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Are There Multiple Kinds of Episodic Memory? An fMRI Investigation Comparing Autobiographical and Recognition Memory Tasks

Hung-Yu Chen
Washington University in St. Louis

WASHINGTON UNIVERSITY IN ST. LOUIS

Department of Psychology

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By

Hung-Yu Chen

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ABSTRACT OF THE THESIS

Are there multiple kinds of episodic memory? An fMRI investigation comparing autobiographical and recognition memory tasks

by

Hung-Yu Chen

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Professor Kathleen McDermott, Chair

What brain regions underlie retrieval from episodic memory? The bulk of research addressing this question has relied upon laboratory-based recognition memory. Another, less dominant tradition has employed autobiographical methods, whereby people recall events from their lifetime, often after being cued with words or pictures. Previous research comparing regions underlying successful memory retrieval between these two methodological approaches has shown mixed results. To examine the neural processes underlying recognition memory for materials encountered in the laboratory and autobiographical memory, we conducted a within-subject study using fMRI. We showed participants indoor and outdoor scenes under two types of instructions: In the lab-based recognition condition we asked participants to report whether they remembered the scene from the prior study phase. In the autobiographical condition, participants were asked to report whether the scene reminded them of a specific event in their lives.

We compared the BOLD activity of successful retrieval of lab-based recognition memory (hits) to the reported successful retrieval of autobiographical memory. We found many regions

differentially activated during the two tasks. Critically, autobiographical retrieval activated the default mode network more whereas recognition hits engaged two subnetworks of the frontoparietal network more. The finding of areas differentially activated during the two types of memory retrieval suggests that successful retrieval in the form of recognition of recently-studied items and successful retrieval in the form of stimulus-evoked autobiographical memories engage different processes and are dissociable.

Introduction:

Episodic memory refers to the ability to remember personal events involving specific people and objects at particular location and time. (Tulving, 1983, 2002; McDermott and Szpunar, 2008). Current understanding of the neural correlates of episodic memory relies heavily on laboratory-based recognition memory paradigms (Cabeza et al., 2004; de Zubicaray et al., 2007; McDermott et al., 2009; Hayama et al., 2012; Okada et al., 2012), which often involve asking participants to recognize recently presented stimuli such as words and pictures. An assumption inherent in the use of laboratory methodology is that mini laboratory episodes (e.g., prior reading of a word) are representative of real-life events (McDermott et al., 2009). Thus, retrieving laboratory "mini-events" is expected to engage the same processes as retrieving memories of everyday events, or autobiographical memories.

However, there are signs suggesting that the ability to retrieve autobiographical memory and performance on laboratory-based tasks such as recognition memory task are dissociable. For instance, people with highly superior autobiographical memory (HSAM) can recall events on any date and year after adolescence with ease but seemed to have normal performance on many laboratory-based memory tasks such as a verbal paired associates test and a logical memory recognition test (LePort et al., 2012); further, they were just as prone to commit false memories in a misinformation paradigm (Patihis et al., 2013). The mediocre performance of people with HSAM on laboratory-based tasks is in sharp contrast to their ability to recall events in their lives; this discrepancy points to a likely dissociation in the psychological and neural mechanisms engaged by laboratory-based and autobiographical tasks.

Currently, there is a dearth of neuroimaging studies have directly compared laboratory-based memory tasks to autobiographical memory tasks (for review, see McDermott et al., 2009;

Kim, 2012), and existing studies show mixed results (**Figure 1**). A common finding is that a set of regions is more activated during autobiographical retrieval than laboratory-based retrieval (Conway et al., 1999; Nyberg et al., 2002; Cabeza et al., 2004; Hassabis et al., 2007; Summerfield et al., 2009), but only a subset of those studies reported regions showing greater activation during laboratory-based tasks (Conway et al., 1999; Nyberg et al., 2002). One study found no such regions, and two others did not report whether such regions exist and whether they performed the necessary statistical test to know.

An example of a study demonstrating the lack of laboratory-based > autobiographical effect was by Cabeza and colleagues (Cabeza et al., 2004), who used a photo paradigm. They found that recognition memory decisions on pictures taken by participants themselves versus other participants' photos led to some similarities, but there were a few regions such as hippocampal formation, parahippocampal gyrus and medial prefrontal cortex showing greater activity when participants correctly identified photos taken by themselves versus other participants' (Cabeza et al., 2004). No regions activated more for the laboratory-based condition than the autobiographical condition. On the other hand, two studies did not report the laboratory > autobiographical contrast, but it was not clear if they performed the statistical test. Hassabis, Kumaran and Maguire (2007) compared the BOLD activation when participants recalled autobiographical episodes or recently studied objects and found the scene construction network more activated during the autobiographical condition, but they did not examine regions more activated during the remembering object condition. Similarly, Summerfield, Hassabis and Maguire (2009) only examined regions showing greater activity during recall of real or imagined autobiographical memory than recall of real or imagined film segments or news.

In contrast, two studies comparing cued recall of words with cued autobiographical retrieval found regions differentially activated in the two tasks. In Nyberg and colleagues (2002) study, regions showing greater activity during cued recall included left precuneus, right frontopolar cortex and right inferior frontal/insular cortex, among others. Regions showing greater activity during their autobiographical condition included medial prefrontal cortex and left angular gyrus. In Conway and colleagues (1999) study, regions more activated during the autobiographical retrieval included superior frontal gyrus and angular gyrus, and regions more activated during cued recall included precuneus and insula. In addition, autobiographical retrieval activated the left hemisphere more, whereas laboratory-based cued recall activated the right hemisphere more.

With only a handful of studies directly comparing the autobiographical and laboratory-based retrieval, it is not clear what led to the discrepancy in the literature such that some studies found regions more activated during laboratory-based retrieval and some did not. The two studies mentioned above showing differences both compared cued recall with cued autobiographical retrieval, and their autobiographical retrieval both involved the Galton word-cuing method. The study by Cabeza and colleagues (2004), which found no region reliably activated more during laboratory-based retrieval, however, did not feature the Galton word-cuing technique. Also, it is not clear whether the large overlap between their autobiographical and laboratory-based conditions was a result of the contamination caused by asking participants to recognize photos taken at the same locations. In other words, viewing other participants' photos might have reminded participants of taking photos at the same locations. On the other hand, their study was more rigorous than previous ones because it attempted to keep retrieval processes, remoteness and emotional content constant. Here, we report a study that Here, we report a study

that strikes a balance between experimental control and ecological validity. We matched variables such as item history and trial duration between autobiographical and laboratory-based recognition memory using an autobiographical task more typical in the literature. An adapted and shortened version of the Galton word-cuing method was chosen to match the response time of recognition memory trials while keeping the autobiographical task in line with much of the autobiographical literature. Scenes were used as visual stimuli for both tasks to match the visual input. With these changes, our study fills in the gap of the literature comparing autobiographical and laboratory-based memory with a recognition memory paradigm, providing critical insight on the neural processes engaged by the two types of memory tasks.

Materials and Methods:

Participants: Thirty-one participants aged 18 to 35 participated in the study. Participants were recruited from Washington University and the St. Louis area. Participants were all right-handed, native speaker of English (acquired by the age of 5), had normal or corrected to normal vision, and were free of psychiatric or neurological disorders. Data from three participants were excluded from analysis due to experimenters' error, and one was excluded due to excessive motion. A final N=27 was included (aged 18-35) in the analysis. Informed consent was obtained for all participants, and the study was conducted in accordance with Washington University human research practices. Participants were paid $25 per hour.

Materials: Part of the difficulty of directly comparing autobiographical memory and recognition memory comes from the differences in the stimuli used. To directly compare the two types of memory, we used indoor and outdoor scenes for both tasks. We chose indoor and outdoor scenes rather than words because unpublished reaction time data by Finley and colleagues (Finley et al., 2011) showed that scenes produced rapid response times for autobiographical retrieval, and a pilot study we conducted that asked participants to make autobiographical memory decisions on scenes showed that scenes were just as good, if not better cues to trigger autobiographical memory. Also, the pilot study suggested that the average response time (RT) for recognition memory fell within 1 second of the response time for autobiographical memory. We collected our indoor and outdoor scene stimuli following the procedure used by Konkle and colleagues (Konkle et al., 2010) by gathering images of various categories (such as cafeteria, lecture hall, tennis courts and airport) using Google Images (images.google.com). Only images with resolution higher than 800 by 600 pixels were collected. None of the scenes contained people.

The scenes were then resized to 400 by 300 pixels. Scenes were rotated across conditions across participants.

Autobiographical and recognition memory tasks: The procedure of the experiment is portrayed in **Figure 2**. All of the tasks took place in the scanner. Participants began by studying 126 indoor or outdoor scenes. Each scene was displayed for 2 seconds, followed by a blank screen of half a second. Participants then made an indoor/outdoor judgment by a button press while learning the scenes. Participants were also told that there would be memory tests. Later, half of the participants began the autobiographical task whereas the other half began the recognition memory task[1]. During the recognition task, each participant was asked to decide for each scene if it had appeared in the study phase. During the autobiographical task, participants were told to decide whether the displayed scene reminded them of a particular episode occurring at a specific time and place in their lives.

The recognition memory task was divided into two blocks (or runs) of 48 trials (16 old or "studied" scenes, 32 new or "nonstudied" scenes). For each trial, a scene appeared on the screen for 4 seconds and then a blank screen lasting 1 second followed. Participants were given 5 seconds to respond with a button press to indicate whether they recognized the scene (old) or did not (new). Similarly, the autobiographical memory task consisted of two runs (48 trials—16 old scenes, 32 new scenes). Again, each scene was displayed for 4 seconds, followed by a blank screen lasting 1 second, and participants were given 5 sec to respond with a button press to indicate whether or not the scene reminded them of a specific event from their lifetime. In sum, the timing and item history was identical for both types of memory judgment.

[1] All participants completed an additional session of autobiographical retrieval with longer (more typical) trial length and no buttonpress Szpunar KK, Watson JM, McDermott KB (2007) Neural substrates of envisioning the future. Proc Natl Acad Sci U S A 104:642-647., but data from that task are not reported here.

fMRI Data Acquisition : Functional and structural scans were acquired on a Siemens 3.0T MAGNETOM Trio system (Erlangen, Germany) using a Siemens 12-channel head coil at the East Imaging Building of Washington University. The scene stimuli were presented with PsyScope (Cohen, 1993) on an iMac computer (Cupertino, CA), which received sync pulses from the scanner. Length of jitter and randomization of trial types were optimized using the program Optseq (http://surfer.nmr.mgh.harvard.edu/optseq/).

Structural images were acquired using a T1-weighted MPRAGE (resolution: 4x4x4mm voxels), which were used along with a T2-weighted image for between subject registration and anatomic localization. Functional imaging was performed using a BOLD contrast sensitive gradient echo echo-planar sequence (TE=27ms, flip angle=90°, in-plane resolution=4x4mm). Whole brain EPI volumes (MR frames) of 32 contiguous, 4mm-thick axial slices were obtained every 2.5 s.

Data Preprocessing

Imaging data from each participant were preprocessed to remove noise and artifacts including: 1) correction for movement within and across scan runs using a rigid-body rotation and translation algorithm (Snyder, 1996), 2) whole-brain normalization to a common mode of 1000 to allow for comparisons across participants (Ojemann et al., 1997), 3) temporal re-alignment using sinc interpolation of all slices to the temporal midpoint of the first slice to account for differences in slice time acquisition, and 4) gradient field map correction to correct for spatial distortion due to local field inhomogeneities using FSL's FUGUE (http://fsl.fMRIb.ox.ac.uk). Functional data were then resampled using 3-mm isotropic voxels and transformed into stereotaxic atlas space (Talairach and Tournoux, 1988). Atlas registration involved aligning each participant's T1-weighted image o a custom atlas-transformed (Lancaster

et al., 1995) target T1-weighted template (711-2C) using a series of affine transforms (Michelon et al., 2003).

Retrieval tasks GLM Coding

Each recognition memory and autobiographical retrieval run consisted of 157 frames. Four initial frames were dropped, leaving 153 frames. One run from one participant was dropped due to within-run movement. Participants' individual retrieval runs were concatenated into a single time series.

The data were modeled with a general linear model, which included 8 regressors of interest, 4 corresponding to recognition memory trial types (hits, misses, correct rejections and false alarms) and 4 corresponding to autobiographical memory trial types (successful retrieval for old items, unsuccessful retrieval for old item, successful retrieval for new items and unsuccessful retrieval for new items). The RT for each trial was included as a regressor to account for the differences in RT between trial types[2]. Regressors of no interest included a trend term to account for linear changes, and a constant term to model the baseline. A standard hemodynamic response function was chosen (Boynton et al., 1996) to estimate the hemodynamic response for each condition, with an onset delay of 2 s.

Analysis and Visualization Software

Imaging analysis was done using Washington University's in-house software, FIDL (http://nil.wustl.edu/~fidl). All atlas coordinates were converted from 711-2C space to MNI152 space using code written by Avi Snyder. All coordinates are reported using MNI152 space. Statistical maps were projected and displayed on a partially inflated representation of the human brain using the Connectome Workbench software (Marcus et al., 2011).

[2] We analyzed the data with and without RT as a regressor, and the result of the contrast between successful autobiographical retrieval and recognition hits did not vary much.

Retrieval Tasks Voxelwise t-test Analysis and ROI Definition

The primary contrast of interest was a voxelwise t-test (paired sample, two-tailed) contrasting activity estimates for successful autobiographical retrieval for old items and recognition hits for each participant. We chose to focus on the contrast involving successful autobiographical retrieval of old items (AutoOldYes) instead of new items (AutoNewYes) to provide a more controlled comparison with recognition hits in that the item history was held constant (i.e., the scenes were recently studied), the response was held constant (i.e., subjects indicate that they do remember), and the difference was the type of "event" that was being remembered (i.e., having studied the scene or an event from one's life). Other contrasts of interest included successful autobiographical retrieval for new items versus recognition hits; hits versus correct rejects in recognition trials; successful autobiographical retrieval for old items versus new items; main effect of recognition hits against fixation baseline; and main effect of AutoOldYes against fixation baseline. For completeness and as a manipulation check, the results of those contrasts are presented in the Appendix.

The resulting statistical maps were then averaged across individuals to create a group average contrast map. The contrast images were smoothed using a spherical smoothing kernel with 6-mm FWHM. The obtained t-test images were multiple-comparison-corrected to a whole-brain familywise error rate of $p<0.05$ using a $z>3$ threshold with at least 17 contiguous voxels (McAvoy et al., 2001). An automated algorithm (peak_4dfp) written by Avi Snyder searched for the location of peaks in the resulting image and drew spheres (16 mm diameter) around each peak. Peaks under 16mm apart were consolidated via coordinate averaging. ROIs were then obtained by masking the 16-mm spheres by the multiple comparison corrected image. Regions located in white matter, CSF, or ventricles were excluded from analysis.

Retrieval tasks network-wide comparison

Results from the whole-brain analyses described above suggested that there might be network-wide dissociation for recognition hits and autobiographical retrieval. To further explore this possibility, we used the 264 ROIs from Power and colleagues' (Power et al., 2011) whole-brain network parcellation study to examine individual networks' activity during successful autobiographical retrieval for old items and recognition hits. For reasons that will become clear, we focused on members of the default mode network and two subnetworks of the frontoparietal network. We drew 10-mm spheres around the peaks, obtained the average magnitude estimates during recognition hits and successful retrieval of autobiographical memory for old items, and took the mean of magnitudes for each task conditions respectively for each network or subnetwork. We then performed paired t-tests to determine if the chosen networks showed differential activities during the two conditions.

Results

Behavioral results

The behavioral performance during the recognition task and the autobiographical task is shown in **Figure 3 and 4**. The proportion of yes responses for old items (hits) during the recognition task is very similar to the proportion of yes responses for old items during the autobiographical task (AutoOldYes) (**Figure 3**. The response time (**Figure 4**), differed however: For recognition hits, the average RT was 1392 ms, whereas for autobiographical "hits", the average RT was 2126 ms, ($t(26)=8.382$, $P < 0.01$). For this reason, we entered trial-by-trial RT as a covariate in our general linear model.

A contrast of autobiographical and recognition task "hits" shows numerous regions differently activated by the two tasks

The BOLD activity of successful retrieval of lab-based recognition memory (hits) was contrasted to the BOLD activity of reported successful retrieval of autobiographical memory for *old items* (**Figure 5**). Twenty nine regions were differentially activated during the two tasks (**Figure 6**). Regions more activated during autobiographical retrieval included bilateral hippocampus, left amygdala, bilateral superior frontal gyrus, and bilateral retrosplenial complex (**see Table 1**). Regions more activated during recognition hits included precuneus, middle cingulate and bilateral insula (**Table 2**). Successful retrieval of autobiographical memory for *new items* versus recognition hits was contrasted, and the result is very similar (**Table 3 and 4**). Because of the similarity of the two contrasts (autobiographical retrieval for old items versus recognition hits and autobiographical retrieval for new items versus recognition hits), further comparison between autobiographical retrieval and recognition refers to the successful autobiographical retrieval given old items versus hits (given the equivalent item history). It is

worth noting that there is a strong hemispheric asymmetry such that most of the laboratory-based > autobiographical differences are in the right hemisphere or midlines, where as the autobiographical > laboratory-based differences are bilateral but stronger in the left hemisphere.

Patterns seen in voxelwise map obey networks defined by resting state fMRI

Regions that showed different activity for successful autobiographical retrieval and recognition hits were further examined, and ROIs were categorized based on their network membership using the parcellation of Power and colleagues' modified voxelwise map (2011). Among the 18 default regions identified from the contrast, all of them showed greater activity during autobiographical retrieval (**Figures 7 and 8**). In addition, two subnetworks of the frontoparietal networks showed opposite patterns: They were more activated during recognition hits (**Figures 9-12**).

The two subnetworks have typically been classified as part of the frontoparietal network. However, when the threshold of network classification becomes more stringent, they become separate networks in graph analyses (Power et al., 2011). They came out as separate components in the Human Connectome Project's ICA analysis of 500 subjects as well (Smith et al., 2013). Although the functions of the two subnetworks remain elusive, they have been previously implicated in memory retrieval (Nelson et al., 2010; Power et al., 2011). Because of their association with memory tasks, we will use memory retrieval I and memory retrieval II to refer to the two subnetworks for the rest of this paper. Please refer to **Figure 9 and 11** to see regions in the two subnetworks sensitive to the contrast of AutoOldYes and recognition hits.

The average activity for the ROIs in the three networks across the two task conditions are shown in **Figure 13**.

The dissociation between networks remains for default mode network and memory retrieval I even when using independently-defined network ROIs.

To examine if the dissociation between autobiographical retrieval and recognition hits is restricted to part of the three networks identified from our contrast, or perhaps other members of the three networks would show the same trend, we obtained coordinates for members of the default mode network and the two subnetworks of the frontoparietal network from the 264 ROIs in the Power and colleagues' parcellation (2011) (**Table 5 and Figure 14**). There are 55 ROIs in the default mode network, 5 ROIs in memory retrieval I, and 5 ROIs in memory retrieval II. We found significant differences in the same direction in the default mode network ($t(54)=6.511$, $P < 0.01$), memory retrieval II ($t(4)=3.608$, $P < 0.05$) but not memory retrieval ($t(4)=1.710$, $P > 0.05$) using two-tailed paired t-tests (**Figure 15**). However, it is worth mentioning that the number of ROIs in memory retrieval I and memory retrieval II are rather small, and it would take a much larger effect size to reject the null hypothesis. As a whole, the five ROIs in memory retrieval I showed a trend of greater activity during recognition hits.

Discussion

Differential activity levels were exhibited during autobiographical and recognition memory tasks. In particular, regions within the default mode network showed greater activity during autobiographical retrieval than laboratory-based recognition hits. In addition, many regions of two subnetworks of the frontoparietal network showed greater activity during recognition hits. An analysis of all members of the networks revealed similar patterns.

The finding of areas differentially activated during the two types of memory retrieval suggests that successful retrieval in the form of recognition of recently-studied items and successful retrieval in the form of stimulus-evoked autobiographical memories engage different processes and are dissociable. These results suggest that findings from old/new recognition memory may not always generalize to the construct of episodic memory. Possible factors contributing to the dissociation are discussed below.

Do recollection and familiarity reflect differences seen in autobiographical and laboratory-based retrieval?

Proponents of the dual process theory on recognition memory have proposed that two separable processes contribute to recognition memory decisions: recollection and familiarity (Yonelinas et al., 2010). Yonelinas and colleagues defined recollection as the retrieval of specific information about a particular episode, such us the time and location of the event. Familiarity, on the other hand, reflects the memory or stimulus recency (Yonelinas et al., 2010). How (or whether) research on recollection and familiarity informs us about the dissociation between recognition memory and autobiographical memory is open for debate. On one hand, a case for autobiographical retrieval engaging more familiarity and less recollection than recognition memory can also be made. One widely-used paradigm assessing recollection and familiarity is

the remember and know paradigm, which typically asks participants to report remember judgments following old decisions based on recollection and to report know judgments for old decisions based on familiarity (Ingram et al., 2012). Studies using this paradigm have demonstrated that remember trials have shorter response times than know trials (Dewhurst and Conway, 1994; Wixted and Stretch, 2004; Rotello and Zeng, 2008). The response time data would suggest that shorter response time during recognition hits than autobiographical retrieval could be a result of recognition trials' higher proportion of recollection processing. Alternatively, the difference in response time could also indicate a difference in confidence (Rotello and Zeng, 2008).

On the other hand, one working hypothesis is that autobiographical retrieval engages more recollection and less familiarity than laboratory-based retrieval. Cabeza and colleagues, for instance, have argued that greater self-referential processing and sensory retrieval should lead to greater recollection due to the enhanced experience of reliving (Cabeza et al., 2004). Although our study was not designed to examine recollection and familiarity in recognition and autobiographical memory, it is possible to examine how regions sensitive to the remember and know contrast responded to our task. We took the coordinates of regions showing remember > know or know > remember from a meta-analysis by Kim (2010). Regions showing greater activity for remember trials than know trails, on average, showed greater activity during autobiographical retrieval. Many of the remember > know regions are members of the default mode network. However, the know > remember regions showed no difference between autobiographical retrieval and recognition hits. This result hints at autobiographical retrieval engaging more recollection, but further work is necessary to examine this possibility. It is worth noting, nevertheless, that autobiographical retrieval engaged the remember regions more despite

being the much longer retention interval. Signal detection theorists supporting an unidimensional memory strength interpretation of recognition memory have argued that remember judgments reflect higher memory strength whereas familiarity judgments refer weaker memory strength (Donaldson, 1996; Dunn, 2004). A longer retention interval should lower memory strength and thus less recollection in dual-process theorists' terminology. Alternatively, it could be the case that the Galton word-cuing technique resulted in stronger memory being retrieved.

Recall versus recognition cannot explain the difference between laboratory-based and autobiographical retrieval

One possible explanation of the dissociation between autobiographical retrieval and recognition memory is the difference between recall and recognition. Nevertheless, this explanation is not sufficient. Comparing autobiographical retrieval versus laboratory-based cued recall should show very similar results. Nyberg and colleagues (2002) and Conway and colleagues (Conway et al., 1999) both compared cued recall of words and autobiographical recall using words using PET and found regions more selectively more activated in each task, with Nyberg and colleagues' results more resembling ours. Closer examination of their data revealed that 5 out of the 6 areas showing greater activity during lab-based cued recall than autobiographical retrieval are members of the frontoparietal network or its subnetworks. Three of the six regions showing greater activity during autobiographical retrieval are members of the default network. Also, retrieval success effects in cued recall paradigms resemble the retrieval success effects in recognition memory paradigms (de Zubicaray et al., 2007; Okada et al., 2012).

Limitations

Although we matched the autobiographical trials with the laboratory-based recognition trials on many aspects such as the stimulus history, trial duration and instruction, some aspects between the two memory tasks were not matched. For instance, autobiographical memory could be more vivid, emotional, self-referential and often occur on a longer timeframe. Self-relevance, for instance, has been shown to activate members of the default mode network, especially ventral mPFC (Summerfield et al., 2009; St Jacques et al., 2011). Emotional autobiographical memory has also be shown to activate structures such as amygdala and hippocampus more (For review, see Cabeza and St Jacques, 2007). In addition, the possibility that the higher difficulty in recognition memory trials leading to more activation in areas in the frontoparietal network cannot be ruled out, yet this is probably not the case because the response time for autobiographical trial is longer than recognition trials. Finally, one concern that might complicate the interpretation of the study is incidental recognition during autobiographical retrieval. It is possible that participants were reminded of the study episode episode while they viewed previously presented stimuli during autobiographical retrieval. Further research is necessary to examine the occurrence of incidental recognition. However, incidental recognition should not an important factor in our study because comparison between autobiographical retrieval with new items as cues and recognition hits yield very similar results. Also, incidental recognition would reduce the differences between autobiographical retrieval and recognition hits rather than enhance them.

In summary, this study demonstrated that laboratory-based and autobiographical retrieval, assessed using methods typically used in the literature, engaged many brain regions especially the default mode network and two subnetworks of the frontoparietal network differently. This result supports a dissociation in the process underlying autobiographical

memory and laboratory-based memory. This paradigm also served as a new way of comparing the neural correlates of autobiographical and recognition memory. Although more research is necessary to examine the role of factors such as recollection and familiarity, the study has paved the way for more research examining the ecological validity of laboratory memory tasks.

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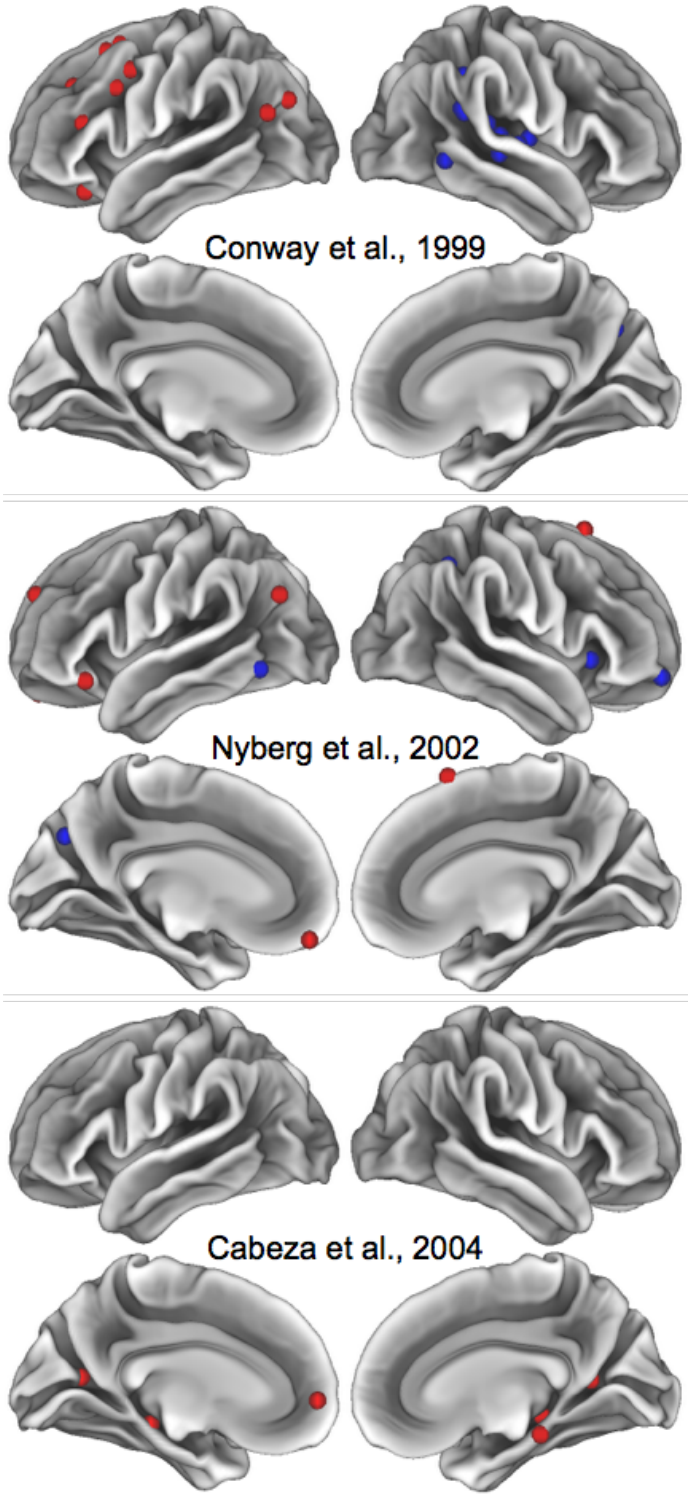


Figure 1. A summary of three studies directly comparing the neural correlates of laboratory-based and autobiographical memory. Peaks of activations are plotted with 5 mm spheres on the surface. Regions with greater activity during autobiographical tasks are shown in red, whereas regions with greater activity during laboratory-based memory tasks are shown in blue.

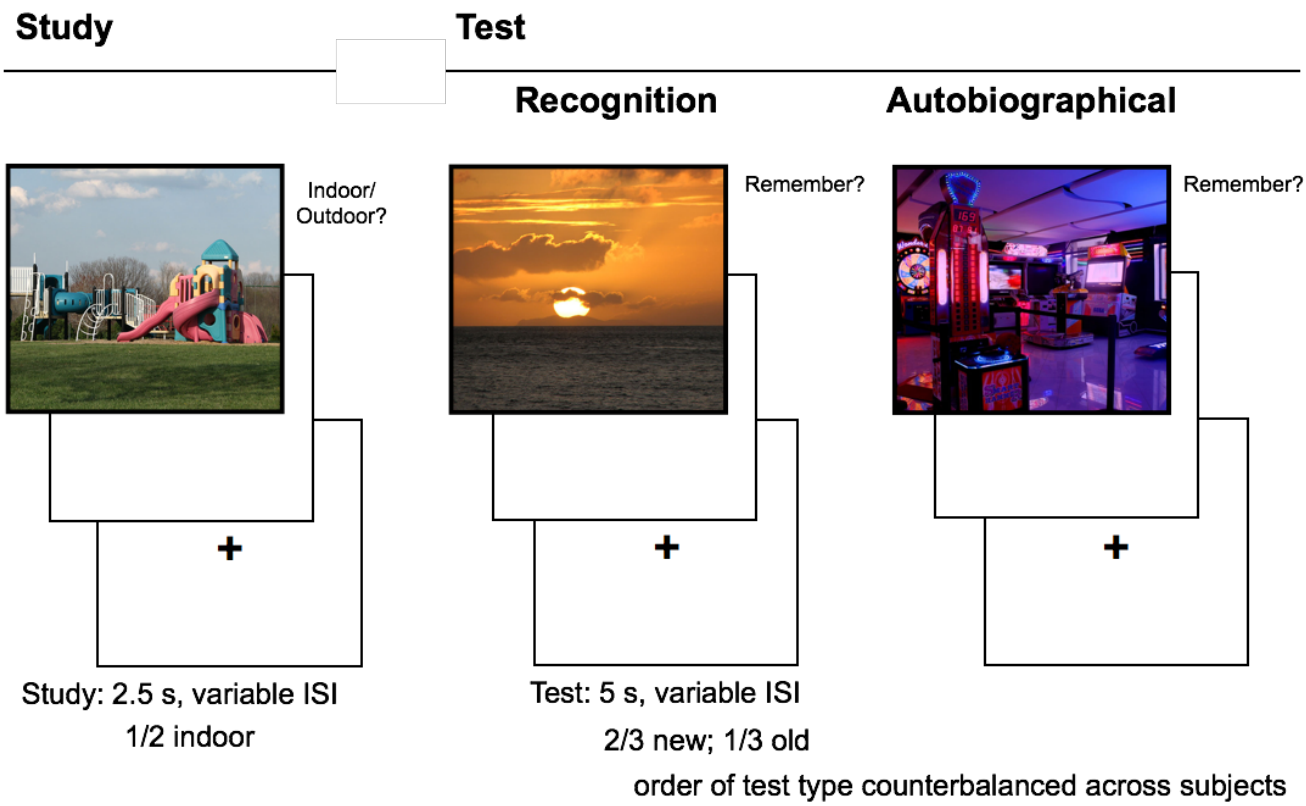


Figure 2. Experimental procedures. Participants viewed 192 scenes (intentional encoding), with a binary judgment for each (indoor or outdoor scenes). They then either began recognition runs or the autobiographical runs. Each recognition or autobiographical run consisted of 48 scenes (32 new and 16 old). Each scene was on the screen for 4 seconds, and a blank screen of one second followed. For recognition runs, participants had 5 seconds to indicate whether they recognized the scene. For autobiographical runs, participants had 5 seconds to indicate whether they remembered an event from their life using the scene as a cue.

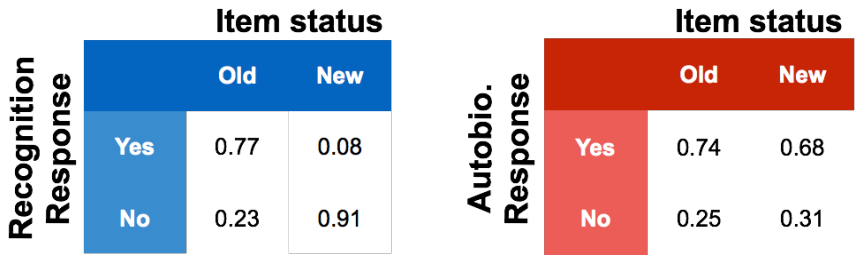


Figure 3. Behavioral performance of recognition and autobiographical retrieval tasks.

Figure

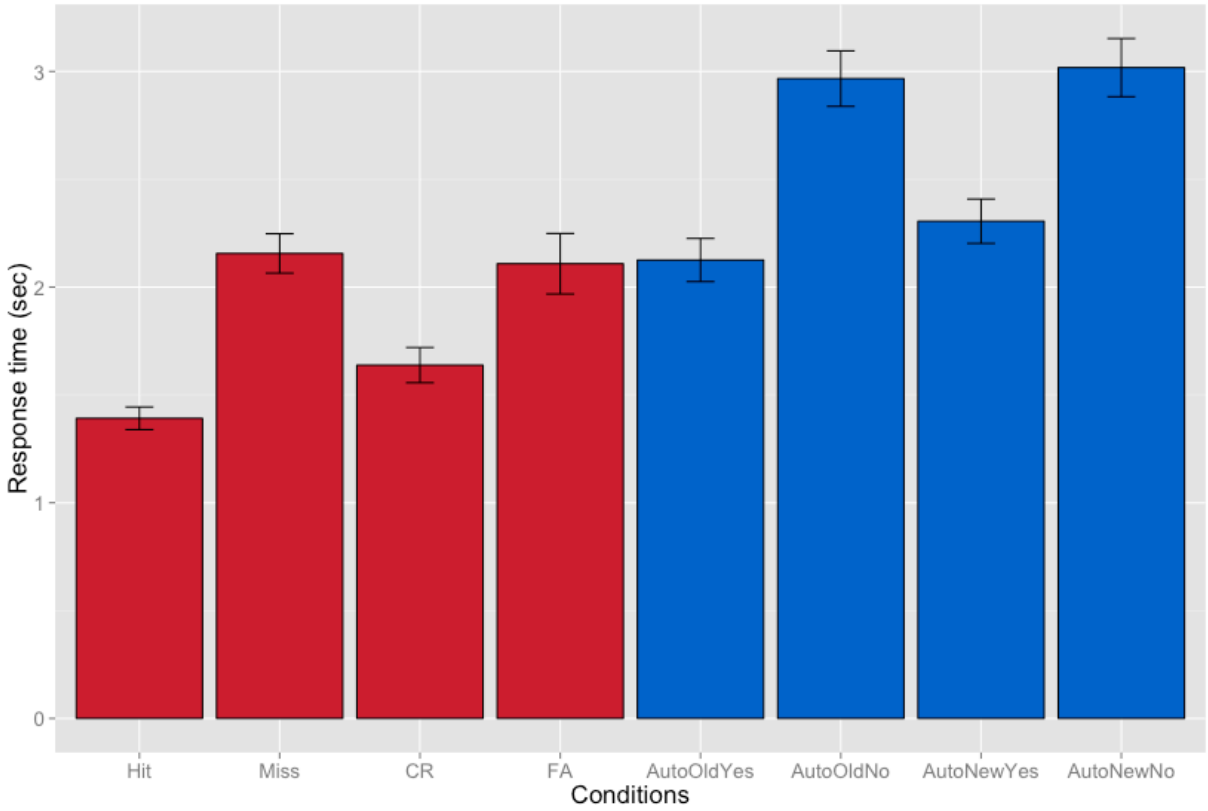


Figure 4. Mean response times for each autobiographical and recognition condition. AutoOldYes = successful autobiographical retrieval with items in the study phase. AutoOldNO = unsuccessful autobiographical retrieval with items in the study phase. AutoNewYes = successful autobiographical retrieval with new items. AutoNewNo = unsuccessful autobiographical retrieval with new items. Error bars represent standard errors.

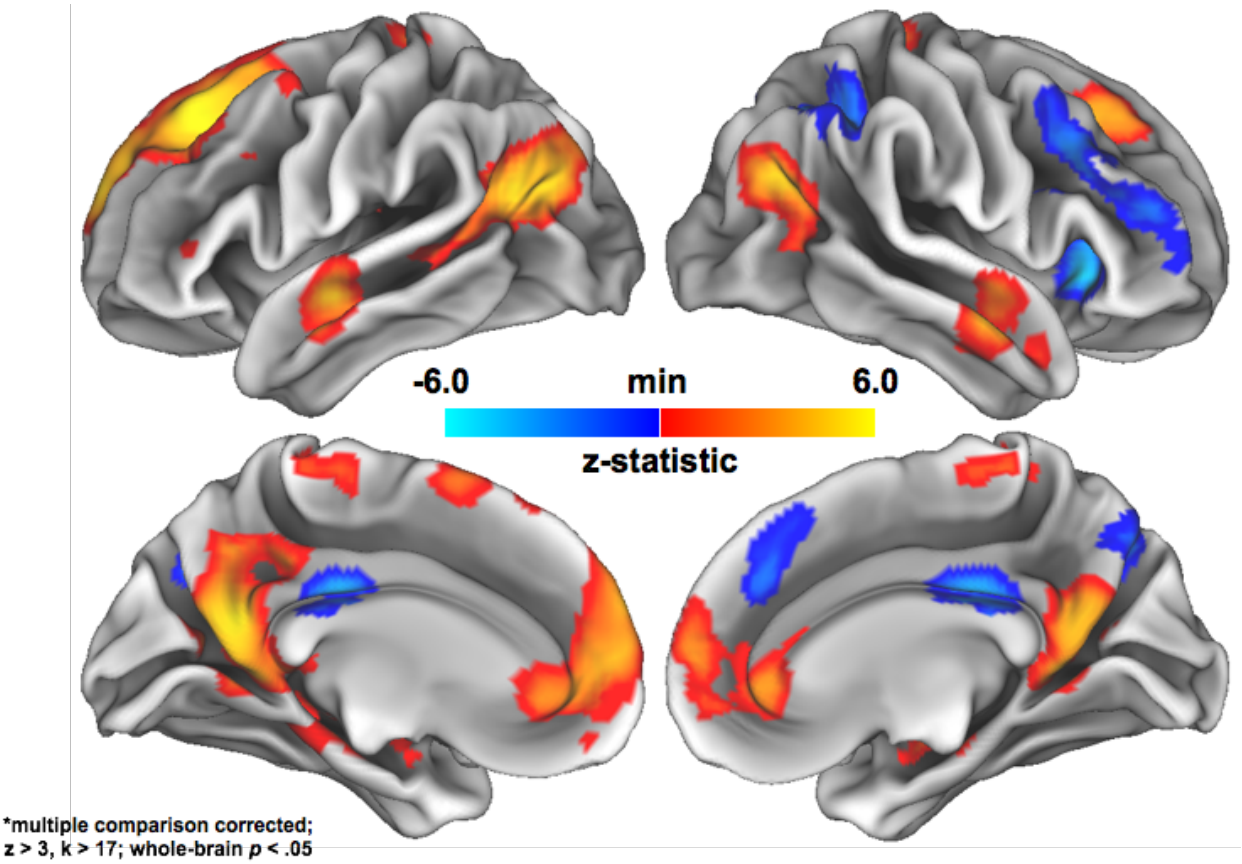


Figure 5. Voxelwise map of a contrast of AutoOldYes (successful autobiographical retrieval for scenes previously studied) and recognition hits. Areas with greater activity during autobiographical retrieval are in warmer colors, and areas with greater activity during recognition hits are in cooler colors.

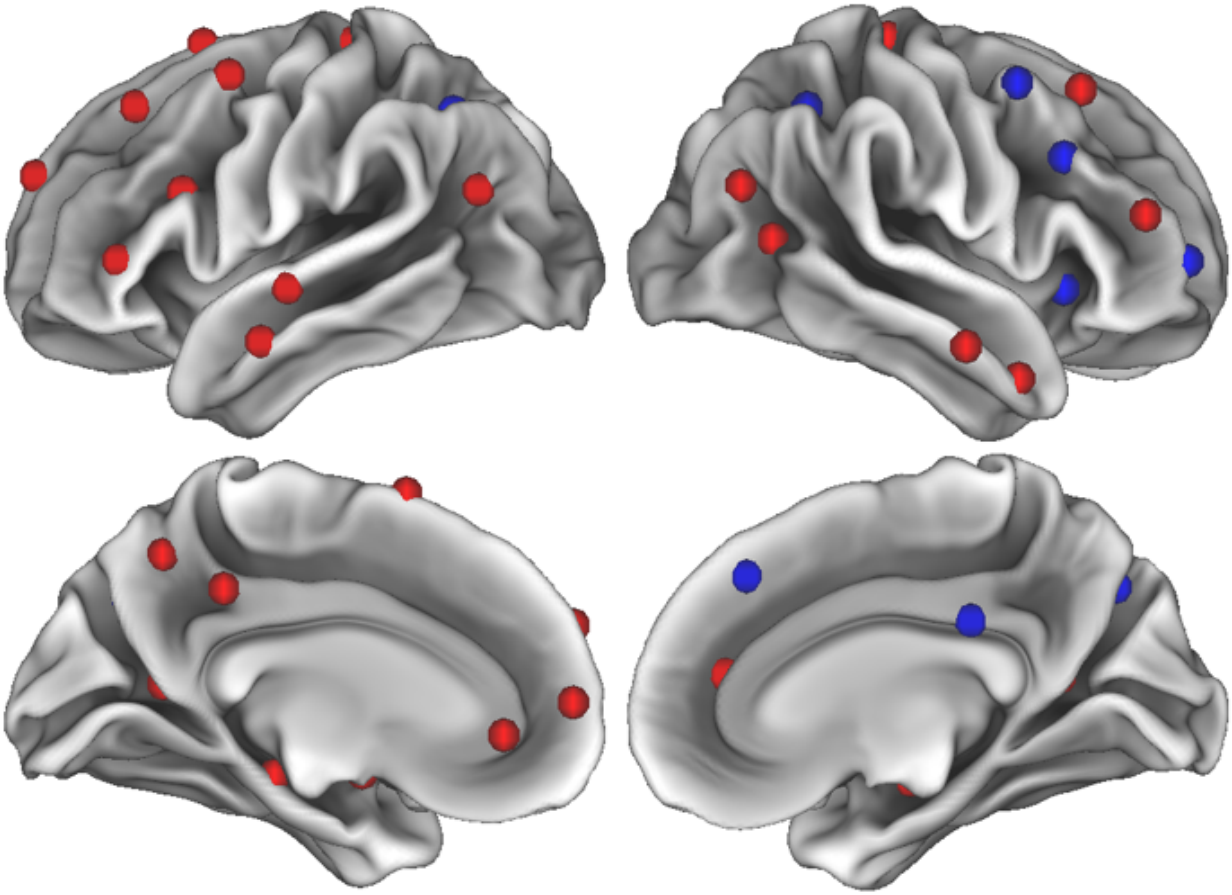


Figure 6. Spheres surrounding peak differences between AutoOldYes (successful autobiographical retrieval for scenes previously studied) and recognition hits. Regions with greater activity during autobiographical retrieval are red, and areas with regions activity during recognition hits are in blue. For illustrative purposes, spheres of 10mm diameter are displayed. Analyses were performed with 16 mm spheres masked with the AutoOldYes versus recognition hits contrast.

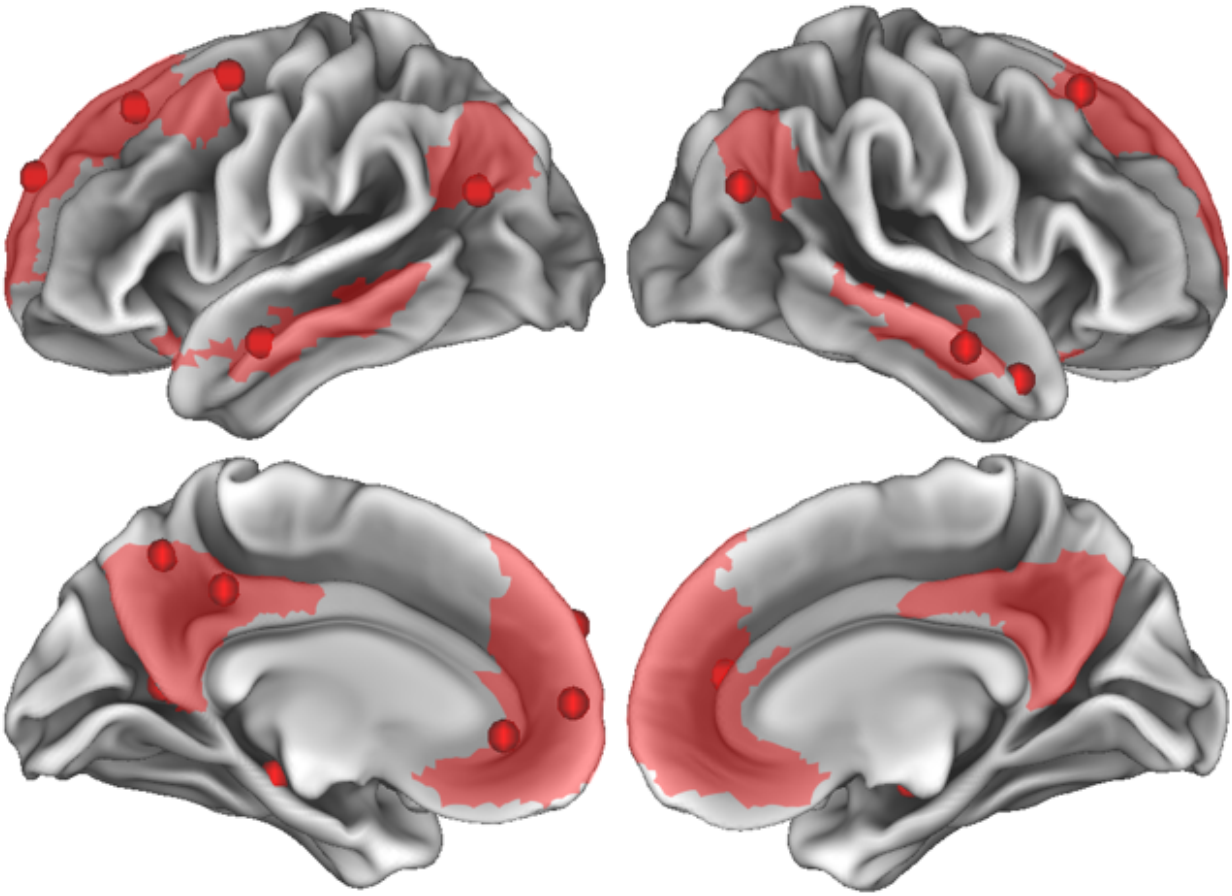


Figure 7. Many of thee regions with greater activity during AutoOldYes than recognition hits are in the default mode network. The shaded area shows the extent of the default mode network according to the Power parcellation (2011). For illustrative purposes, spheres of 10mm diameter are displayed. Analyses were performed with 16 mm spheres masked with the AutoOldYes versus recognition hits contrast.

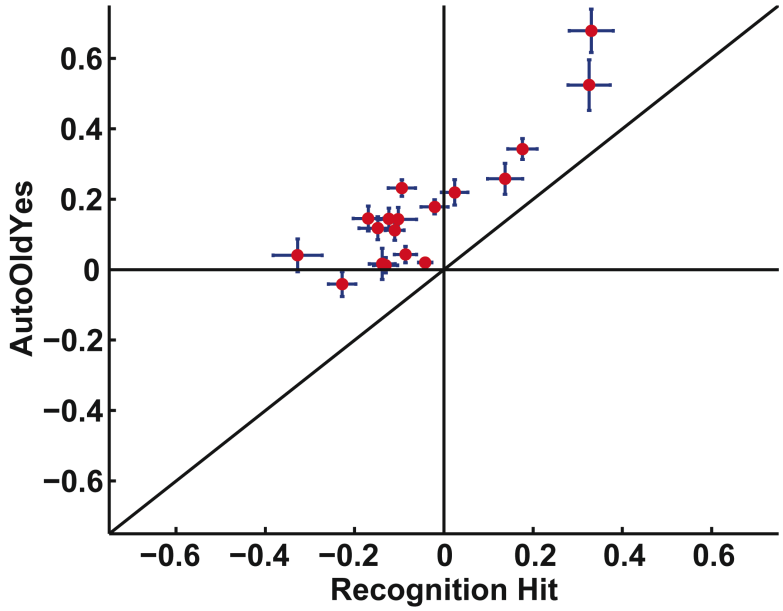


Figure 8. Scatterplot showing the percent signal change of default mode regions sensitive to the contrast of AutoOldYes and recognition hits. All of the default mode regions shown here are on the top-left side of the figure, suggesting that they displayed greater activity during autobiographical retrieval than during recognition hits. Error bars represent standard errors.

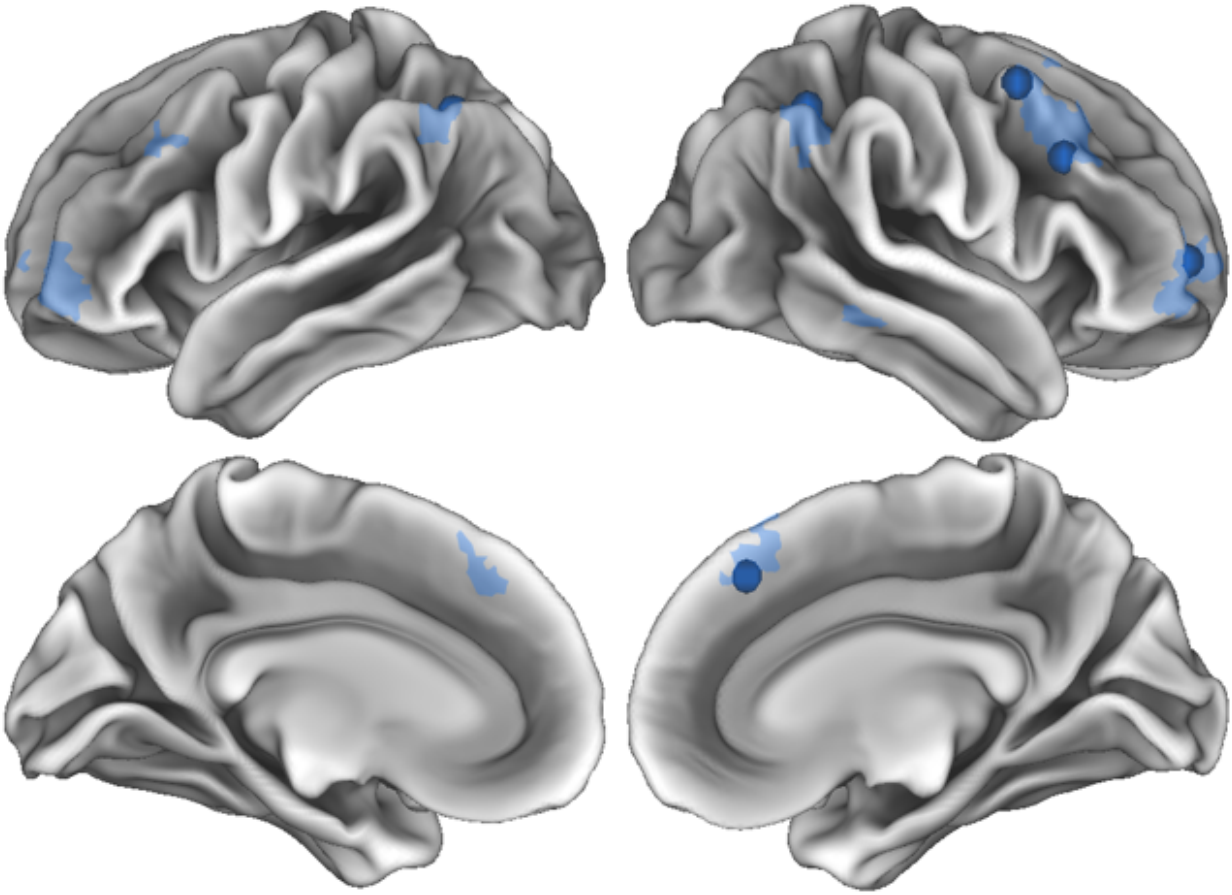


Figure 9. Many regions with greater activity during recognition hits than AutoOldYes are in a subnetwork, memory retrieval I, of the frontoparietal network. The shaded area shows the extent of the network according to the Power parcellation (2011). For illustrative purposes, spheres of 10mm diameter are displayed. Analysis was performed with 16 mm spheres masked with the AutoOldYes versus recognition hits contrast.

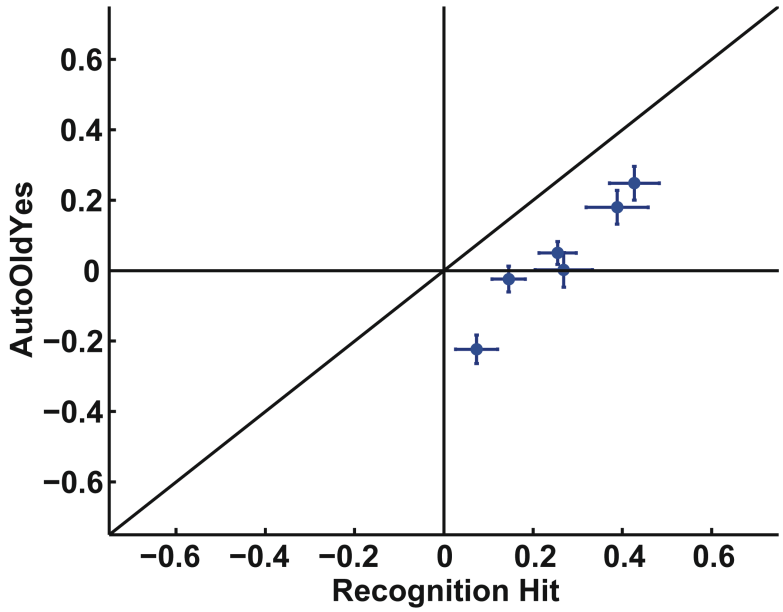


Figure 10. Scatterplot showing the signal change of a subnetwork of the frontoparietal network (memory retrieval I) sensitive to the contrast of AutoOldYes and recognition hits. All of the regions shown here are on the bottom-right side of the figure, suggesting that they displayed greater activity during recognition hits. Error bars represent standard errors.

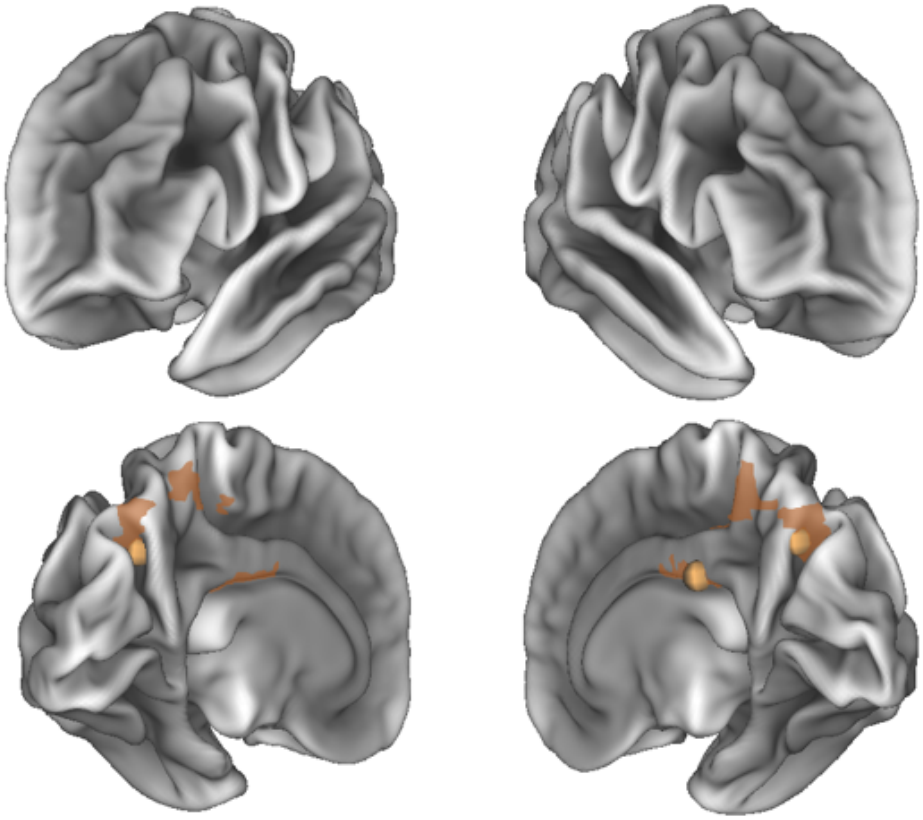


Figure 11. Many of regions with greater activity during recognition hits than AutoOldYes are in a subnetwork, memory retrieval II, of the frontoparietal network. The shaded area shows the extent of the network according to the Power parcellation (2011). For illustrative purposes, spheres of 10mm diameter are displayed. Analysis was performed with 16 mm spheres masked with the AutoOldYes versus recognition hits contrast.

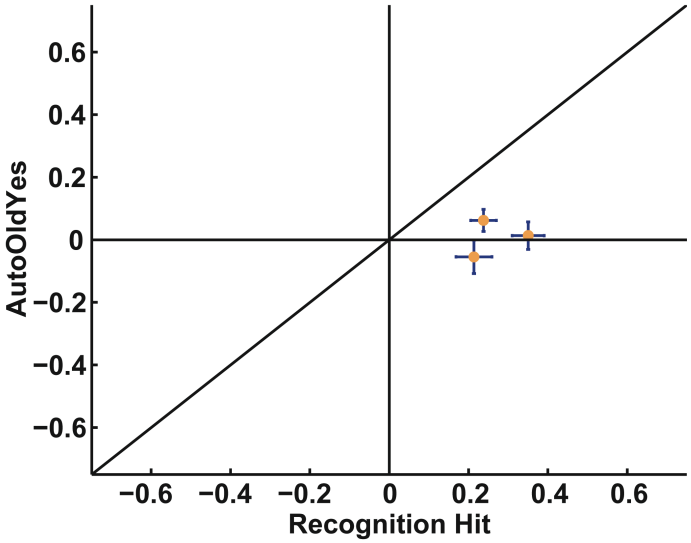


Figure 12. Scatterplot showing the percent signal change of a subnetwork of the frontoparietal network (memory retrieval II) sensitive to the contrast of AutoOldYes and recognition hits. All of the regions shown here are on the bottom-right side of the figure, suggesting that they had greater activity during recognition hits. Error bars represent standard errors.

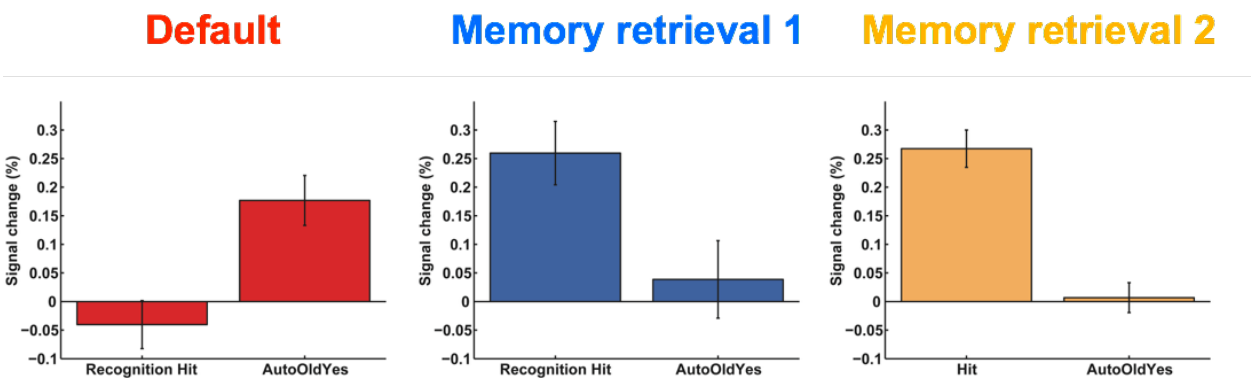


Figure 13. Summary of the BOLD activity of the three networks during recognition hits and AutoOldYes identified from the contrast of the two conditions. Error bars represent standard errors.

Figure

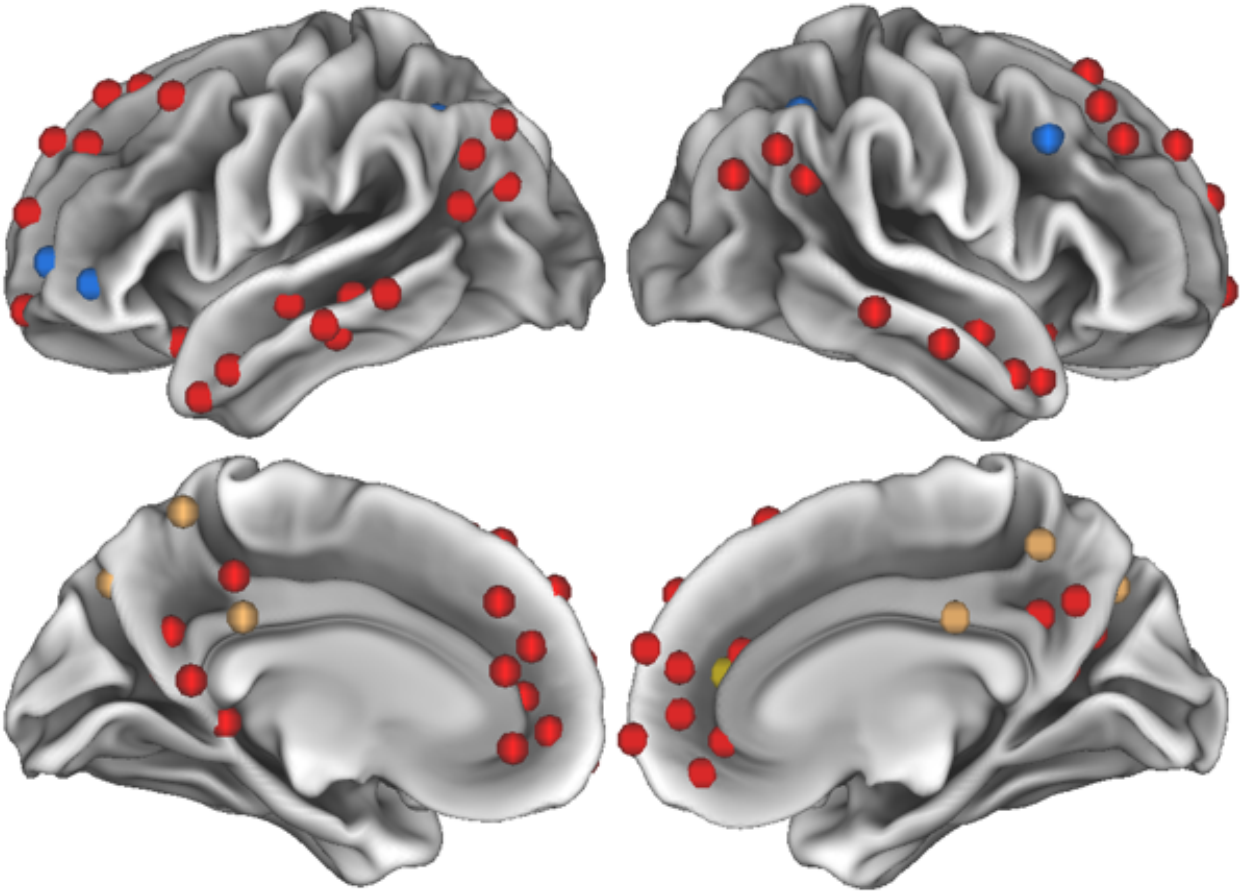


Figure 14. ROIs from the Power et al. parcellation (2011) used in the independently defined ROI analysis comparing AutoOldYes with recognition hits.

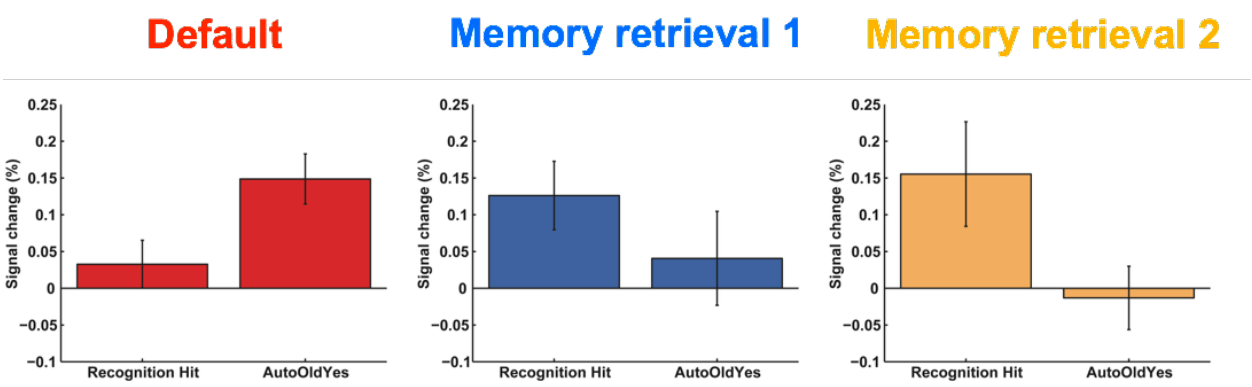


Figure 15. Summary of the three networks during AutoOldYes and recognition hits. The regions were independently defined using the Power and colleagues' parcellation (2011). Error bars represent standard errors. Error bars represent standard errors.

Table 1

AutoOldYes > recognition hits

Region	Size (voxels)	Maximum Z	MNI Maximum coordinates x	y	Z
DMN					
Superior Frontal Gyrus	76	-6.3568	-20	31	49
Superior Frontal Gyrus	47	-4.056	-8	12	67
Superior Frontal Gyrus	33	-4.6383	22	27	53
Retrosplenial Complex	74	-5.5567	-9	-55	12
Retrosplenial Complex	63	-4.4454	14	-49	14
Anterior Middle Temporal Gyrus	65	-6.1172	62	-6	-19
Anterior Middle Temporal Gyrus	59	-5.4552	-60	-4	-17
Angular Gyrus	76	-5.6751	48	-68	26
Angular Gyrus	79	-5.4957	-45	-67	25
mpfc	72	-5.4744	-11	60	29
mpfc	76	-5.4049	-2	57	7
Hippocampus	31	-5.1653	29	-12	-17
Hippocampus	47	-4.7592	-23	-27	-15
Anterior Cingulate Gyrus	73	-4.507	-1	39	-2
Anterior Cingulate Gyrus	37	-4.2301	15	40	14
Precuneus Cortex	16	-3.8142	-8	-58	49
Posterior Cingulate Cortex	48	-4.3066	-4	-41	39
Middle Frontal Gyrus	16	-4.2197	-36	5	57
Temporal Pole	19	-3.9204	51	10	-28
Hand Network					
Precentral Gyrus	43	-4.1806	12	-26	67
Precentral Gyrus	33	-3.9599	-11	-31	67
Other					
Superior Frontal Gyrus	47	-4.056	-8	12	67
Amygdala			-24	-2	-12
Posterior superior temporal gyrus	32	-3.9223	-59	-13	-1
Inferior Lateral Occipital Cortex	36	-3.703	40	-61	9
Inferior Frontal Gyrus, pars triangularis	20	-3.5452	-46	34	4
Inferior Frontal Gyrus, pars opercularis	9	-3.8297	-47	18	25
Cerebellum					

Right IX	57	-5.1345	6	-54	-46
Right Crus I	42	-4.6807	42	-61	-33
Right Crus II/I	32	-4.3548	25	-81	-33

Table 2

Recognition hits > AutoOldYes

Region	Size (voxels)	Maximum Z	MNI Maximum coordinates x	y	Z
Memory retrieval I					
Anterior Middle IPS	69	4.1029	44	-50	53
Middle Frontal Gyrus	64	4.2275	46	20	34
Middle Frontal Gyrus	10	3.6074	43	9	55
Superior Medial Prefrontal Cortex (dmPFC)	35	4.535	4	35	42
Posterior Middle IPS	41	3.9331	-36	-58	50
Anterior PFC	15	3.9361	34	61	5
Memory retrieval II					
Middle Cingulate Gyrus	60	4.8054	1	-29	29
Precuneus Cortex	61	4.9715	12	-70	39
Precuneus Cortex	33	4.6778	-14	-67	37
Frontoparietal					
Middle Frontal Gyrus	42	4.5341	43	45	17
Other					
Insula	68	5.9887	34	24	-5

Table 3

AutoNewYes > recognition hits

Region	Size (voxels)	Maximum Z	MNI Maximum coordinates x	y	Z
DMN					
Superior Frontal Gyrus	79	5.9985	-10	63	19
Superior Frontal Gyrus	79	5.6461	-20	32	48
Retrosplenial Complex	75	4.9519	-9	-54	13
Retrosplenial Complex	68	4.9602	10	-53	10
vmpfc	71	4.8435	-4	49	-7
dmpfc	46	5.5674	-12	50	34
mpfc	29	3.9709	8	58	23
Hippocampus	9	4.4091	36	-13	-23
Angular Gyrus	74	4.657	-43	-73	27
Superior/Middle Frontal Gyrus	53	4.0276	23	27	43
Hand Network					
Precentral/Postcentral Gyrus	17	3.751	-9	-32	67
Other					
Inferior Lateral Occipital Cortex	51	3.3943	47	-69	10
Anterior Superior/Middle Temporal Gyrus	37	5.337	-58	0	-13
Superior Frontal Gyrus	60	5.1062	-13	14	58
Middle Temporal Gyrus, temporooccipital part	24	3.5344	-45	-52	10
Cerebellum					
Right IX	31	5.3376	1	-51	-49
Right Crus II	27	3.8394	22	-80	-36
Right Crus I	9	3.4042	41	-65	-29

Table 4

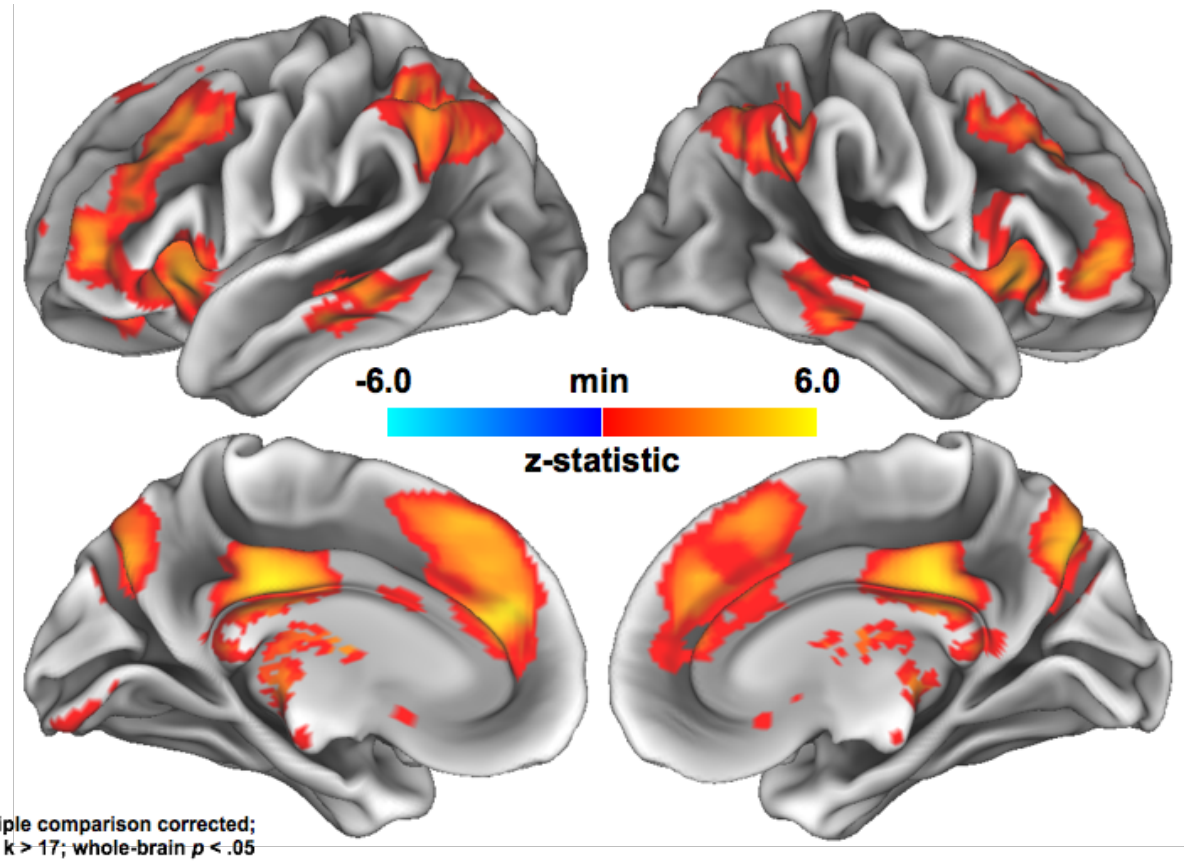
Recognition hits > AutoNewYes

Region	Size (voxels)	Maximum Z	MNI Maximum coordinates x	y	Z
Memory retrieval I					
Posterior Middle IPS	77	5.2973	-36	-60	50
Anterior PFC	14	4.6666	34	58	-4
Anterior Middle IPS	81	4.6853	44	-49	50
Middle Frontal Gyrus	43	4.9317	38	14	52
Middle Frontal Gyrus	71	4.3632	43	20	35
Superior Medial Prefrontal Cortex (dmPFC)	54	4.4165	4	36	38
Memory retrieval II					
Middle Cingulate Gyrus	60	5.2494	2	-29	33
Precuenus Cortex	55	5.4951	-10	-70	40
Precuneus Cortex	68	5.598	12	-69	38
Frontoparietal					
Middle Frontal Gyrus	50	4.716	43	43	18
Other					
Orbitofrontal Cortex	7	4.6797	26	23	-13

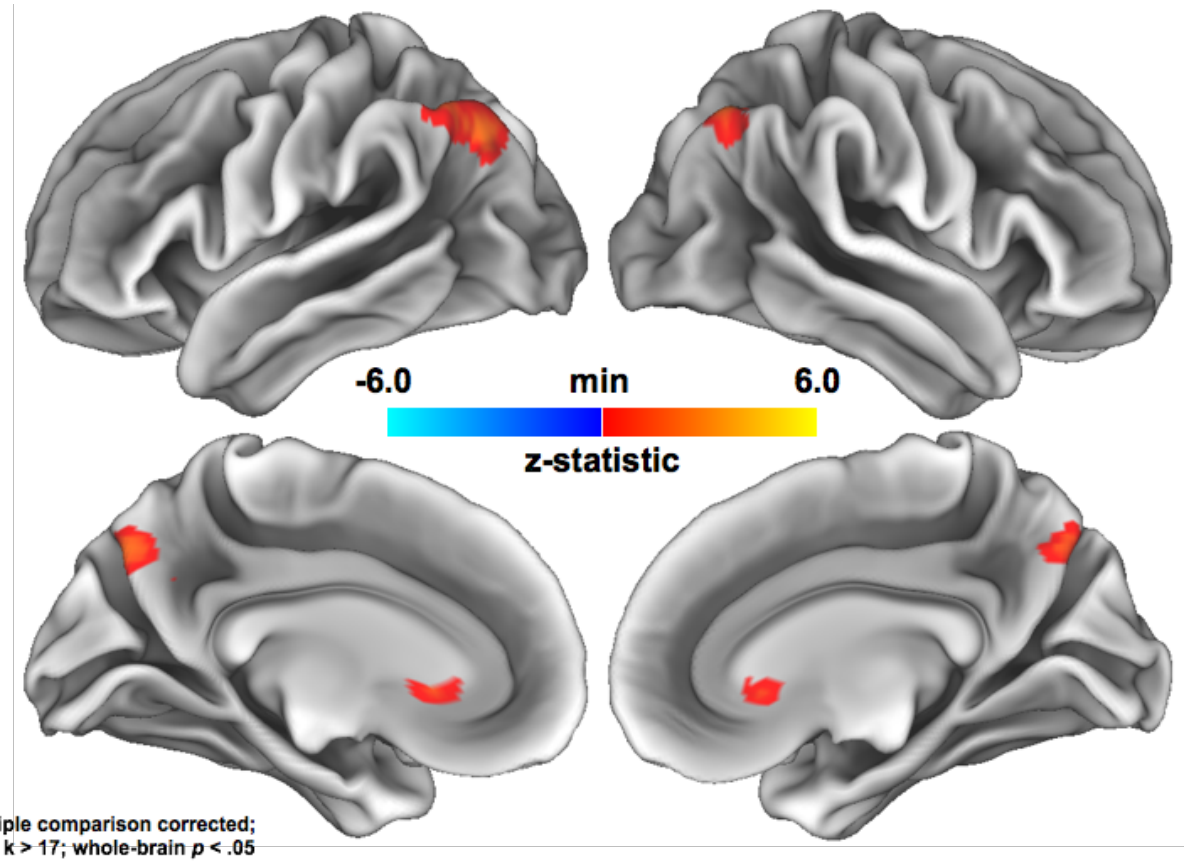
Table 5. Regions from Power et al. (2011) used in network analyses

x	y	z
DMN		
-41	-75	26
6	67	-4
8	48	-15
-13	-40	1
-18	63	-9
-46	-61	21
43	-72	28
-44	12	-34
46	16	-30
-68	-23	-16
-58	-26	-15
27	16	-17
-44	-65	35
-39	-75	44
-7	-55	27
6	-59	35
-11	-56	16
-3	-49	13
8	-48	31
15	-63	26
-2	-37	44
11	-54	17
52	-59	36
23	33	48
-10	39	52
-16	29	53
-35	20	51
22	39	39
13	55	38
-10	55	39
-20	45	39
6	54	16
6	64	22
-7	51	-1
9	54	3
-3	44	-9
8	42	-5
-11	45	8
-2	38	36
-3	42	16
-20	64	19

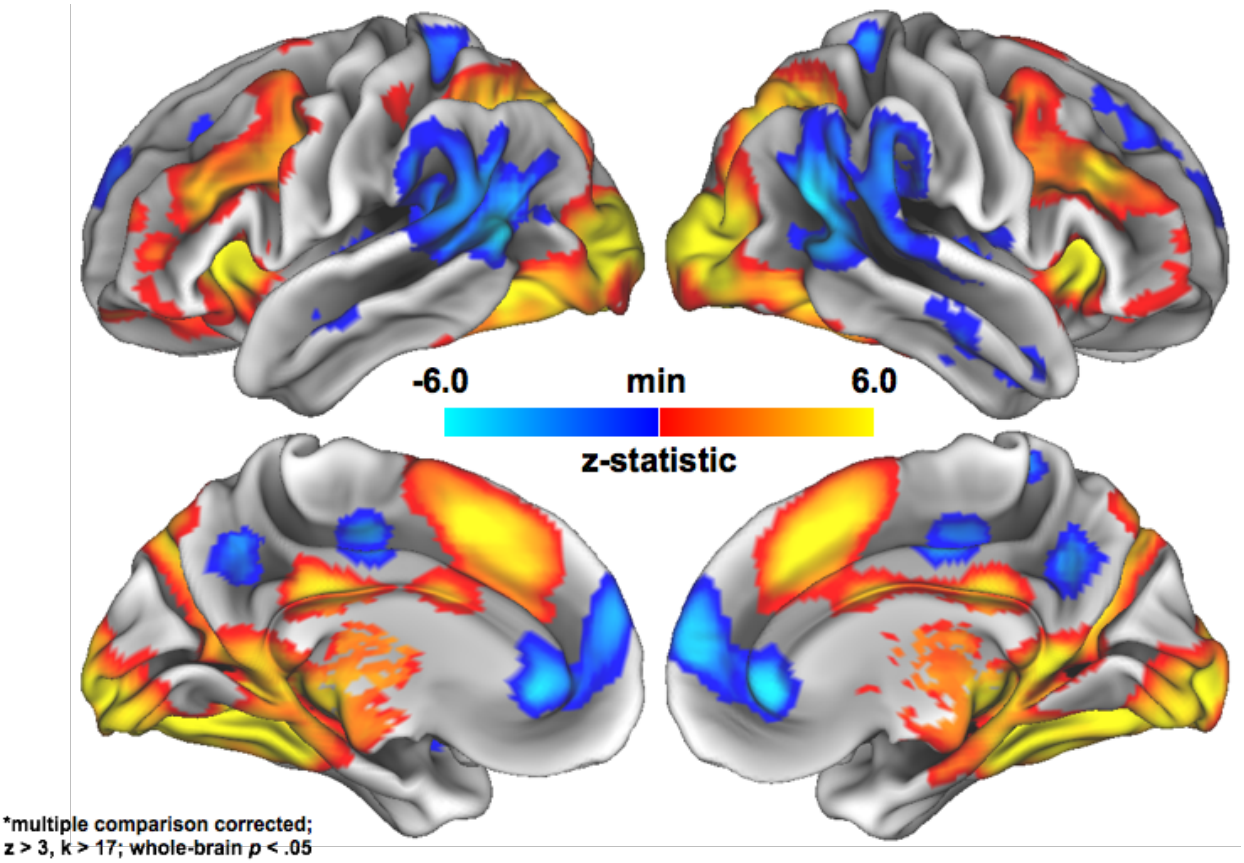
-8	48	23
65	-12	-19
-56	-13	-10
-58	-30	-4
65	-31	-9
-68	-41	-5
13	30	59
12	36	20
52	-2	-16
-26	-40	-8
27	-37	-13
-34	-38	-16
28	-77	-32
52	7	-30
-53	3	-27
47	-50	29
-49	-42	1
-31	19	-19
Memory Retrieval I		
44	-53	47
-42	-55	45
40	18	40
-34	55	4
-42	45	-2
Memory Retrieval II		
-7	-52	61
-2	-35	31
-7	-71	42
11	-66	42
4	-48	51
2	-24	30



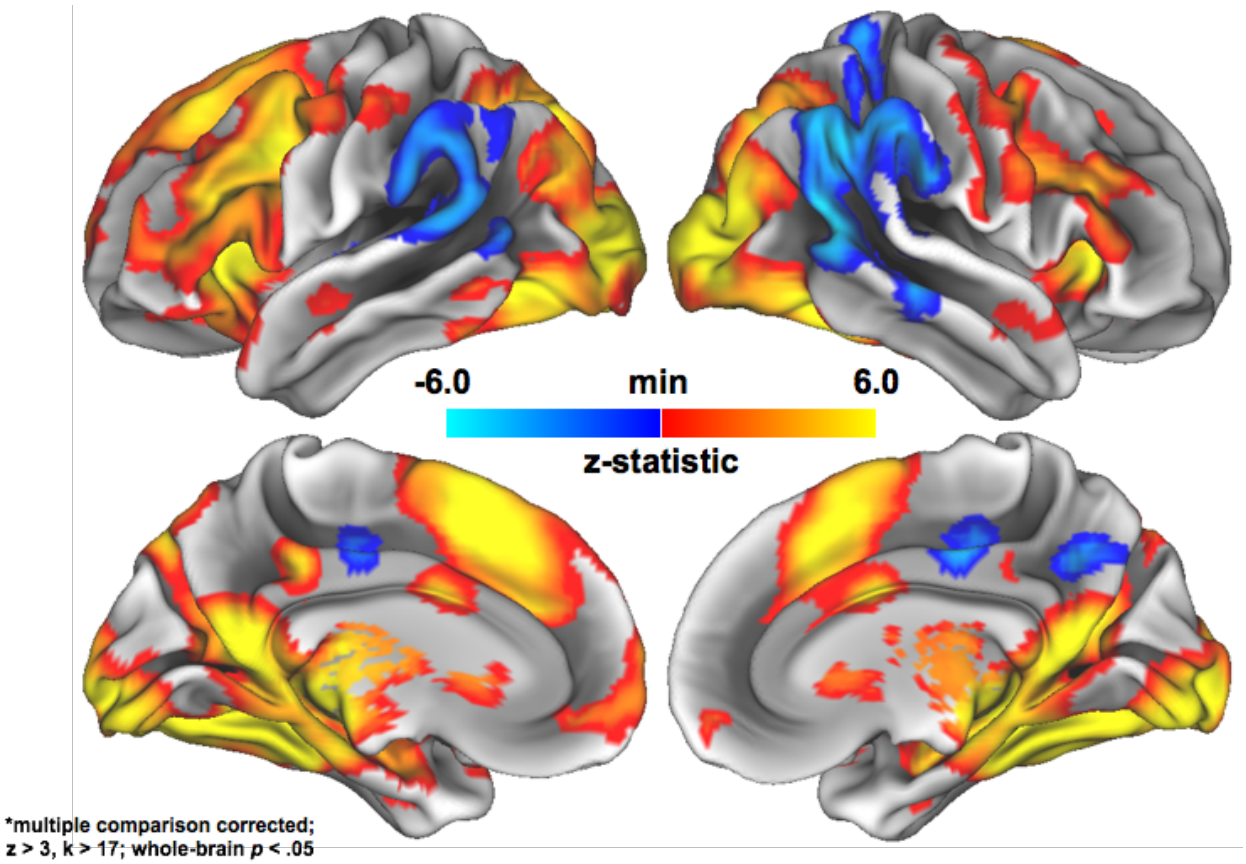
Supplemental Figure 1. Voxelwise map of a contrast of hits and correct rejections during the recognition memory task. Areas with greater activity during recognition hits are in warmer colors. No area with greater activity during correct rejections was found.



Supplemental Figure 2. Voxelwise map of a contrast of AutoOldYes (successful autobiographical retrieval for scenes previously studied) AutoNewYes (successful autobiographical retrieval for non-studied scenes). Areas with greater activity during AutoOldYes are in warmer colors. No area with greater activity during AutoNewYes was found.



Supplemental Figure 3. Voxelwise map of a main effect of tecognition hits against fixation baseline. Areas with significant activation above baseline are in warmer colors, and areas with significant deactivation below baseline are in cooler colors.



Supplemental Figure 4. Voxelwise map of the main effect of AutoOldYes (successful autobiographical retrieval for scenes previously studied) against fixation baseline. Areas with significant activation above baseline are in warmer colors, and areas with significant deactivation below baseline are in cooler colors.

Supplemental Table 1

AutoOldYes greater than AutoNewYes

Region	Size (voxels)	Maximum Z	MNI Maximum coordinates x	y	Z
Posterior IPL	63	3.8075	-40	-63	47
Posterior IPL	40	4.1245	43	-63	47
Precuneus Cortex	51	3.8358	-6	-68	38
Precuneus Cortex	33	3.8311	13	-64	36
Subcallosal cortex	19	3.9597	-1	23	-1

Supplemental Table 2

Recognition Hits > Correct Rejections

Region	Size (voxels)	Maximum Z	MNI Maximum coordinates x	y	Z
Anterior Cingulate Gyrus	81	5.8174	-4	45	20
Posterior IPL	78	5.8138	-36	-61	48
Posterior cingulate	79	5.7604	0	-30	31
Caudate	70	5.7321	10	13	6
Middle Temporal Gyrus	76	5.9128	-55	-34	-9
Precuenus Cortex	76	4.6608	2	-71	37
Insula	75	4.7413	-39	20	-2
Caudate	74	4.9434	-9	7	10
Precuneus Cortex	64	5.4998	17	-61	28
Dorsal Anterior Cingulate Gyrus	76	4.5167	-6	34	36
Insula	73	4.746	38	22	-6
Anterior PFC	21	4.8638	-38	56	0
Superior frontal gyrus	67	4.8043	7	28	52
Posterior IPL	70	4.3132	37	-64	49
Middle temporal gyrus	62	3.9992	56	-34	-12
Anterior PFC	38	5.1989	47	46	-4
Subthalamic Nucleus	28	4.8129	9	-10	-7
Middle Frontal Gyrus	63	4.5381	-41	24	40
Orbitofrontal Cortex	28	3.8696	-44	33	-11
Middle IPS	71	4.4973	-48	-40	48
Posterior Middle Temporal Gyrus	29	5.0017	-62	-20	-19
Precuneus Cortex	50	4.594	11	-74	57
Anterior Cingulate Gyrus	28	4.3194	3	48	4
Middle Frontal Gyrus	46	3.9054	40	32	36
Posterior IPS	25	4.236	-25	-71	57
Ventral Occipital Cortex	42	3.9124	-9	-90	-22
Angular Gyrus/SMG	64	4.2328	51	-45	38
Thalamus	48	4.2351	-2	-22	6
Middle Frontal Gyrus	30	3.646	33	12	55
Middle Frontal Gyrus	60	3.9711	-42	38	23
Anterior Cingulate Gyrus	22	4.5119	2	16	30

Precentral Gyrus	26	4.329	52	12	33
Orbitofrontal Cortex	24	4.045	-20	34	-13
Middle Frontal Gyrus	31	3.809	40	48	27
Posterior Cingulate Gyrus	23	3.9043	4	-41	7
Ventral Occipital Cortex	41	3.8145	21	-90	-21
Middle Frontal Gyrus/Superior Frontal Gyrus	29	3.7192	-29	6	58
Anterior PFC	8	3.0762	-24	60	20
Precuneus Cortex	25	3.6274	-5	-64	67
Precentral Gyrus	11	3.6066	-46	6	32
Inferior Frontal Gyrus, pars opercularis	25	4.2312	54	14	9
Brainstem	14	2.898	-5	-20	-18
Lingual Gyrus	12	3.563	1	-71	-1
Middle Temporal Gyrus, temporooccipital	8	3.285	-60	-57	-3
Insula	16	3.41	39	5	0
Superior Lateral Occipital Cortex	7	3.4089	-13	-83	50