

Differential contributions of default and dorsal attention networks to remembering thoughts and external stimuli from real-life events

Running Title: Memory for internal thoughts and external stimuli

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Abstract. Episodic memories are typically composed of perceptual information derived from the external environment and representations of internal states (e.g., one's thoughts during prior episodes). To date, however, research has mostly focused on the remembrance of external stimuli, such that little is known about how internal mentation is represented within episodic memory. In the present fMRI study, we examined the neural correlates of these two components of episodic memories using a novel method of cuing memories from photographs taken during real-life events. We found that, compared to corresponding semantic memory tasks, memories for internal thoughts and external elements were associated with activity in brain areas supporting episodic recollection. Most importantly, however, the two kinds of memories also showed differential activation in large-scale brain networks: the remembrance of external elements was associated with greater activity in the dorsal attention network, whereas memories of internal thoughts mainly recruited default network areas. These findings shed new light on the representation of internal and external aspects of prior experience within episodic memory. The default network may contribute to the reinstatement of thoughts experienced during past events, whereas the dorsal attention network may support the allocation of attention to visuo-spatial features within episodic memory representations.

Keywords: Episodic memory, Functional neuroimaging, Scene construction, Self-generated thought, Visuo-spatial processing

Historically, research on episodic memory has mostly focused on the remembrance of stimuli from the external environment, such as lists of words or pictures (Baddeley et al. 2002; Tulving 2002). However, recent advances in the study of human cognition have shown that we spend a substantial amount of time and resources generating thoughts and images that are decoupled from sensory input (Andrews-Hanna, Smallwood, et al. 2014; Christoff et al. 2016; Smallwood and Schooler 2015), which may play important roles in planning, decision making, mood regulation, and creativity (Andrews-Hanna 2012; Beaty et al. 2016). Being able to remember one's own thoughts and ideas (e.g., possible solutions to daily life issues, evaluations of recently introduced individuals, personal interpretations of events) may critically contribute to adaptive cognitive and social functioning, yet little is currently known about memory for internal mentation. Most notably, commonalities and differences in the cognitive and neural mechanisms underlying the retrieval of inner thoughts versus stimuli from the external environment remain to be investigated in detail.

Memory for thoughts has been previously investigated in the context of reality monitoring judgments (i.e., as a means to determine whether a past event was real or imagined; Johnson 1988; Horton et al. 2007), but it has rarely been a topic of study in itself (but see Brewer 1988; Muhlert et al. 2010). Neuroimaging studies have revealed that the medial prefrontal cortex shows higher activity when retrieving internally generated versus externally derived source details during recognition memory tasks (for review, see Simons et al. 2017). Furthermore, it has been shown that memory vividness ratings for internal (i.e., thoughts and feelings) and external (i.e., perceptual) contextual details during word recognition correlate with different patterns of hippocampal connectivity (Ford and Kensinger 2016). Taken together, these studies suggest that memory for internal versus external aspects of past events is supported, at least in part, by distinct mechanisms. However, the conclusions that can be drawn from these studies are limited by their focus on memory for laboratory stimuli, which may be fundamentally different from memory for events in one's life (Chen et al. 2017; McDermott et al. 2009; Roediger and McDermott 2013; but see Rissman et al. 2016).

Memory for real-life events relies on a distributed set of brain regions that include the Default Network (DN; Raichle et al. 2001) and fronto-parietal areas (Addis et al. 2004, 2012; Benoit and Schacter 2015; Cabeza and St Jacques 2007; Kim 2012; McDermott et al. 2009; Spreng et al. 2009). The experience of remembering such events is typically composed of multiple components (e.g., sensory and contextual details, thoughts, emotions; Johnson et al. 1988; Rubin et al. 2003), and it is therefore likely that the memories produced in previous neuroimaging studies of real-world memory retrieval involved a mix of internal and external elements from prior experience (Andrews-Hanna, Saxe, et al. 2014). It remains an open question whether these two types of information rely on distinct regions within the brain network supporting episodic remembering.

Here we sought to address this question using a novel paradigm to elicit memories for external details versus internal thoughts occurring during real-life events. Participants were first asked to perform a 30-minute walk on a university campus while wearing a lifelogging camera that continuously and automatically took pictures from the first-person perspective (Chow and Rissman 2017). They then immediately underwent an fMRI session in which they saw short sequences of pictures from their walk, in response to which they had to remember either associated elements from the external environment or internal thoughts that they experienced during the walk. Using these two task conditions, the first aim of this research was to identify brain regions that exhibit differential activity during the retrieval of internal versus external aspects of past events.

A second aim of the present study was to investigate whether these brain regions are specifically involved in remembering external versus internal details from specific past episodes or whether they are also engaged when processing corresponding (i.e., perceptual versus reflective) information in semantic memory. Recent meta-analyses have shown that the neural correlates of episodic and semantic memory tasks overlap substantially, particularly within the DN (Binder et al. 2009; Kim 2016). Yet, it remains unclear whether episodic and semantic memory share common neural substrates for both perceptual and reflective memory representations. To investigate this question, two additional tasks were included in this study, which involved the mental representation of visual scenes versus reflective thoughts that were decontextualized from any specific past event. More specifically, participants performed a scene construction task (Hassabis and Maguire 2007) in which they had to mentally visualize common daily life objects in their typical spatial context, and a conceptual reflection task in which they had to mentally generate definitions of abstract words. Taken together, the four tasks included in this study constituted a 2×2 factorial design that allowed us to investigate commonalities and differences in the processing of perceptual versus reflective information in episodic and semantic memory.

We were particularly interested in examining the respective contribution of the default, dorsal attention, and frontoparietal control networks to the retrieval of internal thoughts and external elements from episodic memory. As noted above, the DN is consistently involved in remembering real-life events and research has shown that it comprises at least two subsystems that converge on two hub-like core regions—the posterior cingulate cortex and anterior medial prefrontal cortex (Andrews-Hanna et al. 2010; Andrews-Hanna, Smallwood, et al. 2014). The first subsystem is anchored in the dorsal part of the medial prefrontal cortex and is thought to play an important role in introspecting about mental states and in processing abstract (compared to perceptual) information (Christoff et al. 2016; Wang et al. 2010, 2013), whereas the second subsystem involves the medial temporal lobe and supports the retrieval and binding of episodic elements (Andrews-Hanna 2012; Andrews-Hanna, Saxe, et al. 2014). Based on this fractionation of the DN and previous studies of reality monitoring (Simons et al. 2017), we predicted that the retrieval of internal and external aspects of past events would both rely on DN regions but that memories for internal thoughts would recruit the medial prefrontal cortex and other regions of the dorsal medial subsystem (such as the lateral temporal cortex; Andrews-Hanna, Smallwood, et al. 2014) to a greater extent than memories for external elements.

The second network of interest in this study was the Dorsal Attention Network (DAN), which supports the top-down control of visuo-spatial attention and thus plays an important role in processing stimuli from the external environment (Corbetta and Shulman 2002; Spreng et al. 2013). The DN and DAN often show anticorrelated activity, which has led to the view that they support opposite or competitive functions respectively corresponding to the processing of internal versus external information (e.g., Fox et al. 2005; Sestieri et al. 2010). However, this view has been challenged by recent studies showing that the DAN can be transiently activated during memory retrieval (in the absence of external cues), and shows an increased functional connectivity with the core midline regions of the DN in this condition (Kragel and Polyn 2015; see also Dixon et al. 2017). While this research reveals a role of the DAN in episodic memory retrieval, its precise function remains unclear. Here, we investigated the possibility that the DAN may not only support the processing of stimuli from the immediate external environment (Corbetta and Shulman 2002), but may also play a role in processing internally-generated information referring to aspects of the external world, such as the sensory-perceptual components of episodic memories. Support for this proposal comes from a source memory study showing that remembering prior perceptual versus conceptual

judgements about visual stimuli recruits DAN areas (Dobbins and Wagner 2005). More generally, studies on mental imagery have shown that some DAN areas (including the precentral sulcus, superior parietal lobule, and visual temporal areas) are not only involved in visual perception but also in visual mental imagery (Ganis et al. 2004; Pearson et al. 2015). To further test the hypothesized role of the DAN in the processing of perceptual memory representations, we examined whether the DAN exhibits increased activation when retrieving perceptual compared to reflective information from episodic and semantic memory.

Finally, besides the DN and DAN, we were also interested in the contribution of the frontoparietal control network (FPCN, Vincent et al. 2008; Spreng et al. 2010), which is also commonly engaged during episodic memory retrieval (Benoit and Schacter 2015; Cabeza and St Jacques 2007; Kim 2012; McDermott et al. 2009). The FPCN is thought to support effortful control processes to meet task goals, and may play a role in integrating information from the DAN and DN (Gao and Lin 2012; Spreng et al. 2010; Vincent et al. 2008). During episodic remembering, this network might support the strategic retrieval, monitoring, and recombination of episodic details to form an integrated and coherent representation of the remembered event (Benoit and Schacter 2015; St Jacques and Cabeza 2012; St Jacques and De Brigard 2015). A previous fMRI study (Dobbins and Wagner 2005) found that retrieving internal source information mainly recruited left FPCN areas, whereas retrieving external source information was associated with right FPCN activity. These results suggest that the retrieval of internal thoughts versus external elements might be associated with distinct activations within the FPCN.

In summary, the aims of the present study were twofold. Our first goal was to investigate the neural correlates of episodic memory for internal thoughts versus elements from the external environment experienced during real-life events. Second, we aimed at determining commonalities and differences in the processing of perceptual versus reflective information in episodic and semantic memory. To do so, we used four task conditions that constituted a 2 (perceptual versus reflective) \times 2 (episodic versus semantic) factorial design and focused our analyses on three major brain networks commonly involved in memory retrieval and externally versus internally directed attention: the DN, DAN, and FPCN.

Materials and Methods

Participants

Participants were 27 right-handed young adults (20 women, mean age = 25.11 years, SD = 4.93, range = 19-34 years). All were students or employees at the University of Liège and were familiar with the university campus. None of the participants reported a current use of psychoactive medication or a history of neurological or psychiatric disorder. Six additional participants were tested but were excluded from the analyses because of excessive head movement during image acquisition (one participant) or task noncompliance either during the pre-scan walk (one participant) or in the scanner (four participants¹). All participants gave their written informed consent to take part in the study, which was approved by the ethics committee of the Medical School of the University of Liège and was performed in accordance with the ethical standards described in the Declaration of Helsinki (1964).

¹ These four participants completed the two task runs, but the debriefing revealed that they either (1) did not press the response key to indicate that they had generated the appropriate mental content, (2) recalled memories of specific past events in the scene construction condition, (3) did not specifically focus on external elements or internal thoughts during the recall conditions, or (4) felt physically uneasy during the second run and could not properly perform the task.

Task Description

Pre-scan Walk with Lifelogging Device

Immediately before scanning, participants were instructed to perform a walk on the campus of the University of Liège while wearing an Autographer (<https://en.wikipedia.org/wiki/Autographer>). The Autographer is a lifelogging device consisting of a small wearable camera that automatically, continuously, and silently takes pictures through a 136° fish-eye lens according to an algorithm based on several electronic sensors (e.g. color, temperature, accelerometer, magnetometer, etc.). The main advantage of this device is that it provides a dynamic flow of pictures taken from the first-person perspective without disrupting ongoing experience by actively taking photographs. A growing number of neuroimaging and behavioral studies have shown that the images taken by this kind of device can be used as individually personalized retrieval cues that are particularly effective in eliciting vivid episodic memories (Chow and Rissman 2017; St Jacques and De Brigard 2015; St Jacques et al. 2013).

The walk consisted in going to several different buildings on the university campus to perform actions chosen to simulate activities that college students perform in their daily life. More specifically, participants had to perform four actions at different locations on the campus in the following order: (a) to post a letter in a mailbox, (b) to buy a local newspaper at an indoor newsstand, (c) to buy a drink at a cafeteria, and (d) to look on the wall of an amphitheater to check the title of a lecture. Following these actions, the participants were asked (e) to come back to the testing room for further instructions regarding the next parts of the study (see Fig. 1a). Participants could take the route they wanted to go from building to building between each action, but they were asked not to perform any additional action during the walk (e.g., listening to music, using their smartphones, discussing with acquaintances, etc.). Otherwise, participants were asked to behave normally (i.e., as they would in their daily life) and they were given a sealed envelope for the first action, as well as five euros to buy the newspaper and the drink. On average, the entire walk lasted 34.11 minutes ($SD = 4.43$). Pictures were taken by the Autographer on average every 6.69 seconds ($SD = 0.30$); the mean total number of pictures taken per walk was 307.30 ($SD = 45.40$). Participants were informed that pictures taken during their walk would be presented in the fMRI session but, importantly, no mention was made of the memory tasks. As a cover story, participants were told that they will have to perform in the scanner aesthetic judgments on the pictures.

fMRI Tasks

Immediately following their walk, participants underwent an fMRI session involving four different conditions (see Fig. 1b). The task comprised 24 trials for each condition, which were presented in two runs of 48 trials (12 trials per condition in each run). The order of presentation of the trials was randomized with the constraint that two trials of the same condition were not presented successively and were not more than seven trials apart.

Episodic memory tasks. In the two episodic memory conditions (hereafter referred to as the external element and internal thought conditions), participants were asked to remember either elements from the external environment or internal thoughts that they experienced during the walk. Each trial began with a one-second fixation cross followed by the presentation of a series of five consecutive pictures taken during the pre-scan walk of the participant (800 ms per pictures). Each sequence of pictures was determined randomly from the pool of pictures taken during the walk, with the following constraints: (a) selected pictures were displayed only once and (b) two consecutive sequences of pictures were not associated with

the same condition (e.g., if pictures 1 to 5 were used for the external element condition, then picture 6 to 10 were used for the internal thought condition). This latter constraint was made in order to maximize the similarity of the cuing sequences between the two conditions without presenting the same pictures several times across trials. In total, 240 pictures were presented (24 trials*5 pictures per condition). When more than 240 pictures were taken during the walk, the presented sequences of pictures were selected such that they covered the entire route. Each set of selected pictures was reviewed by the experimenter before scanning to ensure the absence of excessive blurring or lighting issues, so that the depicted segments of the walk were easily recognizable.

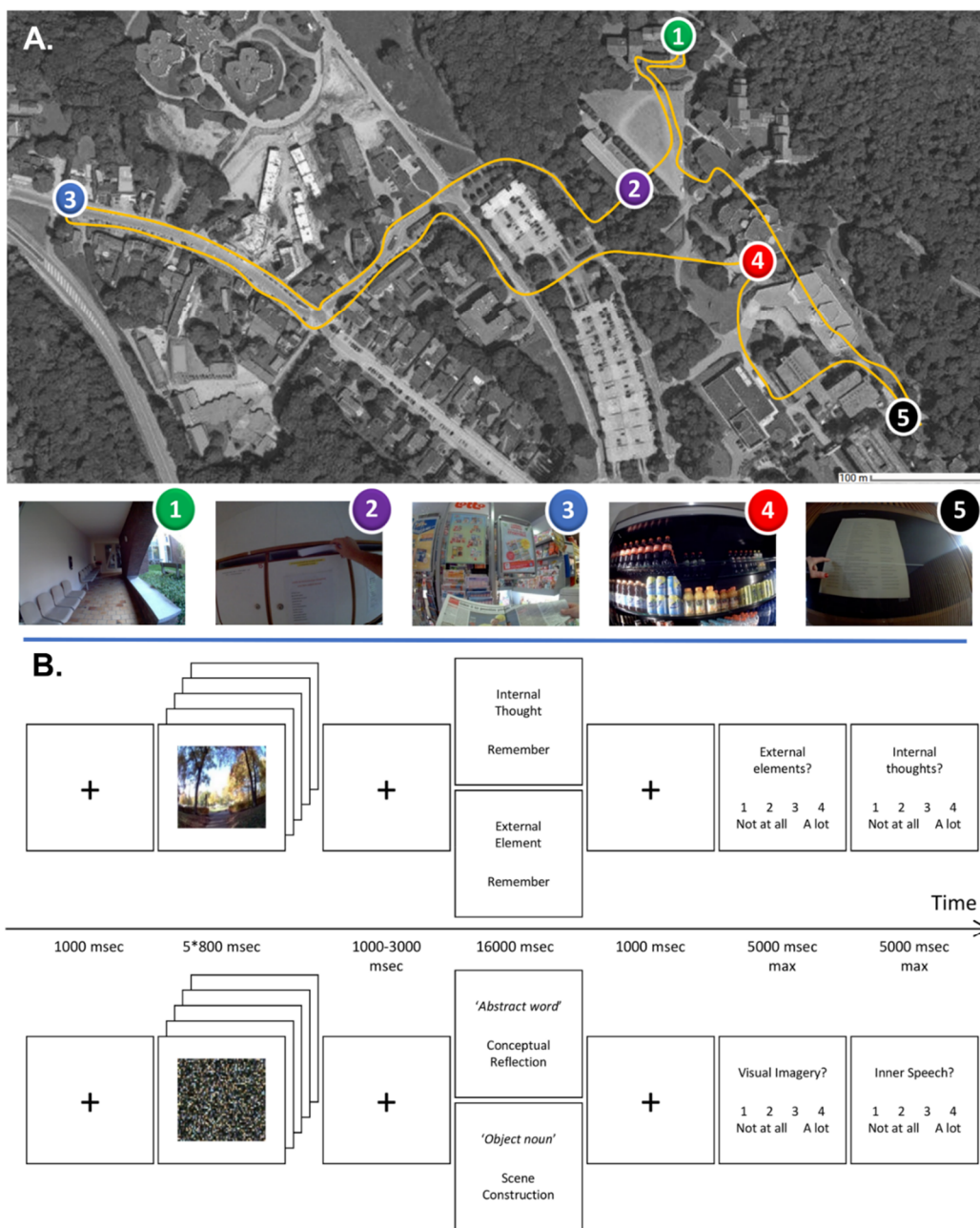


Figure 1. Panel **A.** illustrates the walk performed on the campus of the University of Liège (Belgium) prior entering the scanner. Participants had to (1) leave the testing room, (2) put a letter in a mailbox, (3) buy a newspaper at an indoor newsstand, (4) buy a drink at a cafeteria, and (5) look on the wall of an amphitheater to check the title of a lecture. Panel **B.** illustrates the structure of trials in the episodic (above the timeline) and semantic (below the timeline) memory conditions. In the scanner, participants

were first presented with sequences of five consecutive pictures from their walk (episodic conditions) or five scrambled pictures (semantic conditions). In the two episodic memory conditions, the pictures were followed by a screen asking participants to remember either an internal thought that they experienced during the walk (internal thought condition) or an element from the external environment that was not displayed in detail in the preceding sequence of pictures (external element condition). In the semantic memory conditions, participants were asked to either mentally construct a visual scene associated with an object (scene construction condition) or to reflect on the meaning of semantically associated words (conceptual reflection condition). For each condition, participants were asked to press a response key once they had retrieved the required information, and then to focus on their mental representation until the disappearance of the screen (which was presented for 16 seconds). Finally, each trial ended with the successive presentation of two Likert scales asking participants to rate the kind of mental representation that they experienced. fMRI analyses focused on the time interval between the key press and the end of the 16 seconds, thus corresponding to the main phase of the trials.

During the presentation of each sequence of pictures, participants were asked to focus on the images and to try to remember the corresponding moment of the walk. After the last of the five pictures, a second fixation cross was shown (with a variable duration ranging between one and three seconds), followed by the presentation of written instructions asking participants to remember either an internal thought or an element from the external environment. This retrieval phase lasted 16 seconds during which participants were first instructed to press a response key as soon as they retrieved the requested information, and then to remember this thought or external element in as much detail as possible until the end of the 16 seconds. For the external element condition, participants were told that their memory could be of anything that they encountered during the walk (e.g., people, objects, events, places, etc.) but it had to be something that was not displayed in detail in the immediately preceding sequence of pictures. This latter point was specified to ensure that the external element and internal thought conditions both involved the retrieval of information that is not directly available in the presented pictures. For the internal thought condition, participants were told that they could remember any thought they had experienced during the walk, be it directly related to the walk itself (e.g., thoughts about the actions they had to perform) or not (e.g., thoughts about personal concerns). Participants were also explained that, depending on the current trial condition, they should try to focus their attention only on external elements or on internal thoughts. Finally, the instructions specified that participants should retrieve a different external element or internal thought for each trial.

Following the retrieval phase, participants were shown a one-second fixation cross followed by the successive presentation of two four-point Likert scales, the purpose of which was to obtain a subjective assessment of the extent to which each retrieved memory involved elements from the external environment (first scale) and internal thoughts (second scale). The response options were identical for the two scales and ranged from 1 = *'not at all'* to 4 *'a lot.'* Responses were self-paced with a maximum of five seconds per scale.

Semantic memory tasks. The two semantic conditions were unrelated to the pre-scan walk and required either to imagine a visual scene (scene construction condition) or to reflect upon the meaning of words (conceptual reflection condition, see Fig. 1b). The timing of these two conditions was identical to the two episodic memory conditions. At the beginning of each trial, participants were presented with a sequence of scrambled pictures (the sequences of pictures were the same as in the episodic memory conditions, except that each image was cut into 3072 squares of 14 by 14 pixels that were then randomly rearranged within each frame). During this phase, participants were simply told to look the sequence of images. Next, written instructions (i.e. “scene imagination” or “meaning reflection”) were presented on the screen for 16 seconds along with either an object name for the scene construction condition or an abstract word for the conceptual reflection condition. Twenty-four French words were selected for each condition, based on the norms of Desrochers and Thompson (2009). The two set of words differed in their degree of

imageability [$t(46) = 50.91$; $p < .001$; $M = 6.60$, $SD = 0.31$ for scene construction; $M = 2.61$, $SD = 0.23$ for conceptual reflection] but not in terms of their subjective frequency [$t(46) = 0.20$; $p = .84$; $M = 4.71$, $SD = 0.54$ for scene construction; $M = 4.68$, $SD = 0.48$ for conceptual reflection] or number of letters [$t(46) = -0.24$; $p = .81$; $M = 7.58$, $SD = 1.82$ for scene construction; $M = 7.71$, $SD = 1.83$ for conceptual reflection]. The full list of words is presented in Table S1.

In the scene construction condition, participants were asked to press the response key as soon as they found a place commonly associated with the object named on the screen, and then to imagine a scene involving the place and object in as much detail as possible until the end of the 16 seconds. It was specified that the imagined scene should not refer to personal memories (e.g., in response to the word “parasol”, one could imagine a typical beach with a parasol and other features, but not remember a specific past experience involving this place and object). In the conceptual reflection condition, participants were asked to press the response key as soon as they found a word that was semantically associated with the word on the screen, and then to reflect on the meaning of the two words by mentally defining each of them (i.e., as if they had to explain their meaning to somebody else) until the end of the 16 seconds. In both conditions, trials ended by the successive presentation of two four-point Likert scales assessing to what extent each trial involved visual images (first scale) and inner speech (second scale). The response options and duration of the two scales were identical to those used in the episodic memory conditions. Participants kept their eyes open for the whole duration of each trial in each of the four conditions.

Post-scan Debriefing

Immediately after the fMRI session, the participants were shown the sequences of pictures for 20 of the trials (five randomly chosen per conditions) that they performed in the fMRI session. For each trial, they were asked to describe the external element, internal thought, place, or associated word that they generated while lying in the scanner. This was used as a manipulation check to determine whether the participants correctly performed the four tasks in the scanner. Participants were also asked to rate on seven-point Likert scales (a) to what extent they had guessed during the walk that they would receive a memory task in the scanner (ranging from 1 = ‘not at all’ to 7 ‘completely’), (b) to what extent the scenes they imagined in the scene imagination condition were identical to memories of specific past events (ranging from 1 = ‘not at all’ to 7 ‘completely’), and (c) the subjective difficulty of each of the four conditions (ranging from 1 = ‘very easy’ to 7 ‘very difficult’). In addition to the Likert scales, participants were asked to estimate the number of times they remembered the same external element or internal thought in different trials, and the number of times they remembered something that was part of the pictures (rather than an additional element) in the external element condition.

fMRI Data Acquisition

Data were acquired on a whole-body 3 Tesla scanner (Magnetom Prisma, Siemens Medical Solutions, Erlangen, Germany) operated with a 20-channel receiver head coil and using a T2*-weighted echo-planar imaging (EPI) sequence (TR = 2260 ms, TE = 30 ms, FA 90°, matrix size 72 × 72 × 36, voxel size 3 × 3 × 3 mm³). Thirty-six 3 mm thick transverse slices (FOV 216 × 216 mm²) were acquired, with a distance factor of 25% and interleaved slice ordering, covering the whole brain. Around 590 functional volumes were obtained for each run of the task. The first five volumes were discarded to account for T1 saturation effects. After the EPI acquisitions for the two runs of the task, field maps were generated from a

double echo gradient-recalled sequence (TR = 634 ms, TE = 10 and 12.46 ms, FoV = 192×192 mm², 64×64 matrix, 40 transverse slices with 3 mm thickness and 25% gap, flip angle = 90°, bandwidth = 260 Hz/pixel) and used to correct echo-planar images for geometric distortion due to field inhomogeneities. A structural MR scan was obtained between the two runs of the task [T1-weighted 3D magnetization-prepared rapid acquisition gradient echo (MP-RAGE) sequence, TR = 1900 ms, TE = 2.19 ms, FOV 256×240 mm², matrix size $256 \times 240 \times 224$, voxel size $1 \times 1 \times 1$ mm]. Head movement was minimized by restraining the subject's head using a vacuum cushion. Stimuli were displayed on a screen positioned at the rear of the scanner, which the subject could comfortably see through a mirror mounted on the standard head coil.

fMRI Data Analyses

Data were preprocessed and analyzed using SPM12 software (Wellcome Department of Imaging Neuroscience, <http://www.fil.ion.ucl.ac.uk/spm>) implemented in MATLAB (Mathworks, Inc.). EPI time series were corrected for motion and distortion with “Realign and Unwarp” (Andersson et al. 2001) using the generated field map together with the FieldMap toolbox (Hutton et al. 2002). A mean realigned functional image was then calculated by averaging all the realigned and unwrapped functional scans, and the structural T1-image was coregistered to this mean functional image (rigid body transformation optimized to maximize the normalized mutual information between the two images). The mapping from subject to MNI space was estimated from the structural image with the “unified segmentation” approach (Ashburner and Friston 2005). The warping parameters were then separately applied to the functional and structural images to produce normalized images of resolution $2 \times 2 \times 2$ mm³ and $1 \times 1 \times 1$ mm³, respectively. Finally, the warped functional images were spatially smoothed with a Gaussian kernel of 8-mm full-width at half maximum.

For each participant, BOLD responses were first modeled at each voxel, using a general linear model (GLM). The main phase of each trial was modeled separately for each condition (i.e., external element, internal thought, scene construction, and conceptual reflection) as epoch-related responses (beginning at the key press and ending at the disappearance of the screen after 16 seconds) and convolved with the canonical hemodynamic response function to create the regressors of interest. Trials for which participants did not press the response key or pressed 1 (‘not at all’) to the Likert scale assessing the required mental content were modelled in a separate regressor of no interest. The sequences of pictures were also modelled as epoch-related responses with two regressors, one for the sequences of scrambled pictures preceding the two semantic memory conditions and one for the sequences of normal pictures preceding the two episodic memory conditions. The two Likert scales ending each trial were also modelled as epoch-related responses with a single regressor across all conditions. Finally, we also modelled the motor responses made during the task (i.e., the key press made during the retrieval phase as well as the two responses made to the Likert scales of each trial) as an event-related response, again with a single regressor across all conditions. The design matrix also included the realignment parameters to account for any residual movement-related effect. The canonical hemodynamic response function was used and a high-pass filter was implemented using a cutoff period of 128 seconds to remove the low-frequency drifts from the time series. Serial autocorrelations were estimated with a restricted maximum likelihood algorithm with an autoregressive model of order 1 (+ white noise).

Based on our 2×2 factorial design, a series of linear contrasts were computed to identify the brain regions involved in the processing of perceptual versus reflective representations in episodic and semantic

memory. We first investigated brain regions showing a main effect for perceptual versus reflective representations (External Element and Scene construction > Internal Thought and Conceptual Reflection, and vice versa) and regions showing a main effect for episodic versus semantic memory retrieval (External Element and Internal Thought > Scene Construction and Conceptual Reflection, and vice versa). Next, the interaction terms were examined to determine whether the processing of reflective versus perceptual information is associated with specific neural correlates for episodic versus semantic memory: [(Internal Thought > External Element) > (Conceptual Reflection > Scene Construction)] and [(External Element > Internal thought) > (Scene Construction > Conceptual Reflection)]. Because the first of these interaction terms was associated with significant brain activations (see the Results section), we then computed individual contrasts to identify brain areas associated with reflective versus perceptual representations within episodic (Internal Thought > External Element) and semantic (Conceptual Reflection > Scene Construction) memory. On the other hand, given that the second interaction term was not associated with significant brain activations, we performed a null conjunction analysis to further determine the neural overlap between the two perceptual memory conditions: [(External Element > Internal thought) \cap (Scene Construction > Conceptual Reflection)].

The contrasts of interest were first computed for each participant and were then entered in random-effects one-sample t -tests. For all contrasts, we report activations that were statistically significant using a threshold of $p < .05$, corrected for multiple comparisons (familywise error, FWE) using Gaussian random field theory at the voxel level over masks of the three networks of interest (DN, DAN, and FPCN), as defined by the seven network parcellation of Yeo et al. (2011). For completeness, we also report additional clusters of brain activations whose peak voxels were located outside the three masks and that survived a threshold of $p < .05$, corrected for multiple comparisons (FWE) at the voxel level over the whole brain. Only clusters with a size of $k > 20$ voxels are reported.

RESULTS

Behavioral results

The behavioral results showed that participants successfully generated the requested information for nearly all trials (around 98%, on average, see Table S2), with no difference between conditions [$F(3, 78) = 0.52$; $p = .67$; $\eta_p^2 = .02$]. Participants' ratings of their experience following each trial in the episodic memory conditions confirmed that they retrieved elements from the external environment to a greater extent in the external element condition than in the internal thought condition [$t(26) = 18.27$; $p < .001$; Cohen's $d = 3.58$] and, conversely, they retrieved more internal thoughts in the internal thought condition than in the external element condition [$t(26) = 24.30$; $p < .001$; Cohen's $d = 4.77$]. Responses for the semantic memory conditions also followed the expected pattern, with participants reporting more visual imagery for scene construction than conceptual reflection [$t(26) = 29.92$; $p < .001$; Cohen's $d = 5.87$] and more inner speech for conceptual reflection than scene construction [$t(26) = 29.21$; $p < .001$; Cohen's $d = 5.73$] (see the Supplementary Material for more detailed behavioral results).

fMRI results

Perceptual versus reflective representations

We first examined the main effect of the nature of retrieved information (perceptual versus reflective) to identify the brain regions involved in the processing of perceptual elements versus reflective thoughts, independently of the kind of memory representations under consideration (episodic or semantic).

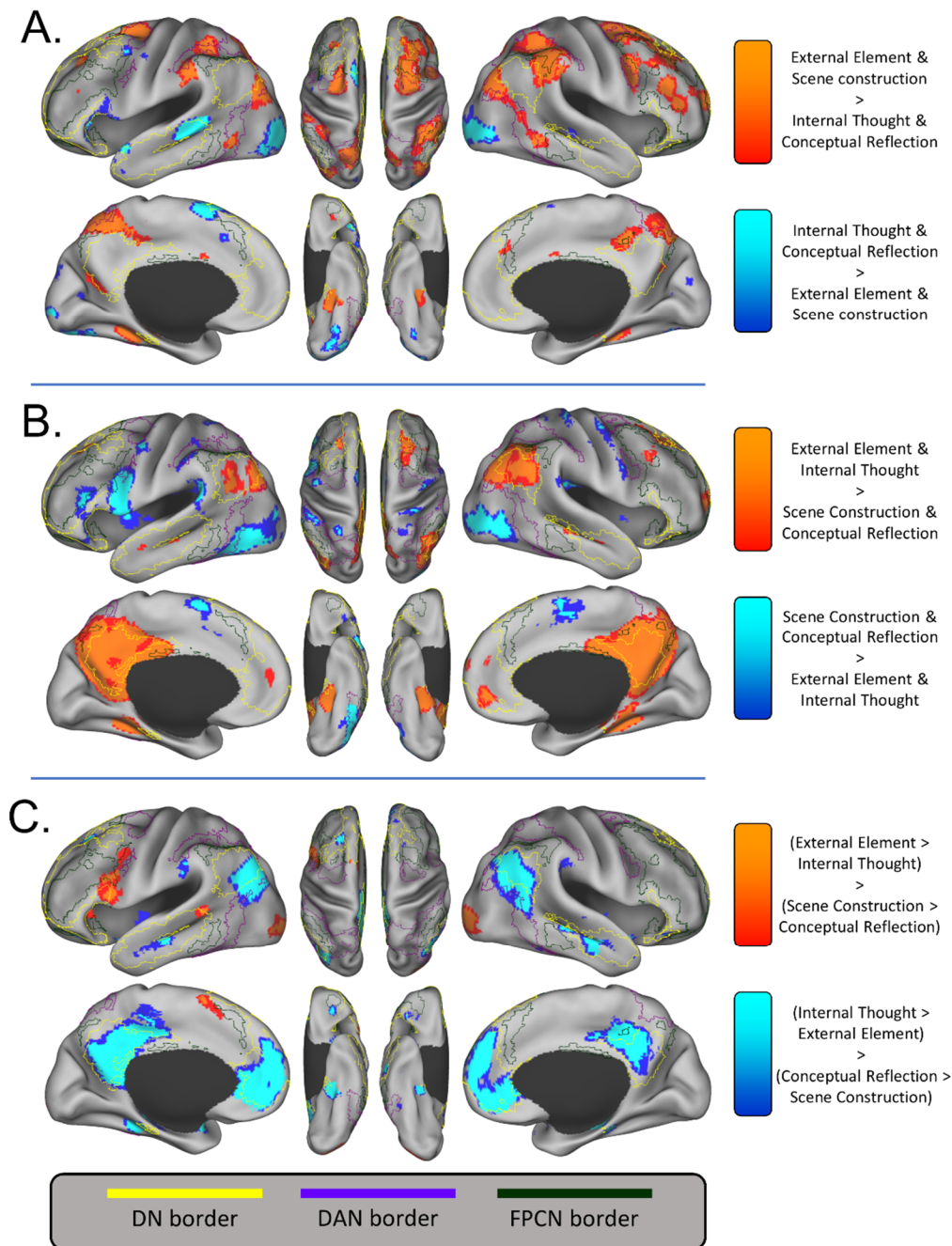


Figure 2. Brain regions activated in the contrasts pertaining to the 2 Representation (perceptual versus reflective) \times 2 Memory (episodic versus semantic) factorial design. Panels **A.** and **B.** respectively show the main effects of representation and memory type. Panel **C.** shows the interaction effects. For all three panels orange/cyan colors correspond to the brain activations that were significant at $p < .05$ (FWE corrected for multiple comparisons) over the whole brain and red/blue colors correspond to the additional brain activations that were significant at $p < .05$ (FWE corrected for multiple comparisons over masks of the networks of interest). Activations are displayed on an inflated surface map (population average landmark surface: PALS-B12) using CARET software (Van Essen 2005).

Results showed that the mental representation of perceptual elements (External Elements and Scene construction > Internal Thoughts and Conceptual Reflection) was mainly associated with increased activation in bilateral DAN and right FPCN areas, including the bilateral frontal eye fields, superior and inferior parietal lobule, temporal motion complex, as well as the right inferior precentral sulcus for the DAN, and the right rostral and dorsolateral prefrontal cortex as well as the anterior inferior parietal cortex

for the FPCN (see Fig. 2a, Table S3). Some activated voxels were located in DN areas (mostly in the lateral prefrontal cortex, posterior inferior parietal cortex, and midline parietal areas) but an examination of Fig. 2a shows that these voxels belonged to clusters that were mainly located in the DAN or FPCN and slightly extended into DN areas. To get a quantitative estimation of the extent of brain activations in each of the three networks, we computed the number of voxels activated in each network relative to the total number of voxels comprised in each corresponding mask. This analysis showed that the representation of perceptual elements was associated with an activation of 57% of the total number of voxels within the DAN, 28% of the total number of voxels within the FPCN, and only 4% of the total number of voxels within the DN. Outside of these three networks, other notable clusters of activation were found in the bilateral posterior parahippocampal cortex.

The reverse contrast (Internal Thoughts and Conceptual Reflection > External Elements and Scene construction) revealed some clusters of activation in DN areas, mostly in the left lateral temporal cortex and left inferior frontal gyrus, but these accounted for only 6% of the total number of voxels in the DN mask (see Fig. 2a, Table S4). Almost no voxels were activated in the DAN (0.03%) or FPCN (0.13%). Outside of the three networks of interest, activity was detected in the bilateral occipital cortex and right cerebellum.

Episodic versus semantic memory retrieval

Next, we examined the brain regions that exhibited differential activity for episodic versus semantic memory retrieval, independently of the reflective versus perceptual nature of represented information (see Fig. 2b, Table S5). First, we found that the episodic memory conditions were associated with increased activation in posterior DN regions, with the largest clusters of activity being located in the bilateral posterior inferior parietal lobule and posterior cingulate cortex/precuneus. Smaller clusters were also found in the lateral temporal cortex, parahippocampal cortex, and prefrontal cortex. In total, 29% of DN voxels were activated in this contrast. Some clusters of activation were also located in the FPCN (accounting for 12% of FPCN voxels), including the right lateral prefrontal and parietal cortices, as well as the precuneus. Finally, some activity was also found in posterior areas of the DAN (accounting for a total of 10% of DAN voxels), but it mostly consisted of DN and FPCN clusters that extended to the DAN. Outside the three masks, additional activity was also found in the posterior hippocampus and parahippocampal areas, bilaterally.

The only region of the DN showing higher activation during semantic compared to episodic memory tasks was the left inferior frontal gyrus (2% of DN voxels). Other clusters of activation were located in the FPCN, more specifically in the left inferior frontal gyrus and precentral sulcus (4% of FPCN voxels). Finally, activations in the DAN were also detected, particularly in the left posterior inferior temporal gyrus extending to occipital areas, the left precentral sulcus, and the left lateral parietal cortex (13% of DAN voxels). For this contrast, substantial activation was found outside the three networks of interest, with clusters of activation being located in the bilateral occipital cortex, supramarginal gyrus, inferior frontal gyrus, precentral and postcentral sulci, and cerebellum (see Fig. 2b, Table S6).

Common and differential activity for reflective versus perceptual representations in episodic and semantic memory

As expected, the preceding analyses indicated that the DAN and right FPCN were activated when mentally representing aspects of the external environment. On the other hand, the main effects showed only a modest activation of the DN when representing internal thoughts, with no significant activation in core DN regions. To investigate the possibility that the contribution of DN areas to reflective representations

may depend on the kind of memory involved (i.e., episodic versus semantic), we examined brain regions that were associated with the following interaction term: [(Internal Thought > External Element) > (Conceptual Reflection > Scene Construction)] (see Fig. 2c, Table S7). This revealed large clusters of activation in the DN, especially in its core regions (medial prefrontal and posterior cingulate cortices) and in the bilateral posterior inferior parietal lobules and lateral temporal cortex. In total, 42% of DN voxels were activated in this contrast. This interaction term was also associated with a small cluster of activation in the FPCN, more specifically in the precuneus (1% of FPCN voxels), and some activations in the DAN were also detected (representing 6% of total DAN voxels), which were mostly located ventrally to the posterior inferior parietal lobules and corresponded to extensions of DN clusters. Outside the three masks, substantial activity was also found in the bilateral medial temporal lobe, including the hippocampus/parahippocampal gyrus and amygdala.

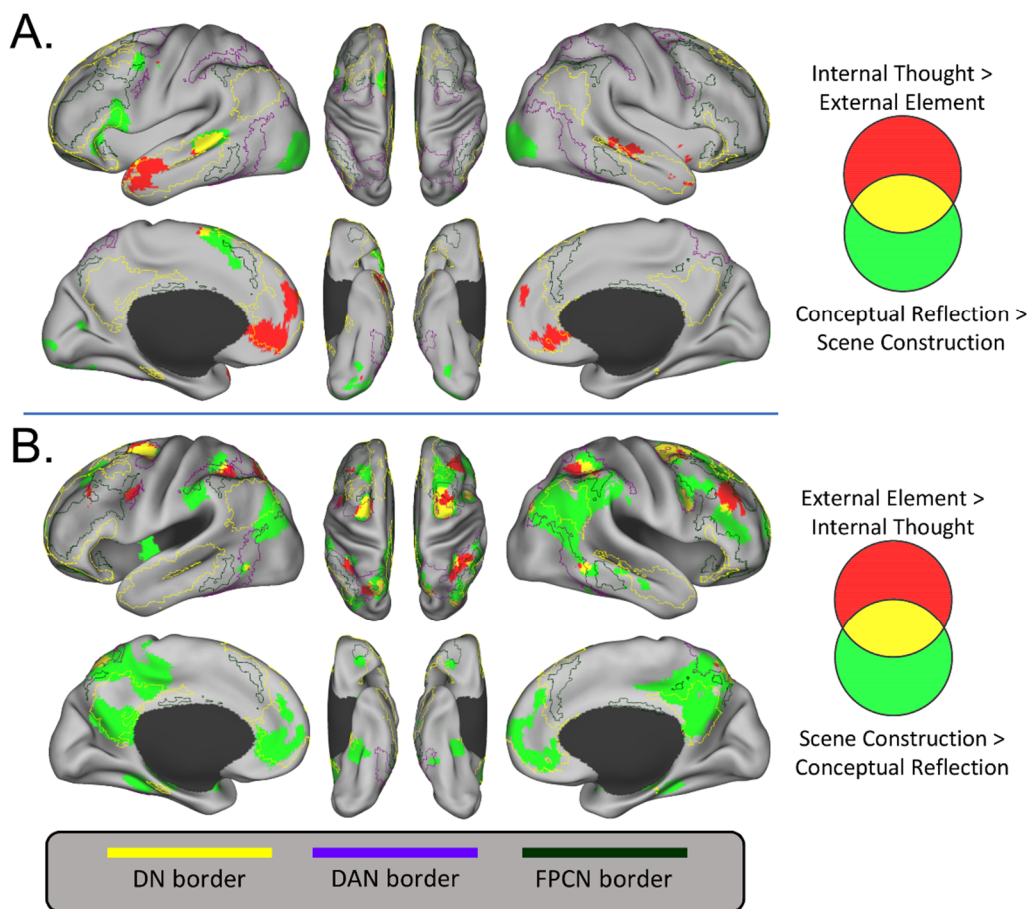


Figure 3 Panel **A.** illustrates the brain regions showing common and specific activation when representing reflective versus perceptual information in episodic and semantic memory. Panel **B.** illustrates the brain regions showing common and specific activation when representing perceptual versus reflective information in episodic and semantic memory. Both panels are displayed at $p < .05$ (corrected for multiple comparisons over masks of the networks of interest) on an inflated surface map (population average landmark surface: PALS-B12) using CARET software (Van Essen 2005).

Single contrasts performed for each type of memory retrieval confirmed that episodic memory for reflective versus perceptual information was associated with DN activations, more specifically in the medial prefrontal cortex, bilateral temporal cortex, left temporal pole, and left inferior frontal gyrus (Fig. 3a, Table S8). The corresponding contrast for semantic memory (Conceptual Reflection > Scene Construction) revealed DN activity in the left dorsolateral prefrontal cortex, inferior frontal gyrus, lateral temporal cortex,

and supplemental motor area, but not in the medial prefrontal cortex. A null conjunction analysis revealed that these two contrasts overlapped only in the posterior middle/superior temporal gyrus (MNI coordinates: -50, -38, 4; cluster size $k = 107$; $t = 6.24$).

The other interaction term [(External Element > Internal thought) > (Scene Construction > Conceptual Reflection)] did not reveal substantial activation in either of the three networks of interest (see Fig. 2c, Table S9), suggesting that the processing of perceptual information in episodic and semantic memory involves largely similar brain areas. To further determine the extent of overlapping activity when representing perceptual (versus reflective) information in episodic and semantic memory, we computed a null conjunction analysis: [(External Element > Internal thought) \cap (Scene Construction > Conceptual Reflection)]. This analysis revealed clusters of overlapping activity in the DAN (see Fig. 3b, Table S10), more specifically in the bilateral frontal eye fields, dorsal precuneus, superior and anterior inferior parietal lobule, temporal motion complex, and right precentral sulcus. In addition, overlapping activity was found in the right lateral prefrontal cortex and anterior inferior parietal lobule from the FPCN. No overlapping activity was found in the DN. The complete sets of regions activated in each of these two contrasts are presented in Table S11 and S12.

In summary, the above analyses show that the DAN and right FPCN are more activated when processing perceptual compared to reflective representations in both episodic and semantic memory. On the other hand, the recruitment of core DN areas (and in particular the medial prefrontal cortex) when processing reflective thoughts seems specific to episodic remembering. Additional ROI analyses confirmed these patterns of activation in the three networks across the four conditions and further demonstrated that the level of medial prefrontal and overall DN activity was highest during the episodic remembering of internal thoughts (see Supplemental Material).

DISCUSSION

The main goal of the present study was to investigate the neural correlates of the retrieval of internal thoughts and elements from the external environment experienced during real-life events. Our results showed that remembering these external and internal aspects of prior experience activated DN and FPCN regions that have been previously associated with episodic recollection (Addis et al. 2012; Benoit and Schacter 2015; Kim 2012; Moscovitch et al. 2016; Rugg and Vilberg 2013; Spreng et al. 2009). Episodic remembering was associated with particularly marked activity in posterior regions of the DN, which might support the retrieval and integration of episodic details to form coherent representations of past events (Addis et al. 2004; Gilmore et al. 2017; Martinelli et al. 2013). More importantly, however, episodic remembering was also associated with distinct activation profiles depending on the nature of the retrieved information: remembering external elements relied to a greater extent on the bilateral DAN and right FPCN, whereas memories for internal thoughts were associated with higher activity in some DN regions, notably the medial prefrontal and lateral temporal cortices. Our second aim was to determine whether these brain regions are specifically involved in remembering external versus internal elements of past episodes or whether they are also engaged when processing perceptual versus reflective information in semantic memory. We found that the DAN and FPCN were engaged when representing perceptual information in both episodic and semantic memory. On the other hand, the recruitment of some DN areas (particularly the medial prefrontal cortex) for reflective representations was specific to episodic memory.

Previous neuroimaging studies have shown that remembering real-life events recruits an extended brain network mostly comprising DN and fronto-parietal areas (Addis et al. 2004, 2012; Benoit and Schacter

2015; Cabeza and St Jacques 2007; Kim 2012; McDermott et al. 2009; Spreng et al. 2009). This widespread brain activity suggests that memory for complex, real-life events involves the retrieval and binding of various types of information that were processed at the time of encoding, including visuo-spatial representations of the environment initially gathered through perceptual input and self-generated thoughts that were experienced during the remembered events (Andrews-Hanna, Saxe, et al. 2014). Little is known, however, about how self-generated thoughts are processed within episodic memory. Here we showed that remembering such thoughts involves specific sections of the DN: the medial prefrontal cortex and the dorsal medial subsystem (including the temporal pole, lateral temporal cortex, and dorsal medial prefrontal cortex). Activity was particularly prominent in the medial prefrontal cortex, in line with previous studies showing activation of this region when remembering internal mentation in the context of laboratory memory tasks, such as previous cognitive operations performed on task stimuli (Simons et al. 2005, 2017) or source information about previously imagined stimuli (Turner et al. 2008).

The medial prefrontal cortex and dorsal medial subsystem of the DN have been associated with reflective and introspective processes (Andrews-Hanna et al. 2010; Andrews-Hanna, Smallwood, et al. 2014) and are among the key areas supporting the formation of self-generated thoughts (Christoff et al. 2016; Fox et al. 2015; Stawarczyk and D'Argembeau 2015; Stawarczyk et al. 2011). The activation of these regions when remembering internal thoughts may reflect the cortical reinstatement of the brain activity involved in the initial formation of these thoughts during prior episodes. It is now well established that the brain regions supporting the encoding of external information in episodic memory are partially reactivated when that information is later remembered, suggesting that the process of remembering an episode involves returning to the brain state that was present during that particular episode (Danker and Anderson 2010). This reinstatement process has previously been demonstrated in sensory and temporal areas for the retrieval of various aspects of external stimuli (e.g., contextual associations; Danker and Anderson 2010; Gordon et al. 2014; Wheeler et al. 2000). Our results suggest that a similar replay of neural activity occurs in some DN areas when remembering internal thoughts. Studies using techniques such as multi-voxel pattern analyses could be conducted to further test this hypothesis, and to investigate whether the reinstatement of particular patterns of brain activity is involved in the remembrance of various forms of internal mentation such as, for instance, episodic future thoughts (Schacter et al. 2012; Szpunar 2010; Szpunar et al. 2014), creative ideas (Beaty et al. 2016; Ellamil et al. 2012), and counterfactual thoughts (Schacter et al. 2015; Van Hoeck et al. 2013).

While our findings suggest that specific regions of the DN support the retrieval of inner thoughts, the precise processing operations implemented in these regions remain to be determined. In this respect, the role of the medial prefrontal cortex deserves further discussion. Possible explanations of the observed activity include that the medial prefrontal cortex represents records of cognitive operations involved in self-generated thoughts (Simons et al., 2017), mediates self-reflection processes (Murray et al. 2012; Northoff et al. 2006; van der Meer et al. 2010) or mentalizing (Spreng et al. 2009; Van Overwalle 2009), or represents the subjective value of remembered contents (D'Argembeau 2013; Lin et al. 2016). Another possibility is that the observed medial prefrontal activity reflects the influence of pre-existing knowledge structures, such as personal goals and schemas, on memory retrieval (Gilboa and Marlatte 2017; Stawarczyk and D'Argembeau 2015; van Kesteren et al. 2012), which may contribute to remembering internal aspects of prior experience. The role of the medial prefrontal cortex in schema processing might also explain the intermediate level of medial prefrontal activity that was observed during scene construction in the present study (i.e., medial prefrontal activity in the scene construction condition was lower than in the internal

thought condition, but higher than in the external element condition; see Supplemental Material). Indeed, it is likely that in the absence of a specific past event of reference, the scenes that participants mentally constructed relied to a large extent on schematized knowledge about the imagined places and objects, whereas memories for external elements of the walk depended more on episodic details processed in the medial temporal lobes and posterior regions of the DN (Bonnici et al. 2013; Bonnici and Maguire 2017; Gilmore et al. 2017).

Our finding that the medial prefrontal cortex showed increased activation when processing reflective versus perceptual representations in episodic but not semantic memory might also be related to differences in the personal relevance of represented contents in the two memory conditions. Indeed, in the episodic memory condition, remembered mentation mainly referred to personal reflections on environmental stimuli (46% of thoughts) or personal thoughts that were unrelated to the walk (18% of thoughts; see Supplementary Material), whereas the corresponding semantic memory condition required participants to process non-personal conceptual information (i.e., the meaning of abstract words). In future studies, it would thus be interesting to compare the episodic retrieval of inner thoughts with tasks that involve the processing of semantic representations that are more personally relevant (Renoult et al. 2012), such as personality trait judgments (Kelley et al. 2002) or theory of mind and other social cognition tasks (Spreng et al. 2009; Van Overwalle 2009).

Another important finding of the present study is that the DAN showed higher activity when remembering external elements compared to internal thoughts, and also when processing perceptual versus reflective representations in semantic memory. There is ample evidence that the DAN supports the top-down allocation of attention to visuo-spatial features of the external environment (Corbetta and Shulman 2002). However, recent studies suggest that this network may not be exclusively involved in controlling attention to the external world but may also contribute to memory retrieval (Kragel and Polyn 2015; Wantz et al. 2016). Our results fit well with these findings and further suggest that DAN activity during episodic and semantic memory retrieval may reflect a greater focus of attention on mental representations of the external world rather than internal thoughts. Taken together, the present and previous findings thus suggest that the DAN may not only support the top-down processing of stimuli from the immediate external environment, but also the controlled allocation of attention to visuo-spatial features within episodic and semantic memory representations. This view is consistent with previous studies showing overlapping activation in DAN areas when orienting attention to locations in the external world or within mental representations (e.g., Nobre et al. 2004; Dobbins and Wagner 2005). Furthermore, our data are also in line with the proposal that some regions of the DAN (such as the superior parietal lobe) mediates top-down attention to episodic memory contents (Cabeza et al. 2008), and further suggest that such process is particularly engaged when attention focuses on representations of the external environment within memory representations.

Interestingly, the proposal that the DAN supports top-down visuo-spatial processing for both external stimuli and internal representations is paralleled by recent findings showing that the DN, for its part, is not exclusively involved in internal mentation but can also be recruited during externally oriented tasks, provided that the processing of perceived stimuli can benefit from prior internal knowledge (Bar 2004; Crittenden et al. 2015; Konishi et al. 2015; Spreng et al. 2014). Importantly, a recent study investigating the functional connectivity of the DN and DAN across a wide range of tasks has shown that, on average, the DN and DAN have an independent rather than anticorrelated relationship (Dixon et al. 2017). When considered together with the present study, these findings suggest that the DAN and DN might

not consist of purely opposing networks defined by their role in processing exclusively external versus internal information, as is often assumed in the neuroscientific literature (e.g., Fox et al. 2005; Sestieri et al. 2010, 2017). Instead, a growing body of evidence suggests that the DAN and DN support different cognitive functions (i.e., top-down visuo-spatial processing versus the activation and manipulation of internal mentation or knowledge) that can be applied, in varying degrees, to the processing of both externally derived and internally generated representations, depending on task goals or other environmental circumstances (Spreng et al. 2014; Crittenden et al. 2015; Konishi et al. 2015; Kragel and Polyn 2015; Dixon et al. 2017).

Finally, besides the DN and DAN, our results showed that the right FPCN was activated when forming episodic and semantic representations of the external environment. The FPCN is commonly engaged in the remembrance of complex daily life events and might support the strategic retrieval, monitoring, and recombination of memory details to form an integrated and coherent representation of remembered events (Benoit and Schacter 2015; St Jacques and Cabeza 2012; St Jacques and De Brigard 2015). The present findings suggest that the right FPCN might be more specifically involved in the retrieval of perceptual memory components, in agreement with previous findings on source memory judgments (Dobbins and Wagner 2005). Furthermore, our results suggest that the role of the right FPCN in retrieving perceptual information is not restricted to episodic remembering but extends to the formation of mental scenes of the external environment based on semantic memory.

To conclude, the present study provides new insights into how different aspects of prior experience from real-life events are processed during episodic remembering. Specifically, our findings revealed that the retrieval of internal versus external aspects of prior experience was associated with different activation profiles within large-scale brain networks: the remembrance of previous thoughts mainly relied on some DN areas (in particular, medial prefrontal and lateral temporal cortices), suggesting a reinstatement of the brain activity involved in the initial formation of these thoughts, whereas the retrieval of external elements recruited the right FPCN and the DAN, a set of brain areas known to support top-down visuo-spatial processing. Furthermore, our results showed that the DAN and right FPCN were engaged when retrieving information about the external environment from both episodic and semantic memory, whereas the recruitment of some DN areas (in particular the medial prefrontal cortex) when retrieving internal representations was specific to episodic memory. Future studies should be conducted to determine whether these distinct contributions of the DN and DAN in the processing of reflective versus perceptual information are specific to memories or extend to other kinds of mental representations such as, for instance, future thoughts (Schacter et al. 2012; Szpunar 2010; Szpunar et al. 2014) or counterfactual thoughts (Schacter et al. 2015; Van Hoeck et al. 2013). Furthermore, it would also be interesting to investigate whether the brain networks supporting memory for internal mentation versus external stimuli evolve with age. Indeed, older adults tend to remember more thoughts, but fewer perceptual and spatial details, than younger adults (Hashtroudi et al. 1990), suggesting that aging might be associated with a shift in the balance between perceptual and reflective information within episodic memory representations (Maillet and Rajah 2014).

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Supplementary Material

Supplementary Results

fMRI task performance

The time needed to access information differed between conditions [$F(3, 78) = 10.15; p < .001; \eta_p^2 = .28$], with post-hoc tests showing that response times (RTs) were slower in the external element than in the internal thought condition, and slower in the conceptual reflection condition than in both the internal thought and scene construction conditions (all p 's $< .05$, Bonferroni corrected). Although these differences in RTs were statistically significant, it should be noted that they were relatively small compared to the duration of the main phase of each trial that was modelled in the fMRI analyses, with the largest difference being tasks being less than 800 ms (representing a difference of 6% in the mean duration of trials between conditions; see Table S2).

Post-scan Debriefing

In their answer to the Likert scales in the post-scan debriefing, participants reported that they somewhat suspected that the walk would be followed by a memory task ($M = 4.58; SD = 1.45$), although none of them knew what the nature of this task would be or reported to expect that they will be asked to remember their thoughts in the scanner. There was a significant difference in the subjective ratings of difficulty between conditions [$F(3, 78) = 5.51; p = .002; \eta_p^2 = .17$], with post-hoc tests revealing that the scene construction condition was judged easier than the two episodic memory conditions (both p 's $< .05$, Bonferroni corrected, see Table S3 for descriptive statistics); note, however, that difficulty ratings were below the midpoint of the scale (i.e., 4 corresponding to 'moderately easy/difficult') for all conditions, suggesting that participants experienced no difficulty in generating the required mental representations. The number of times in which participants reported having erroneously retrieved the same information in different trials was very low and did not differ between the two memory conditions [$t(26) = .08; p = .94$; Cohen's $d = .02$], the number of times that participants reported having remembered something shown on the pictures for the external element condition (rather than an additional element as specified by the instructions) was also very low ($M = 0.37; SD = 0.95$). Finally, the Likert scales confirmed that the scenes imagined by the participants in the scene construction condition did not involve memories of specific events ($M = 1.59; SD = 0.75$), indicating that, as requested, participants were able to mentally construct scenes that were uncontaminated by episodic details from specific past events.

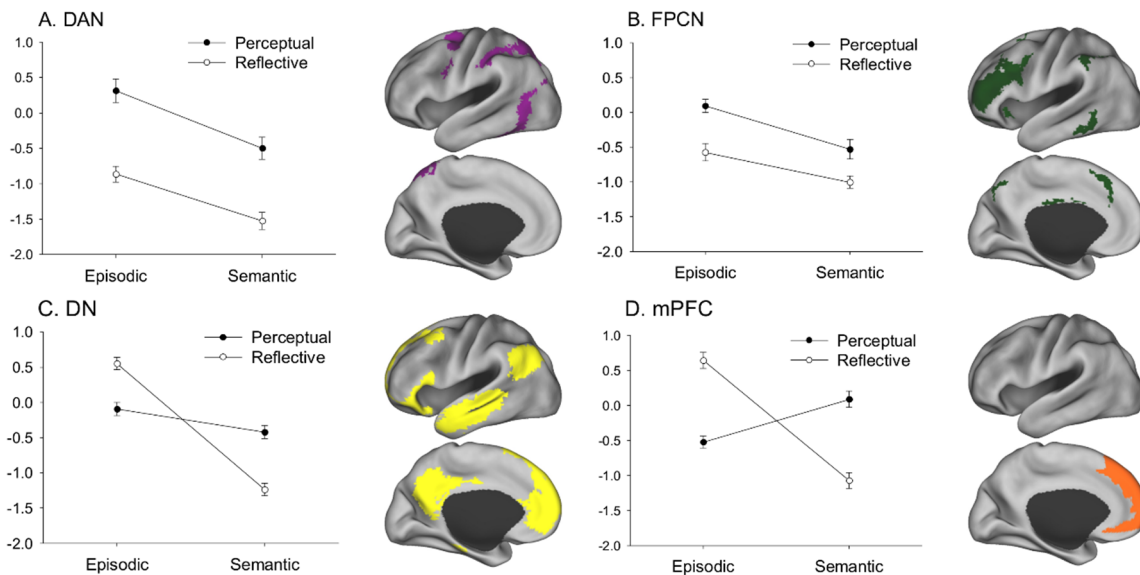
Finally, to get an idea of the kind of episodic details that were recalled during the fMRI session, we analyzed the content of the five internal thoughts and five external elements trials that the participants were asked to describe in the post-scan debriefing. The external elements were classified into two categories: (1) 'objects' when the memories were mainly focused on inanimate objects such as cars, busses, or (parts of) buildings and construction sites, and (2) 'person' when the memories were mainly focused on a single or a group of individuals. The internal thoughts were classified into three categories: (1) 'Instruction-related' when the participants were thinking about what they had to do during the walk (e.g., wondering which way to take to go to the cafeteria after buying the newspaper), (2) 'stimulus-dependent' when the content of the thoughts was related to something that the participants directly perceived (e.g., thinking that the current weather was nice for an outside walk), and (3) 'stimulus-independent' when the content of the thought was focused on something that the participants were not directly perceiving (e.g., thinking about what to do after the experiment). Descriptions for 25 participants (data for two participants were missing) were classified by two independent raters (DS and OJ) and the interrater agreement was good for both conditions, with a Cohen's $\kappa = .98$ for external elements and $.74$ for internal thoughts. Of the 125 external element trials, 55% referred to objects and 38% to people, and participant reported that they did not exactly remember what they retrieved in the scanner for the remaining 6% of trials. For the internal thoughts, 27% were instruction-related, 46% were stimulus-dependent, and 18% were stimulus-independent; no responses were given for the remaining 8% of trials. These proportions of internal thoughts are consistent with previous studies on the occurrence of different types of thoughts during task performance (e.g., Stawarczyk et al. 2011).

ROI analyses of parameter estimates for each network of interest

To further determine the pattern of brain activity in the three networks of interest across the four conditions, we extracted the parameter estimates for each condition in each of the three masks from Yeo et al. 2011 (see Methods). For each network, we then computed a 2 Memory (episodic versus semantic) \times 2 Representation (perceptual versus reflective) ANOVAs on the extracted parameter estimates (see Fig. S1). For the DAN, the ANOVA revealed significant main effects of memory type [$F(1, 26) = 18.73; p < .001; \eta_p^2 = .42$] and representation type [$F(1, 26) = 32.85; p < .001; \eta_p^2 = .81$], but no interaction [$F(1, 26) = .30; p = .59; \eta_p^2 = .01$]. Similarly, the ANOVA for the FPCN revealed significant main effects of memory type [$F(1, 26) = 17.24; p < .001; \eta_p^2 = .40$] and representation type [$F(1, 26) = 25.76; p < .001; \eta_p^2 = .50$], but no interaction [$F(1, 26) = .79; p = .38; \eta_p^2 = .03$]. The ANOVA for the DN showed a different pattern of results with a significant main effect of memory type [$F(1, 26) = 93.86; p < .001; \eta_p^2 = .76$] and a significant interaction [$F(1, 26) = 127.74; p < .001; \eta_p^2 = .83$], but no main effect of representation type [$F(1, 26) = .86; p = .36; \eta_p^2 = .03$]. Bonferroni corrected post-hoc analyses revealed significant differences between each of the four conditions in DN activity (all p 's $< .001$, except $p = .008$ for the difference between the scene construction and external element conditions). As shown on Fig. S1, DN activity was highest when retrieving internal thoughts from episodic memory.

Finally, we also extracted the parameter estimates for each condition in the medial prefrontal cortex, based on an anatomical mask built from the AAL atlas (Rolls et al. 2015; Tzourio-Mazoyer et al. 2002). An ANOVA on these parameters estimates (see panel D on Fig. S1) revealed a significant main effect of memory type [$F(1, 26) = 25.27; p < .001; \eta_p^2 = .49$] and a significant interaction [$F(1, 26) = 127.74; p < .001; \eta_p^2 = .83$], but no effect of representation type [$F(1, 26) < .001; p = .98; \eta_p^2 < .001$]. Post-hoc analyses revealed significant differences between all of the four conditions (all p 's $< .01$, Bonferroni corrected). As can be seen from Fig. S1, medial prefrontal activity was highest when retrieving internal thoughts from episodic memory.

Figure S1. Mean parameter estimates for each experimental condition in each network of interest and in the mPFC



Note: DAN = Dorsal attention network; DN = Default network; FPCN = Fronto-parietal control network; mPFC = Medial prefrontal cortex. Error bars represent the standard error of the mean.

Table S1. Words used in the semantic memory conditions

	Scene Construction		Conceptual Reflection	
	French	English translation	French	English translation
1.	<i>Oreiller</i>	Pillow	<i>Dilemme</i>	Dilemma
2.	<i>Imprimante</i>	Printer	<i>Permission</i>	Permission
3.	<i>Chaussette</i>	Sock	<i>Hâte</i>	Haste
4.	<i>Balançoire</i>	Swing	<i>Avenir</i>	Future
5.	<i>Lampe</i>	Lamp	<i>Solution</i>	Solution
6.	<i>Pinceau</i>	Paintbrush	<i>Volonté</i>	Will
7.	<i>Cravate</i>	Necktie	<i>Catégorie</i>	Category
8.	<i>Bateau</i>	Boat	<i>Exigence</i>	Demand
9.	<i>Balle</i>	Ball	<i>Durée</i>	Duration
10.	<i>Peigne</i>	Comb	<i>Concept</i>	Concept
11.	<i>Ceinture</i>	Belt	<i>Opinion</i>	Opinion
12.	<i>Ciseaux</i>	Scissors	<i>Ordinaire</i>	Ordinary
13.	<i>Cartable</i>	Schoolbag	<i>Propos</i>	Remarks
14.	<i>Frigidaire</i>	Fridge	<i>Progrès</i>	Progress
15.	<i>Aspirateur</i>	Vacuum	<i>Introduction</i>	Introduction
16.	<i>Étagère</i>	Shelf	<i>Compromis</i>	Compromise
17.	<i>Miroir</i>	Mirror	<i>Simplicité</i>	Simplicity
18.	<i>Cadenas</i>	Padlock	<i>Variation</i>	Variation
19.	<i>Drapeau</i>	Flag	<i>Mystère</i>	Mystery
20.	<i>Guitare</i>	Guitar	<i>Format</i>	Format
21.	<i>Téléviseur</i>	Television	<i>Inverse</i>	Opposite
22.	<i>Couvercle</i>	Lid	<i>Pouvoir</i>	Power
23.	<i>Bague</i>	Ring (jewelry)	<i>Conséquence</i>	Consequence
24.	<i>Ticket</i>	Ticket	<i>Sélection</i>	Selection

Table S2: Means and standard deviations (in brackets) for the indices of task performance and responses to the post-scan debriefing questionnaire.

	External Element	Internal Thought	Scene Construction	Conceptual Reflection
Key press (%)	97.84 (3.72)	96.91 (4.71)	97.99 (3.34)	97.99 (4.23)
Trial duration (ms)	12,735 (1085)	13,199 (958)	12,888 (1149)	12,408 (1214)
EE rating	3.68 (0.28)	1.55 (0.45)	/	/
IT rating	1.42 (0.36)	3.74 (0.23)	/	/
VI rating	/	/	3.82 (0.24)	1.27 (0.29)
IS rating	/	/	1.26 (0.32)	3.84 (0.24)
Subjective difficulty	3.33(1.36)	2.93 (1.36)	1.89 (2.05)	2.78 (1.45)
Similar memories	1.74 (1.48)	1.72 (1.36)	/	/

Note: EE = external element, IT = internal thought, VI = visual imagery, IS = inner speech. The scores of the EE, IT, VI, and IS rating made during the task ranged from 1 = 'not at all' to 4 'a lot.' The scores for the post-scan subjective difficulty ratings ranged from 1 = 'very easy' to 7 = 'very difficult.' Similar memories are the mean number of times that the participants reported in the post-scan debriefing having remembered identical external elements or internal thoughts across different trials.

Table S3. Brain regions showing increased activity for perceptual vs reflective representations

Brain regions	Side	MNI coordinates			Cluster Size	<i>t</i>
		<i>x</i>	<i>y</i>	<i>z</i>		
1. DN clusters						
pIPL	L	-34	-80	36	86	10.34
	R	48	-70	28	34	8.08
Precuneus / PCC	L/R	-4	-40	48	30	8.20
	L	-10	-58	48	23	7.19
	L	-18	-60	22	72	6.08
SMG/aIPL	R	54	-44	32	62	6.59
Rostral IPFC	R	20	62	10	55	7.88
Dorsal IPFC	R	34	26	46	140	7.01
2. DAN clusters						
FEF	L	-28	-6	52	393	11.42
	R	32	0	52	436	12.08
Precuneus / aIPL / pIPL / SPL / Middle OC / MT+	L/R	-8	-64	58	2715	10.00
		-38	-84	30		10.94
		14	-68	48		10.22
		38	-42	48		8.68
		46	-78	28		7.89
		58	-48	-10		7.77
aIPL / SPL	L	-58	-32	42	401	8.17
MT+	L	-56	-66	4	124	8.58
Prec. Sulcus	R	42	6	26	259	10.18
3. FPCN clusters						
Prec. Sulcus / Dorsal IPFC / Rostral IPFC	R	24	14	58	1549	11.28
		44	8	38		8.57
		44	32	22		8.25
		36	32	42		7.56
		46	40	12		7.52
		24	58	12		7.46
Dorsal IPFC	L	-26	6	58	57	6.48
Precuneus	L/R	-8	-62	50	50	8.63
	L/R	2	-38	44	47	7.83
SPL / Middle OC	R	30	-72	48	62	6.84
SMG / aIPL	R	52	-34	44	513	11.14
Dorsal ACC / mPFC	R	8	34	32	32	6.13
4. Other clusters						
PHC	L	-36	-26	-18	427	11.94
	R	34	-28	-18	116	8.92
Insula	L	-46	-10	0	47	7.91
Cerebellum	L	-40	-50	38	25	7.49

Note: ACC = anterior cingulate cortex; aIPL = anterior inferior parietal lobule; DAN = Dorsal attention network; DN = Default network; FEF = Frontal eye fields; FPCN = Frontoparietal control network; IPFC = Lateral prefrontal cortex; MT+ = Temporal motion complex; OC = Occipital cortex; PCC = Posterior Cingulate Cortex; PHC = Parahippocampal cortex; pIPL = Posterior inferior parietal lobule; Prec. Sulcus = Precentral sulcus; SMG = Supramarginal gyrus; SPL = Superior parietal lobule. $p < .05$ (FWE corrected for multiple comparisons *over masks of the networks of interest or over the whole brain for the clusters falling outside these masks*) with a minimum cluster size of 20 voxels.

Table S4. Brain regions showing increased activity for reflective vs perceptual representations

Brain regions	Side	MNI coordinates			Cluster Size	<i>t</i>
		<i>x</i>	<i>y</i>	<i>z</i>		
1. DN clusters						
MTG / STG	L	-50	-38	4	327	10.51
SMA	L/R	-4	12	68	115	8.94
Ventral IPFC	L	-46	22	-10	321	8.78
Temporal Pole	L	-54	8	-14	36	7.98
2. DAN clusters						
	/	/	/	/	/	/
3. FPCN clusters						
	/	/	/	/	/	/
4. Other clusters						
OC	L	-32	80	-10	1108	10.56
	R	38	-82	0	608	8.57
Cuneus / Superior OC	L	-10	-94	30	33	7.24
Prec. Sulcus / Dorsal IPFC	L	-44	4	48	37	6.87
SMA	L/R	-4	4	62	353	8.54
Cerebellum	L	-18	-62	-20	36	6.85
	R	32	-58	26	460	8.78

Note: DAN = Dorsal attention network; DN = Default network; FPCN = Frontoparietal control network; IPFC = Lateral prefrontal cortex; MTG = middle temporal gyrus; OC = Occipital Cortex; SMA = Supplementary motor area; STG = Superior temporal gyrus. $p < .05$ (FWE corrected for multiple comparisons *over masks of the networks of interest or over the whole brain for the clusters falling outside these masks*) with a minimum cluster size of 20 voxels.

Table S5. Brain regions showing increased activity for episodic vs semantic memory retrieval

Brain regions	Side	MNI coordinates			Cluster Size	<i>t</i>
		<i>x</i>	<i>y</i>	<i>z</i>		
1. DN clusters						
pIPL / aIPL	L	-34	-80	36	581	8.60
		-48	-58	26		7.58
Rsp / PCC / Precuneus	R	44	-70	32	759	11.47
		50	-52	40		7.12
	L/R	16	-54	18	2287	12.91
mPFC	L/R	10	-46	36		12.19
		8	48	-6	220	7.12
MTG	L/R	8	48	18	32	5.71
	L	-12	50	10	63	5.83
	L	-62	-18	-10	57	6.21
PHC	R	60	-28	-8	62	6.60
	R	54	-8	-18	21	5.75
Dorsal IPFC	L	-28	-32	-16	23	7.30
Rostral IPFC	L	-24	-28	42	76	7.69
	R	26	28	44	167	7.66
	R	24	64	10	24	5.66
2. DAN clusters						
pIPL / Middle OC	L	-36	-84	32	71	8.42
	R	40	-72	30	106	10.83
Precuneus	L/R	10	-74	50	564	8.74
3. FPCN clusters						
pIPL / Middle OC	R	40	-78	40	226	8.15
Precuneus	L/R	14	-62	30	253	10.95
	L/R	8	-42	40	52	9.42
Middle Cingulate Cortex	L/R	-4	26	30	69	9.01
Dorsal IPFC	R	40	22	36	67	8.00
	R	26	20	48	151	6.43
Rostral IPFC	R	32	58	8	225	7.30
4. Other clusters						
PHC / Hippocampus	R	34	-38	-10	480	9.90
PHC / Hippocampus	L	-30	-44	-8	423	11.65

Note: aIPL = anterior inferior parietal lobule; DAN = Dorsal attention network; DN = Default network; FPCN = Frontoparietal control network; IPFC = Lateral prefrontal cortex; mPFC = Medial prefrontal cortex; MTG = Middle temporal gyrus; OC = Occipital cortex; PCC = Posterior Cingulate Cortex; PHC = Parahippocampal cortex; pIPL = Posterior inferior parietal lobule; Rsp = Retrosplenial cortex. $p < .05$ (FWE corrected for multiple comparisons over masks of the networks of interest or over the whole brain for the clusters falling outside these masks) with a minimum cluster size of 20 voxels.

Table S6. Brain regions showing increased activity for semantic vs episodic memory retrieval

Brain regions	Side	MNI coordinates			Cluster Size	<i>t</i>
		<i>x</i>	<i>y</i>	<i>z</i>		
1. DN clusters						
Ventral IPFC	L	-54	14	12	231	6.53
2. DAN clusters						
aIPL	L	-46	-36	42	257	6.96
SPL	R	22	-52	70	47	5.93
MT+ / ITG / Middle OC / inferior OC	L	-46	-50	-18	411	8.53
		-40	-66	0		
Prec. Sulcus	L	-50	6	24	110	8.96
	L	-42	-4	50	21	6.20
	R	58	10	32	40	6.85
Postc. Sulcus	R	60	-20	48	37	6.80
3. FPCN clusters						
Prec. Sulcus / Ventral IPFC	L	-48	10	24	53	8.21
Ventral IPFC	L	-50	36	12	195	7.67
4. Other clusters						
OC	L	-40	-68	-2	468	8.87
	L	-34	-88	10	31	6.86
	R	44	-70	-2	652	8.17
SMG	L	-56	-40	24	131	8.37
	R	42	-34	22	83	7.47
Cerebellum	L	-8	-54	-12	105	7.99
	R	28	-66	22	135	8.13
SMA	L/R	0	0	64	253	7.29
Prec. Sulcus / Ventral IPFC	L	-52	8	24	570	9.63
Postc. Sulcus	R	32	-40	72	144	7.24

Note: aIPL = anterior inferior parietal lobule; DAN = Dorsal attention network; DN = Default network; FPCN = Frontoparietal control network; ITG = Inferior temporal gyrus; IPFC = Lateral prefrontal cortex; OC = Occipital cortex; Postc. Sulcus = Postcentral sulcus; Prec. Sulcus = Precentral sulcus; SMA = Supplementary motor area; SMG = Supramarginal gyrus; SPL = Superior parietal lobule. $p < .05$ (FWE corrected for multiple comparisons *over masks of the networks of interest or over the whole brain for the clusters falling outside these masks*) with a minimum cluster size of 20 voxels.

Table S7. Brain regions showing increased activity for reflective vs perceptual representations during episodic compared to semantic memory retrieval [(Internal Thought > External Element) > (Conceptual Reflection > Scene Construction)]

Brain regions	Side	MNI coordinates			Cluster Size	<i>t</i>
		<i>x</i>	<i>y</i>	<i>z</i>		
1. DN clusters						
pIPL	L	-48	-72	30	454	12.85
	R	50	-60	28	674	10.31
Rsp / PCC / Precuneus	L/R	14	-44	34	1609	10.81
		-6	-52	14		9.71
mPFC	L/R	-2	54	10	2762	9.93
		-2	48	24		9.47
		8	50	-12		9.42
Dorsal mPFC	R	14	48	40	27	5.95
MTG	L	-62	-18	-14	159	7.41
MTG / ITG	R	58	-12	24	409	8.51
PHC	L	-28	-32	-16	27	10.35
Dorsal IPFC	L	-24	28	46	141	7.47
Rostral IPFC	L	-18	62	10	29	6.33
Orbitofrontal cortex	R	40	32	-14	22	6.49
2. DAN clusters						
pIPL / Middle OC	L	-46	-78	28	91	11.20
	L	-44	-70	20	46	8.15
pIPL / Middle OC / MTG	R	46	-62	20	230	7.43
Fusiform Gyrus	R	44	-44	-18	28	5.87
3. FPCN clusters						
Precuneus	R	4	-42	40	53	10.28
4. Other clusters						
PHC / Hippocampus	L	-28	-34	-16	276	10.89
	R	26	-28	-18	184	9.77
SMG	R	60	-30	-30	25	6.75
Insula	R	40	-10	-10	20	6.55
Amygdala	L	-30	2	-18	99	10.07
	R	34	2	16	39	7.47
Orbitofrontal cortex	L	-26	34	-14	23	7.11

Note: DAN = Dorsal attention network; DN = Default network; FPCN = Frontoparietal control network; ITG = Inferior temporal cortex; IPFC = Lateral prefrontal cortex; mPFC = Medial Prefrontal Cortex; MTG = Middle temporal gyrus; OC = Occipital cortex; PCC = Posterior Cingulate Cortex; PHC = Parahippocampal Cortex; pIPL = Posterior inferior parietal lobule; Rsp = Retrosplenial Cortex; SMG = Supramarginal gyrus. *p* < .05 (FWE corrected for multiple comparisons *over masks of the networks of interest or over the whole brain for the clusters falling outside these masks*) with a minimum cluster size of 20 voxels.

Table S8. DN activity for reflective vs perceptual representations within each type of memory retrieval (episodic and semantic)

Brain regions	Side	MNI coordinates			Cluster Size	<i>t</i>
		<i>x</i>	<i>y</i>	<i>z</i>		
1. Internal Thoughts > External Elements						
Dorsal mPFC	L/R	-2	58	22	171	8.83
mPFC	L/R	-4	40	-8	311	7.5
		-4	54	-2		5.22
MTG / STG	L	-50	-36	-2	205	7.99
MTG	R	54	-20	-12	22	5.87
	R	56	-30	4	20	5.75
Temporal Pole	L	-54	4	-16	299	7.83
Ventral IPFC	L	-40	26	-6	42	5.65
2. Conceptual Reflection > Scene Construction						
MTG / STG	L	-52	-40	6	303	10.50
SMA	L	-6	16	68	123	9.28
Ventral IPFC	L	-46	22	-2	431	9.26
Dorsal IPFC	L	-40	6	46	23	6.58

Note: IPFC = Lateral prefrontal cortex; mPFC = Medial prefrontal cortex; MTG = Middle Temporal Gyrus; SMA = Supplementary motor area; STG = Superior temporal gyrus. $p < .05$ (FWE corrected for multiple comparisons *over the DN mask*) with a minimum cluster size of 20 voxels.

Table S9. Brain regions showing increased activity for perceptual vs reflective representations during episodic compared to semantic memory retrieval [(External Element > Internal thought) > (Scene Construction > Conceptual Reflection)]

Brain regions	Side	MNI coordinates			Cluster Size	<i>t</i>
		<i>x</i>	<i>y</i>	<i>z</i>		
1. DN clusters						
MTG / STG	L	-52	-42	4	34	6.47
Ventral IPFC	L	-54	14	12	136	7.43
	L	-46	24	-4	55	6.47
2. DAN clusters						
		/	/	/	/	/
3. FPCN clusters						
Prec. Sulcus / Ventral IPFC	L	-48	12	28	171	9.41
4. Other clusters						
OC	L	-26	-96	-4	149	7.92
	R	34	-92	-4	233	7.42
Cerebellum	R	30	-60	-30	206	8.22

Note: DAN = Dorsal attention network; DN = Default network; FPCN = Frontoparietal control network; IPFC = Lateral prefrontal cortex; MTG = Middle temporal gyrus; OC = Occipital cortex; Prec. Sulcus = Precentral Sulcus; STG = Superior temporal gyrus. $p < .05$ (FWE corrected for multiple comparisons *over masks of the networks of interest or over the whole brain for the clusters falling outside these masks*) with a minimum cluster size of 20 voxels.

Table S10. Brain regions showing common activity when representing perceptual vs reflective information in episodic and semantic memory (External Element > Internal thought) \cap (Scene Construction > Conceptual Reflection)

Brain regions	Side	MNI coordinates			Cluster Size	<i>t</i>
		<i>x</i>	<i>y</i>	<i>z</i>		
1. DN clusters						
	/	/	/	/	/	/
2. DAN clusters						
FEF	L	-24	-6	52	228	6.59
	R	22	-4	60	310	6.48
Precuneus / SPL	L	-10	-66	54	281	7.68
	R	14	-70	48	62	6.37
	R	8	-64	60	18	5.22
aIPL	L	-32	-42	44	99	6.12
	R	36	-44	50	219	6.64
pIPL/ Middle OC	R	38	-76	30	62	6.84
Middle OC	L	-40	-86	26	14	5.85
Prec. Sulcus	R	11	8	26	150	7.05
MT+	L	-64	-52	8	18	5.41
	R	58	-48	-10	9	5.11
3. FPCN clusters						
Dorsal IPFC	R	26	14	56	119	6.56
	R	46	32	22	46	6.08
	R	36	32	42	9	5.19
aIPL	R	46	-46	50	87	5.73
4. Other clusters						
	/	/	/	/	/	/

Note: aIPL = Anterior inferior parietal lobule; DAN = Dorsal attention network; DN = Default network; FEF = Frontal eye fields; FPCN = Frontoparietal control network; IPFC = Lateral prefrontal cortex; MT+ = Temporal motion complex; OC = Occipital cortex; pIPL = Posterior inferior parietal lobule; Prec. Sulcus = Precentral Sulcus; SPL = Superior parietal lobule. $p < .05$ (FWE corrected for multiple comparisons over masks of the networks of interest).

Table S11. Brain activity for external vs internal representations within episodic memory (External Element > Internal Thoughts)

Brain regions	Side	MNI coordinates			Cluster Size	<i>t</i>
		<i>x</i>	<i>y</i>	<i>z</i>		
1. DN clusters						
	/	/	/	/	/	/
2. DAN clusters						
FEF	L	-24	-4	60	329	8.84
	R	28	4	54	395	9.27
aIPL / SPL	L	-34	-46	46	191	6.40
	R	36	-44	46	340	7.83
		38	-54	48		5.71
MT+	L	-56	-64	-6	31	5.99
	R	56	-48	8	52	7.25
Prec. Sulcus	L	-44	2	32	31	7.31
	R	46	8	24	138	6.81
Precuneus / SPL	L	-12	-62	54	422	6.68
		-22	-64	48		6.56
	R	14	-62	52	185	6.04
pIPL / Middle OC	L	-40	-86	26	28	6.50
	R	36	-76	34	59	6.39
3. FPCN clusters						
Dorsal IPFC	L	-22	10	64	28	5.59
	L	-40	32	36	110	6.13
	R	30	6	58	179	9.53
	R	40	32	30	352	8.08
aIPL / SMG	R	44	-42	44	191	8.37
4. Other clusters						
	/	/	/	/	/	/

Note: aIPL = Anterior inferior parietal lobule; DAN = Dorsal attention network; DN = Default network; FEF = Frontal eye fields; FPCN = Frontoparietal control network; IPFC = Lateral prefrontal cortex; MT+ = Temporal motion complex; OC = Occipital cortex; pIPL = Posterior inferior parietal lobule; Prec. Sulcus = Precentral Sulcus; SMG = Supramarginal gyrus; SPL = Superior parietal lobule. $p < .05$ (FWE corrected for multiple comparisons *over masks of the networks of interest*) with a minimum cluster size of 20 voxels.

Table S12. Brain activity for external vs internal representations within semantic memory (Scene Construction > Conceptual Reflection)

Brain regions	Side	MNI coordinates			Cluster Size	<i>t</i>
		<i>x</i>	<i>y</i>	<i>z</i>		
1. DN clusters						
pIPL	L	-36	-78	34	212	12.83
pIPL / aIPL	R	42	-70	38	679	7.78
		52	-46	34		6.67
		-10	-52	50		8.57
Rsp / PCC / Precuneus	L/R	-6	-52	14	1423	10.53
		4	-64	30		6.97
		62	-14	-20		45
MTG	R	62	-14	-20	45	6.76
PHC	L	-28	-32	-16	28	10.38
mPFC	L/R	6	38	-12	1569	6.73
		-8	40	0		7.54
		16	64	10		9.38
		6	44	26		6.36
Dorsal IPFC	L	-26	30	42	174	9.54
	R	32	28	44	257	8.10
Rostral IPFC	L	-20	62	8	20	6.48
2. DAN clusters						
FEF	L	-26	-8	48	298	8.93
	R	28	-4	50	403	7.88
Precuneus / SPL	L/R	-8	-66	54	1042	11.34
		-18	-64	60		6.48
		30	-68	58		5.19
aIPL	L	-42	-32	36	327	7.10
	R	34	-38	42	361	6.88
Middle OC / MTG	L	-44	-70	20	52	7.60
		-48	-66	8	5.28	
Middle OC / MTG / MT +	R	40	-74	30	476	9.99
		54	-56	8	7.48	
MT+	L	-56	-66	-4	65	6.51
Prec. Sulcus	R	42	6	26	236	8.24
Postc. Sulcus	R	54	-28	46	25	6.56
ITG / Fusiform Gyrus	R	46	-42	-14	51	6.01
3. FPCN clusters						
Precuneus	L/R	-8	-62	50	91	11.04
		4	-38	42	52	10.19
Dorsal IPFC	R	48	40	12	369	8.37
		24	20	46	515	7.96
		44	6	38	7.81	
Rostral IPFC	R	24	58	12	91	7.41
SMG / aIPL / pIPL	R	56	-34	40	360	7.80
		36	-72	42	7.65	
MTG / ITG	R	62	-46	-10	25	7.12
4. Other clusters						
PHC / Hippocampus	L	-32	-34	-12	604	16.18
	R	34	-30	14	414	11.42
Amygdala	L	-30	2	-18	49	8.03
	R	34	0	16	128	7.83
Insula	L	-42	-8	0	164	8.03
Orbitofrontal cortex	R	-28	36	-14	39	8.67

Note: aIPL = Anterior inferior parietal lobule; DAN = Dorsal attention network; DN = Default network; FEF = Frontal eye fields; FPCN = Frontoparietal control network; ITG = Inferior temporal gyrus; IPFC = Lateral prefrontal cortex; mPFC = Medial prefrontal cortex; MT+ = Temporal motion complex; MTG = Middle temporal gyrus; OC = Occipital cortex; PCC = Posterior cingulate cortex; PHC = Parahippocampal cortex; pIPL = Posterior inferior parietal lobule; Postc. Sulcus = Postcentral sulcus; Prec. Sulcus = Precentral Sulcus; Rsp = Retrosplenial cortex; SMG = Supramarginal gyrus; SPL = Superior parietal lobule. $p < .05$ (FWE corrected for multiple comparisons *over masks of the networks of interest or over the whole brain for the clusters falling outside these masks*) with a minimum cluster size of 20 voxels.