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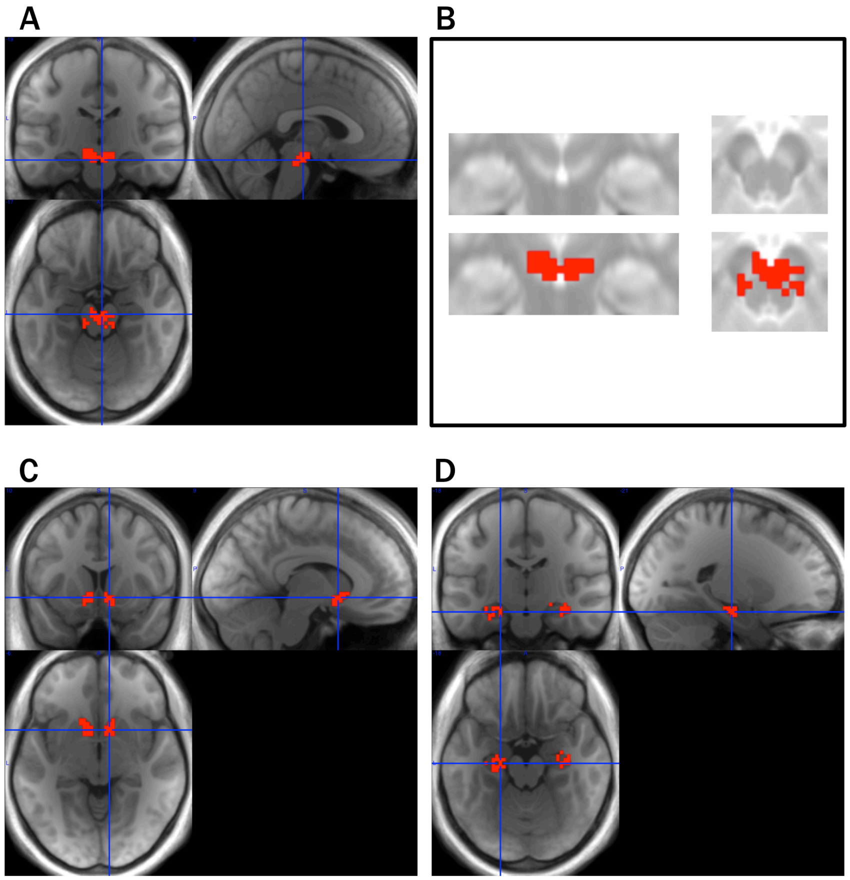

Figure S1. Regions of interest (ROIs). To have maximally sensitive ROIs, voxels were selected that have been previously associated with reward-related activity within three anatomical masks: **(A)** the SN/VTA (MNI: *x*=3, *y*=-19, *z*=-17), **(C)** the nucleus accumbens (MNI: *x*=9, *y*=10, *z*=-6), and **(D)** the hippocampus (MNI: *x*=-21, *y*=-18, *z*=-19). ROI clusters are shown for coronal, sagittal, and transverse slices on the average, normalized anatomical image in our group of participants. **(B)** The SN/VTA ROI is also shown on a magnetization transfer image (Bunzeck and Düzel, 2006). On these images, the VTA/ SN complex is visible as a white band. Depicted are a coronal and a transverse slice (top) and the same slices overlaid with the SN/VTA ROI (bottom) for the same MNI coordinates as in (A). See fMRI results for ROIs in Figure 2-4 and Figure S3-S5.

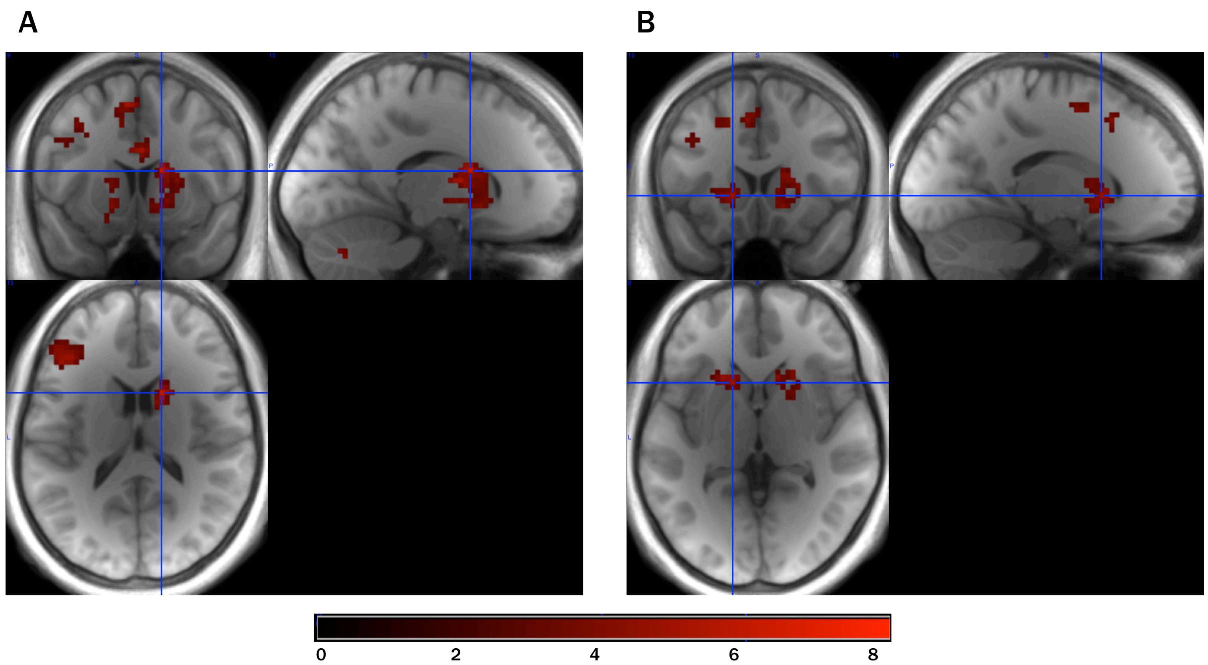

Figure S2. Whole-brain analyses for curiosity-related activation based on parametric modulation analyses. (A) Peak activation is shown for the right striatum cluster (MNI: *x*=15, *y*=9, *z*=15) and **(B)** for the left striatum cluster (MNI: *x*=-15, *y*=15, *z*=0) based on a cluster threshold of *p*<0.05 (see also Table S1). See ROI results in Figure 2.

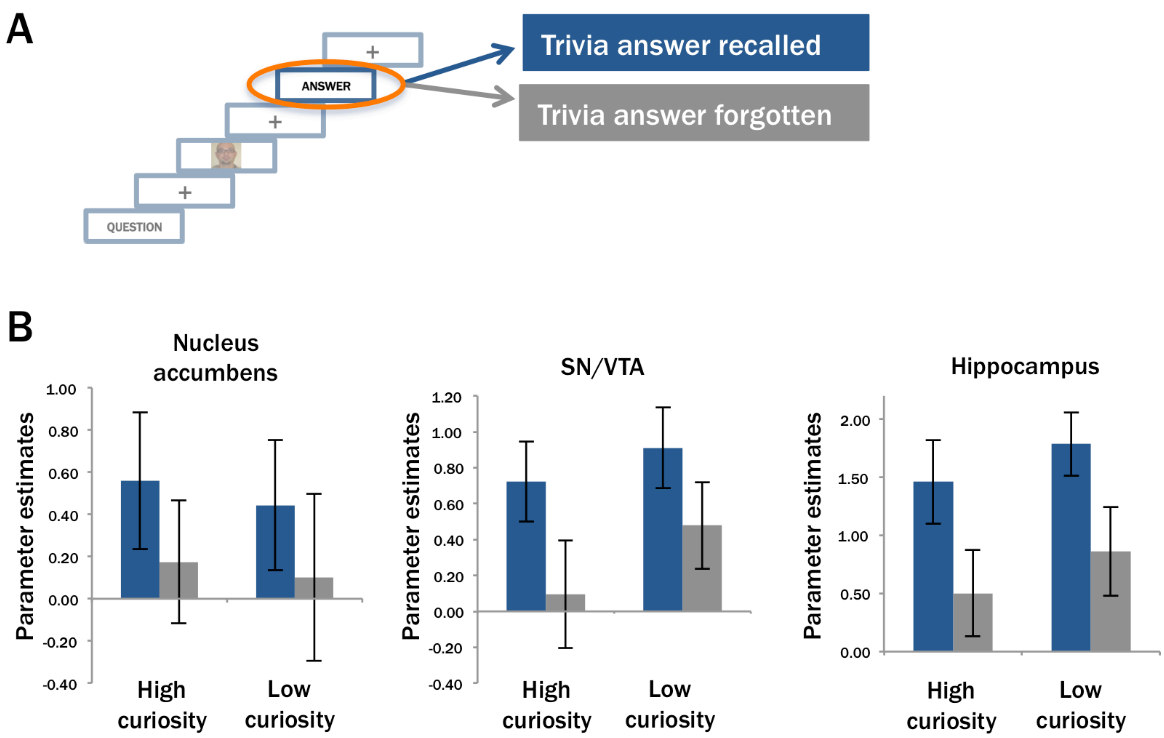

Figure S3. Stimulus-evoked activity of trivia answers predicted later memory performance independent of curiosity. (A) Brain activity elicited by trivia answers in high and low curiosity conditions was analyzed based on whether the associated answer was later recalled or forgotten. These analyses therefore were based on stimulus-related activation. **(B)** Stimulus-related brain activity in our three ROIs sorted by curiosity ratings and memory for the trivia answer. Error bars indicate ±SEM. No significant differences were found in the bilateral nucleus accumbens (left). Stimulus-related activity in the left SN/VTA (middle) and in the bilateral hippocampus (right) was enhanced for later recalled compared to later forgotten answers independent of curiosity conditions. Related to Figure 3.

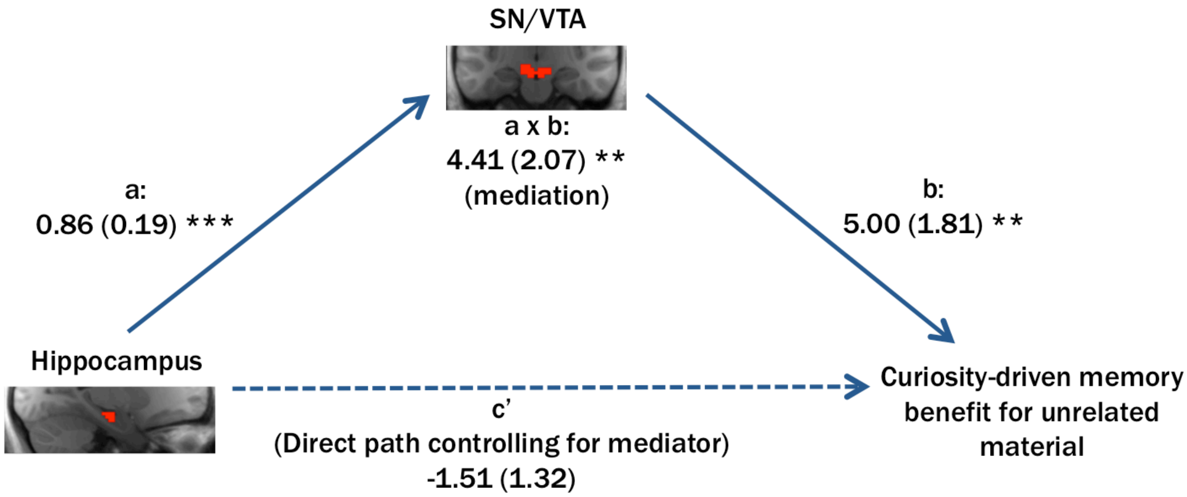

Figure S4. Activation in the SN/VTA mediated hippocampal activation in support of a curiosity-driven memory benefit for neutral faces. The mediation path diagram shows significant path *a*, *b*, and *a* X *b* (mediation) effects but no significant effect for *c*' path (direct path controlling for mediator). The mean path coefficients (SE) are shown (i.e. averaged across all 10,000 Bootstrap iterations). **$p<0.005$, ***$p<0.001$. Related to Figure 4 and Figure S5.

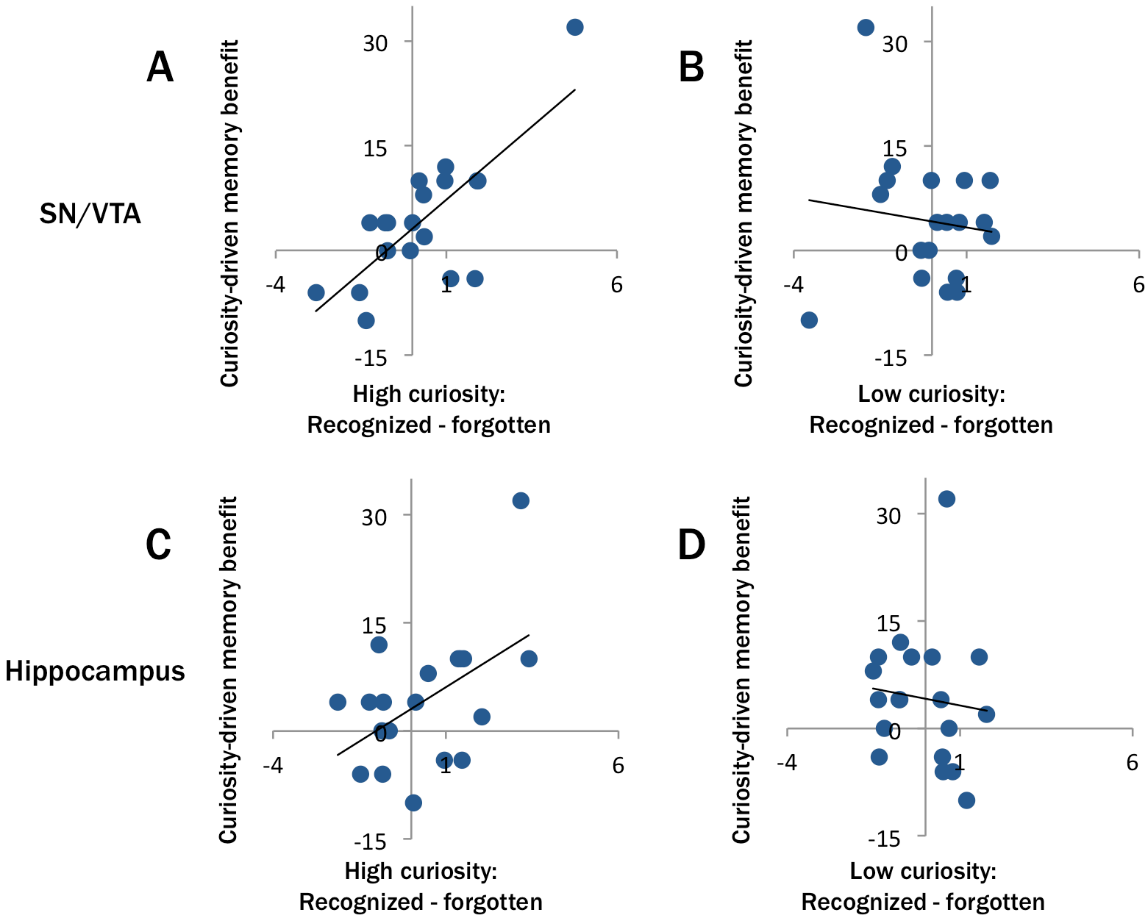

Figure S5. Memory-predicting activation during high – but not low – curiosity states was highly correlated with the curiosity-driven memory benefit for neutral faces. Significant positive correlations between the memory benefit (plotted on the y-axis) and memory-predicting activation during high curiosity states (i.e. onset of a high curiosity trivia question) were found in the bilateral SN/VTA **(A)** and the right hippocampus **(C)**. In contrast, memory benefits for neutral information during low curiosity states did not significantly correlate with memory-predicting activation (i.e. onset of a low curiosity trivia question) in the bilateral SN/VTA **(B)** and the right hippocampus **(D)**. Related to Figure 4 and Figure S4.

Table S1. Whole-brain analyses for curiosity-related activation based on parametric modulation analyses. MNI coordinates for the peak voxels of significant clusters ($p<0.05$), along with their *t* values and voxel cluster size (3mm isotropic) (L = left hemisphere; R = right hemisphere). Related to Figure 2.

Region	**Cluster size**	**t(18)**	**MNI coordinates**
Trivia question interval:			
R cerebellum	100	8.29	27 -63 -36
L inferior frontal gyrus	140	5.95	-48 33 9
R striatum	293	5.89	15 9 15
L superior medial gyrus	163	5.61	-3 24 39
L striatum	95	4.88	-15 15 0
Trivia answer interval:			
L inferior frontal gyrus	93	5.8	-36 36 -12

Table S2. Mean proportions (SEM) of confidence judgments during the recognition test phase for old (high and low curiosity) and new faces in the fMRI experiment (immediate memory test). Related to Figure 4A.

	confident old	unconfident old	unconfident new	confident new
old, high curiosity	39.2 (2.9)	29.3 (2.4)	21.2 (2.0)	10.2 (1.6)
old, low curiosity	40.4 (2.9)	23.8 (2.1)	24.1 (2.5)	11.5 (1.5)
new	8.4 (2.1)	17.7 (1.6)	36.7 (2.7)	37.0 (3.4)

Table S3. Mean proportions (SEM) of confidence judgments during the recognition test phase for old (high and low curiosity) and new faces in the behavioral follow-up experiment (one-day delayed memory test). Related to Figure 5B.

	confident old	unconfident old	unconfident new	confident new
old, high curiosity	45.6 (3.4)	16.4 (2.5)	17.1 (2.1)	20.1 (3.2)
old, low curiosity	41.6 (3.6)	18.9 (2.2)	16.1 (2.1)	22.9 (3.9)
new	10.4 (1.8)	12.1 (1.4)	29.8 (4.3)	47.1 (5.2)

Supplemental Experimental Procedures

Participants

FMRI experiment: Twenty-four healthy young adults took part in the experiment. Five participants were excluded from the analyses due to the following reasons: one participant due to excessive movement artifacts in the fMRI data, two participants due to failure to comply with the instructions, and two participants not showing above-chance memory performance. Results are based on the remaining nineteen participants. The behavioral and imaging analyses regarding memory for trivia answers are based on eighteen participants because of insufficient number of trials for one participant. Participants' mean age was 22.7 years (range: 18-31). Seventeen participants were right-handed and two were left-handed. They were compensated with $50 for their total time in the laboratory.

Behavioral follow-up experiment: Thirty-three healthy young adults took part in the behavioral follow-up experiment. Five participants were excluded from the analyses due to the following reasons: two participants due to failure to comply with the instructions and three participants not showing above-chance memory performance. Results are based on the remaining twenty-eight participants for the analyses of incidental memory for the faces and on twenty-seven participants for memory for the trivia answers due to a technical problem for one participant during the memory test for trivia answers. Participants' mean age was 20.4 years (18-24). Twenty-five participants were right-handed and three were left-handed. They received course credits for participation in the experiment on the first day and were compensated with $10 for participation on the second day.

In both experiments, all participants had normal or corrected-to-normal vision and were native English speakers. The UC Davis Institutional Review Board approved both experiments.

Material

Trivia questions and answers. We generated a pool of 375 trivia questions along with their corresponding answers from online trivia websites. Questions corresponded to trivia categories that might elicit different levels of curiosity in young adults: history/geography, movies/TV, music, nature, science, space, sports, food, and other miscellaneous facts. The pool only included trivia questions for which the answers were likely to be unknown to the majority of participants because participants should not have prior knowledge but learn the answers during the study phase. On average (min-max), trivia questions contained 11 (4-20) words and trivia answers 2 (1-8) words. The selected 112 trivia items for the study phase differed across participants because trivia questions were randomly drawn from the trivia pool in the screening phase and the allocation of trivia questions to high or low curiosity conditions depended on participants' ratings during the screening phase.

Faces. A pool of 168 photographs of emotionally neutral faces with naturalistic backgrounds was used in the experiment. This pool was a subset of stimuli that have previously been used in the literature (Bialleck et al., 2011). The face stimuli were divided into three sets (56 stimuli each) and these sets were counterbalanced across participants for the following three trial types: faces presented in high and low curiosity conditions during the study phase and faces that served as new stimuli during the test phase.

Presentation

Throughout all phases of the experiment, stimuli were presented on a gray background and in the center of the computer screen. The Cogent 2000 toolbox (http://www.vislab.ucl.ac.uk/cogent.php) was used for the experimental phases in the lab that were conducted outside of the MRI scanner and the Psychophysics Toolbox (http://psychtoolbox.org) was used for the presentation of all stimuli inside the MRI scanner. In the screening phase, a trivia question was presented for 6 s followed by two consecutively presented rating scales that were self-paced (see Experimental Procedures and Figure 1A). After a response was given for the second rating, an inter-trial cross hair was presented with a duration of 1 s. In the study phase (Figure 1B), a trial started with a trivia question that was presented for 4 s and ended with a 1 s long presentation of the trivia answer or the letter string ‘xxxxx’ on catch trials. During the 14 s long anticipation phase (i.e. from the onset of the trivia question to the onset of the trivia answer), a cross hair was presented after the presentation of the trivia question and the cross hair was replaced by a face from 8 to 10 s after the onset of the trivia question. A cross hair was also presented during the inter-trial interval, which was temporally jittered with an average of 4 s within a scanning run. In the recognition test phase for faces, a face was presented for 1.5 s preceded by a warning stimulus (i.e. “!”) with a duration of 1 s. The inter-trial interval displaying a cross hair was temporally jittered with a 3-4.5 s duration. In the recall test phase for trivia answers, a Microsoft Excel spreadsheet was presented that included one column with a random order of all 112 trivia questions presented during the study phase and participants were instructed to fill in the answers in the column right next to the question.

Trial numbers

For analyses of subsequent memory for faces, average numbers of trials per bin were as follows: high curiosity recognized: 34 (range=22-45) trials; high curiosity missed: 16 (5-28) trials; low curiosity recognized: 32 (16-44); low curiosity missed: 18 (6-34). For analyses of subsequent memory for trivia answers, average numbers of trials per bin were as follows: high curiosity recalled: 37 (13-45) trials; high curiosity forgotten: 13 (5-26); low curiosity recalled: 26 (13-38); low curiosity forgotten: 24 (12-37). Importantly, participants with very low trial numbers in a particular bin (i.e. 5-7 trials) did not affect the pattern of results for memory-related findings for faces or trivia answers.

Supplemental Behavioral Analyses

Above-chance memory for incidental material (faces)

In both experiments, the proportion of old faces that were correctly judged 'confident old' during both high and low curiosity states was significantly higher than the proportion of new faces that incorrectly received this judgment ($p<0.001$). Importantly, this was also true for 'unconfident old' judgments in both curiosity conditions ($p<0.05$). This suggests that memory accuracy for neutral faces was above chance for both response types during high and low curiosity states. Therefore, collapsing responses across confidence for the behavioral and fMRI data still enabled us to reliably measure memory responses. For an overview, Table S1 (fMRI experiment with immediate memory tests) and Table S2 (behavioral experiment with 1-day delayed memory tests) show the proportions of recognition responses for neutral faces depending on the level of confidence.

Supplemental Neuroimaging Analyses

Stimulus-evoked activity generally predicted successful memory performance for interesting and uninteresting information (trivia answers)

In line with decades of research on how stimulus-related factors contribute to successful encoding (Paller and Wagner, 2002), and given the finding that memory performance for interesting and uninteresting trivia answers was well above chance, we did not expect any interactions between curiosity and memory-related activity at the time of the trivia answer in the hippocampus (see Figure S3A). Indeed, a 2 (curiosity: high/ low) x 2 (memory: recalled/ forgotten) repeated measures ANOVA revealed a main effect of memory in the bilateral hippocampus (left: $F_{(1,17)}$=23.53, p<0.001; right: $F_{(1,17)}$=10.55, p=0.005) and no interaction between curiosity and memory (left: $F_{(1,17)}$=0.00, p=0.971; right: $F_{(1,17)}$=0.01, *p*=0.934) (see Figure S3B, right). This suggests that hippocampal activity during processing of the trivia answer was generally associated with successful memory formation, regardless of curiosity. This effect is in contrast to the effects of curiosity on anticipatory activity in the hippocampus. For the left SN/VTA (see Figure S3B, middle), a repeated measures ANOVA on activity at the onset of the trivia answer also revealed a main effect of memory (left: $F_{(1,17)}$=11.77, p=0.003; right: $F_{(1,17)}$=2.99, p=0.102) and no interaction of curiosity and memory (left: $F_{(1,17)}$=0.33, p=0.571; $F_{(1,17)}$=0.23, right: p=0.638). Such finding in the SN/VTA at the time of trivia answers is consistent with the findings at the time of the trivia questions, suggesting that the SN/VTA supported memory for trivia answers regardless of the level of curiosity. For the nucleus accumbens (Figure S3B, left), a repeated measures ANOVA did not indicate any stimulus-related activity that predicted later memory performance for trivia answers (main effect of memory: left: $F_{(1,17)}$=1.97, p=0.178; right: $F_{(1,17)}$=2.17 p=0.159; interaction curiosity and memory: left: $F_{(1,17)}$=0.01, p=0.927; right: $F_{(1,17)}$=0.09, p=0.769).

In summary, in our three ROIs, stimulus-related activity that predicted later memory performance did not differ between answers to interesting and uninteresting trivia questions. This is in stark contrast to the findings reported in the main text in which we found that question-evoked activity in the nucleus accumbens and hippocampus only predicted later memory performance for interesting - but not for uninteresting - trivia answers.

Stimulus-evoked activity generally predicted successful memory performance for irrelevant material (faces) during high and low curiosity states

In line with the predictions for stimulus-evoked activity of trivia answers, we also hypothesized that stimulus-evoked activity for faces should be independent of whether a face stimulus is presented on a high or low curiosity trial. Indeed, 2 (curiosity: high/ low) x 2 (memory: recognized/ forgotten) repeated measures ANOVAs revealed a main effect of memory in the left hippocampus (left: $F_{(1,18)}$=8.55, p=0.009; right: $F_{(1,18)}$=0.32, p=0.577) but no interaction between curiosity and memory (left: $F_{(1,17)}$=0.16, p=0.691; right: $F_{(1,17)}$=1.45, p=0.244). Repeated measures ANOVAs for the nucleus accumbens and the SN/VTA did not indicate any stimulus-related activity that predicted later memory performance for faces (all $F's \leq 0.96$, $p's \geq 0.341$). The findings suggest that left hippocampal activity during processing of faces was generally associated with successful memory formation, regardless of curiosity.

Mediation analysis on SN/VTA and hippocampus activity in support of curiosity-driven memory benefits for incidental material

In the main text, we report that memory-predicting activity during high curiosity states shows significant correlations for the bilateral SN/VTA and right hippocampus ROI with curiosity-driven memory benefits for irrelevant material (faces). To more effectively characterize how such individual differences in activity in the SN/VTA and hippocampus related to curiosity-driven memory benefits, we performed a mediation analysis. In particular, we tested whether between-individual variability in activation of the bilateral SN/VTA ROI mediated hippocampal activity in support of later curiosity-driven memory benefits for faces. As in the main manuscript, we targeted anticipatory activity following high curiosity question onsets that predicted later memory for faces (recognized vs. forgotten faces) on the same trial. The bilateral SN/VTA ROI was used because left and right SN/VTA showed similar correlations with memory benefits (see main text).

We used the Mediation Toolbox (Wager et al., 2008; http://wagerlab.colorado.edu/wiki/doku.php/help/mediation/m3_mediation_fmri_toolbox) employing a bootstrap significance test (10,000 iterations with replacements, one-tailed) for the effects on path a, b, a X b, and c'; see Figure S4 for path coefficients and standard errors). The interaction (a X b) of path *a* (i.e. anticipatory hippocampal activity to SN/VTA activity both predictive of later memory for faces) and path *b* (i.e. anticipatory SN/VTA activity predictive of later memory to curiosity-driven memory benefits, controlling for hippocampus activity) was used to identify a mediation effect.

As seen in Figure S4, we found that activation between the bilateral SN/VTA and right hippocampus ROIs (path a) correlated significantly ($p<0.001$). As expected from the correlation analyses in the main text, activation between the SN/VTA (mediating variable) and the curiosity-driven memory benefit (path b) showed a significant correlation ($p=0.004$). However, the direct path (path c': controlling for midbrain activity) of hippocampus activity to memory benefits did not suggest a significant influence on memory ($p=0.147$). Importantly, the mediation of the SN/VTA on hippocampal activity (i.e. interaction of path a x b) was significant in predicting curiosity-driven memory benefits ($p=0.002$). In contrast, the alternative mediation analysis that tested whether the hippocampus mediated SN/VTA activity in support of memory benefits did not show a significant mediation effect ($p>0.05$). This result is consistent with the idea that anticipatory activity in the SN/VTA during states of high curiosity mediates activation in the hippocampus, thereby promoting incidental learning of unrelated material.

Supplemental References

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