti, Chiorri, & Mazzoni, 2016). The main finding from this report was that individuals who were classified as high object imagers were quicker to report autobiographical memories in response to cued word phrases (e.g., relaxing on the beach) and did so with more sensory and perceptual detail than those classified as low object imagers. There are two limitations to this study. First, this study did not directly contrast object and spatial imagers. Additionally, since the participants were asked to select any autobiographical event to remember, it is not clear if the relation between imagery ability and memory is due to differences in the *type* of event selected for remembering or the details with which that memory is recalled. In the current study, we overcome these issues by directly comparing how object and spatial imagery modulate the recovery of details from a controlled complex event.

Current study

The main objective of our study was to compare the relationships between spatial and object imagery and remembering episodic details from a complex event. Our specific research question was concerned with how these forms of imagery impacted the accuracy to which an event memory can be retrieved. We measured spatial and object imagery via a well-validated self-report questionnaire (Blajenkova et al., 2006). To appropriately measure event memory accuracy and to remove the potential confound that imagery differences affect event selection processes, we had participants encode complex autobiographical-like stimuli (i.e., videos) instead of recalling autobiographical events. Memory for details from these videos was tested using an experimental design that incorporated a visual interference technique that selectively manipulated the availability of imagery processing during a recognition memory task. The interference technique (dynamic visual noise, DVN; McConnell & Quinn, 2004; Figure 1) consisted of a moving matrix of black and white squares that passively occupied visuo-perceptual imagery processes. Simultaneously presenting DVN disrupts performance on imagery tasks that require reactivating or constructing perceptual information from memory, such as imagery-guided list learning (Andrade, Kemps, Werniers, May, & Szmalec, 2002; Quinn & McConnell, 2006) and image generation (Dean et al., 2008), but not working memory tasks that require simple maintenance of visual information (e.g., maintaining static spatial patterns in mind for later recognition; Andrade et al., 2002). DVN also seems to affect long-term memory processes. For example, one study found that DVN interfered with the ability to recall concrete but not abstract words from a studied list (Parker & Dagnall, 2009). These findings are in agreement with reports that visually distracting displays at retrieval impair event memory accuracy (Perfect, Andrade, & Syrett, 2012) and that reducing visual interference or increasing the availability of imagery processes (e.g., with instructed

Figure 1. An example of DVN and a control grey screen (25%). Concurrent presentation of DVN selectively disrupts visual imagery (McConnell & Quinn, 2004; for an example: https://www.youtube.com/watch?v=Z9hgbM6jsk8).

eye-closure) leads to better event memory (Parker & Dagnall, 2009; Wagstaff et al., 2004).

This reviewed literature suggests that a stimulus like the DVN affects the use of conscious and constructive imagery processing. If using these processes for remembering is determined by imagery ability, then the negative consequences of DVN on event memory performance will be modulated by how well an individual forms different kinds of images. Based on the particular importance of spatial imagery processes in establishing a framework for remembering events (e.g., Robin, Wynn, & Moscovitch, 2016), the disruptive effects of DVN are expected to be specific to spatial imagery ability. We further propose that spatial imagery processes help form a general schematic or "background" for remembering, which is different than the proposed role of object imagery to memory by Vannucci et al. (2016). To test this hypothesis, we included recognition memory questions that targeted three different aspects of the event memory: broad event details (*The man was happy to see the woman*), spatial location (*The guitar player was on the left*), and specific features of objects (*The sweater was orange*). Although event, location, and feature details likely interact during retrieval, we probed these content areas separately to directly examine the role of spatial imagery to event memory. If spatial information provides a strong scaffold for remembering events, then spatial imagery ability should modulate only broad event details (e.g., spatial and event), and not recal of specific feature details that do not require retrieving spatial-contextual information. Thus, in addition to predicting that the interfering effect of DVN will be related to spatial imagery ability, we further predicted this effect would be specific to spatial and event, but not feature-based memory.

Methods

Participants

Thirty-seven healthy young adults were recruited from the Rotman Research Institute Participant Database at Baycrest Health Sciences Centre. Two participants were excluded due to a failure to follow instructions and a later disclosed medical condition. Our sample of 35 participants (12 males; average age = 22 ± 2 years; average education = 16 ± 2 years) is comparable to sample sizes used in previous studies that have incorporated interference techniques and complex memory material (Parker & Dagnall, 2009; Wais, Rubens, Boccanfuso, & Gazzaley, 2010). Participants were fluent in English, had normal or corrected-to-normal vision, were not colour-blind, and gave informed consent in accordance with institutional ethical guidelines. They received compensation for their participation. For four participants included in our sample, some recognition memory responses were not recorded due to computer failure (4–21 trials). Their performance was calculated based on the remaining responses.

Imagery ability measures

The Object-Spatial Imagery questionnaire (OSIQ; Blajenkova et al., 2006) assesses individual differences in object imagery (the ability to imagine objects' shape, colour, and texture) and spatial imagery (the ability to imagine location, movement, spatial relationships, and transformations). It contains 30 questions about imagery use in the real world that participants are asked to rate on a 5-point scale (for sample items, please see the original paper). This questionnaire is reliable, ecologically valid, and more sensitive than questionnaires that do not differentiate between these imagery constructs (e.g., The Verbalizer-Visualizer Questionnaire (VVQ), see Antonietti & Giorgetti, 1998). Even so, we sought to confirm the criterion validity of these sub-scores in our sample using separate paper-and-pencil tests of imagery: the Paper Folding test (PFT) and the Hooper Visual Organization Test (HVOT).

The PFT is a classic measure of spatial imagery ability (Service, 1962). In this test, participants are presented with images of a paper folded multiple times with a final drawing indicating a hole punched through the paper. They judge which image from an array of five would result once the paper is unfolded. The dependent variable is the proportion correct.

The HVOT (Walker, 1956) measures visual integration and perception. Participants are given single line drawings of familiar objects (e.g., a teapot) that have been divided into pieces, rotated, and spatially scrambled. They are asked to determine the object. This measure entails object identification imagery processes (Moritz, Johnson, McMillan, Haughton, & Meyerand, 2004; Warren, Duff, Jensen, Tranel, & Cohen, 2012); however, it is important to note that it also engages more complex visuospatial skills (Moritz et al., 2004). The dependent variable is the average reaction time to identify the objects.

Recognition memory test

Stimuli

Event video stimuli. Thirty short audio-free video-clips that depicted real-world events (10–20 sec) were collected from youtube.com. Each video portrayed naturalistic scenarios analogous to typical everyday experiences (e.g., shopping; entering a café) and contained a unique set of contextual and perceptual features. Fifteen videos had both a mix of males/females, seven had only female characters, four had only male characters, and four videos contained animals. Fifteen of the videos took place outside, while 15 took place indoors. The videos were distinct from each other so that the memory of a video-clip could be triggered by an event title.

Interference stimuli. Six different 15-second DVN clips were created using the available source code (http://www.st-andrews.ac.uk/~www_sp/people/personal/jgq/). A 25% grey screen was created in movie file format (~15 sec) and was used for the control condition. All visual stimuli were presented on a square computer screen (1280 × 1024 pixels).

Recognition memory question. For each video, six true/false statements (90 true questions, 90 false lures in total) that probed for *event* (e.g., the woman and man had an argument), *feature* (e.g., the man was wearing a black fedora; half (43%) of the questions referred to object colour and the other half referred to object type (e.g., a cup versus a plate)), or *location* information (e.g., the guitarist was sitting on the left) were created and audio-recorded. Four raters judged the classification of each question to the given question category with an acceptable inter-rater reliability of 87.6%. Out of all the 19 incorrectly classified questions, 7 involved the confusion of event and feature questions (37%), 6 confused location and feature questions (31.5%), and 6 confused event and location questions (31.5%).

Procedure

During testing, participants were positioned approximately 60 cm from a computer display. We used a chin-rest and visual barriers on the side of the computer to ensure that the participants' visual field would be occupied by the display. Auditory stimuli were delivered through noise-cancelling headphones. The test was administered in three runs of encoding/recognition.

Encoding phase (Figure 2(a)). During this phase, participants viewed 10 videos. They were instructed to pay close attention to the details of each video because their memory would be tested shortly after viewing. Each video was preceded by a 3-second audiovisual title (e.g., "The girl and boy dancing"). Based on pilot results, we presented each video twice consecutively to maximise encoding of the events described in each video. The order of the 10 videos was randomised across participants.

Recognition phase (Figure 2(b)). In this phase, participants answered 60 true or false questions about the contents of the viewed events. For each of the 10 videos, there were 6 questions: 2 event, feature, and location questions. These questions were presented randomly across participants and were also randomly assigned to the interference or control conditions. This assignment was done in such a way that there were an equal number of event, feature, and location questions in each condition.

For each question, the participants were first given a 3-second audiovisual presentation of the video title to allow initial retrieval of the video. Next, the true/false recognition memory question was presented through headphones while the participants simultaneously viewed either the DVN stimuli (interference condition) or the grey control screen (control condition). Participants responded to the question by pressing "1" for True or "2" for False on a keypad. Their hand was positioned so that a response could be made without looking at the keypad, allowing the participants to continually view the visual stimuli while answering these questions. We also implemented four measures to ensure that the participants were viewing the visual stimuli during this phase of the experiment. First, as previously noted, we installed barriers on the side of the computer monitor and used a chin-rest so that the stimuli would occupy the participants' field of view. Second, we emphasised in our instructions to the participants that they must pay attention to the visual stimuli while answering these questions. Third, the experimenter observed the gaze of the participants during this recognition memory phase to affirm that they were viewing the stimuli. Finally, the visual (interference or control) stimuli remained on the screen until the true/false judgment was made.

Following each recognition memory response, the visual stimulus was cleared from the screen and participants rated aloud the associated confidence and difficulty levels on a 6-point scale (1 = not confident/not difficult; 6 = very confident/difficult) for all questions. The experimenter recorded these ratings.

Encoding and recognition were separated by a 10-minute delay period during which participants completed pencil and paper tasks (see page 7). The order in which these imagery tests were delivered was randomised across participants to ensure that order effects did not influence test results.

The main dependent variable from the recognition memory test was the average proportion correct (hits + correct rejections). The effect of interference on recognition memory was operationalised as the difference in proportion correct between the control and DVN conditions.

Results

Overall Performance

Accuracy

Across all participants, there was no effect of condition (DVN versus control) on proportion correct ($F(1, 34) = 1.76$, $p = .68$, $\eta_p^2 = .005$; see Table 1 for additional response characteristics for which no differences emerged). When question type (event, location, feature) was taken into account, there was no effect of interference condition ($F(2, 68) = 0.48$, $p = .62$, $\eta_p^2 = .028$), but a main effect of

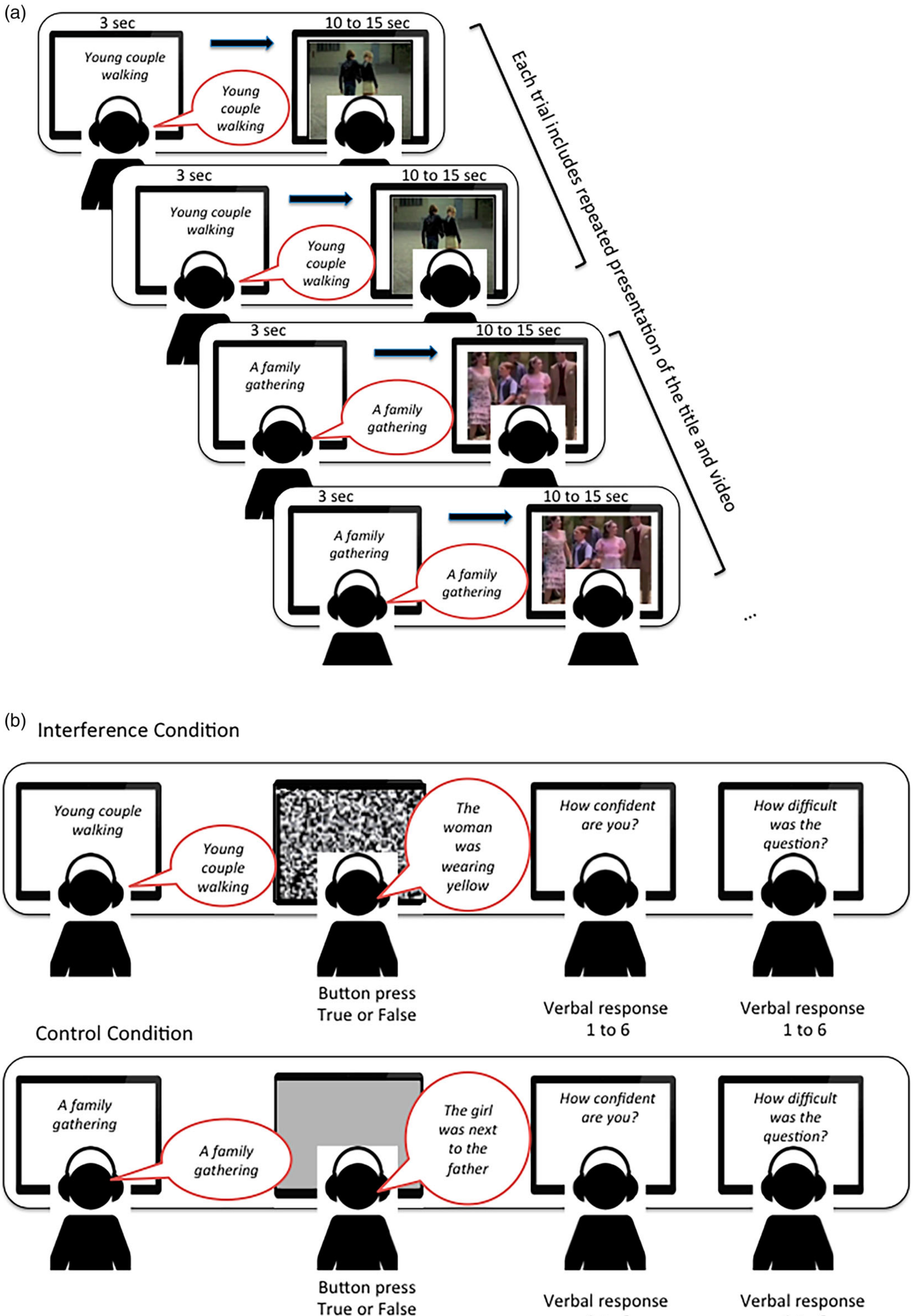

Figure 2. The recognition memory test was administered in three runs, each comprised of an encoding and recognition phase. (a) A schematic of the encoding phase. At encoding, 10 videos were presented, preceded by the audiovisual presentation of a video title (3 sec). Each title/video combination was presented twice consecutively. (b) A schematic of the recognition phase. Following the encoding phase, 60 true/false questions related to the 10 previous videos were presented. The questions were randomly allocated to the DVN interference (top) or control (bottom) condition. Each trial began with the audiovisual presentation of the video title (3 sec) followed by the visual presentation of the interference stimuli or control screen that occurred simultaneously with the audio presentation of the true/false recognition question. The visual stimuli remained on the screen until a response (true or false) was made via a button press. After entering the response, participants orally rated their confidence in their response and the difficulty of the question on a scale of 1–6. This response was recorded by the experimenter.

Table 1. The profile of performance in the DVN and control condition across all participants.

Condition	Accuracy	Hits	False alarms	Correct rejections	Misses
DVN	.76 (.01)	.76 (.01)	.24 (.02)	.76 (.02)	.24 (.02)
Control	.77 (.01)	.76 (.01)	.23 (.02)	.77 (.02)	.24 (.02)

Note: Standard errors are shown in parentheses.

question type ($F(2, 68) = 14.59$, $p < .001$, $\eta_p^2 = .44$), such that the feature questions (mean = 0.72, SE = .01) had a lower proportion correct than event (mean = 0.80, SE = .1; $p < .001$) and location (mean = 0.77, SE = .2; $p = .01$) questions. The difference between event and location proportion correct was not significant ($p = .06$; all *post hoc* tests were corrected using the Bonferroni procedure).

Confidence and difficulty ratings

The patterns for confidence ratings for correctly answered items and difficulty ratings were similar to those observed for accuracy; both were confirmed with repeated measures ANOVAs. For average confidence ratings, the main effect of question type ($F(2, 68) = 80.34$, $p < .001$, $\eta_p^2 = .70$) was driven by high confidence ratings for event questions (mean = 4.8, SE = .08) and location questions (mean = 4.5, SE = .09) compared to feature questions (mean = 4.10, SE = .11; $p < .001$ for both comparisons). The significant main effect of question type for difficulty ratings ($F(2, 68) = 56.07$ $p < .001$, $\eta_p^2 = .63$) was driven by differences amongst all types ($p < .001$ for all comparisons) in that feature questions were rated as the most difficult (mean = 3.00, SE = .11), followed by location (mean = 2.74, SE = .11) and then event questions (mean = 2.4, SE = .10).

Individual differences in imagery

Object and spatial OSIQ scores were derived according to established procedures (average response to object and spatial items; Blajenkova et al., 2006). The mean object score was 3.34 (SD = 0.42) and the mean spatial score was 3.08 (SD = 0.52). These scores and distributions were consistent with previous reports (Blajenkova et al., 2006). The correlations between object and spatial scores with the PFT (mean = 0.67, SD = 0.17) and HVOT (mean = 10.9 sec, SD = 2.2) are reported in Table 2. The OSIQ spatial scores significantly correlated with the PFT and not the HVOT. The OSIQ object scores significantly correlated with the HVOT and not the PFT. This validates the imagery scores in our sample. Critically, spatial and object imagery scores did not correlate with one another ($r = -.01$, $p = .95$), ensuring we could examine these subscores independently. The relationship between object and spatial imagery scores with test performance was examined using imagery scores as a continuous variable.

Table 2. Pearson correlation values between objective tests of imagery (HVOT – Hooper Visual Organization Test; PFT – paper folding test) and subjective reports of imagery (OSIQ spatial and object).

	OSIQ spatial	OSIQ object
HVOT (reaction time, seconds)	−.21, $p = .24$	−.49, $p = .003$
PF (proportion correct)	.57, $p < .001$	−.013, $p = .94$

Overall accuracy

Both object and spatial imagery scores were entered into a linear regression predicting the difference in proportion correct between the control and DVN conditions. This difference score was used as a measure of accuracy to account for variability across individuals in their overall response rates. While this model was significant ($F(2, 34) = 9.96$, $p < .001$), only spatial imagery scores were a significant predictor ($b = .61$, $t(34) = 4.42$, $p < .001$; object imagery scores, $b = .09$, $t(34) = 0.68$, $p = .50$). Confirming this result, a regression model with only spatial imagery as a predictor ($R^2 = .38$ ($F(1, 33) = 19.78$, $p < .0001$) was significant and performed as well as the full model with both object and spatial imagery scores ($R^2 = .38$; R^2 change = −.009, $F(1, 32) = 0.46$, $p = .50$). A model with object imagery had an $R^2 = .008$ ($F(1, 33) = 0.25$, $p = .62$) and did not perform as well as the full model (R^2 change = −.38, $F(1, 32) = 19.52$, $p < .001$). In Figure 3, the nature of the relation between imagery ability and the difference in proportion correct is illustrated. Higher spatial imagery scores were related to a strong effect of DVN interference on memory performance (right panel). This relation was not evident for object imagery scores (left panel).

Response type

Next, we examined the effect of DVN for each response type (hits, correct rejections, misses, and false alarms) using an ANOVA with the four response conditions as within-subjects variables and object and spatial scores as covariates of interest. This analysis revealed that there was no interaction between response type and object imagery ($F(3, 96) = 0.608$, $p = .611$). There was a significant interaction between spatial imagery ability and response type ($F(3, 96) = 4.125$, $p = .008$). Exploring this interaction effect further, a multiple regression analysis showed that differences in false alarms and hits were significant ($F(1, 33) = 4.510$, $p = .041$; $F(1, 33) = 9.97$, $p = .003$, respectively), but misses or correct rejections were not ($F(1, 33) = 0.350$, $p = .45$; $F(1, 33) = 0.584$, $p = .558$, respectively).

The nature of this relation is illustrated in Figure 4. For descriptive purposes only, we categorised participants as high or low object and spatial imagers by a median split and plotted the average accuracy for each response type under the two conditions (control vs. DVN). This figure demonstrates that DVN impaired performance for both hits (yes to true items) and false alarms (yes to false items) for high spatial imagers.

Confidence and difficulty

First, a regression model for average confidence rating with spatial and object imagery scores as predictors was not significant ($F(2, 34) = 2.25$, $p = .10$). However, a linear regression model for average difficulty rating with these

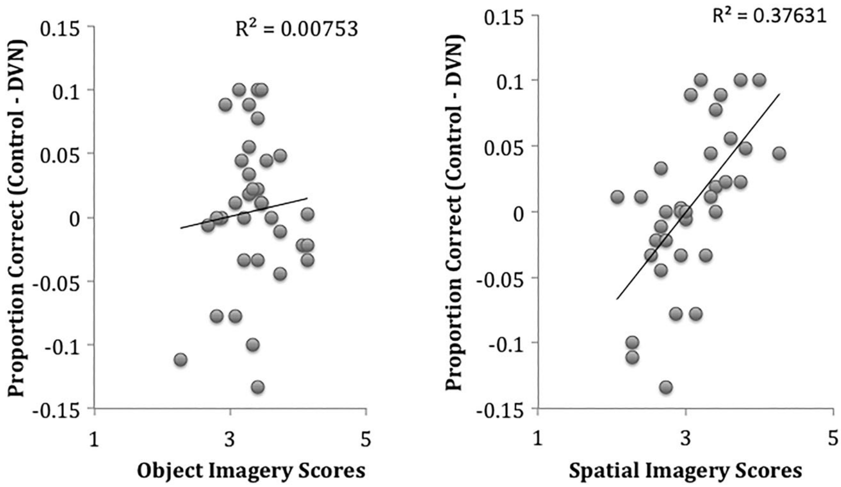

Figure 3. Scatterplots illustrating a significant positive relation between spatial imagery scores (top) and a non-significant relation between object imagery scores (bottom) to the difference in proportion correct between the control and DVN memory retrieval conditions.

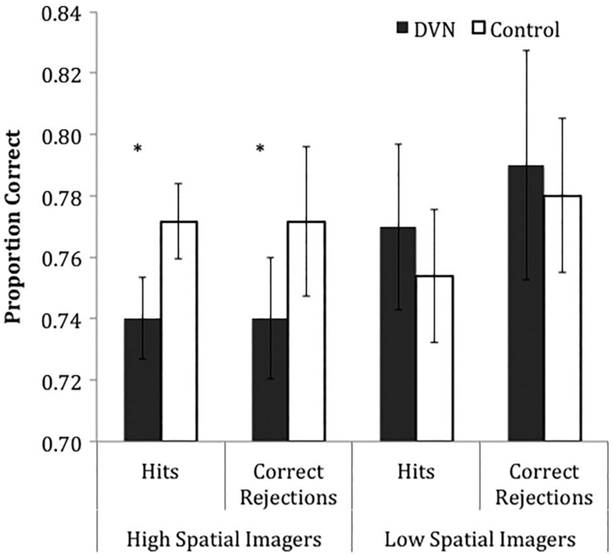

Figure 4. The average number of hits (true items correctly judged as true) and false alarms (false items incorrectly judged as true) expressed as proportion correct for high and low spatial imagers as classified via an OSIQ spatial score median split under DVN and control conditions.

predictors was significant (*F*(2, 34) = 5.46, *p* = .01). Specifically, spatial imagery scores (*b* = –.48, *t*(34) = –3.15, *p* < .005) but not object imagery scores (*b* = .14, *t*(34) = 0.88, *p* = .39) were a significant predictor of difficulty ratings.

Accuracy across question category

To examine the effect of DVN on memory performance for each question category, we first ran a correlation analysis (Table 3). This analysis revealed a significant positive relation between spatial imagery scores and proportion correct differences for the event and location, but not feature questions. None of these relations held for the object imagery scores. Next, we ran separate linear regressions on the differences in proportion correct for each question type. Whereas the model for the feature questions was not significant (*F*(2, 34) = 1.84, *p* = .18), the model for the location questions was significant (*F*(2, 34) = 3.41, *p* = .05). For the location questions, spatial imagery significantly predicted difference scores (*b* = .40, *t*(34) = 2.45, *p* < .002), but object imagery did not (*b* = –.12, *t*(34) = –0.74, *p* = .46). The model for event questions approached significance (*F*(2, 34) = 3.02, *p* = .06) and spatial imagery significantly predicted difference scores (*b* = .40, *t*(34) = 2.44 , *p* = .02), but object imagery did not (*b* = .05, *t*(34) = 0.30, *p* = .77).

Table 3. Between-subject correlations of proportion correct difference scores between the DVN and control memory retrieval conditions and imagery ability factor scores overall and for each question subtype (event, location, and feature).

	Overall	Event	Location	Feature
Spatial imagery score	*r* = .61**	*r* = .40*	*r* = .40*	*r* = .26
	p < .001	*p* = .02	*p* = .02	*p* = .13
Object imagery score	*r* = .09	*r* = .05	*r* = –.05	*r* = .14
	p = .92	*p* = .76	*p* = .77	*p* = .41

* p < 0.05, ** p < 0.01.

Discussion

In the present study, we found that inter-individual variability in visual imagery, specifically spatial imagery, modulated the contribution of conscious and constructive imagery processes to the accuracy of event memory retrieval. Spatial imagery abilities, as measured by a validated self-report questionnaire, predicted the negative effect of simultaneous imagery interference stimuli (DVN) when retrieving details from encoded videos of complex real-world events. We localised this effect of retrieving details from these videos as relating to how an event unfolded over time (event details) or spatial relations among elements (i.e., where things were located), and not for remembering specific details about objects depicted in the videos (e.g., colours, size).

Broadly, our results advocate for including imagery ability differences when assessing the way complex events are recalled. The effect of the DVN stimuli on event memory was only apparent when we took individual differences in imagery ability into consideration. This finding follows other reports that trait-based individual differences are fundamentally related to the processes that are used for remembering (Keogh & Pearson, 2011; Palombo, Williams, Abdi, & Levine, 2013; Sheldon, Farb, Palombo, & Levine, 2016). More specifically, our findings indicate that spatial imagery ability modulates the processes used to remember. There are multiple processes involved in abilities like imagery (Carroll, 1993; Richardson, 1969) and even in spatial imagery (Thompson et al., 2009). Thus, from this study alone we cannot establish the precise mechanism that underlies the relationship between imagery and event memory. However, we speculate that spatial imagery ability differences are related to the preferential engagement of imagery-related processes, such as those supported by the occipital and parietal cortices, when remembering (Greenberg & Rubin, 2003).

We considered a number of plausible interpretations of our results. First, we considered the possibility that our findings reflect differences in general resources (e.g., attentional engagement, distractibility) associated with imagery scores. If these results were due to deficits in general resources, we would have expected the opposite pattern than what we report. That is, if individuals with high imagery ability are those with additional resources to draw upon when completing a task, this would have led to less interference from the DVN. Moreover, this interpretation would have predicted that high spatial imagers would have equivalent impairments from DVN across all question types. On the contrary, imagery ability was related to the DVN effect for event and location questions, but not for the more demanding feature questions. We speculate that the feature questions were more demanding, or at least different, than the event or location questions because they probe for fine-grained object details rather than coarse-grained details. Coarse-grained details can benefit from reinstating a spatial context of the event (e.g., where was the man in the scene?), but this reinstatement is less likely to benefit remembering feature-based details (e.g., what colour was the vase in the scene?). We come back to the dissociations among these question types at a later point in our discussion.

We also interpreted our results based on findings from previous studies that have used DVN. The reported inconsistencies among these studies have suggested the precise imagery processes that are impacted by DVN. First, DVN interference effects seem to be specific to visual tasks. For example, weak or no DVN effects are seen for list learning tasks (for a recent example, see Rae & Perfect, 2014), or tasks that do not require the recovery of highly vivid images (Avons & Sestieri, 2005). Second, DVN effects are often not reported for tasks that require simply maintaining visual images in mind, such as working memory tasks (Andrade et al., 2002; Dent, 2010; Kemps & Andrade, 2012). Instead, DVN interference is more apparent for tasks that require the conscious recovery or retrieval of perceptual input, such as using imagery-guided mnemonic devices or rating vividness or confidence (Parker & Dagnall, 2009; Quinn & McConnell, 2006). Thus, when a task requires some form of imagery-based construction and not simply recall or rehearsal of a visual detail in mind, DVN stimuli will negatively impact performance.

Our findings show that spatial imagery and not object imagery ability was predictive of the effect of DVN on recognition accuracy. Guided by the findings noted above, we suggest that spatial imagery ability is critical for constructing an event in mind. This interpretation is in line with the established role of spatial processing in creating a viable “context” or space for one to remember (Hassabis et al., 2007; Hassabis et al., 2014; Mullally & Maguire, 2013; Mullally, Vargha-Khadem, & Maguire, 2014). However, this role for spatial imagery in event memory opens up questions about the precise nature of spatial imagery processes in memory and the dissociable contributions of spatial and object imagery. To explore these issues, we return to the different patterns of results found for the three types of recognition memory questions.

As noted, the disruptive effect of DVN on spatial imagers was specific to answering questions about how an event unfolded over time or spatial elements that require relating or binding different elements from the remembered past event (Konkel & Cohen, 2009). Imagining these forms of relations are not needed for remembering item-specific details, such as questions concerning the perceptual features of objects, which rely on distinct processes (Mayes & Montaldi, 1999; Mayes, Montaldi, & Migo, 2007). This suggests that spatial imagery specifically modulates relational processing needed for remembering higher-level details from an event and not for remembering feature-based event representations (Sheldon & Levine, 2016). In fact, a dissociation between relational and feature-based imagery processes can reconcile seemingly contrasting results from a recent investigation that linked object imagery ability to remembering sensory perceptual details from autobiographical events (Vannucci et al., 2016). In our study, DVN interfered with imagery processes needed to construct the contextual representation of a past event associated with spatial imagery. One interpretation of the findings from the Vannucci study is that object imagery is related to the recovery of feature-based event details from past events, which underlies the recovery of sensory and perceptual details. These feature-level imagery processes are not affected by the DVN, which is why we saw neither an effect of the DVN on feature questions for spatial imagers nor a link between object imagery ability and DVN effects. Such a hypothesis, however, warrants further investigation.

A final interpretation of our findings rests on the general dominance of imagery in the recovery of complex event information (Greenberg & Rubin, 2003; Rubin & Umanath, 2015). On this view, DVN simply removed the tendency to use imagery in accessing event knowledge such that those with low spatial imagery ability would benefit from the DVN by accessing information from their preferred route via verbalised knowledge. In other words, for low imagers, it could be that accessing event information in the interference condition is not confounded by an impoverished image. Again, this interpretation requires further investigation before such a view can be justified.

Limitations

We note two potential limitations of our current study. One limitation is that we did not monitor eye movements as participants viewed the DVN or control screen during the recognition memory phase. Although we did take several steps to ensure that participants were viewing these stimuli, it is possible that the reported results are because high spatial imagers simply fixated more on the DVN stimuli more than those with lower spatial imagery ability. Another limitation is that we used a recognition experimental design to test the role of imagery in complex event memory. Our reasoning for using this approach was to disentangle the precise contributions of imagery to memory accuracy; however, it raises questions about whether our findings extend to real-world remembering.

Summary

In this study, we report that the interfering effects of simultaneously presenting imagery-impairing stimuli as one retrieves event information is only present when individual differences in spatial imagery are taken into account. This study suggests that such differences in cognitive ability can lead to a differential reliance on the component processes of memory (i.e., spatial imagery), ultimately having consequences on the quality of how one experiences remembering of the past.

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