Supplementary Materials for

Embodiment in episodic memory through premotor-hippocampal coupling

Authors

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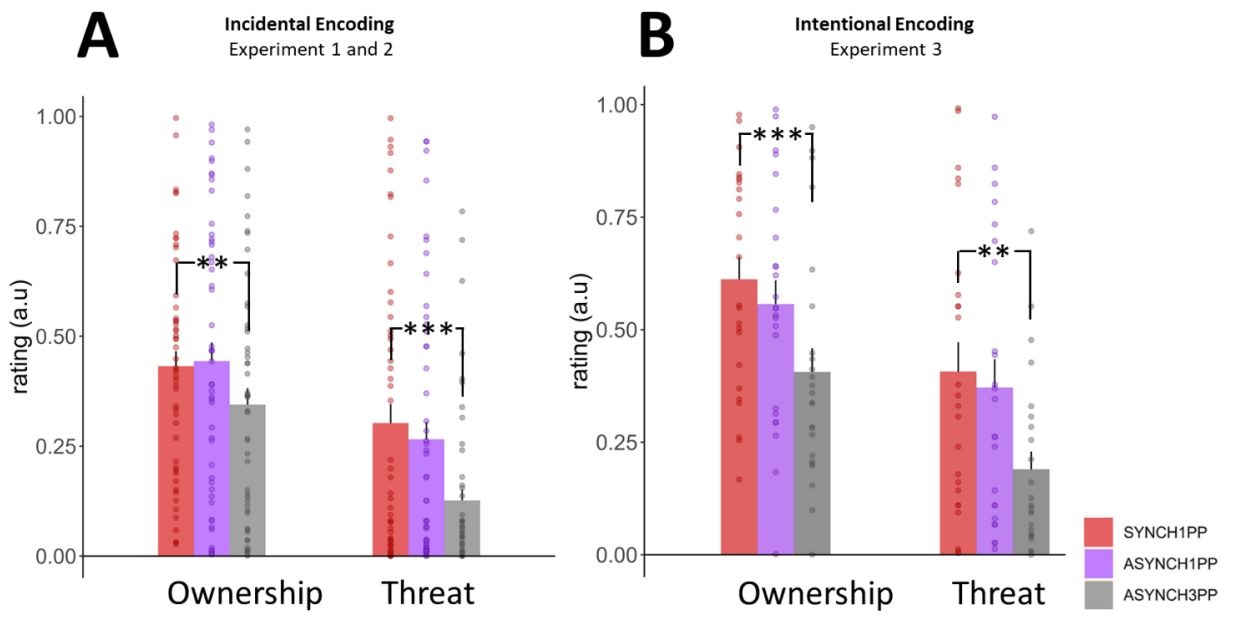
This PDF file includes:

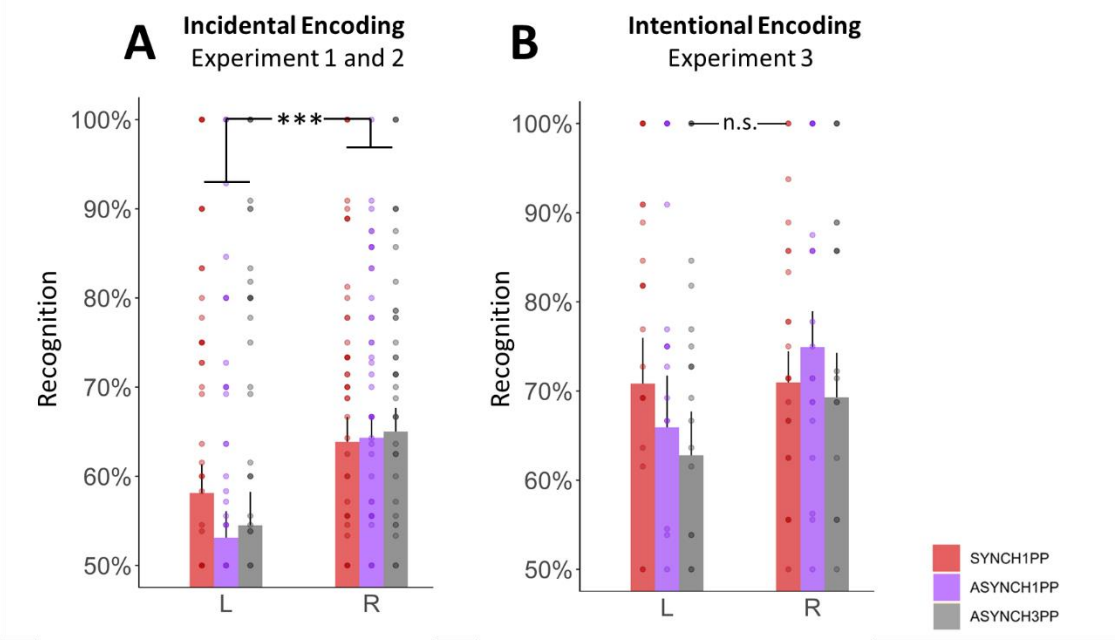
Other Supplementary Materials for this manuscript include the following:

Fig. S1. BSC ratings during encoding of scenes under different visuomotor conditions.



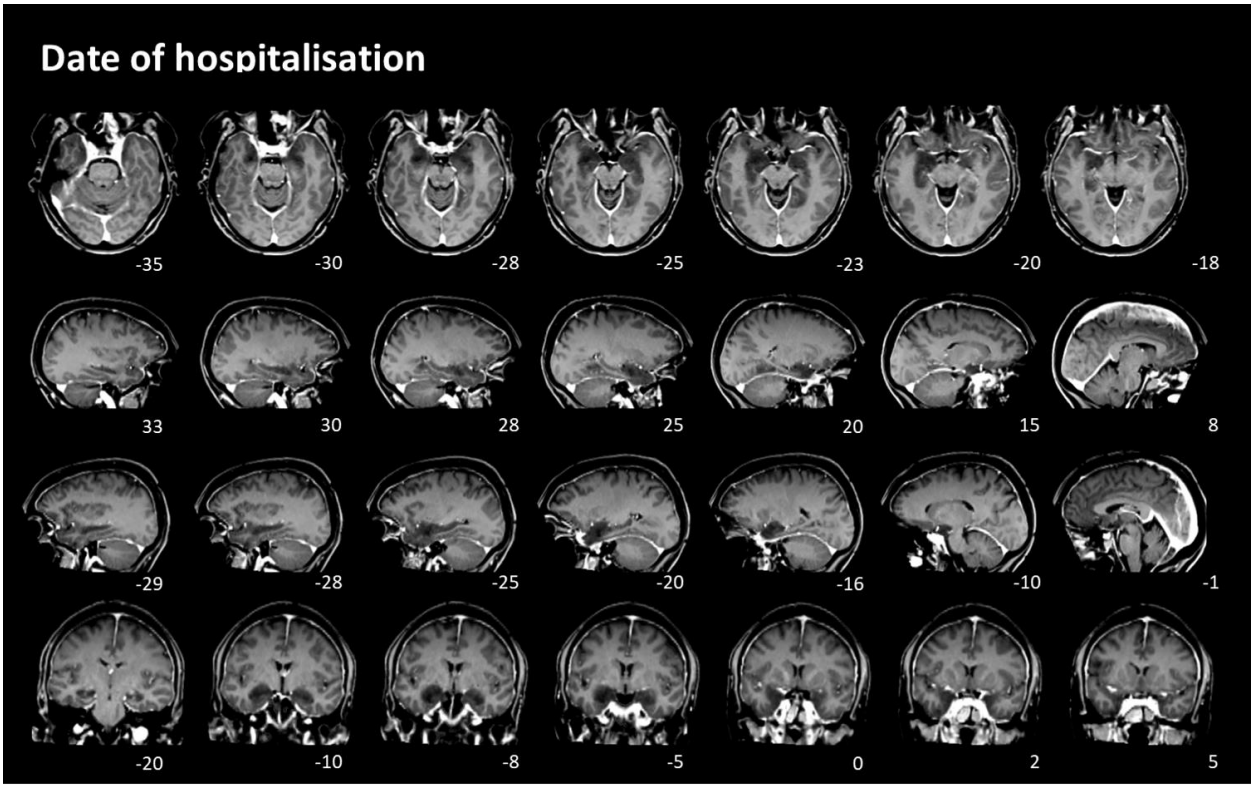
(**A**) Participants had a higher body ownership rating and were more afraid of the under visuomotor and perspectival congruency (SYNCH1PP, red) compared to visuomotor and perspectival mismatch (ASYNCH3PP, grey), no difference was observed between visuomotor and perspectival congruency (SYNCH1PP) and visuomotor mismatch (ASYNCH1PP, purple). **,*** indicates significance level with p-value <0.01, < 0.001 respectively, as tested with a linear mixed model ; N = 50. (**B**) Participants had a higher body ownership and were more afraid of the threat under visuomotor and perspectival congruency (SYNCH1PP, red) compared to visuomotor and perspectival mismatch (ASYNCH3PP, grey), no difference was observed between visuomotor and perspectival congruency (SYNCH1PP) and visuomotor mismatch (ASYNCH1PP, purple). **, *** indicates significance level with p-value <0.01 , < 0.001 respectively as tested with a linear mixed model N = 25.

Fig. S2. Effect of objects changes laterality on recognition.



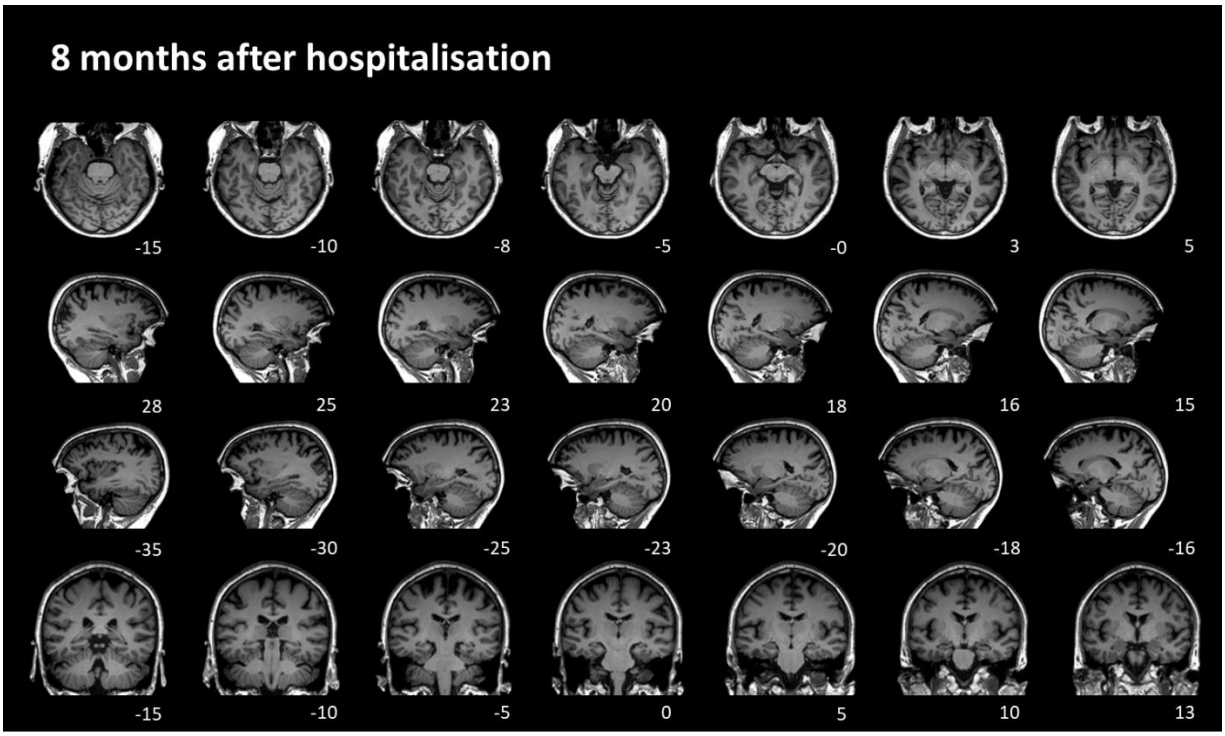
(**A**) There was a significant main effect of object side but no interaction between conditions and object side under the incidental encoding instruction (experiment 1& 2) as tested with linear mixed model, N = 48. *** indicates significance level with p-value <0.001. (**B**) There was no effect of object laterality under intentional encoding instruction (experiment 3). linear mixed model, N = 24.

Fig. S3. Patient's lesion on the day of hospitalisation.



Anatomical scan of the patient on the day of the hospitalisation acquired with a Siemens MR-scanner (3T). dark regions around the left hippocampus show sign of inflammation.

Fig. S4. Patient's lesion eight month after hospitalisation.



Anatomical scan of the patient taken eight months after the diagnosis. Clear amelioration of the inflammation around the hippocampal regions based on clinical report, although the patient did not recover from her amnestic deficit.

	Estimate	t-value	p-value
(Intercept)	0.654	12.383	<0.001 ***
factor(Conditions)ASYNCH1PP	-0.067	-2.931	0.003**
factor(Conditions)ASYNCH3PP	-0.065	-2.841	0.005**
factor(Experiment)MRI	-0.045	-0.652	0.515

Table S1.1

Effect of conditions on sense of agency ratings in Experiment 1 and 2: Agency ~ Conditions + Experiment + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.464	8.285	<0.001 ***
factor(Conditions)ASYNCH1PP	0.012	0.387	0.699
factor(Conditions)ASYNCH3PP	-0.087	-2.903	0.004 **
factor(Experiment)MRI	-0.833	-0.833	0.405

Table S1.2.

Effect of conditions on ownership ratings in Experiment 1 and 2: Ownership ~ Conditions + Experiment + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.289	5.557	<0.001 ***
factor(Conditions)ASYNCH1PP	-0.037	-0.936	0.349
factor(Conditions)ASYNCH3PP	-0.176	-4.451	<0.001 ***
factor(Experiment)MRI	0.024	0.384	0.701

Table S1.3.

Effect of conditions on threat ratings in Experiment 1 and 2: Threat ~ Conditions + Experiment + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.068	2.678	0.007 **
factor(Conditions)ASYNCH1PP	0.012	0.942	0.346
factor(Conditions)ASYNCH3PP	-0.013	-1.043	0.297
factor(Experiment)MRI	0.061	1.829	0.067

Table S1.4.

Effect of conditions on control ratings for experimental bias in Experiment 1 and 2: Control ~ Conditions + Experiment + random(Participants).

	Estimate	z-value	p-value
(Intercept)	0.643	6.925	<0.001 ***
factor(Conditions)ASYNCH1PP	0.025	0.355	0.723
factor(Conditions)ASYNCH3PP	0.064	0.929	0.353
factor(Environment)ENV2	0.207	2.969	0.003 **
factor(Environment)ENV3	-0.002	-0.031	0.975
factor(Experiment)MRI	-0.025	-0.243	0.808

Table S2

Effect of conditions on performance (Experiment 1-2): Performance ~ Conditions + Scene + Experiment + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.695	13.684	<0.001 ***
factor(Conditions)ASYNCH1PP	-0.042	-1.202	0.229
factor(Conditions)ASYNCH3PP	-0.111	-3.159	0.002 **

Table S3.1

Effect of conditions on sense of agency ratings in Experiment 3: Agency ~ Conditions + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.612	11.760	<0.001 ***
factor(Conditions)ASYNCH1PP	-0.055	-1.226	0.220
factor(Conditions)ASYNCH3PP	-0.206	-4.590	<0.001 ***

Table S3.2.

Effect of conditions on ownership ratings in Experiment 3: Ownership ~ Conditions + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.407	7.136	<0.001 ***
factor(Conditions)ASYNCH1PP	-0.035	-0.508	0.612
factor(Conditions)ASYNCH3PP	-0.217	-3.126	0.002 **

Table S3.3.

Effect of conditions on threat ratings in Experiment 3: Threat ~ Conditions + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.179	5.600	<0.001 ***
factor(Conditions)ASYNCH1PP	-0.010	-0.557	0.578
factor(Conditions)ASYNCH3PP	-0.028	-1.503	0.133

Table S3.4.

Effect of conditions on control ratings for experimental bias in Experiment 3: Control ~ Conditions + random(Participants).

	Estimate	z-value	p-value
(Intercept)	1.211	8.607	<0.001 ***
factor(Conditions)ASYNCH1PP	-0.328	-3.058	0.002 **
factor(Conditions)ASYNCH3PP	-0.316	-2.949	0.003 **
factor(Environment)ENV2	0.013	0.119	0.905
factor(Environment)ENV3	0.100	0.943	0.346

Table S4.

Effect of conditions on performance (Experiment 3): Performance ~ Conditions + Scene + random(Participants).

	Estimate	z-value	p-value
(Intercept)	0.212	1.348	0.178
factor(Conditions)ASYNCH1PP	-0.201	-1.421	0.155
factor(Conditions)ASYNCH3PP	-0.177	-1.238	0.216
Factor(Laterality) R	0.288	2.028	0.043 *
factor(Environment)ENV2	0.645	6.440	<0.001 ***
factor(Environment)ENV3	0.091	0.917	0.359
factor(XP)MRI	-0.277	-1.946	0.052
factor(Conditions)ASYNCH1PP × factor(Laterality)R	0.145	0.737	0.461
factor(Conditions)ASYNCH3PP × factor(Laterality)R	0.162	0.820	0.412

Table S5.

Effect of object laterality on performance (Experiment 1-2): Performance ~ Conditions*ObjectLaterality(L/R) + Scene + random(Participants).

	Estimate	z-value	p-value
(Intercept)	0.671	3.087	0.002 **
factor(Conditions)ASYNCH1PP	-0.399	-1.87	0.062
factor(Conditions)ASYNCH3PP	-0.398	-1.864	0.062
Factor(Laterality) R	0.037	0.168	0.867
factor(Environment)ENV2	0.5	283	0.001 **
factor(Environment)ENV3	0.255	1.662	0.095
factor(Conditions)ASYNCH1PP × factor(Laterality)R	0.502	0.737	0.097
factor(Conditions)ASYNCH3PP × factor(Laterality)R	0.194	0.650	0.515

Table S6.

Effect of object laterality on performance (Experiment 3): Performance ~ Conditions*ObjectLaterality(L/R) + Scene + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.039	1.700	0.089
factor(Conditions)ASYNCH1PP	-0.045	-2.570	0.010
factor(Conditions)ASYNCH3PP	-0.045	-2.596	0.009 **
factor(Environment)ENV2	-0.012	-0.668	0.504
factor(Environment)ENV3	-0.006	-0.323	0.747

Table S7.

Effect of conditions on hippocampal ERS: Hippocampal ERS Success ~ Conditions + Scene + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.008	0.327	0.743
factor(Conditions)ASYNCH1PP	-0.048	-2.769	0.006 **
factor(Conditions)ASYNCH3PP	-0.011	-0.637	0.524
factor(Environment)ENV2	0.033	1.910	0.056
factor(Environment)ENV3	0.001	0.083	0.934

Table S8.

Effect of conditions on middle temporal gyrus ERS: middle temporal gyrus ERS Success ~ Conditions + Scene + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.039	2.254	0.024 *
factor(Conditions)ASYNCH1PP	-0.010	-0.478	0.633
factor(Conditions)ASYNCH3PP	-0.033	-1.628	0.103
factor(Environment)ENV2	-0.009	-0.462	0.644
factor(Environment)ENV3	-0.002	-0.120	0.904

Table S9.

Effect of conditions on orbitofrontal ERS: orbitofrontal ERS Success ~ Conditions + Scene + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.061	1.795	0.073
factor(Conditions)ASYNCH1PP	-0.001	-0.043	0.966
factor(Conditions)ASYNCH3PP	-0.030	-1.590	0.112
factor(Environment)ENV2	0.003	0.155	0.877
factor(Environment)ENV3	-0.029	-1.544	0.123

Table S10.

Effect of conditions on visual ERS: visual ERS Success ~ Conditions + Scene + random (Participants).

	AIC	BIC	logLik	deviance	Chisq	Df	Pr(>Chisq)
Model 0	159.731	146.071	85.86549	171.731			
Model 1	159.834	137.068	89.91708	179.834	8.103189	4	0.087871

Table S11.

Model comparison : performance explained by ERS Hippocampus with or without conditions. (Model 0) Performance ~ ERS Hippocampus + Scene + random(Participants). **(Model1)** Performance ~ ERS Hippocampus * Conditions + Scene + random(Participants)

	Estimate	t-value	p-value
(Intercept)	0.661	40.842	<0.001***
ERS	0.291	2.723	0.006 **
factor(Environment)ENV2	0.052	2.748	0.006 **
factor(Environment)ENV3	-0.008	-0.409	0.682

Table S12.

Effect of hippocampal ERS on performance: *Performance ~ Hippocampal ERS + Scene + random(Participants).*

	AIC	BIC	logLik	deviance	Chisq	Df	Pr(>Chisq)
Model 0	3580.075	3627.8	1782.04	3564.075			
Model 1	3416.513	3500.031	1694.26	3388.513	175.5622	6	<0.001

Table S13.1

Model comparison: performance (trial-by-trial) explained by hippocampal ERS and conditions or hippocampal ERS, conditions, and stimulus type. (Model 0) Performance (binomial) ~hippocampal ERS * Conditions + Trials +random(Participants).(Model 1) Performance (binomial) ~hippocampal ERS * Conditions *Stimulus+ Trials +random(Participants)

	Estimate	z-value	p-value
(Intercept)	-0.368	-2.910	<0.001***
factor(Conditions)ASYNCH1PP	0.088	0.661	0.509
factor(Conditions)ASYNCH3PP	0.104	0.780	0.435
ERS	-0.411	-1.168	0.243
Factor(Stimulus)NoChange	1.009	6.874	<0.001***
Trials	0.028	7.684	0.001 **
factor(Conditions)ASYNCH1PP × ERS	0.650	1.293	0.196
factor(Conditions)ASYNCH3PP × ERS	0.684	1.342	0.180
factor(Conditions)ASYNCH1PP × Stimulus(NoChange)	0.168	0.791	0.429
factor(Conditions)ASYNCH3PP × Stimulus(NoChange)	0.056	3.524	0.787
ERS x factor(Stimulus) NoChange	1.862	3.524	<0.001***
factor(Conditions)ASYNCH1PP × ERSx factor(Stimulus) NoChange	-1.073	-1.380	0.168
factor(Conditions)ASYNCH3PP × ERSx factor(Stimulus) NoChange	-2.043	-2.604	0.009 **

Table S13.2

Effect of hippocampal ERS , conditions and type of stimuli (Original scene or changed scene) on performance: Performance ~ Hippocampal ERS Conditions*Stim +Trials + random(Participants)

	Estimate	z-value	p-value
(Intercept)	-0.105	-0.686	0.493
factor(Conditions)ASYNCH1PP	0.089	0.670	0.503
factor(Conditions)ASYNCH3PP	0.112	0.835	0.403
ERS	-0.509	-1.429	0.153
Trials	0.028	7.684	0.001 **
factor(Conditions)ASYNCH1PP × ERS	0.725	1.435	0.151
factor(Conditions)ASYNCH3PP × ERS	0.777	1.516	0.130

Table S13.3

Effect of hippocampal ERS and conditions on performance for recognition of changed scene (Change): Performance (Change) ~ Hippocampal ERS *Conditions +Trials + random(Participants).

	Estimate	z-value	p-value
(Intercept)	0.324	1.487	0.137
factor(Conditions)ASYNCH1PP	0.276	1.587	0.112
factor(Conditions)ASYNCH3PP	0.180	1.065	0.287
ERS	1.545	3.527	<0.001***
Trials	0.052	8.290	<0.001***
factor(Conditions)ASYNCH1PP × ERS	-0.593	-0.916	0.360
factor(Conditions)ASYNCH3PP × ERS	-1.665	-2.551	0.011 *

Table S13.4.

Effect of hippocampal ERS and conditions on performance for recognition of original scene (No change): Performance (NoChange) ~ Hippocampal ERS *Conditions +Trials + random(Participants).

	Estimate	z-value	p-value
(Intercept)	-0.013	-0.042	0.966
ERS	1.720	3.520	<0.001***
Trials	0.075	6.260	<0.001***

Table S13.5.

Effect of hippocampal ERS on performance for recognition of original scene (No change) in SYNCH1PP: Performance (No Change) ~ Hippocampal ERS SYNCH1PP +Trials + random(Participants).

	Estimate	z-value	p-value
(Intercept)	0.742	2.512	0.012 *
ERS	-0.223	-0.429	0.668
Trials	0.043	4.036	<0.001***

Table S13.6.

Effect of hippocampal ERS on performance for recognition of original scene (No change) in ASYNCH3PP: Performance (No Change) ~ Hippocampal ERS ASYNCH3PP +Trials + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.66	30.77	<0.001***
ERS	0.08	0.6	0.55
factor(Environment)ENV2	0.04	1.8	0.08
factor(Environment)ENV3	-0.02	-0.61	0.54

Table S14.

Effect of middle temporal gyrus ERS on performance: Performance ~ Middle temporal gyrus ERS + Scene + random(Participants).

	[x y z]	k	p-value FEW corrected
Cluster	[6 -2 54]	856	0.02

Table S15.

Cluster sensitive to the BSC manipulation at encoding:*SYNCH1PP-(ASYNCH1PP+ASYNCH3PP) BSC session.*

	Estimate	t-value	p-value
(Intercept)	0.019	0.877	0.380
factor(Conditions)ASYNCH1PP	-0.013	-1.147	0.252
factor(Conditions)ASYNCH3PP	-0.008	-0.714	0.475
ERS	0.199	7.404	<0.001***
Trials	-0.002	-4.674	<0.001***
factor(Conditions)ASYNCH1PP × ERS	-0.192	-5.264	<0.001***
factor(Conditions)ASYNCH3PP × ERS	-0.069	-1.896	0.058

Table S16.1

Left dPMC and hippocampal ERS coupling: *Hippocampal ERS ~ Premotor ERS * Conditions +Trials + random(Participants).*

	Estimate	t-value	p-value
(Intercept)	0.035	1.269	0.205
ERS	0.194	6.765	<0.001***
Trials	-0.003	-3.730	<0.001***

Table S16.2

Left dPMC and hippocampal ERS coupling for SYNCH1PP: *Hippocampal ERS ~ Premotor ERS +Trials + random(Participants).*

	Estimate	t-value	p-value
(Intercept)	0.001	0.045	0.964
ERS	-0.038	-1.366	0.172
Trials	-0.002	-2.254	0.024 *

Table S16.3

Left dPMC and hippocampal ERS coupling for ASYNCH1PP: *Hippocampal ERS ~ Premotor ERS +Trials + random(Participants).*

	Estimate	t-value	p-value
(Intercept)	0.012	0.564	0.573
factor(Conditions)ASYNCH1PP	-0.019	-1.692	0.091
factor(Conditions)ASYNCH3PP	-0.012	2.454	0.262
ERS	0.061	7.404	0.014 *
Trials	-0.001	-2.961	0.003 **
factor(Conditions)ASYNCH1PP × ERS	0.007	0.216	0.829
factor(Conditions)ASYNCH3PP × ERS	0.006	0.171	0.864

Table S17.

Left SMA and hippocampal ERS coupling: Hippocampal ERS ~ Left SMA ERS *Conditions +Trials + random(Participants).

	Estimate	t-value	p-value
(Intercept)	0.020	0.946	0.344
factor(Conditions)ASYNCH1PP	-0.019	-1.674	0.094
factor(Conditions)ASYNCH3PP	-0.012	-1.106	0.269
ERS	0.006	0.260	0.795
Trials	-0.002	-3.962	<0.001***
factor(Conditions)ASYNCH1PP × ERS	-0.002	-0.059	0.953
factor(Conditions)ASYNCH3PP × ERS	0.046	1.366	0.172

Table S18.

Right SMA and hippocampal ERS coupling: Hippocampal ERS ~ Right SMA ERS *Conditions +Trials + random(Participants).

Test	Raw scores	VIN	IN	SIN	N	SSN	SN	VSN
Orientation								
Orientation Questionnaire (Von Cramon & Säring, 1982)	Oriented in 4 modes : 18/29 Temporal orientation : 5/5, spatiale : 5/5, personal : 4/5, situation : 4/5				X			
Mnesic function								
Short-term memory Empan verbal WAIS-IV (Welcher, 2011) Empan visuospatial Corsi (CHUV, 1985)	4 5			X	 X			
Rivermead Behavioural Memory Test (Wilson et al., 2008)	Name: 4 Personal objects : 8 Delayed images: 13 Delayed history: 5 Orientation and date : 9	 X	 	 X 	X X X 	 	 	
RL-RI 16 (Van der Linden et al., 2004)	Immediate recall: 16 RL delayed: 6/16 RL delayed (7 days): 0 /9	 X	 X 	 	X 	 	 	
TEMPau (Piolino et al., 2008)	0-17 y.o. global score: 3, episodic score 1 18-30 y.o. global score: 6, episodic score 2 >30 y.o. global score: 6, episodic score 2 Last 5 years global score: 5, episodic score 2 Last 12 months global score: 2, episodic score 1	X X X X X						
EVE-10 Batteries (Thomas-Antérion et al., 2006)	Public events : 38% correct Famous people : 54% correct	X 	 X					
Screening confabulation	No provoqued confabulation				X			
Modified Camel and Cactus test	32/32				X			

Table S19.

Neuropsychological tests performed in amnesia patient.
Summary of the main tests performed three months prior to Experiment 4. VIN = very inferior to the norm, IN = inferior to the norm, N = norm, SIN = Slightly inferior to the norm, SSN = Slightly superior to the norm, SN = superior to the norm, VSN = very superior to the norm. y.o. = years old.

Volumes	Total (cm^3/%)	Right (cm^3/%)	Left (cm^3/%)	Assymetry (%) Right - Left
Hippocampus	2.46 / (0.1944) [0.28 - 0.43]	1.12 / (0.0883) [0.14 - 0.22]	1.34 / (0.1061) [0.14 - 0.22]	-18.2331 [-16.78 - 10.90]
CA1	0.93 / (0.0738) [0.10 - 0.15]	0.44 / (0.0349) [0.05 - 0.08]	0.49 / (0.0389) [0.05 - 0.08]	-11.0065 [-21.32 - 15.49]
CA2-CA3	0.16 (0.0128) [0.02 - 0.03]	0.08 / (0.0062) [0.01 - 0.02]	0.08 / (0.0066) [0.01 - 0.02]	-5.5468 [-66.14 - 27.57]
CA4-DG	0.55 / (0.0434) [0.07 - 0.11]	0.24 / (0.0189) [0.03 - 0.06]	0.31 / (0.0245) [0.03 - 0.06]	-26.0628 [-66.14 - 27.57]
SR-SL-SM	0.46 / (0.0360) [0.03 - 0.04]	0.20 / (0.0160) [0.03 - 0.04]	0.25 / (0.0200) [0.03 - 0.04]	-22.5932 [-24.20 - 23.20]
Subiculum	0.36 / (0.0285) [0.03 - 0.05]	0.16 / (0.0124) [0.02 - 0.03]	0.20 / (0.0160) [0.02 - 0.03]	-25.2172 [-16.68 - 29.38]
Amgydala	1.68 / (0.135) [0.117, 0.172]	0.89 / (0.072) [0.059, 0.086]	0.79 / (0.063) [0.057, 0.087]	12.5550 [-11.868, 13.681]
Entorhinal area	3.80 / (0.305) [0.226, 0.348]	2.06 / (0.165) [0.113, 0.178]	1.74 / (0.140 [0.105, 0.178]	16.8496 [-19.903, 25.976]
Parahippocampal gyrus	5.12 / (0.411) [0.332, 0.500]	2.44 / (0.196) [0.157, 0.248]	2.69 / (0.216) [0.170, 0.261]	-9.7990 [-24.494, 10.192]

Table S20.

Volumetry analysis of the inflamed regions from the diagnosis date eight months after the infection. Eight months after the infection, the patient had significantly smaller bilateral hippocampi volume but spared amygdala, entorhinal cortex and parahippocampal gyrus as compared with 600 healthy participants using the volbrain software. For each region, the software provide the absolute volume in cubic centimeters (cm^3) and in percent, computed as the ratio between the region's volume and the intracranial volume (considered as 100%). Number in brackets correspond to the normative value of neurologically intact population provided by the software. CA = cornu ammoni, DG = dentate gyrus, SR = stratum radiatum, SL = stratum lacunosum, SM = stratum moleculare.

Statement	Scale	Reference
My memory for this event involves sound	1-7 little/A lot	MCQ
My memory for this event involves smell	1-7 little/A lot	MCQ
My memory for this event involves touch	1-7 little/A lot	MCQ
The overall tone of the memory is	Negative/Neutral/Positive	MCQ
In this event I was	An observer /A participant	MCQ
I remember the event through my own eyes as during the event	1-7 Not at all/Definitely	MCQ
When you picture this event do you visualize it as a continuous video that plays with break, moving video clips with some breaks, one moving image or is it more like a set of snapshot with no movement, or something else?	1-7 One smooth video/video clips with breaks/one moving image/snapshot in sequence/one static snapshot/Hazy image/no image no image / Hazy image/one static snapshot /snapshot in sequence /one moving image /video clips with breaks /One smooth video	EAMI
How often would you estimate you have thought about this memory since it first occurred?	1- 4 Frequently/Occasionnaly/Rarely/Never Never/Rarely/Occasionnaly/Frequently	EAMI
How often would you estimate you have spoken about this memory since it first occurred?	1-4 Frequently/Occasionnaly/Rarely/Never Never/Rarely/Occasionnaly/Frequently	EAMI
When you recall this event are you viewing the scene through your « own eyes » or can you see yourself in the memory from a third-person perspective?	Own eyes/Mixture/Third person/something different/no imagery	EAMI
When you recall this event how would you describe it in terms of vividness? This can apply to the richness of sights, sounds, smells, tastes, touch, and any movements you may have made.	1-7 very vivid/very vague 1-7 very vague/very vivid	EAMI
The relative spatial arrangement of people in my memory for the event is	1-7 Vague/Distinct	MCQ
My memory for the time when the event takes place is	1-7 Vague/Distinct	MCQ
When I remember the event, I see myself entirely in the scene as if I was watching a movie	1-7 Not at all/Definitely	MCQ
When I think about or tell this memory, I feel like I relive it as it happened	1-7 Not at all/Definitely	MCQ
I remember the movements and gestures I made with my body at the time of the event	1-7 / Vague/Distinct	In-house
My memory for this event is	1-7 Dim/Clear	MCQ
My memory for this event involves visual details	1-7 Little/ A lot	MCQ
My memory for this event is	1-7 Sketchy/very detailed	MCQ
My memory for the location where the event takes place is	1-7 Vague/Distinct	MCQ
Relative spatial arrangement of objects in my memory for the event is	1-7 Vague/Distinct	MCQ
When you think about this event now, do you re-experience any of the emotion you originally felt at the time? To what extent are you re-experiencing this emotion as a percentage?	0/25/50/75/100%	EAMI
To what extent are you re-experiencing this memory as a percentage?	0/25/50/75/100%	EAMI
Would you say you are reliving this memory or looking back on it?	Reliving/Looking back	EAMI

I remember how I felt at the time when the event took place	1-7 Not at all/Definitely	MCQ
I remember what I thought at the time	1-7 Not at all/Definitely	MCQ

Table S21.

Autonoetic consciousness questionnaire. Scale from original questionnaire is indicated in black, new scale is indicated in green.

Movie S1.

Supplementary Video 1

Experimental design: (Upper panel) 3D scene with the embedded avatar, as observed by a participant performing the virtual reality task. (Lower panel) Movements performed by a participant inside the MR scanner. Due to physical constraint (MR scanner magnetic field), this was filmed in a replicate of an MR scanner, similar to the one used for Experiment 1 and 3.

Supplementary Note 1

Results

Intentional encoding. Higher SoA and better recognition performance for intentional encoding when immersed with visuomotor and perspectival congruency (behavior, Experiment 3)

Although there was no significant difference for SoA ratings when comparing the conditions SYNCH1PP and ASYNCH1PP in Experiment 3, we note that the results in this experiment are going in the same direction as those from Experiments 1 and 2 (i.e., higher SoA in SYNCH1PP than in ASYNCH1PP and ASYNCH3PP). We compared the effect size from Experiments 1 and 2 with the effect size of Experiment 3 regarding the difference between SYNCH1PP and ASYNCH1PP. In Experiments 1 and 2, the difference between SYNCH1PP and ASYNCH1PP was comprised within a confidence interval between -0.43 and -0.08, while the standard coefficient is of -0.26. In Experiment 3, the confidence interval is comprised between -0.45 and 0.11, and the standard coefficient is of -0.17. Accordingly, the difference is not significant. However, when we performed additional analysis pulling the three experiments together, the SoA was consistently higher in the SYNCH1PP compared to the two other conditions, independent of Experiment (SYNCH1PP compared to ASYNCH1PP: estimate = -0.059, t = -3, p = 0.003; SYNCH1PP compared to ASYNCH3PP: estimate = -0.08, t = -4.28, p <0.001), with a confidence interval between -0.38 to -0.08, and a standard coefficient of -0.23, which is similar to what is obtained when applying the model on Experiments 1 and 2 only.

Supplementary Note 2

ERS analysis. Reinstatement in the left hippocampus is higher for visuomotor and perspectival congruency and indexes recognition memory.

Model selection to explain recognition performance with hippocampal ERS

To better understand the link between hippocampal ERS and memory, we compared a model which explains recognition performance using hippocampal ERS and conditions (Model 1) with a model considering only hippocampal ERS irrespective of conditions (Model 0). We found that both models were equally good (i.e. had the same AIC; m1 AIC = -159.83, m0 AIC = -159.73, X_2= 8.10, p = 0.088, Table S13). Therefore we used the model with the smaller number of parameters (Model 0) for further analysis.

Supplementary Note 3

ERS analysis. Reinstatement in the left hippocampus is higher for visuomotor and perspectival congruency and indexes recognition memory.

Hippocampal ERS and performance, Trial-by-Trial

The positive correlation between left hippocampal ERS and recognition performance was found for average hippocampal ERS (per session average of successful and failed trials) and for the overall recognition performance (percent of correct answers). To investigate whether this relation holds for single trials, we applied a logistic mixed effect model to investigate trial-by-trial recognition performance with trial-by-trial hippocampal ERS (as described in the main text). This analysis revealed a significant triple interaction between condition, stimulus (same scene than the one at encoding versus changed scene), and left hippocampal ERS, when SYNCH1PP was compared to ASYNCH3PP (estimate = -2.04, z = -2.6, p = 0.009, Table S13). P*ost-hoc* analysis revealed that the significant effect was driven by the significantly positive relationship between recognition performance and left hippocampal ERS in SYNCH1PP (Fig. 4B, Table S13), but only when the stimulus presented was the same scene as the one observed at encoding (estimate = 1.7, z = 3.5, p <0.001). The relation between hippocampal ERS and recognition performance was not significant for the ASYNCH3PP conditions (Table S13). This shows that only the main experimental condition with visuomotor and perspectival congruency, associated activity in left hippocampus with recognition performance on a trial by trial basis.

Supplementary Note 4

Hippocampal-neocortical interactions revealed by ERS are modulated by visuomotor and perspectival congruency

We found that participant's SoA was correlated with the activity of the BSC regions at encoding (Premotor left: r = 0.22, df = 79, t = 1.98, p = 0.05, right SMA: r = 0.35, df = 79, t = 3.38, p = 0.001, left SMA: r = 0.3, df = 79, t = 2.81, p = 0.006 , suggesting that these regions identified using the contrast (SYNCH1PP > ASYNCH1PP +ASYNCH3PP) are involved in the subjective outcome of the BSC manipulation (SoA).

Supplementary Note 5

Amnestic patient with bilateral hippocampal damage is impaired in recognizing objects encoded with visuomotor and perspectival congruency

We tested the patient five months after her hospitalization. At that time, the patient's scored 25 at the Montreal Cognitive Assessment test, with 100% correct answer on the memory part of the test although she still suffered from autobiographical memory deficit.
The difference in the patient's SoA ratings between the SYNCH1PP condition and both ASYNCH1PP and ASYNCH3PP was modulated in the same way as observed in the healthy participants and her sensitivity to the manipulation was even higher compared to healthy participants as tested using Crawford test, due to larger SoA differences across conditions

(SYNCH1PP compared to ASYNCH1PP: mean = 0.05, sd ± = 0.16, p <0.001; ASYNCH1PP compared to ASYNCH3PP: mean = 0.03, sd ± = 0.16, p = 0.004). The SoA difference between SYNCH1PP and ASYNCH3PP was not significantly different compared to healthy participants but going in the same direction (SYNCH1PP-ASYNCH3PP: mean = 0.08, sd ± = 0.18, p = 0.134). Similar findings were obtained for ownership ratings (SYNCH1PP-ASYNCH1PP: mean = 4.00e-03, sd ± = 0.21, p = 0.002). The other difference between conditions were in the same range than the healthy participants rating (SYNCH1PP-ASYNCH3PP: mean = 0.12, sd ± = 0.23, p < .001; ASYNCH1PP-ASYNCH3PP: mean = 0.12, sd ± = 0.21, p = 0.314). The patient's ratings for control items were low, did not differ between conditions, and also did not differ from those of healthy participants (SYNCH1PP-ASYNCH1PP: mean = -0.008, sd ± = 0.09, p = 0.257; SYNCH1PP-ASYNCH3PP: mean = 0.02, sd ± = 0.07, p = 0.295; ASYNCH1PP-ASYNCH3PP: mean = 0.03, sd ± = 0.11, p = 0.438).

Supplementary Note 6

Methods

VR scenes

Each scene contained the following objects: Living room: mug, tennis ball, gloves, soccer ball, slippers, coat, forks, umbrella, toy-train, radio, phone, carpet, pillow, bottle, fan, bucket, soap, golf swing; Changing room: dice, knife, shoes, bike, teapot, basketball, apron, alarm clock, plant, glasses, sledge, camera, vase, chair, Ping-Pong racket, guitar, diving mask, beanbag; Cabin: pen, ice skate shoes, broom, tie, book, skis, tennis racket, belt, water can, pants, remote controller, skate, treadmill, microwave, cane, computer, calculator, helmet; BSC scene (forest): hammer, pocket clock, sponge, box gloves, snowboard, flipflop, scooter, socks, bowling ball, bowtie, baseball bat, vacuum cleaner, paddle, cane, coffee maker, dumbbell, smoking pipe, phonograph.