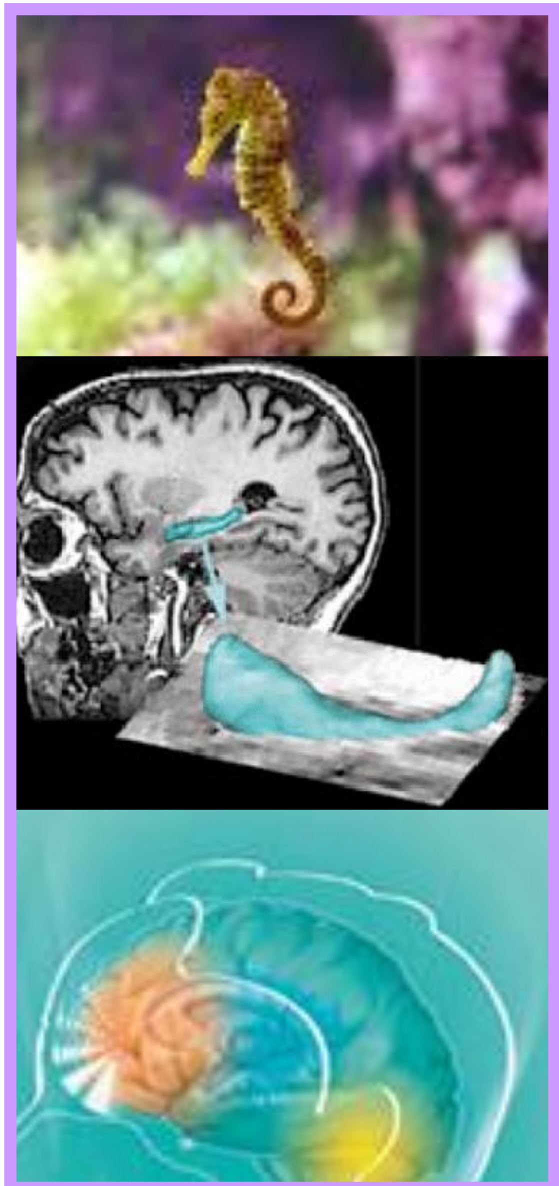
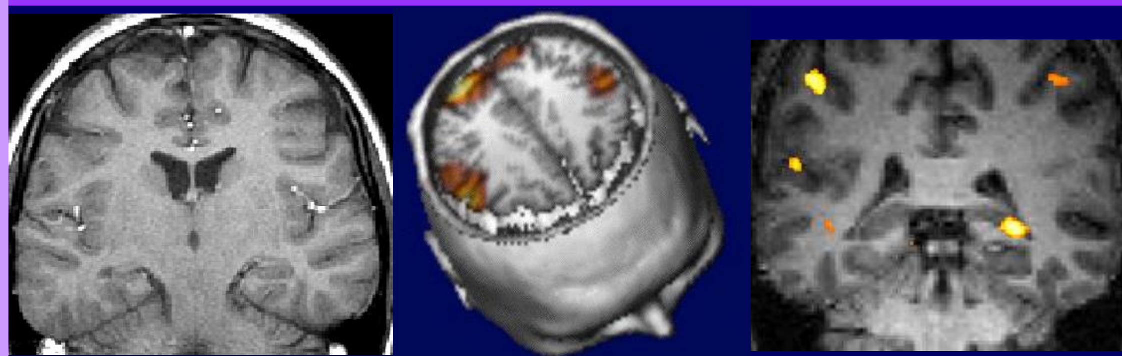
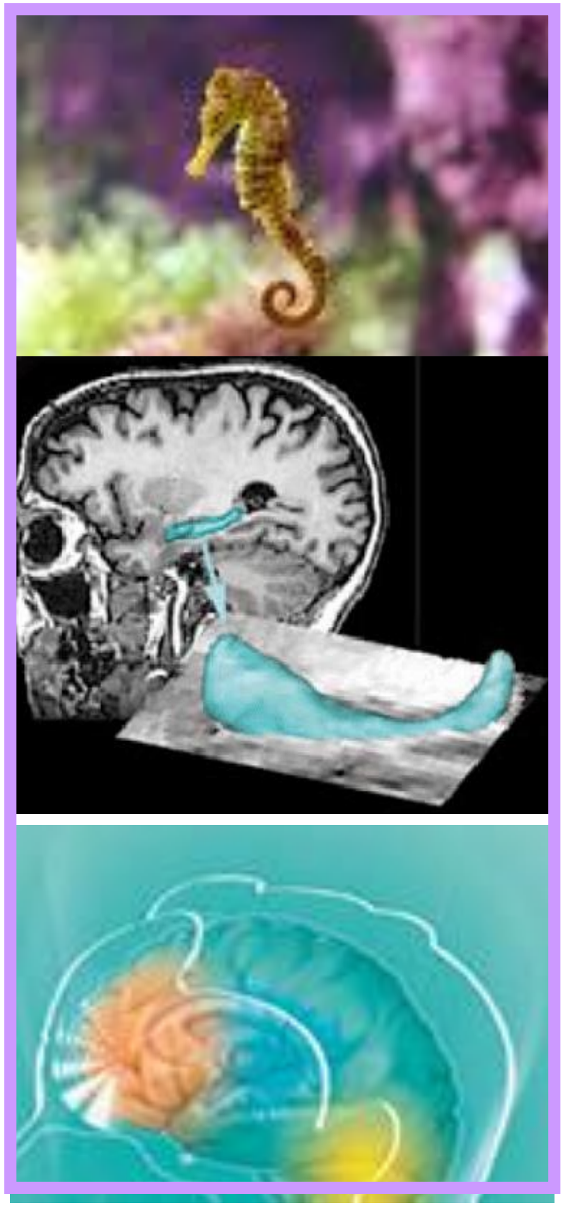


Hippocampus and episodic memory in humans



Sophie Dupont
Unité d 'Epileptologie
Hôpital Pitié-Salpêtrière

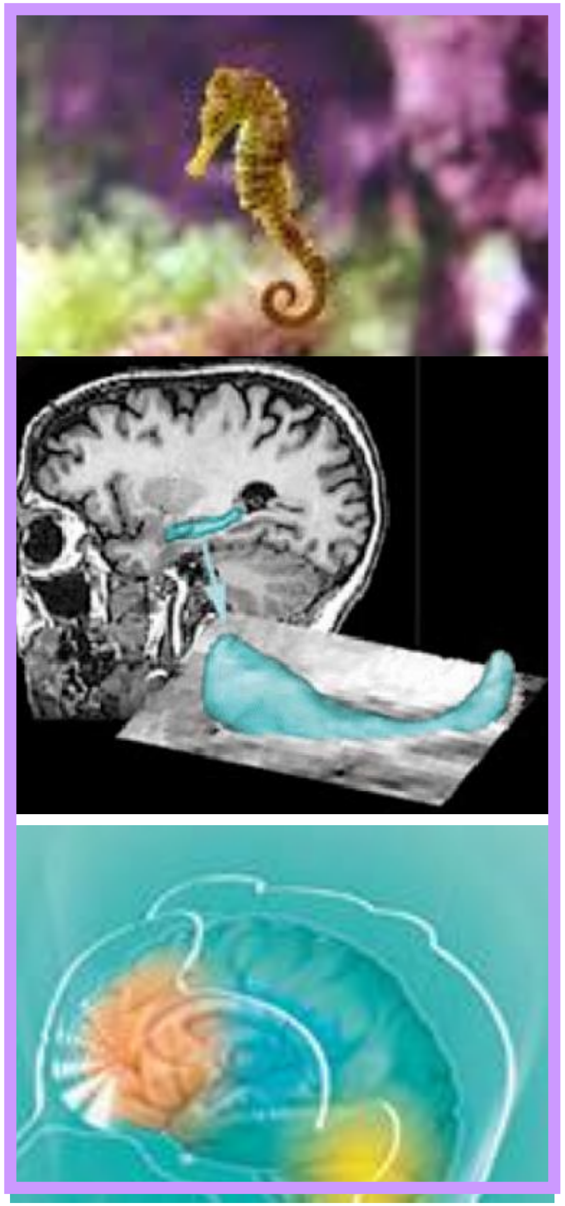


Definitions

Traditional approach

Neuroimaging

Insights from pathology



Definition

Traditional approach

Neuroimaging

Insights from pathology

2 clinical ways to explore memory in clinical practice

Anatomo-clinical:

Case reports

Animal studies

→ A region = a function

Neuropsychological

Models

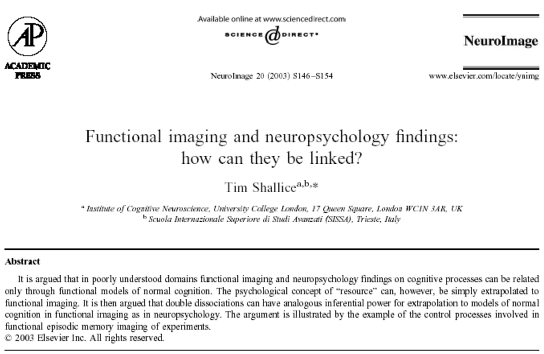
Neuropsychological testing

→ A model explains a function

?

Functional brain imaging

→ Cerebral network = a function



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Available online at www.sciencedirect.com

SCIENCE DIRECT

NeuroImage

NeuroImage 20 (2003) S146–S154

www.elsevier.com/locate/ynimg

Functional imaging and neuropsychology findings: how can they be linked?

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[b] Scuola Internazionale Superiore di Studi Avanzati (SISSA), Trieste, Italy

Abstract

It is argued that in poorly understood domains functional imaging and neuropsychology findings on cognitive processes can be related only through functional models of normal cognition. The psychological concept of "resource" can, however, be simply extrapolated to functional imaging. It is then argued that double dissociations can have analogous inferential power for extrapolation to models of normal cognition in functional imaging as in neuropsychology. The argument is illustrated by the example of the control processes involved in functional episodic memory imaging of experiments.

Localization of memory systems

Short term memory/working memory

Long term memory

Declarative memory (explicit/conscious)

Non declarative memoryMémoire (implicit/unconscious)

Semantic memory

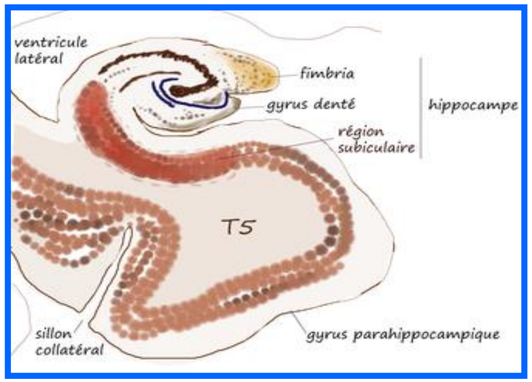
(knowledges)

« I know that…. »

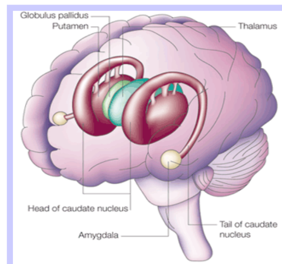
Episodic memory

(autobiographical)

« I rememeber that…. »

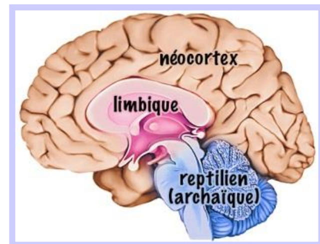


Procedural memory



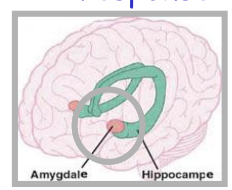
Priming

« Minimal modifications induced/ a known stimulus »

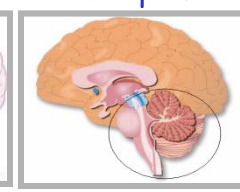


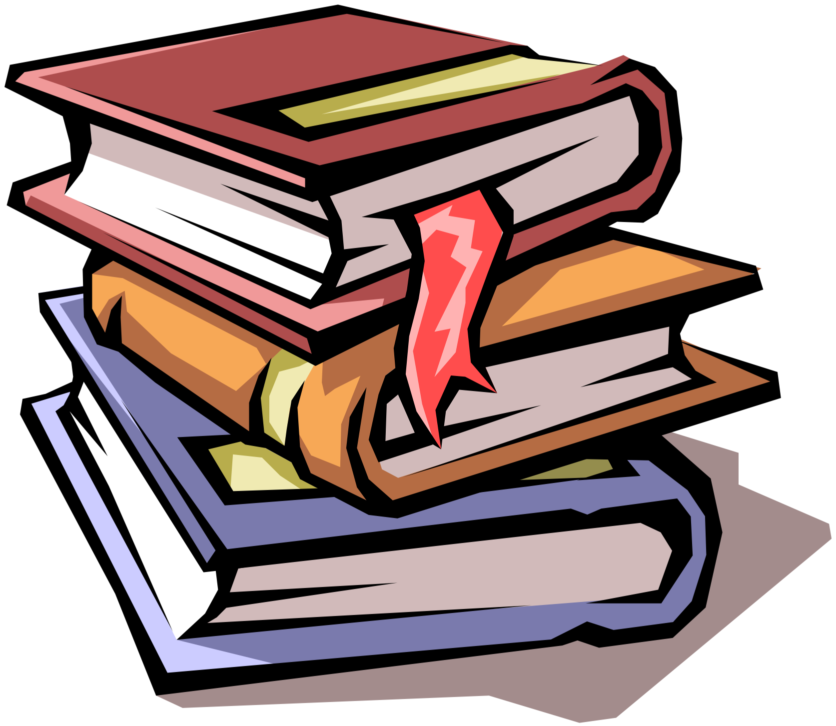
Conditionning

Emotional response



Motor response



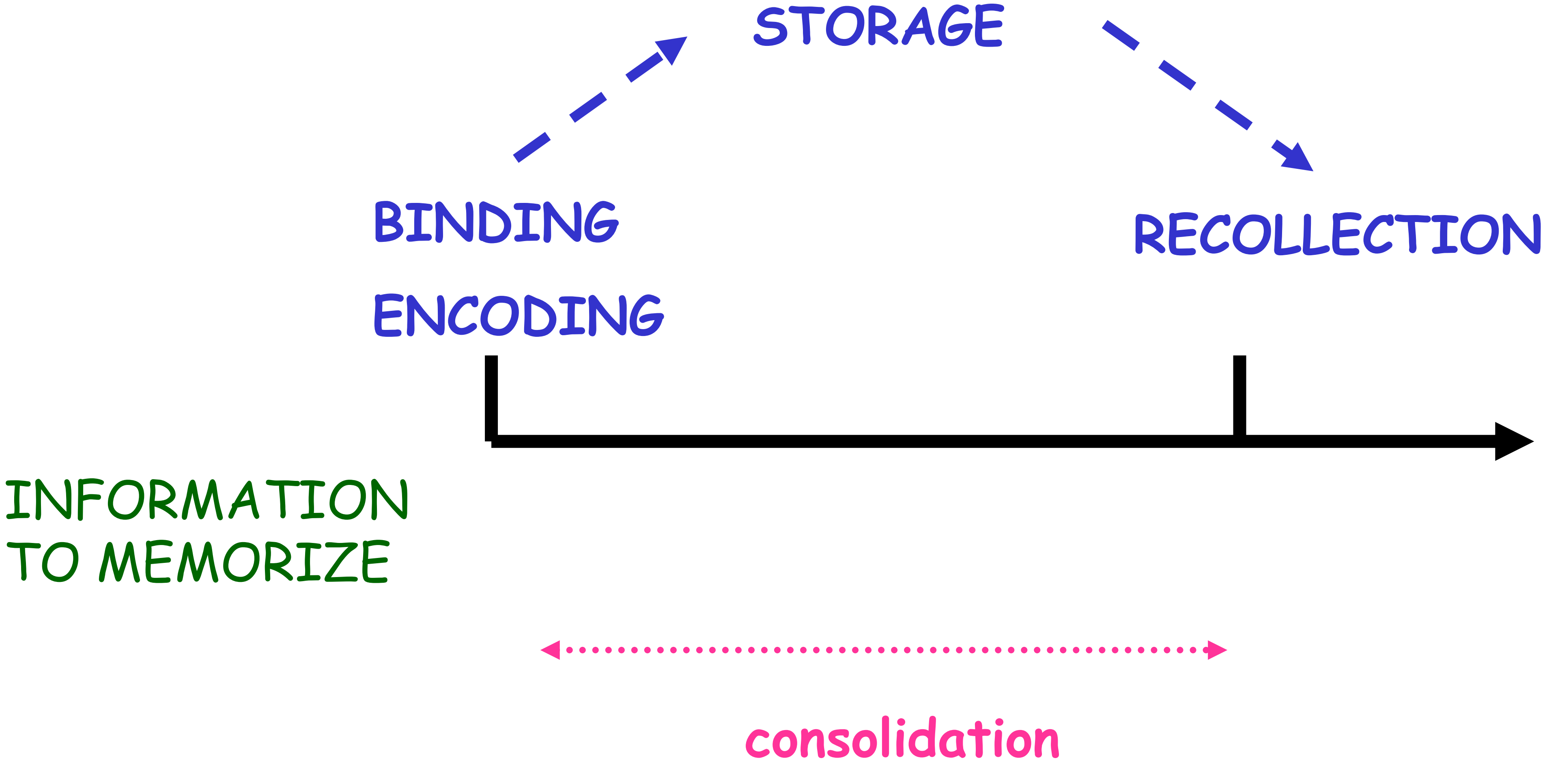


Episodic memory

Contextual memory

Autobiographical with a strong spatial and temporal link

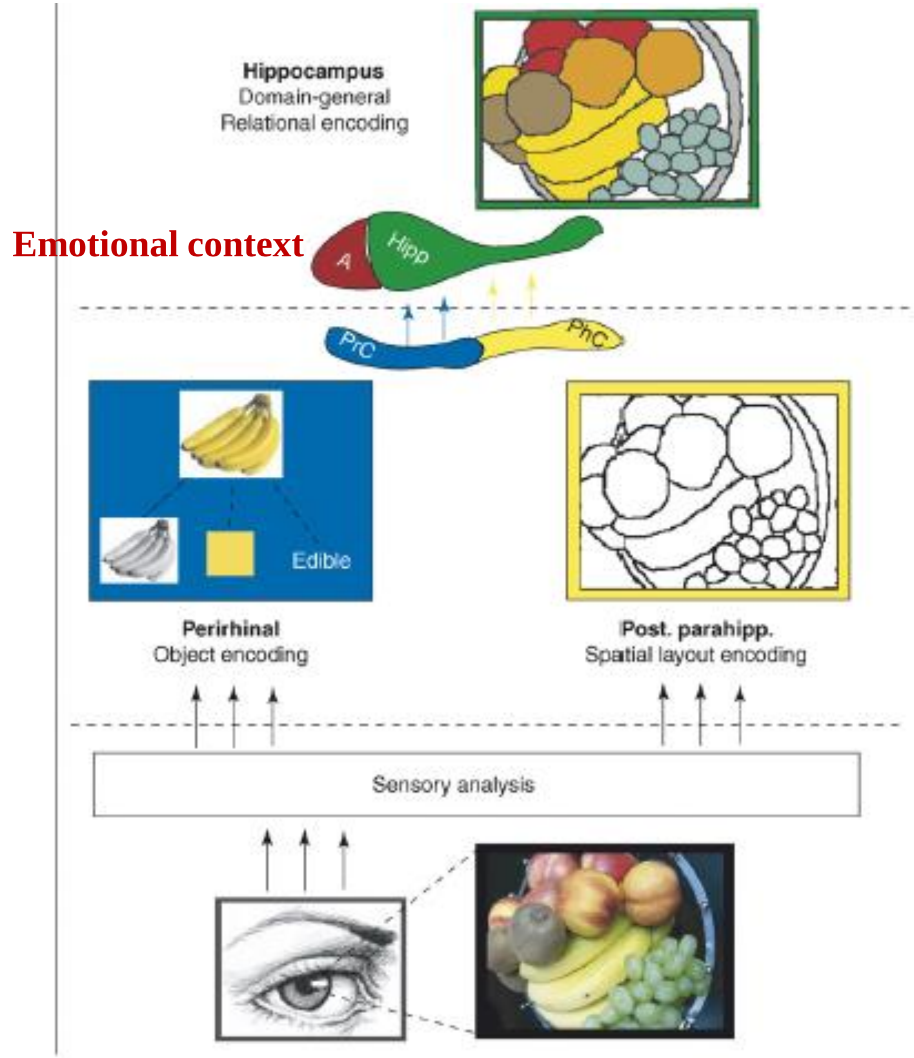
: « when, where regarding to me »


STORAGE
BINDING
ENCODING
RECOLLECTION
INFORMATION
TO MEMORIZE
consolidation

Encoding-binding

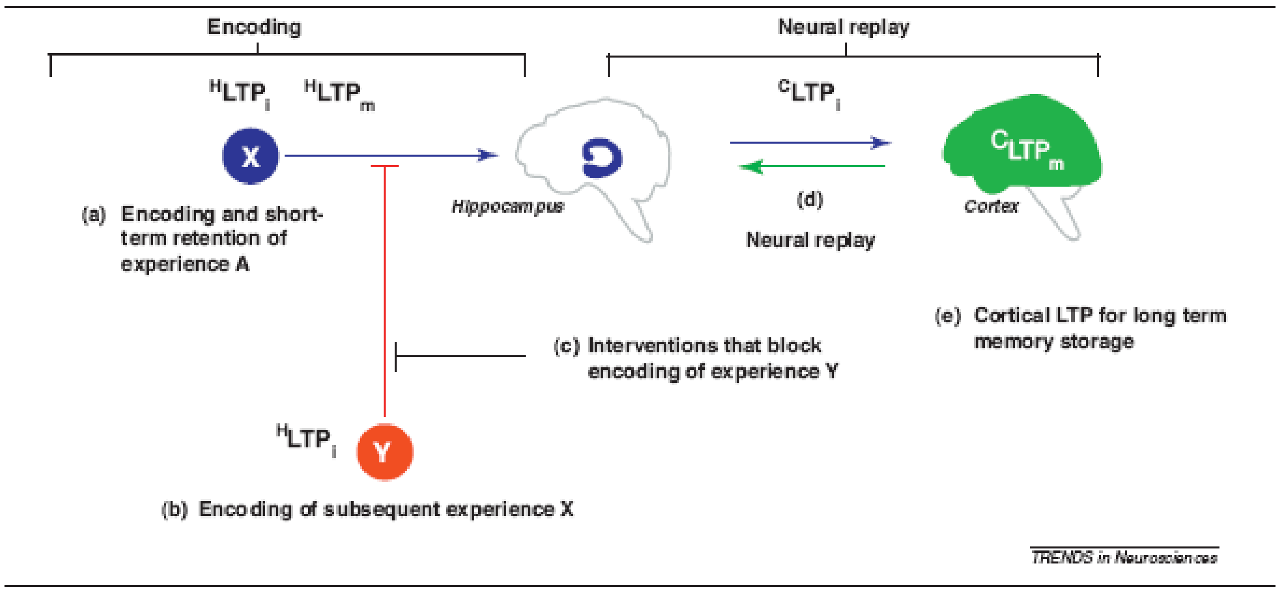
- Encoding: presentation of a set of traits representative of the different attributes or items of this episode: physical attributes (shape, color ...) and contextual (emotional, semantic, spatial, temporal, social, ...)

- then their binding by a so-called binding process to form a coherent and non-fragmentary representation.



Consolidation

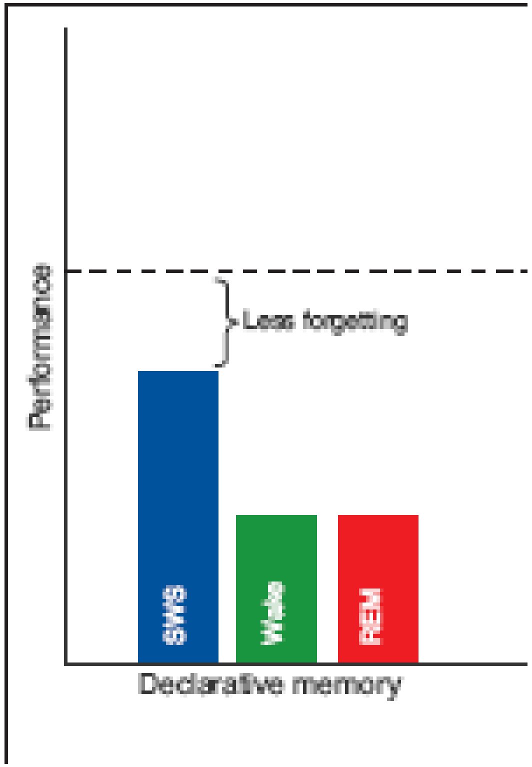
- Reactivation and thus reinforcement of the mnemic trace of the constituent features of the episode (LTP)



When a memory is created, activity patterns in the neurons become inscribed in their connections, leaving a trace known as an engram

Consolidation

- Early stage: takes place in the hippocampus during sleep



Less forgetfulness after period with slow sleep "SWS" (slow wave sleep) that with waking or REM (REM sleep)

- Late stage: is the hippocampus involved?

Consolidation: late stage

Exp Physiol 99.3 (2014) pp 471–486 471

Joan Mott Prize Lecture

Memory consolidation in humans: new evidence and opportunities

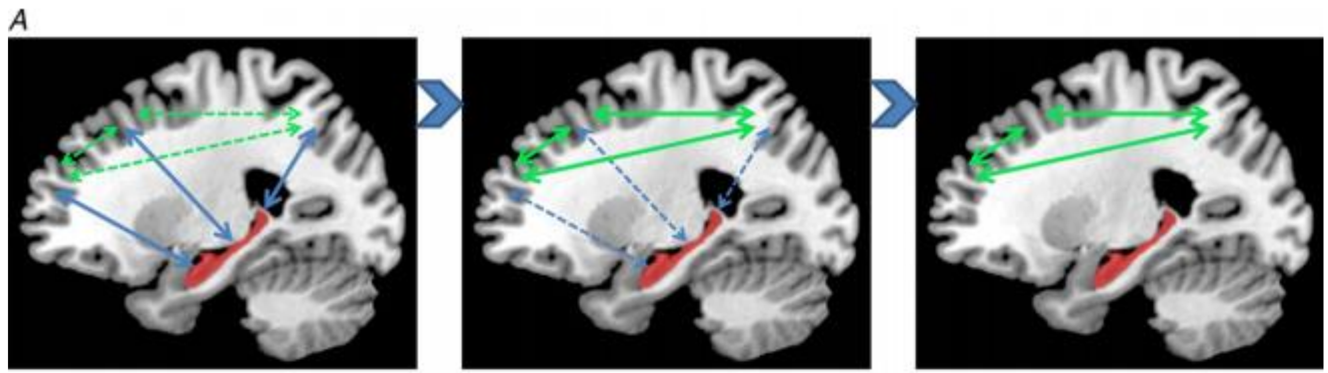
Eleanor A. Maguire

Wellcome Trust Centre for Neuroimaging, Institute of Neurology, University College London, UK

THEORY 1

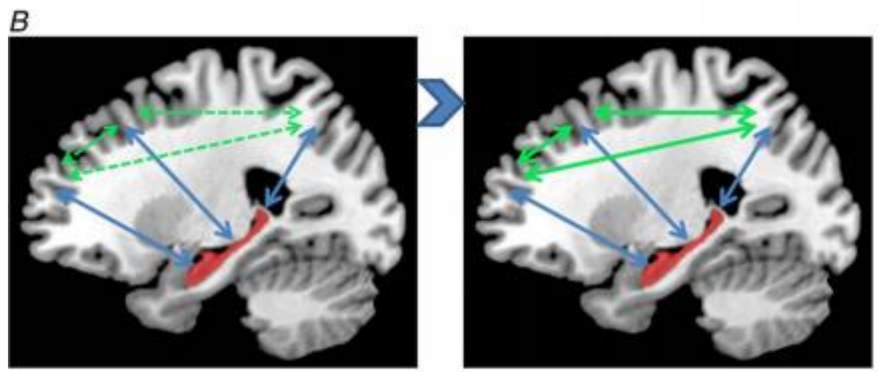
Standard consolidation theory (SCT) posits that memory ultimately becomes reliant solely on neocortex.

Theory 1: Hippocampus doesn't act



THEORY 2 (alternative)

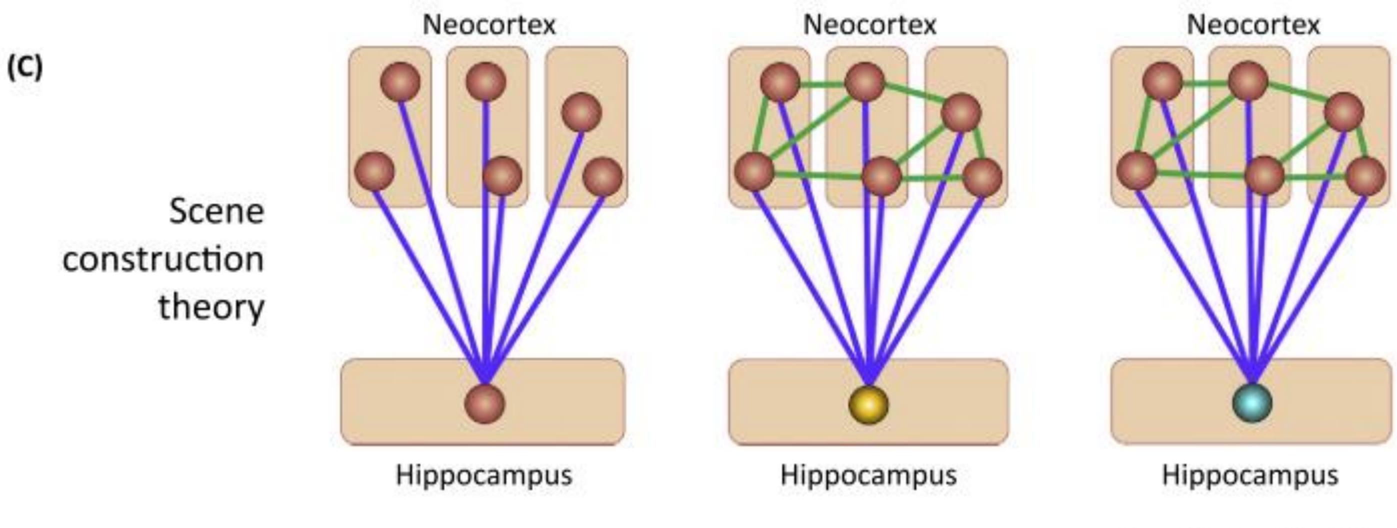
multiple trace theory (MTT) posits that consolidation generates in cortico-hippocampal networks multiple traces, converting memory to a widely distributed form resistant to hippocampal damage



Theory 2: Hippocampus acts equally with neocortex

Consolidation

Theory 3: Scene construction theory



When recalling a recent event, the hippocampus constructs a series of coherent scenes from this episode through hippocampo-neocortical interactions. These quickly disappear from the hippocampus when the representations are consolidated in the neocortex.

Theory 3: The hippocampus can reconstruct past experience in the absence of the original trace

Consolidation

-summary-

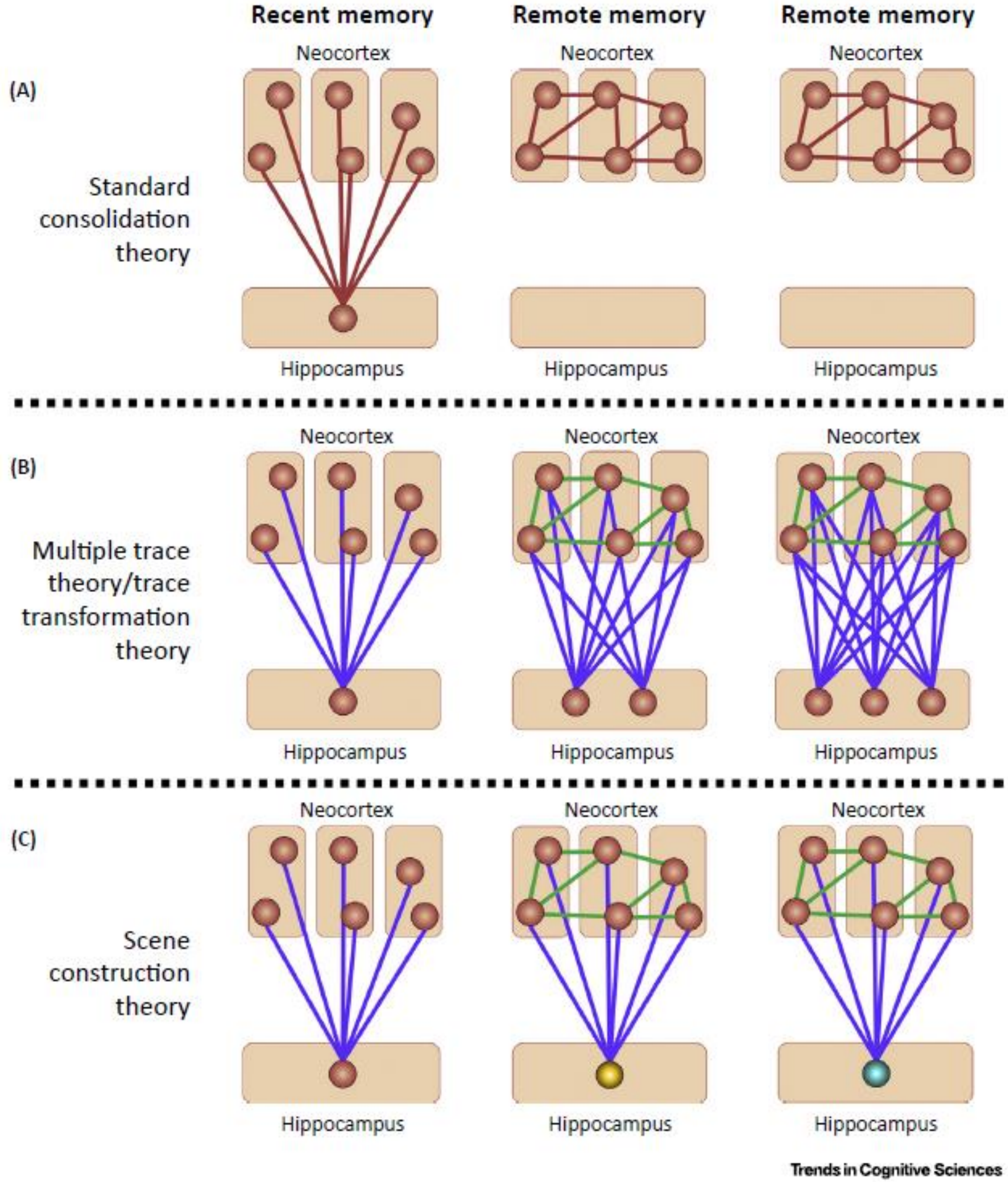
Trends in Cognitive Sciences

CellPress REVIEWS

Opinion

Remote Memory and the Hippocampus: A Constructive Critique

Daniel N. Barry[1] and Eleanor A. Maguire[1,*]



Pattern separation & pattern completion

- Pattern separation :
  - process that minimizes overlap between patterns of neuronal activity representing similar experiences.
  - Supported by the dentate gyrus
- Pattern completion:
  - the ability to recall a whole memory from a partial cue
  - supported by CA3 and CA1?
  - may mediate cortical reinstatement during retrieval.

Pattern separation and pattern completion are independent processes

frontiers in SYSTEMS NEUROSCIENCE

REVIEW ARTICLE
published: 30 October 2013
doi: 10.3389/fnsys.2013.00074

The mechanisms for pattern completion and pattern separation in the hippocampus

Edmund T. Rolls[1,2]*

[1] Oxford Centre for Computational Neuroscience, Oxford, UK
[2] Department of Computer Science, University of Warwick, Coventry, UK

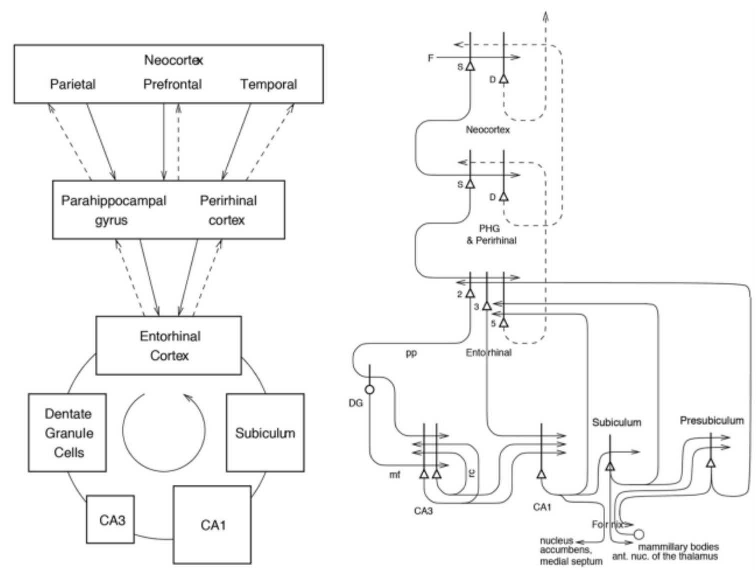


FIGURE 1 | Forward connections (solid lines) from areas of cerebral association neocortex via the parahippocampal gyrus and perirhinal cortex, and entorhinal cortex, to the hippocampus; and backprojections (dashed lines) via the hippocampal CA1 pyramidal cells, subiculum, and parahippocampal gyrus to the neocortex. There is great convergence in the forward connections down to the single network implemented in the CA3 pyramidal cells; and great divergence again in the backprojections. **Left**: block diagram. **Right**: more detailed representation of some of the principal excitatory neurons in the pathways. Abbreviations: D, deep pyramidal cells; DG, dentate granule cells; F, forward inputs to areas of the association cortex from preceding cortical areas in the hierarchy; mf, mossy fibres; PHG, parahippocampal gyrus and perirhinal cortex; pp, perforant path; rc, recurrent collateral of the CA3 hippocampal pyramidal cells; S, superficial pyramidal cells; 2, pyramidal cells in layer 2 of the entorhinal cortex; 3, pyramidal cells in layer 3 of the entorhinal cortex. The thick lines above the cell bodies represent the dendrites.

Storage

- Unknown phenomenon

Recollection

- Process specifically allowing to activate the trace in memory of the episode and to make it accessible to the conscience.

- Different stages involving:
  - a recovery effort (level of processing resources devolved to the recovery attempt)
  - a recovery strategy
  - a monitoring of recovery (process of control and verification that the recovered episode is the one sought)
  - a step of success of recovery when all the aforementioned parameters result in the correct (efficient) reminder of the episode.

Recollection

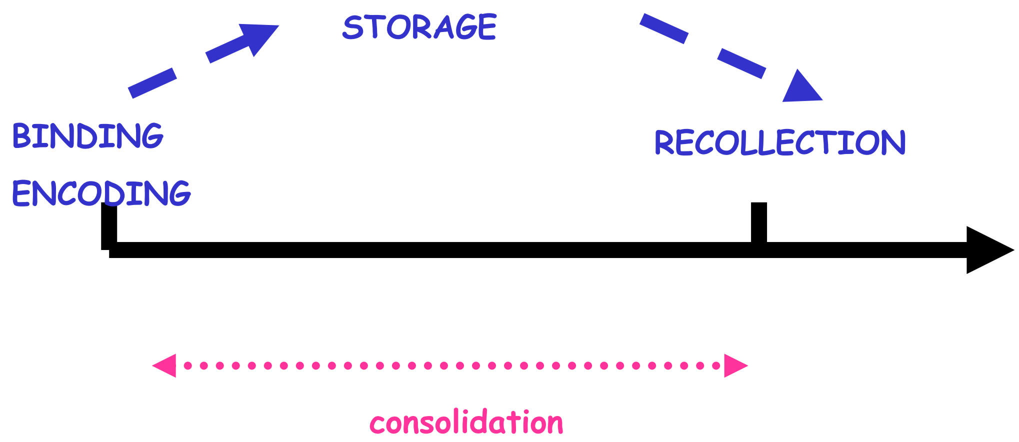
- Recalling past events with detail and accuracy depends on :
  - the ability to remember the contextual features of an event (i.e., source memory)
  - the ability to distinguish among similar events in memory (i.e., pattern separation)
  - the ability to mediate cortical reinstatement from a partial cue (i.e pattern completion)

Recollection

- to distinguish from a recognition based on a simple sensation of familiarity without specific details on the items characterizing the episode recognized (non-episodic memory)

- Paradigms Remember (conscious recovery in episodic memory) versus Know (non-episodic memory familiarity) "R-K"

Modalities



Liste des mots de KENT & ROSANOFF

1	table	26	souhait	51	tige	76	amer
2	foncé	27	rivière	52	lampe	77	marteau
3	musique	28	blanc	53	rêve	78	assoiffé
4	maladie	29	beau	54	jaune	79	cité
5	homme	30	fenêtre	55	pain	80	carré
6	profond	31	rude	56	justice	81	beurre
7	doux	32	citoyen	57	garçon	82	docteur
8	nourriture	33	pied	58	lumière	83	bruyant
9	montagne	34	araignée	59	santé	84	voleur
10	maison	35	aiguille	60	bible	85	lion
11	noir	36	rouge	61	mémoire	86	joie
12	mouton	37	sommeil	62	brebis	87	lit
13	confort	38	colère	63	bain	88	lourd
14	main	39	tapis	64	chaumière	89	tabac
15	court	40	fille	65	rapide	90	bébé
16	fruit	41	eau	66	bleu	91	lune
17	papillon	42	laborieux	67	affamé	92	ciseaux
18	lisse	43	sûr	68	prêtre	93	tranquille
19	commande	44	terre	69	océan	94	vert
20	chair	45	trouble	70	tête	95	sel
21	tendre	46	soldat	71	poêle	96	rue
22	sifflet	47	choux	72	long	97	roi
23	femme	48	dur	73	religion	98	fromage
24	froid	49	aigle	74	whisky	99	bouton
25	lent	50	estomac	75	enfant	100	effrayé

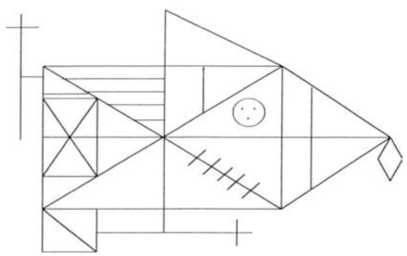
verbal

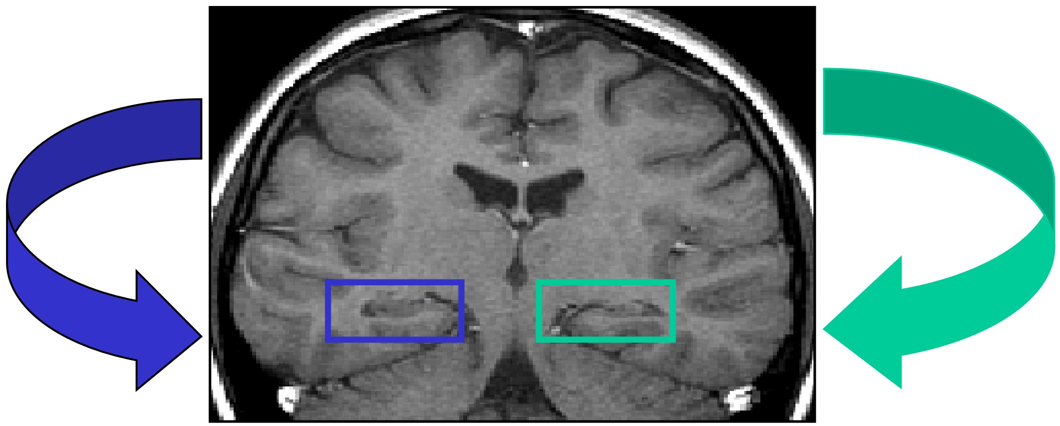
non verbal (visuo spatial)

olfactive

Lateralization of episodic memory systems

Visuo-spatial memory



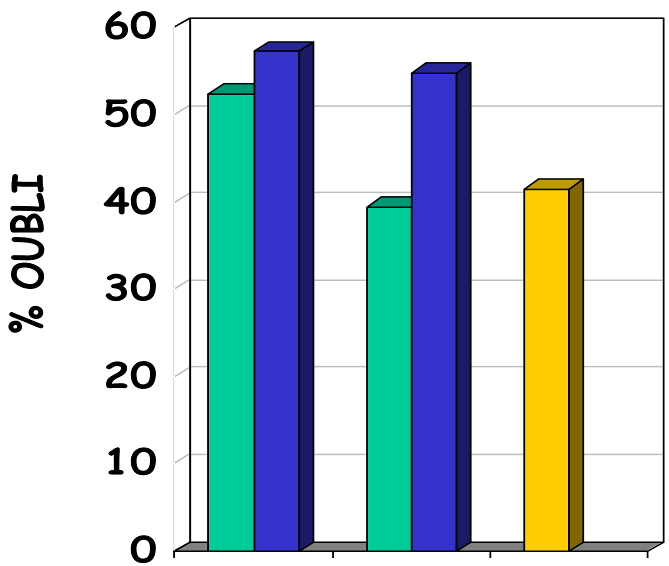


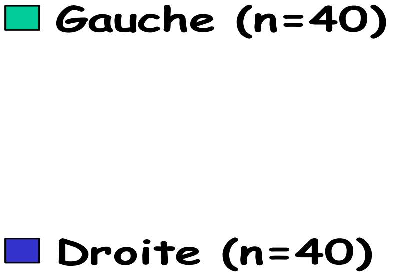
Verbal memory

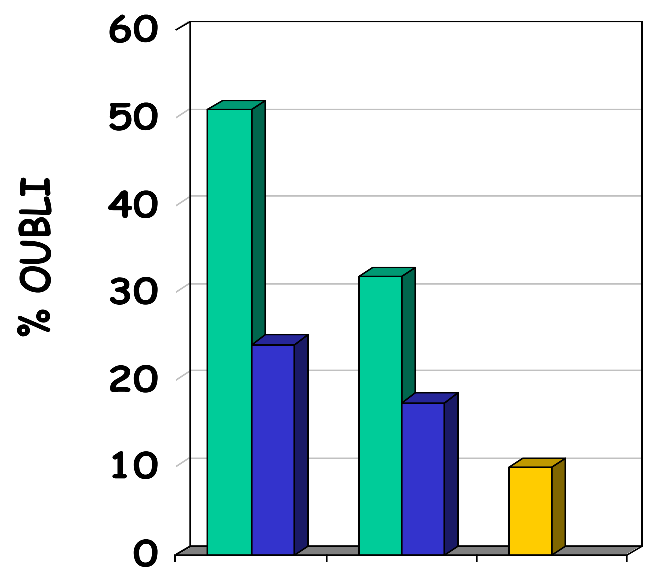
PRESENTATION
CHOU - PLUME
ENFANT - EPICERIE
ACCIDENT - OBSCURITE
….

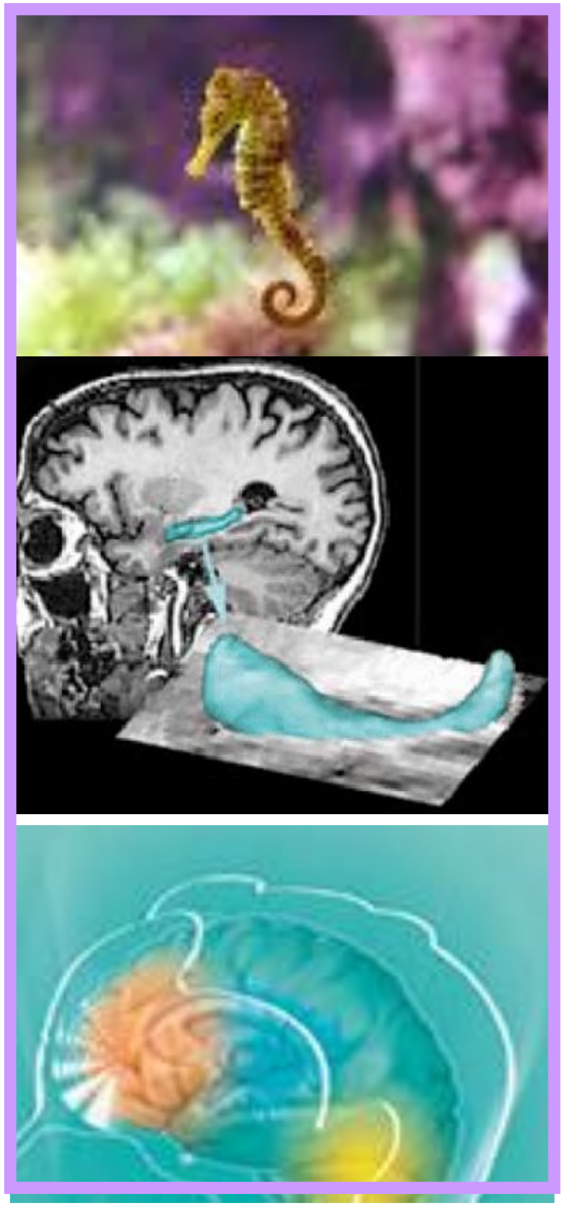
RAPPEL INDICE
CHOU ?
…

MTLE









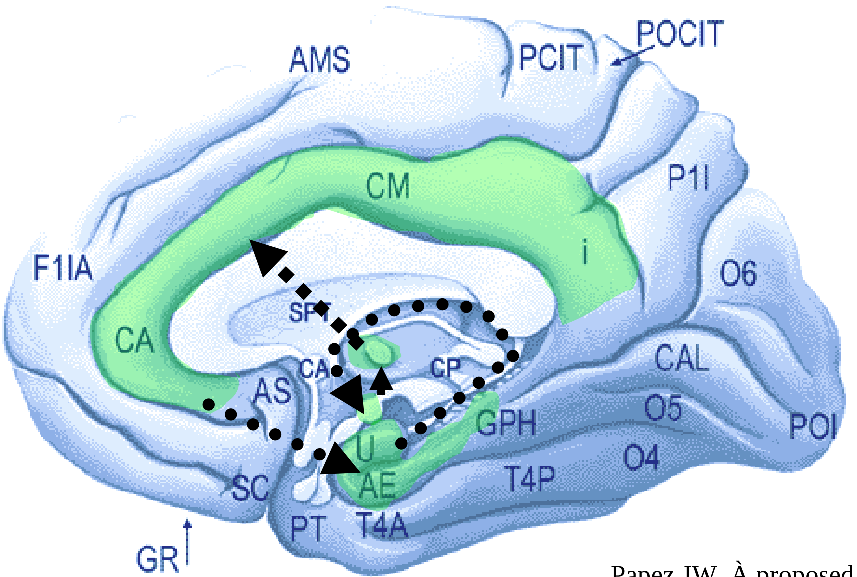
Definitions

Traditional approach

Neuroimaging

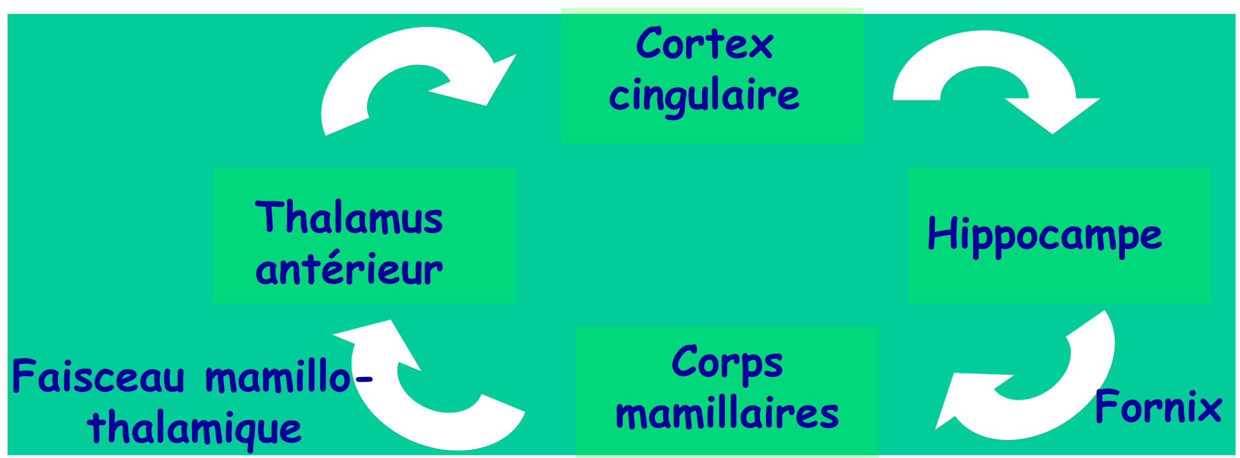
Insights from pathology

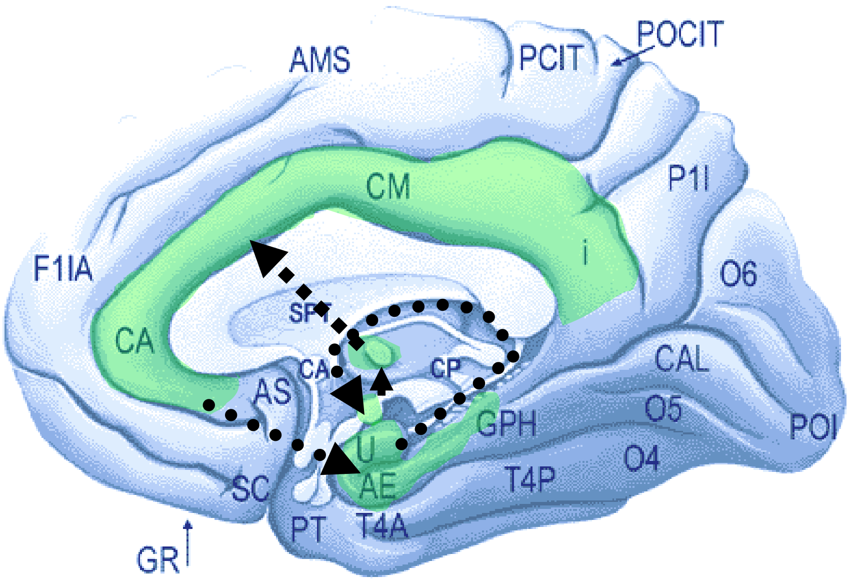
Papez circuit



Is emotion a magic product or is it a physiological process which depends on an anatomic mechanism?

Papez JW. À proposed mechanism of emotion. 1937. J Neuropsychiatry Clin Neurosci.





Korsakoff syndrome

Memory deficit related to alcool abuse

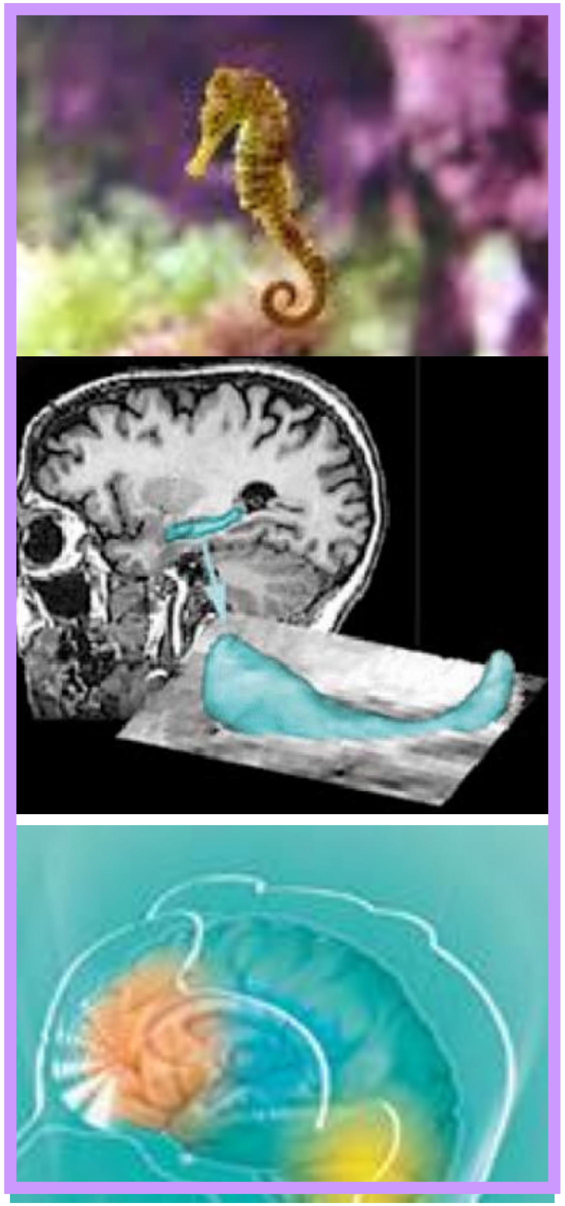
Anterograde amnestic syndrome
Confabulation
False recollections
Bilateral necrosis of mamillary bodies

HM patient, Scoville et Millner, 1957

bitemporal epilepsy??

Normal IQ

Anterograde amnesia



Definitions

Traditional approach

Neuroimaging

Insights from pathology

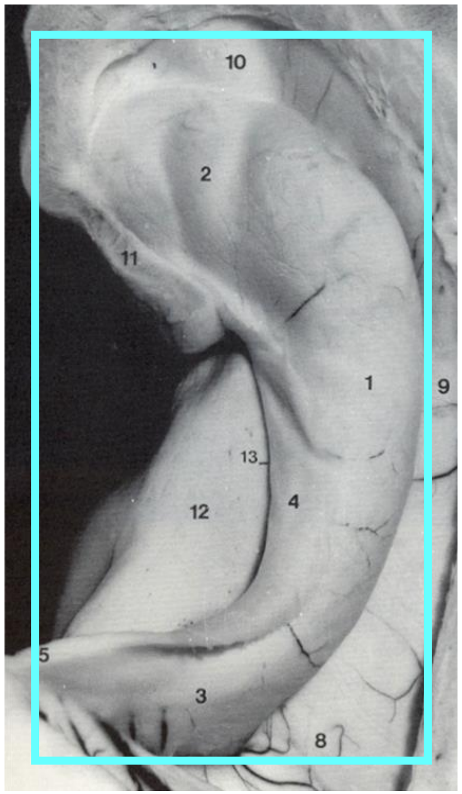
fMRI activations

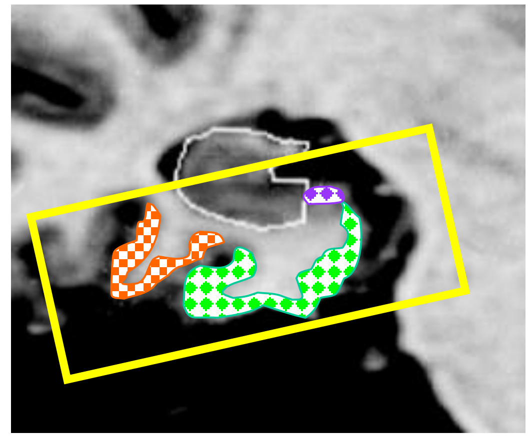
- Network Localization:
  - Interconnected regions operating in a network
  - Crucial regions?
  - Exact role of these regions?
  - Intercurrent processes?
  - Link between the degree of activation and the efficiency of the task?
  - Activation timeline in the network?
  - Activations / deactivations?
  - Outstanding issues………………

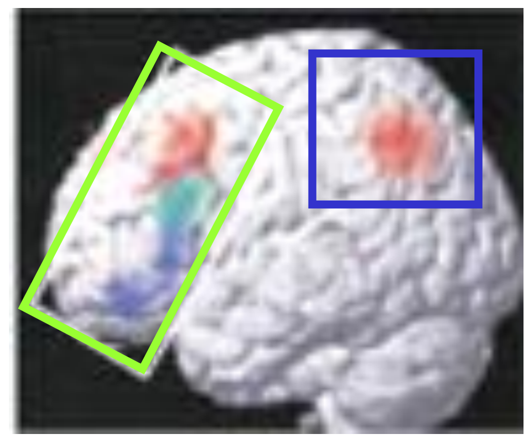
Network memory

Joaquín M. Fuster

Key regions







New actors

- Prefrontal cortex
- Parietal cortex

Pre frontal Activation

Proc. Natl. Acad. Sci. USA
Vol. 91, pp. 2012–2015, March 1994
Psychology

Neuroanatomical correlates of retrieval in episodic memory: Auditory sentence recognition

(positron emission tomography/prefrontal cortex/parietal lobes/consciousness/auditory priming)

ENDEL TULVING*†, SHITIJ KAPUR‡, HANS J. MARKOWITSCH*, FERGUS I. M. CRAIK*†, REZA HABIB†, AND SYLVAIN HOULE‡

*Rotman Research Institute of Baycrest Centre, 3560 Bathurst Street, North York, ON Canada M6A 2E1; †Department of Psychology, University of Toronto, Toronto, ON Canada M5S 1A1; and ‡Positron Emission Tomography Centre, Clarke Institute of Psychiatry, University of Toronto, 250 College Street, Toronto, ON Canada M5T 1R8

Contributed by Endel Tulving, December 6, 1993

Proc. Natl. Acad. Sci. USA
Vol. 91, pp. 2016–2020, March 1994
Psychology

Hemispheric encoding/retrieval asymmetry in episodic memory: Positron emission tomography findings

(frontal lobes/semantic memory/laterality)

ENDEL TULVING*†, SHITIJ KAPUR‡, FERGUS I. M. CRAIK*†, MORRIS MOSCOVITCH*†, AND SYLVAIN HOULE‡

*Rotman Research Institute of Baycrest Centre, 3560 Bathurst Street, North York, ON Canada M6A 2E1; †Department of Psychology, University of Toronto, Toronto, ON Canada M5S 1A1; and ‡Positron Emission Tomography Centre, Clarke Institute of Psychiatry, University of Toronto, 250 College Street, Toronto, ON Canada M5T 1R8

Table 1. Summary of PET findings with healthy human subjects concerning prefrontal activation associated with episodic memory encoding and retrieval processes

Study	Left	Right
Encoding		
Kapur *et al.* (14)	+	−
Petersen *et al.* (27)	+	−
Petersen *et al.* (30)	+	−
Frith *et al.* (31)	+	−
Frith *et al.* (32)	+	−
Wise *et al.* (33)	+	−
Raichle *et al.* (28)		
Trial 1	+	−
Trial 5	−	−
Buckner *et al.* (34)	+	−
Retrieval		
M.M. *et al.* (unpublished)		
Spatial Information	−	+
Object Information	−	+
Tulving *et al.* (16)	+	+
Squire *et al.* (35)	−	+
Buckner *et al.* (34)		
Different case	−	+
Auditory	−	+
Haxby *et al.* (36)	−	+
Jones–Gottman *et al.* (37)	−	+

Statistically significant evidence of prefrontal involvement is indicated by +, absence of similar evidence by −.

(*i*) The HERA model asserts that the left and the right prefrontal cortical regions are differentially involved in episodic and semantic memory processes.

(*ii*) Left prefrontal cortical regions are involved in retrieval of information from semantic memory to an extent that right prefrontal areas are not, at least insofar as verbal information is concerned.

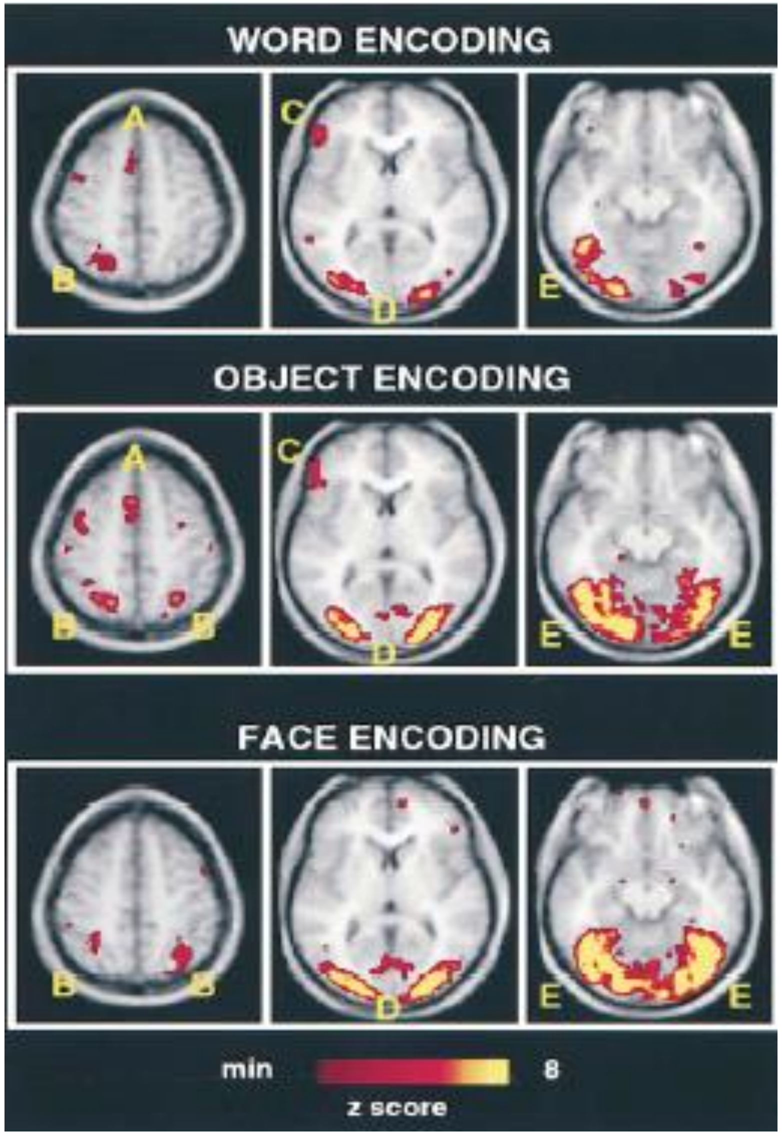
(*iii*) Left prefrontal cortical regions are involved in encoding information about novel happenings into episodic memory to an extent that right prefrontal areas are not, at least insofar as verbal information is concerned.

(*iv*) Right prefrontal cortical regions are involved in retrieval of episodic information to an extent that left prefrontal areas are not.

(*v*) Right prefrontal cortical regions are involved in retrieval of episodic information to an extent that does not hold for retrieval of semantic information.

HERA model: controversies

L



R

Kelley et al. Neuron 98, 20: 927-936

Left prefrontal activation during encoding depends on the type of material:

- ✓ Left: verbal material
- ✓ Right: nonverbal material

Hera model revisited

Opinion TRENDS in Cognitive Sciences Vol.7 No.6 June 2003 241

Hemispheric asymmetries of memory: the HERA model revisited

Reza Habib[1], Lars Nyberg[2] and Endel Tulving[1]

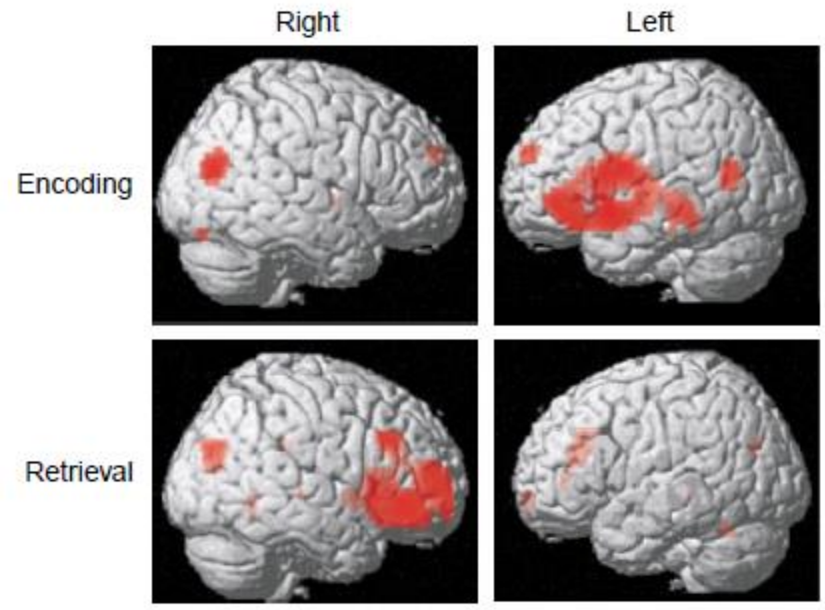
[1]Rotman Research Institute, Baycrest Centre for Geriatric Care, 3560 Bathurst Street, Toronto, Ontario, Canada M6A 2E1.
[2]Department of Psychology, Umeå University, Umeå S901-87, Sweden.

the encoding component of HERA is:

- supported if: (Enc L-Ret L) > (Enc R-Ret R)
- violated if (Enc L-Ret L) < (Enc R-Ret R)

the retrieval component of HERA is:

- supported if (Ret R-Enc R) > (Ret L-Enc L)
- violated if (Ret R-Enc R) < (Ret L-Enc L)



TRENDS in Cognitive Sciences

Hera model revisited

Opinion TRENDS in Cognitive Sciences Vol.7 No.6 June 2003 241

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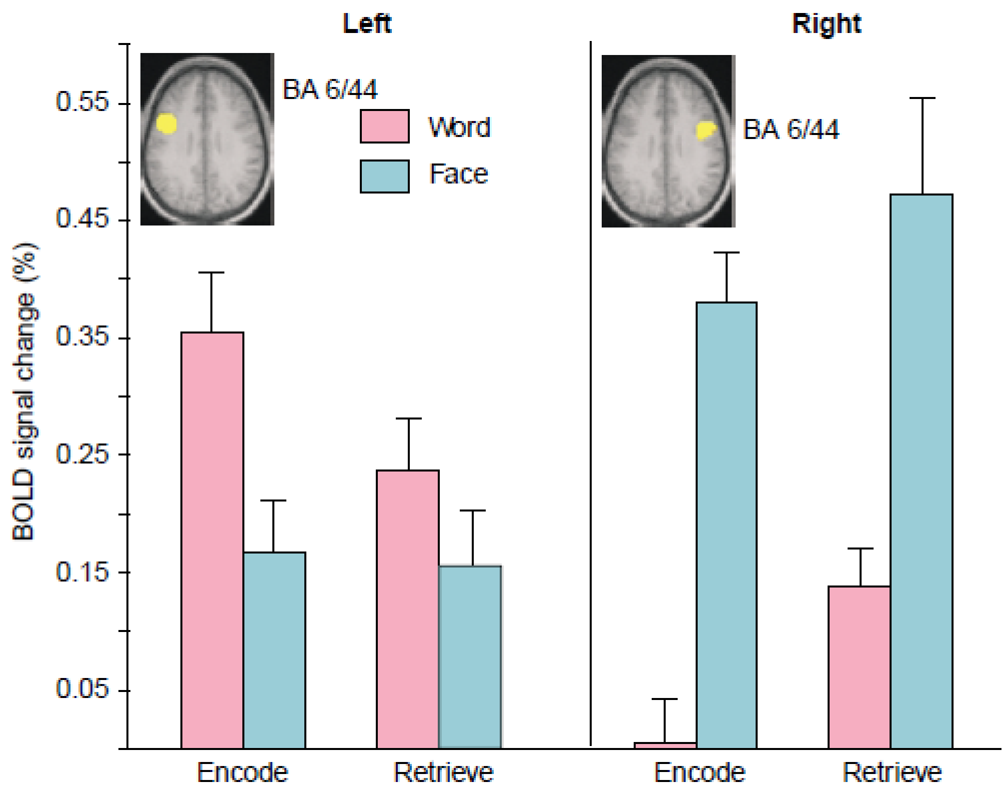
Box 1. Process-specific versus material-specific asymmetry



TRENDS in Cognitive Sciences

Two hypotheses to explain the asymmetry:

Process-specific asymmetry: the HERA system itself

Material-specific asymmetry: depends on the type of material (verbal versus non verbal)

Hera model revisited

Opinion TRENDS in Cognitive Sciences Vol.7 No.6 June 2003 241

Hemispheric asymmetries of memory: the HERA model revisited

Reza Habib[1], Lars Nyberg[2] and Endel Tulving[1]

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Process-specific asymmetry

Why is the left hemisphere specialized in semantic memory and episodic encoding and the right in episodic retrieval?

- It is known that episodic encoding relies heavily on semantic processes, so it is reasonable to imagine that the left lateralization of encoding is attributable to semantic processing of incoming information,

- The right lateralization of episodic retrieval has been explained in terms of "retrieval mode".

- Hypothesis that, at the beginning of evolution, mental functions were less numerous than today and that their cortical basis was bilateral. As more sophisticated mental abilities evolved, the demand for cortical space increased. The solution to this problem was hemispheric specialization: new functions were taken over by one hemisphere, at the cost of displacing earlier functions that were nevertheless retained in the other hemisphere.

Parietal activation

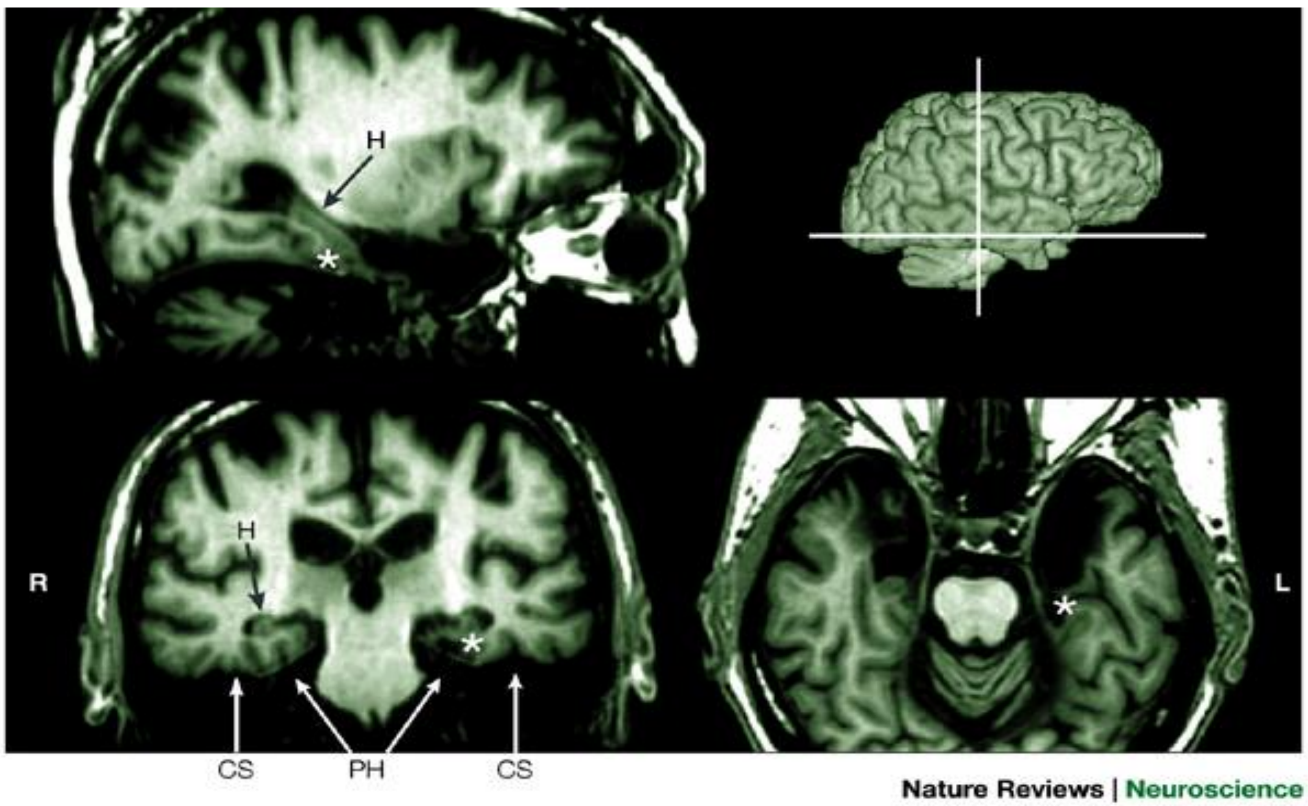
- Reproducible activations of the left and right parietal cortex and precuneus in encoding and recollection tasks

LATERAL PARIETAL

MEDIAL PARIETAL

Crucial regions (Lesion = dysfunction)

❑ Imaging can not answer this question



Role of these regions?

- Hippocampus
- Parahippocampal Cortex
- Neocortical regions
  - Prefrontal
  - pariétal

Hippocampal role

- ✓ Role in all stages of episodic memory?
- ✓ Preferential lateralization?
- ✓ Preferential intrahippocampal segregation?
  - ✓ along the anteroposterior axis
  - ✓ among hippocampal fields

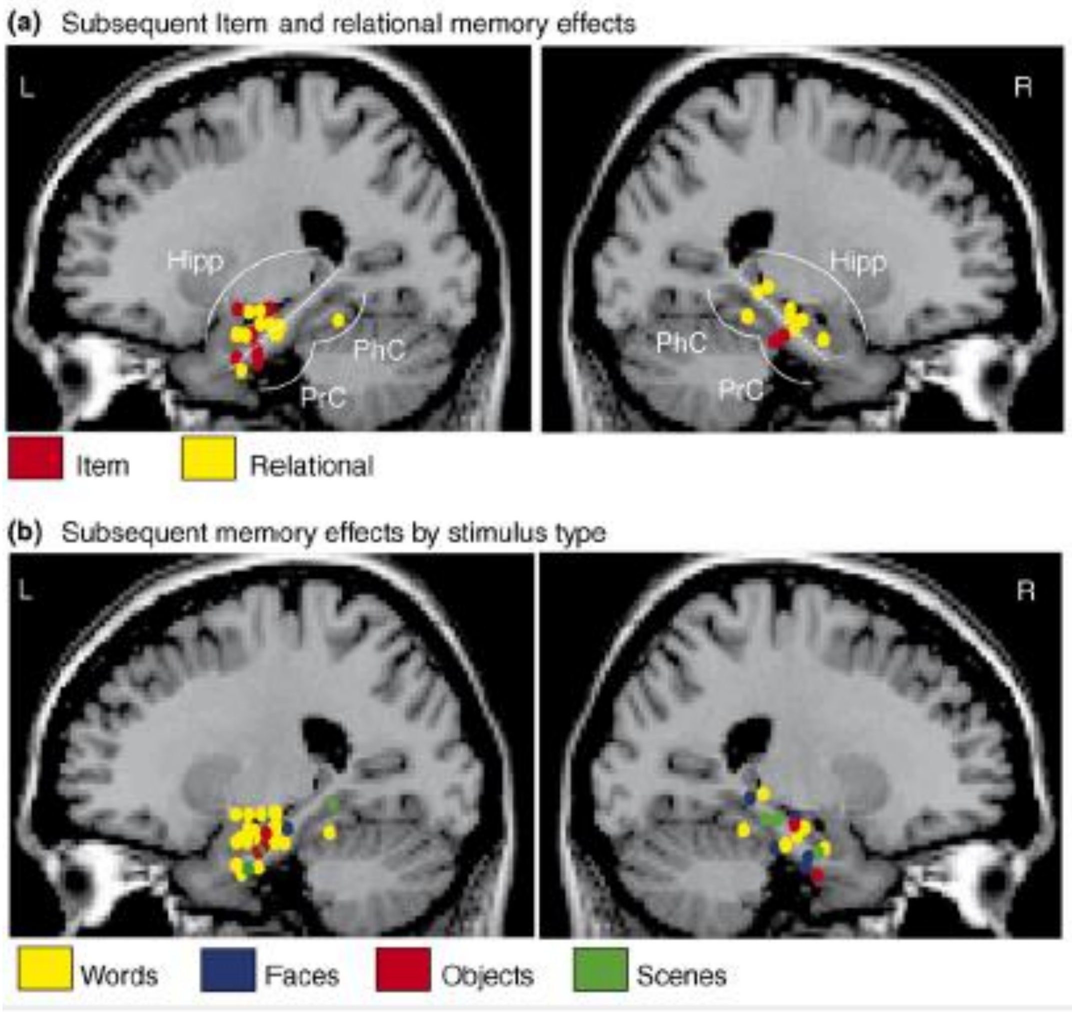
Hippocampal role

Role in all stages of episodic memory?

1. Encoding & binding

Crucial for binding

items encoding is processed in parahippocampal regions



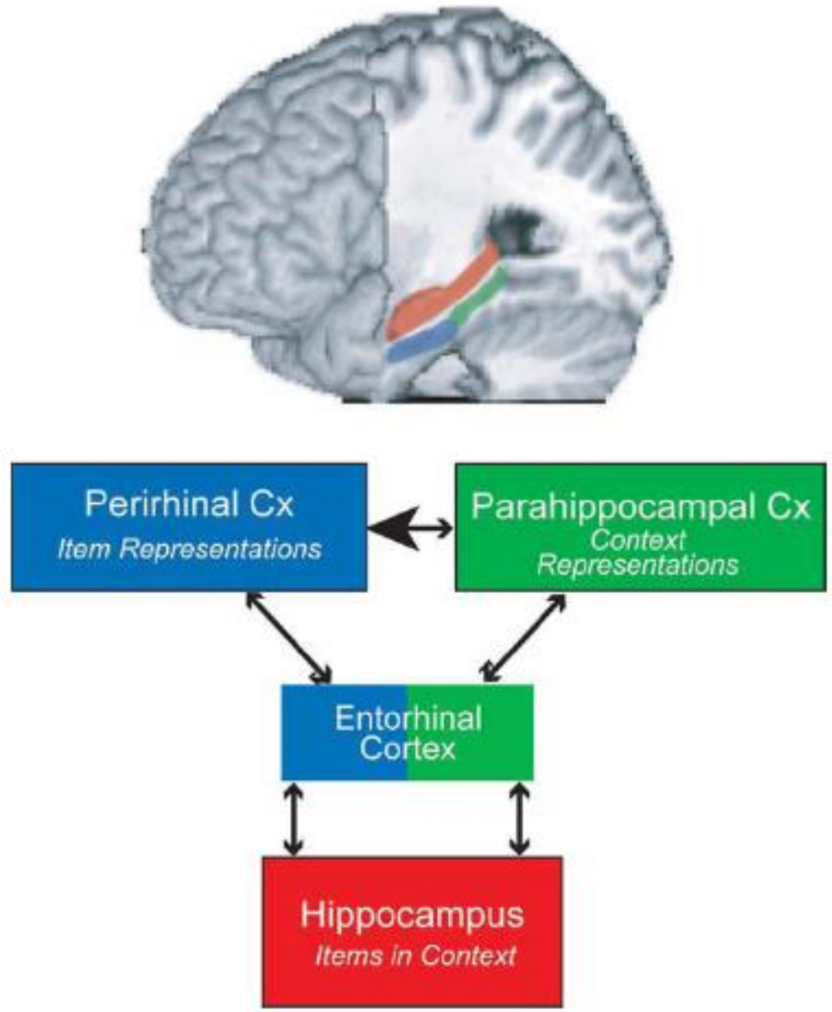
Davachi, 2006

Role in all stages of episodic memory?

1. Encoding & binding

BIC model: tri-compartimental model : Binding of Item and Contexts (Ranganath, 2010):

a. The perirhinal cortex preferentially receives afferences from the areas of the visual processing of the items (the way of the What) & has a role of concrete representation of the item (example for an object: characteristics of form, color, size ... ..) .
b. The parahippocampal cortex has a role of contextual representation of the item (spatial, temporal, semantic, social...) because of its privileged afferences with areas (posterior parietal cortex in particular) more involved in the spatial representation, and contextual items (the where way)
c. The emotional context seems supported by the amygdala
d. The hippocampus allows the coherent association of the different physical and contextual traits of the items forming the episode to memorize

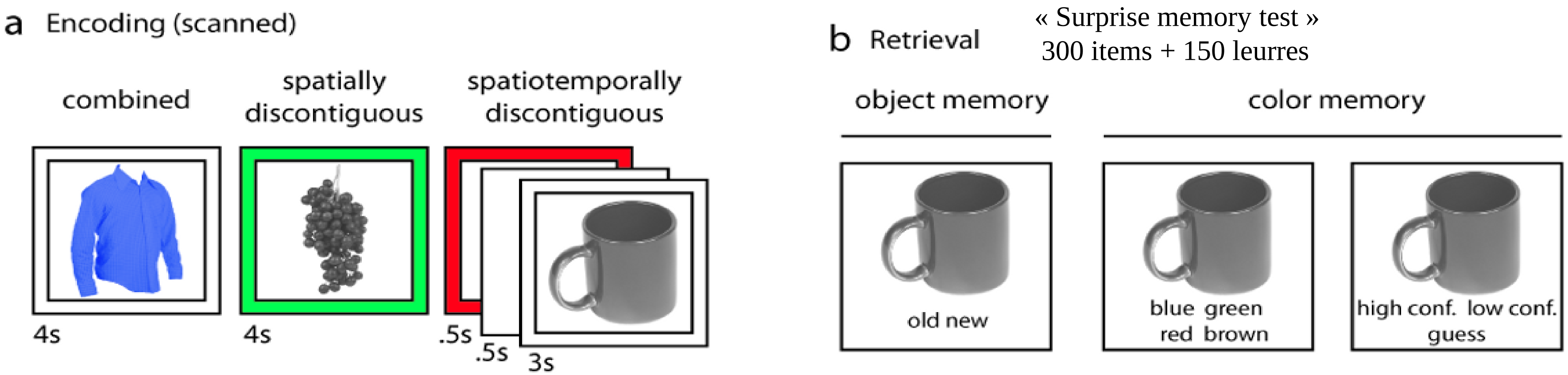


Staresina & Davachi, Neuron, 2009

Mind the gap: Binding experiences across space and time in the human hippocampus

4 couleurs
25 essais/ couleur

n=3x100



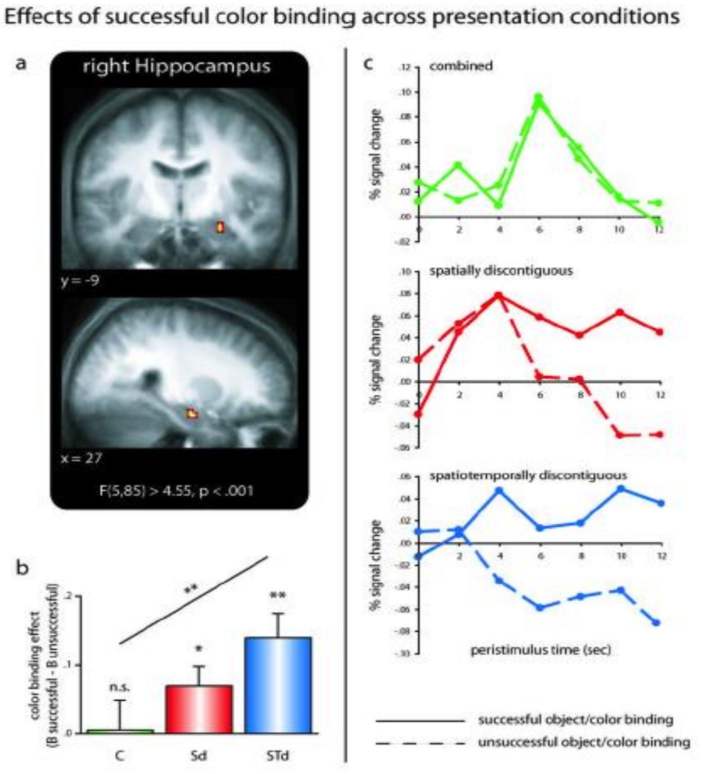
« Surprise memory test »
300 items + 150 leurres

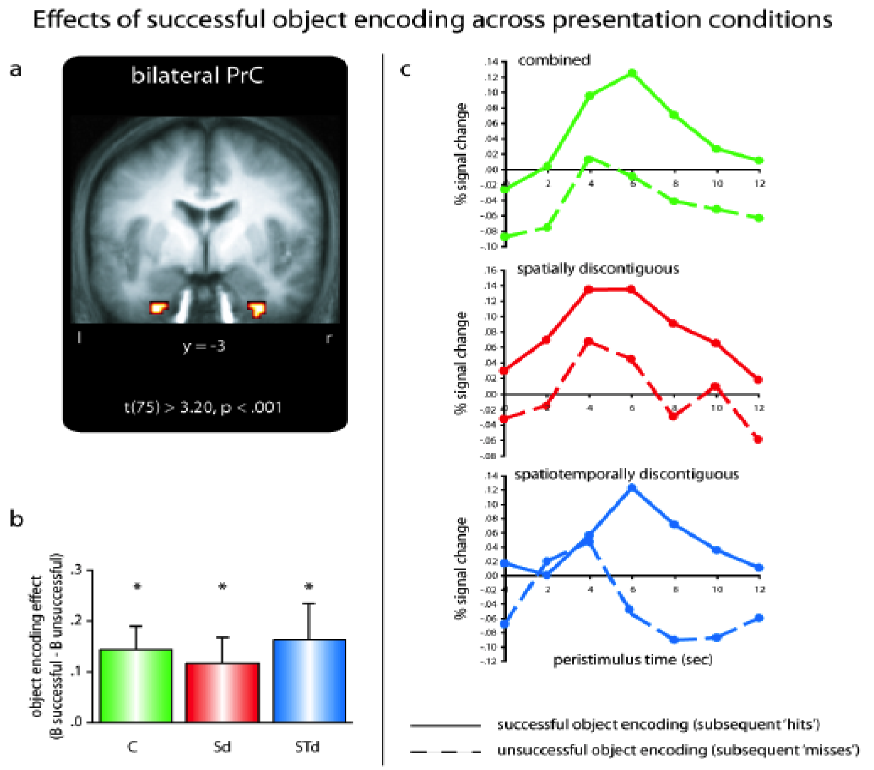
Sûr/ pas sûr

Imagine and give the probability of the association object-color

Staresina & Davachi, Neuron, 2009

Mind the gap: Binding experiences across space and time in the human hippocampus





➔Binding across time and space: in the hippocampus

Allows the link in episodic memory

Hippocampal role

1. encoding & binding

The binding is facilitated if the new episode to memorize is linked to semantic knowledge already acquired

The Journal of Neuroscience, August 3, 2016 • 36(31):8103–8111 • **8103**

Behavioral/Cognitive

Knowledge Acquisition during Exam Preparation Improves Memory and Modulates Memory Formation

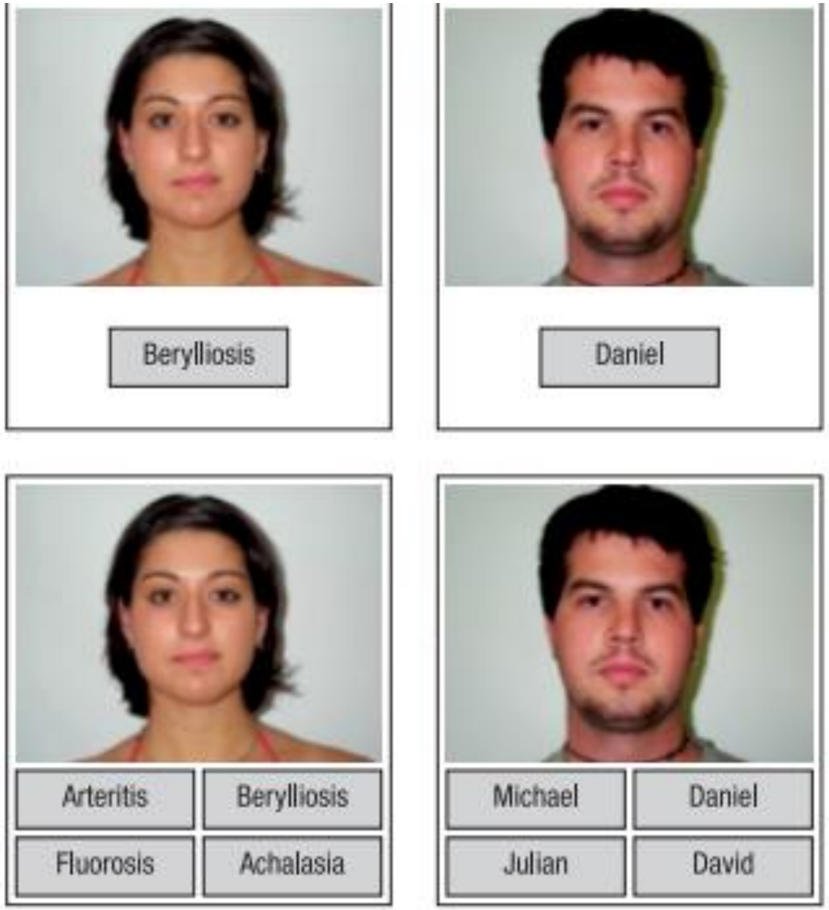
Garvin Brod,[1] Ulman Lindenberger,[1,2] Anthony D. Wagner,[3,4] and Yee Lee Shing[1,5]
[1]The Center for Lifespan Psychology, Max Planck Institute for Human Development, 14195 Berlin, Germany, [2]European University Institute, 50014 San Domenico di Fiesole, Italy, [3]Department of Psychology and [4]Neurosciences Program, Stanford University, Stanford, California 94305, and [5]Division of Psychology, University of Stirling, Stirling FK9 4LA, United Kingdom

Rôle de l'hippocampe

1. Encoding & binding

The binding is facilitated if the new episode to memorize is linked to semantic knowledge already acquired

Thirty-five medical students (20 women; age range, 23–29 years; mean age, 25.9 years)



Face learning:
 In association with a medical diagnosis
 In association with a first name

Encoding in MRI
 Recognition outside

2 MRI sessions:
T1: 3 months before exam
 T1-T2: platform learning
 T2: 3 months after, after revision, at the moment exams

Hippocampal role

1. encodage et binding

The binding is facilitated if the new episode to memorize is linked to semantic knowledge already acquired

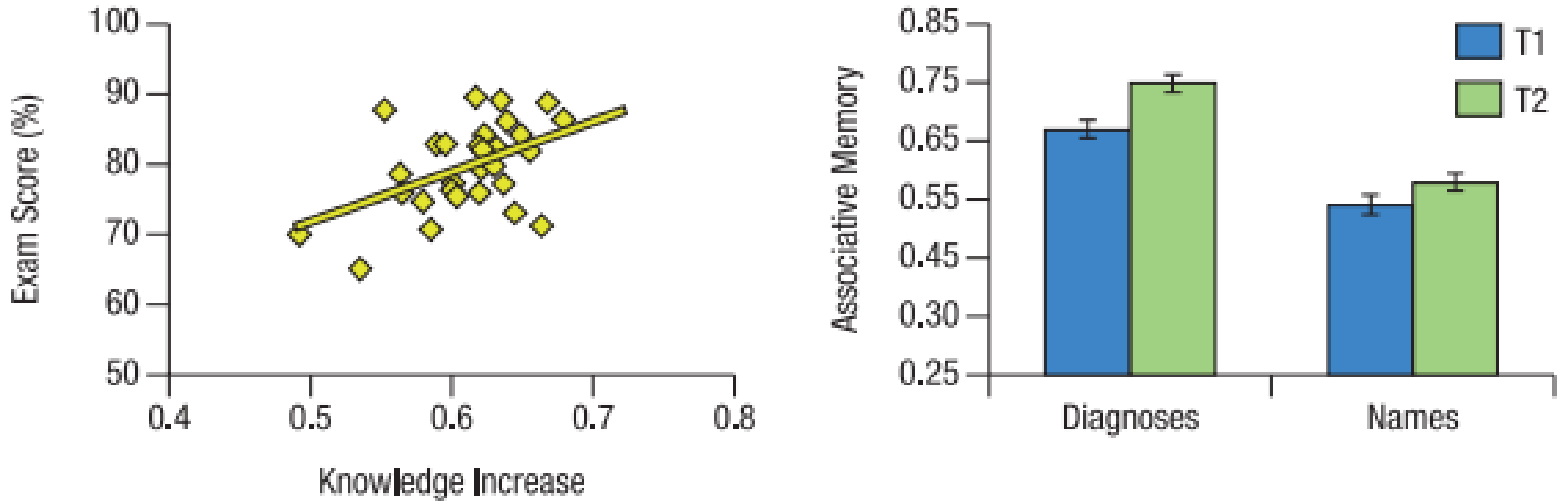


Figure 2. Correlation between medical knowledge gains and final exam score; memory performance. *Left*, Gains in medical knowledge, assessed via the web-based learning platform, correlated with the final exam score ($r = 0.53$, $p < 0.001$). *Right*, Gains in associative memory performance were more pronounced for face– diagnosis pairs than for face–name pairs. SEs reflect the pooled error term of the within-subjects F statistic.

Better performance if association with medical knowledge

Improved performance with improved medical knowledge for category 1

Hippocampal role

Hippocampal initial involvement

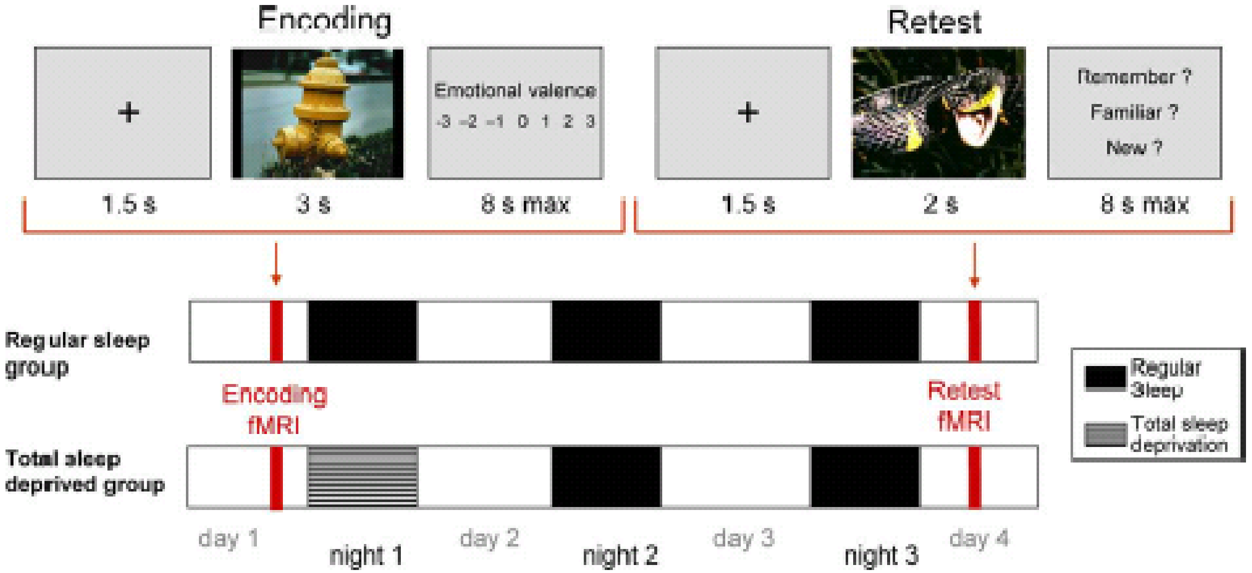
2. consolidation

OPEN ACCESS Freely available online PLOS BIOLOGY

Sleep-Related Hippocampo-Cortical Interplay during Emotional Memory Recollection

Virginie Sterpenich[1], Geneviève Albouy[1], Mélanie Boly[1], Gilles Vandewalle[1], Annabelle Darsaud[1], Evelyne Balteau[1], Thien Thanh Dang-Vu[1,2], Martin Desseilles[1,3], Arnaud D'Argembeau[4], Steffen Gais[1], Géraldine Rauchs[1], Manuel Schabus[1,5], Christian Degueldre[1], André Luxen[1], Fabienne Collette[1,4], Pierre Maquet[1,2*]

1 Cyclotron Research Centre, University of Liège, Liège, Belgium, **2** Department of Neurology, Centre Hospitalier Universitaire de Liège, Domaine Universitaire du Sart Tilman, Liège, Belgium, **3** Department of Psychiatry, Centre Hospitalier Universitaire de Liège, Domaine Universitaire du Sart Tilman, Liège, Belgium, **4** Department of Cognitive Sciences, University of Liège, Liège, Belgium, **5** Department of Psychology, University of Salzburg, Salzburg, Austria



Hippocampal role

consolidation. The recruitment of hippocampo-neocortical networks during recollection is enhanced after sleep and is hindered by sleep deprivation. After sleep deprivation, recollection of negative, potentially dangerous, memories recruits an alternate amygdalo-cortical network, which would keep track of emotional information despite sleep deprivation.

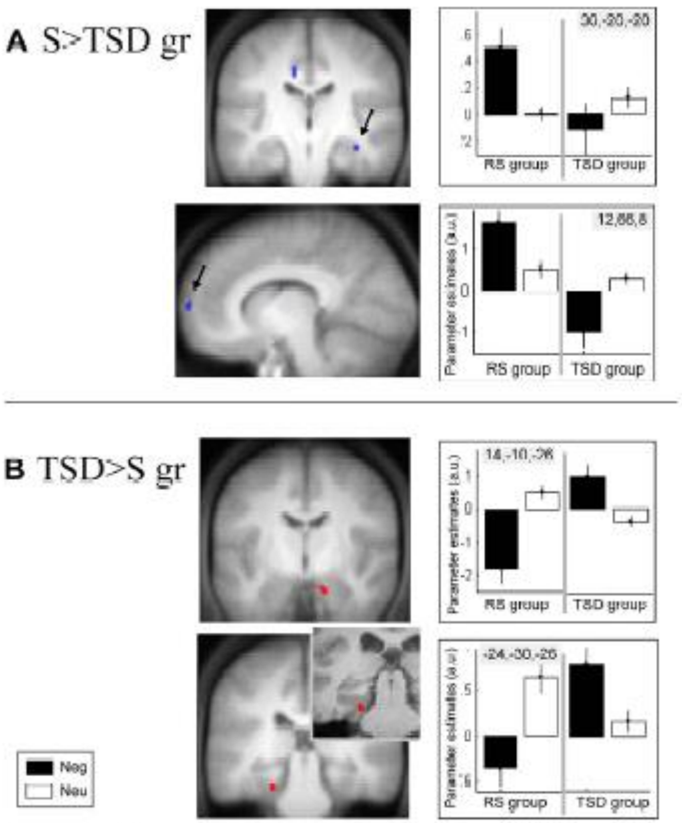


Figure 3. Effect of Sleep on Emotional (Negative) Memory

(A) Memory (R > K) × emotion (Neg > Neu) × sleep status (RS > TSD) interaction. From the top to the bottom: the hippocampus and the medial prefrontal cortex.

(B) Memory (R > K) × emotion (Neg > Neu) × sleep status (TSD > RS) interaction. From the top to the bottom: amygdala and fusiform gyrus (inset: enlarged mesio-temporal region in a representative subject).

Neu: neutral; Neg: negative. Left panels: functional results are displayed on the mean structural MR image, normalized to the same stereotactic space (display at $p < 0.001$, uncorrected). Right panels: parameter estimates of recollection minus familiarity (arbitrary units ± SEM).

doi:10.1371/journal.pbio.0050282.g003

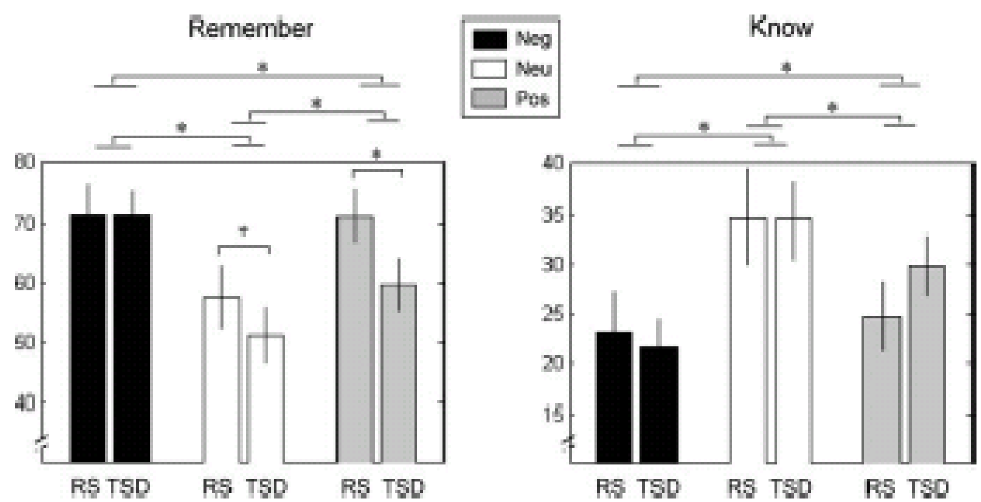


Figure 2. Behavioral Data

Percentage of correctly remembered and known images as a function of sleep groups. RS: regular sleep, TSD: total sleep deprivation, Neg: negative, Neu: neutral, Pos: Positive.

doi:10.1371/journal.pbio.0050282.g002

Hippocampal role

Hippocampal initial involvement

2. consolidation

SCIENCE ADVANCES | RESEARCH ARTICLE

NEUROSCIENCE

Rehearsal initiates systems memory consolidation, sleep makes it last

L. Himmer[1*†], M. Schönauer[1,2*†], D. P. J. Heib[3], M. Schabus[3], S. Gais[1]

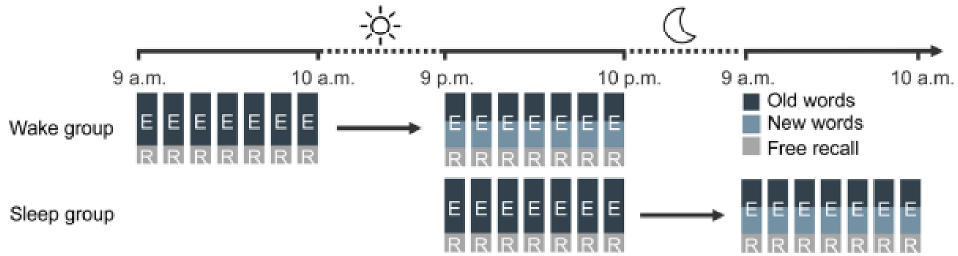
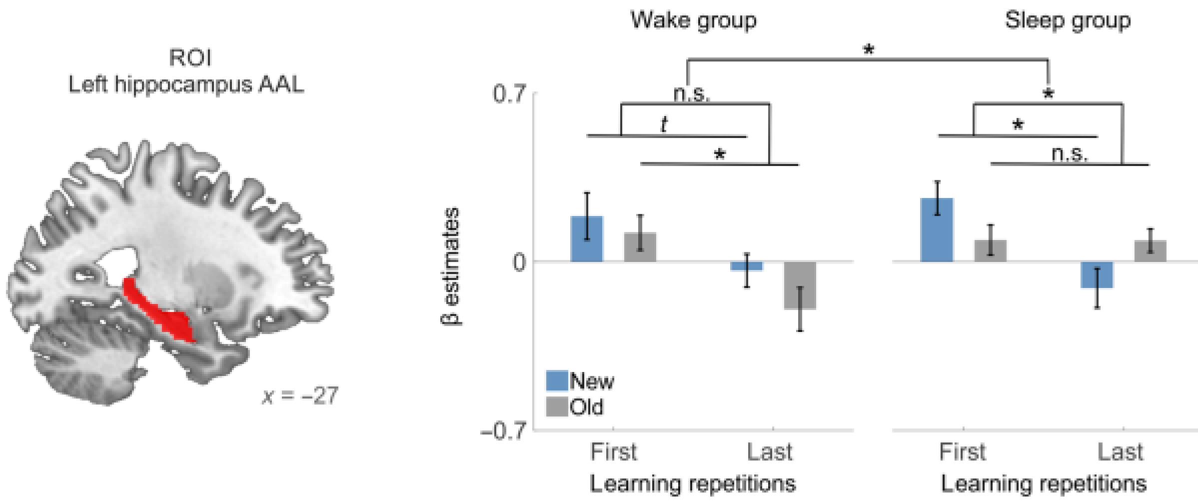


Fig. 1. General design. Participants visited the laboratory twice and spent the 12-hour interval in between either awake during the day (wake group, $n = 16$) or went to bed normally (sleep group, $n = 15$). Each session consisted of seven encoding repetitions (E) of a word list of 28 concrete German nouns. Every repetition was followed by a self-paced free recall (R) of all remembered words. We refer to the encoding-recall repetition as rehearsal. During the second session, the word list consisted of 14 words known from the first session (dark blue) and 14 new words (light blue). Words were presented in each repetition one at a time in randomized order.



sleep and repeated rehearsal jointly contribute to memory consolidation

Hippocampal role

Role in all stages of episodic memory?

2. consolidation

Late consolidation?

ELSEVIER
Neuropsychologia 43 (2005) 479–496
NEUROPSYCHOLOGIA
www.elsevier.com/locate/neuropsychologia

Rapid publication

Medial temporal lobe structures are needed to re-experience remote autobiographical memories: evidence from H.M. and W.R.

Sarah Steinvorth[a, b, *], Brian Levine[c], Suzanne Corkin[a, b]

[a] Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, NE20-392, Cambridge, MA 02139, USA
[b] MGH/MIT/HMS Athinoula A. Martinos Center for Biomedical Imaging, Charlestown, MA, USA
[c] Rotman Research Institute, Baycrest Centre for Geriatric Care, Department of Psychology and Medicine (Neurology), University of Toronto, Toronto, Ont., Canada

Received 26 July 2004; received in revised form 28 December 2004; accepted 7 January 2005

HM

WR

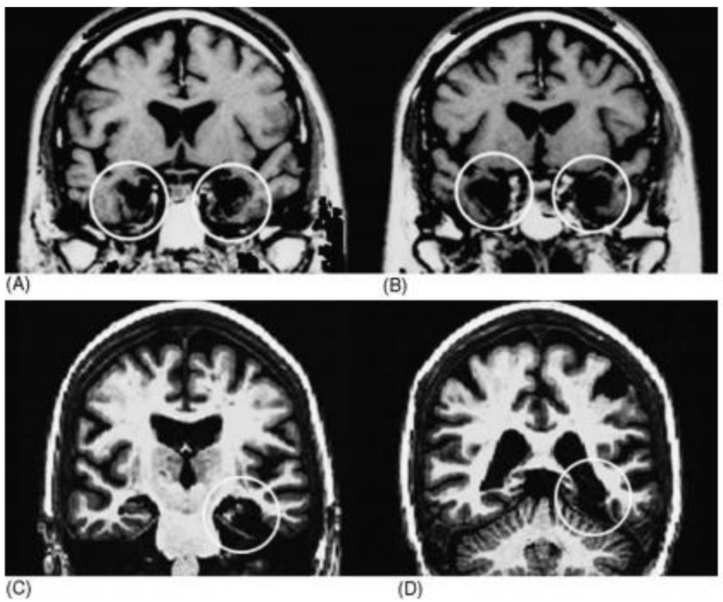


Fig. 1. T1-weighted images showing the locus and extent of bilateral MTL lesions in H.M. and W.R. H.M.'s removal includes approximately half of the rostrocaudal extend of the hippocampal formation (A), and most of the entorhinal cortex (B). W.R.'s lesions include the left parahippocampal gyrus and the hippocampal formation (C), and the left fusiform gyrus (D). Her lesion included the entire left hippocampus, except for the posterior aspect, left fusiform gyrus, and the major part of the left parahippocampal gyrus. The anterior part of the right hippocampus as well as the right parahippocampal gyrus were atrophic. Both amygdalae were intact.

2 amnesic patients (HM, WR) with bilateral medial temporal lobe lesions

Hippocampal role

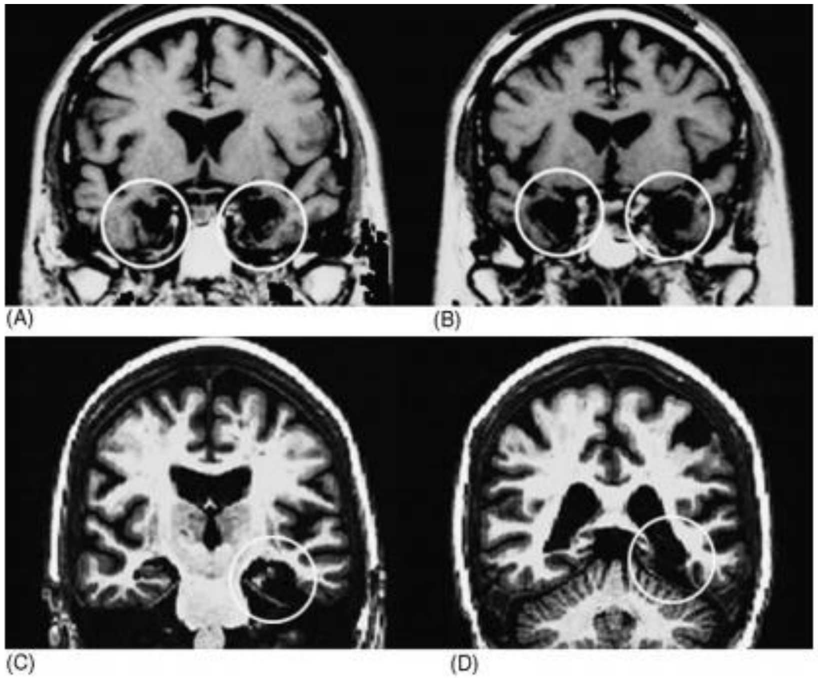
Role in all stages of episodic memory?

2. consolidation

Late consolidation?

HM

WR



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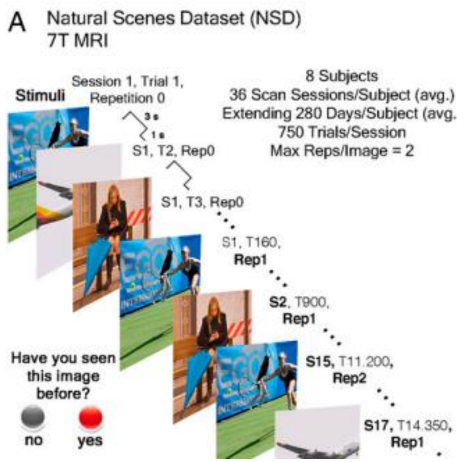
Both patients presented with severe autobiographical memory deficit, with no time gradient (even before the hippocampal damage).

Clinical data suggest an hippocampal long term involvement

Hippocampal long term involvement

2. Late consolidation

Study of natural scene image recognition spanning a year with 7-Tesla fMRI



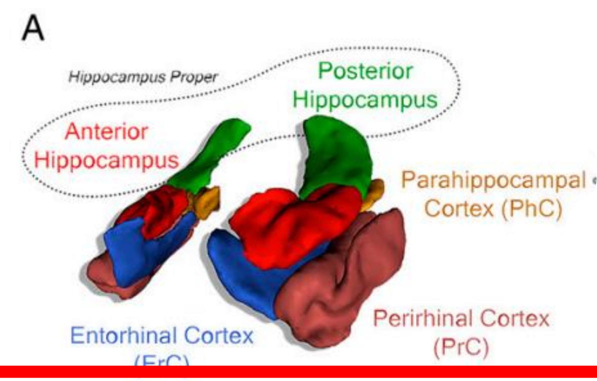
Medial temporal lobe (MTL) contribution to recognition persists over 200 days, supporting multiple-trace theory and contradicting a trace transfer (from MTL to cortex) point of view

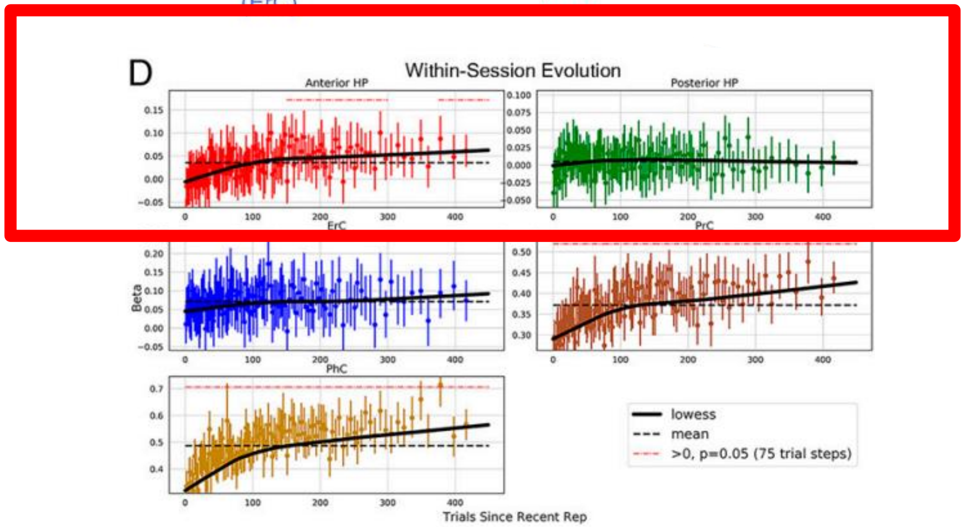
PNAS SPECIAL FEATURE | PSYCHOLOGICAL AND COGNITIVE SCIENCES NEUROSCIENCE

Multiple traces and altered signal-to-noise in systems consolidation: Evidence from the 7T fMRI Natural Scenes Dataset

Thomas J. Vanasse[a], Melanie Boly[a], Emily J. Allen[b,c], Yihan Wu[d], Thomas Naselaris[e], Kendrick Kay[b], Chiara Cirelli[a], and Giulio Tononi[a,1]

Edited by Lynn Nadel, The University of Arizona, Tucson, AZ; received January 31, 2022; accepted May 18, 2022





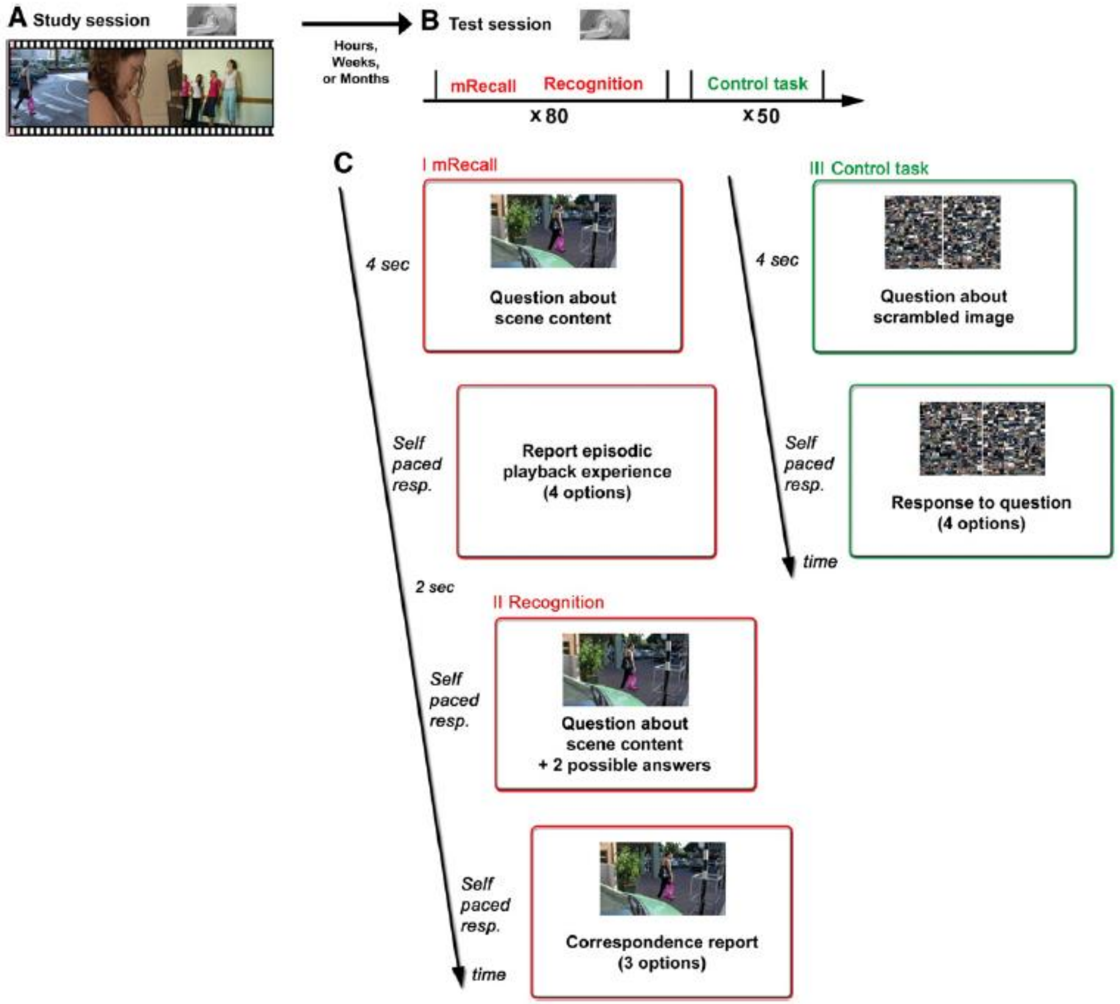
Hippocampal role

2. Late consolidation

Research

The episodic engram transformed: Time reduces retrieval-related brain activity but correlates it with memory accuracy

Orit Furman,[1] Avi Mendelsohn, and Yadin Dudai
Department of Neurobiology, The Weizmann Institute of Science, Rehovot 76100, Israel



Three groups of participants were scanned during a memory test either hours, weeks, or months after viewing a documentary movie.

Hippocampal long term involvement

2. consolidation

Research

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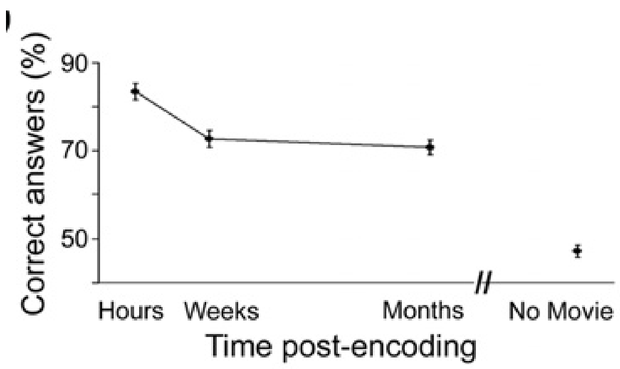
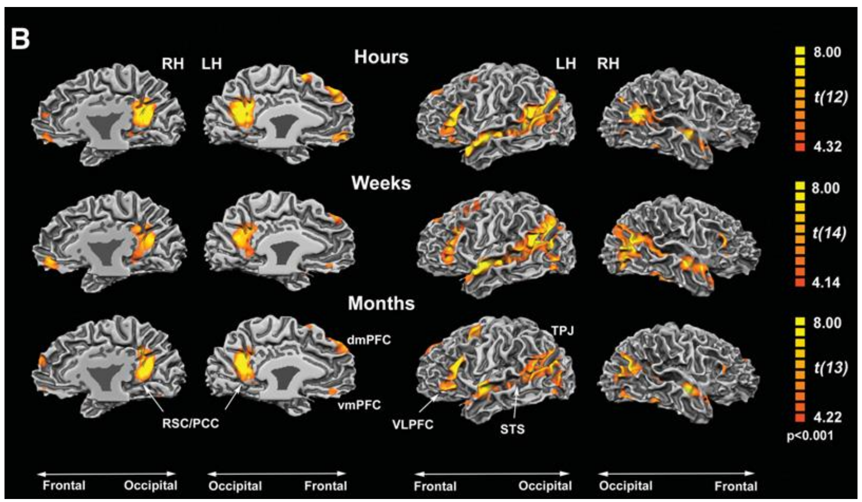


High recognition accuracy after hours decreased after weeks and remained at similar levels after months



Hippocampal engagement during retrieval remained similar over time

Hippocampal role

2. Late consolidation

Exp Physiol 99.3 (2014) pp 471–486 471

Joan Mott Prize Lecture

Memory consolidation in humans: new evidence and opportunities

Eleanor A. Maguire

Wellcome Trust Centre for Neuroimaging, Institute of Neurology, University College London, UK

Results in favor of alternative theory

recent and remote autobiographical memories is represented in the hippocampus

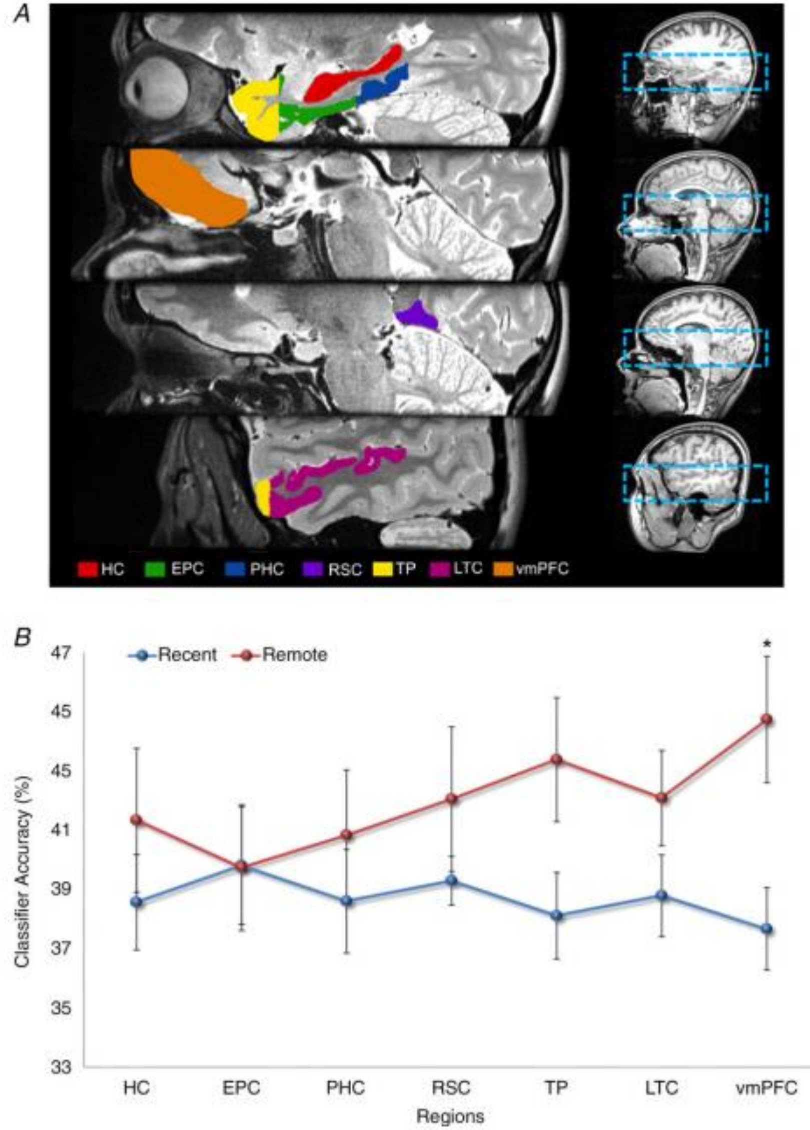


Figure 4. Representations of recent and remote autobiographical memories
A, the brain areas examined by Bonnici *et al.* (2012). The right panels show the bounding box of the high-resolution partial volume that was acquired for every subject. The left panels show the regions of interest that were demarcated, namely: hippocampus (HC), entorhinal and perirhinal cortices (EPC; combined because their responses were so similar), parahippocampal cortex (PHC), retrosplenial cortex (RSC), temporal pole (TP), lateral temporal cortex (LTC) and ventromedial prefrontal cortex (vmPFC). *B*, the MVPA results for memory decoding in each of the demarcated brain regions for recently formed autobiographical memories (blue) and for autobiographical memories that were formed 10 years ago (red). There was no significant difference in the classifier accuracy values for recent and remote memories in the hippocampus, but in vmPFC there was more accurate decoding of remote memories compared with recent memories (data from Bonnici *et al.* 2012; $*P < 0.05$; chance is 33%).

Hippocampal role

Role in all stages of episodic memory?

3. storage

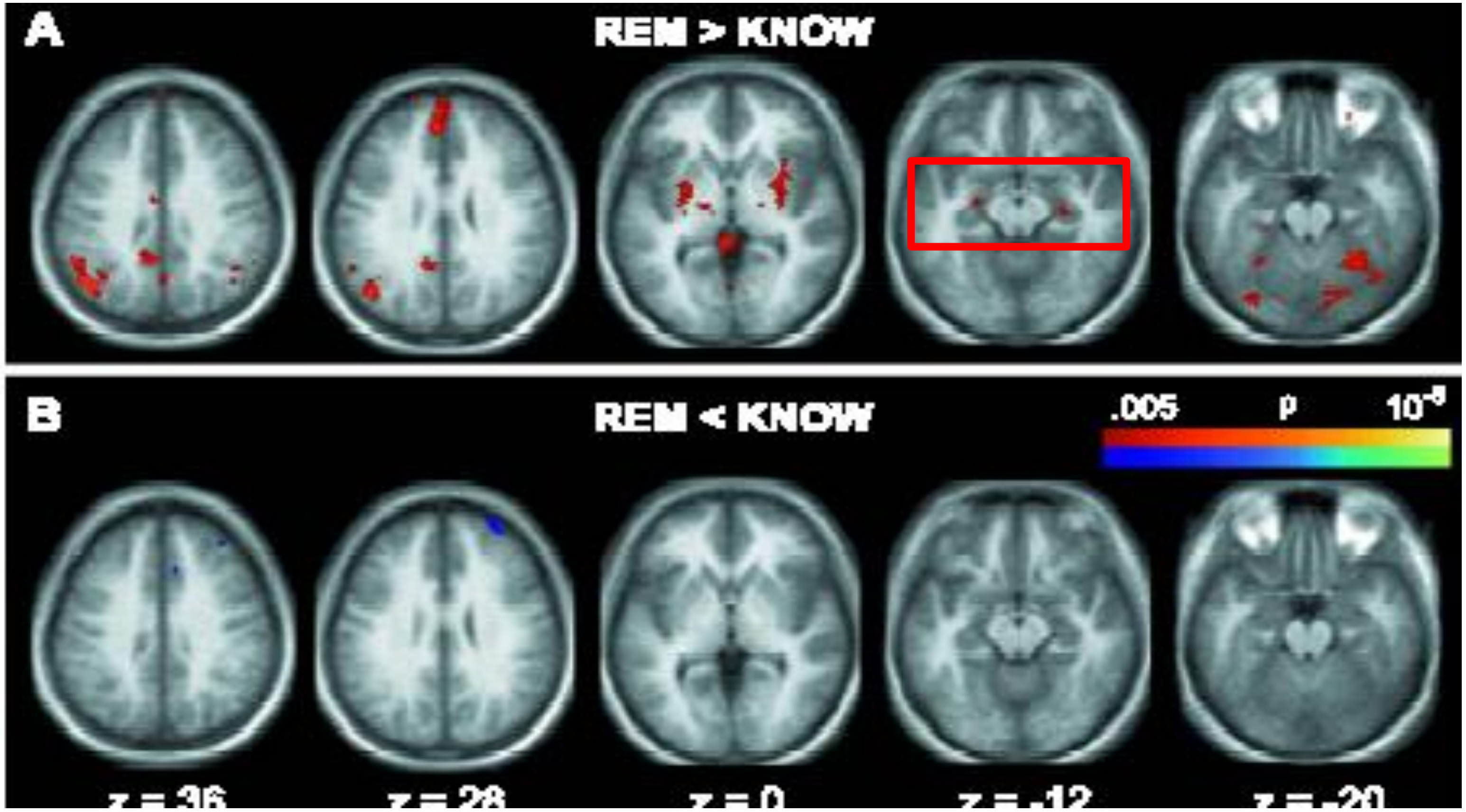
See the late consolidation theory: inside or outside of the hippocampus

Hippocampal role

Role in all stages of episodic memory?

4. recollection

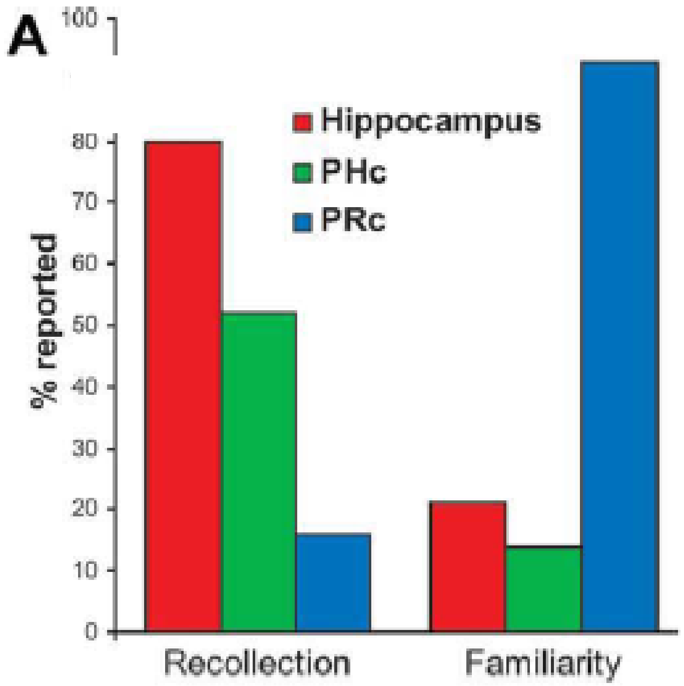
Conscious recollection of information (vs familiarity)



Wheeler et al. Neuroimage 2004, 21: 1337-1349

Hippocampal role

4. recollection



Review of 20 fMRI studies Diana, 2007,

Hippocampal role

Preferential lateralization?

Lateralization ?

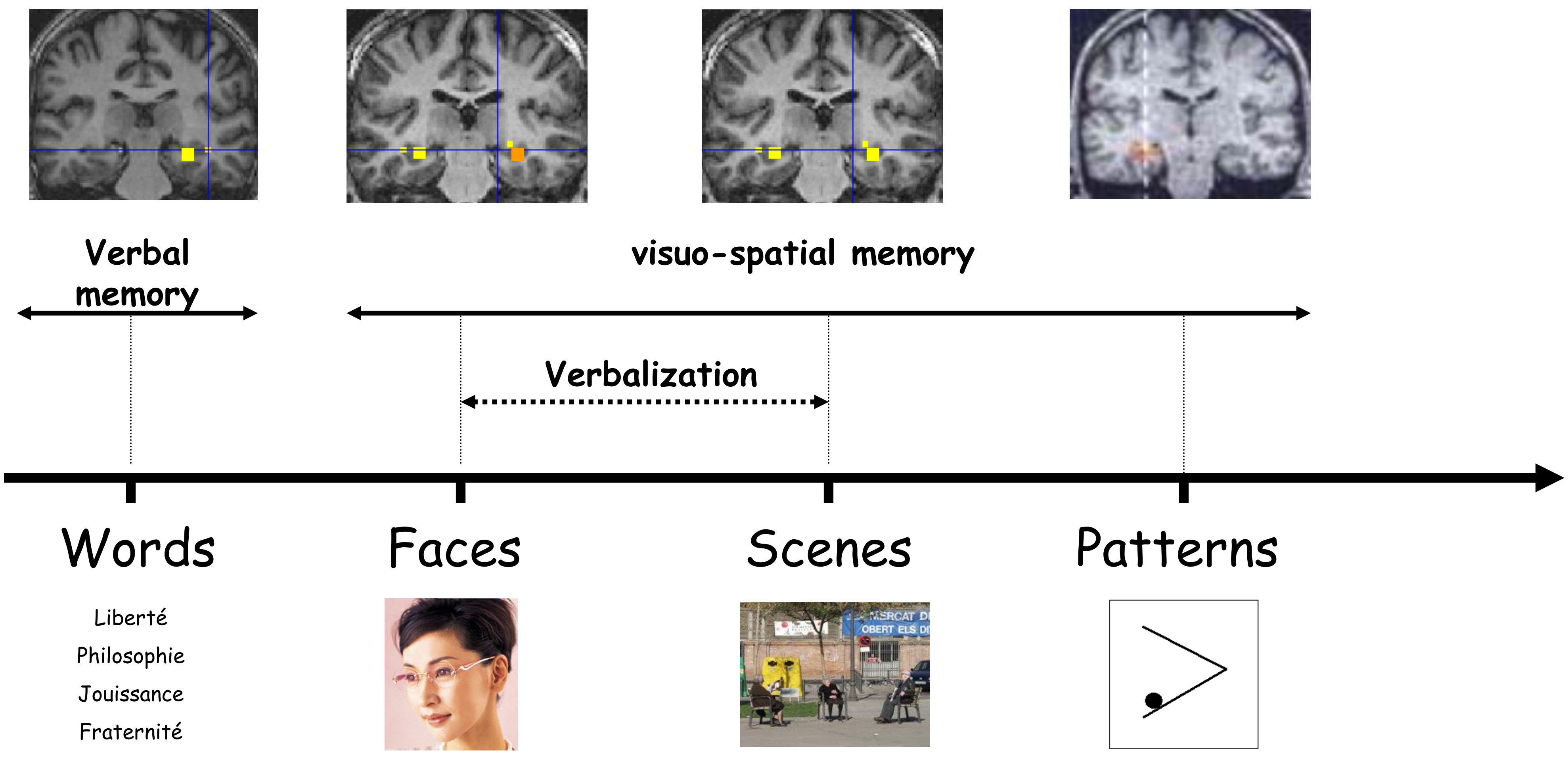
META-ANALYSIS PET: 52 studies from 1992 to 1998

	Left Hippocampus	Right Hippocampus
Encoding		
Verbal	**7**	**0**
Visuospatial	**5**	**8**
Recollection		
Verbal	**5**	**9**
Visuospatial	**9**	**9**

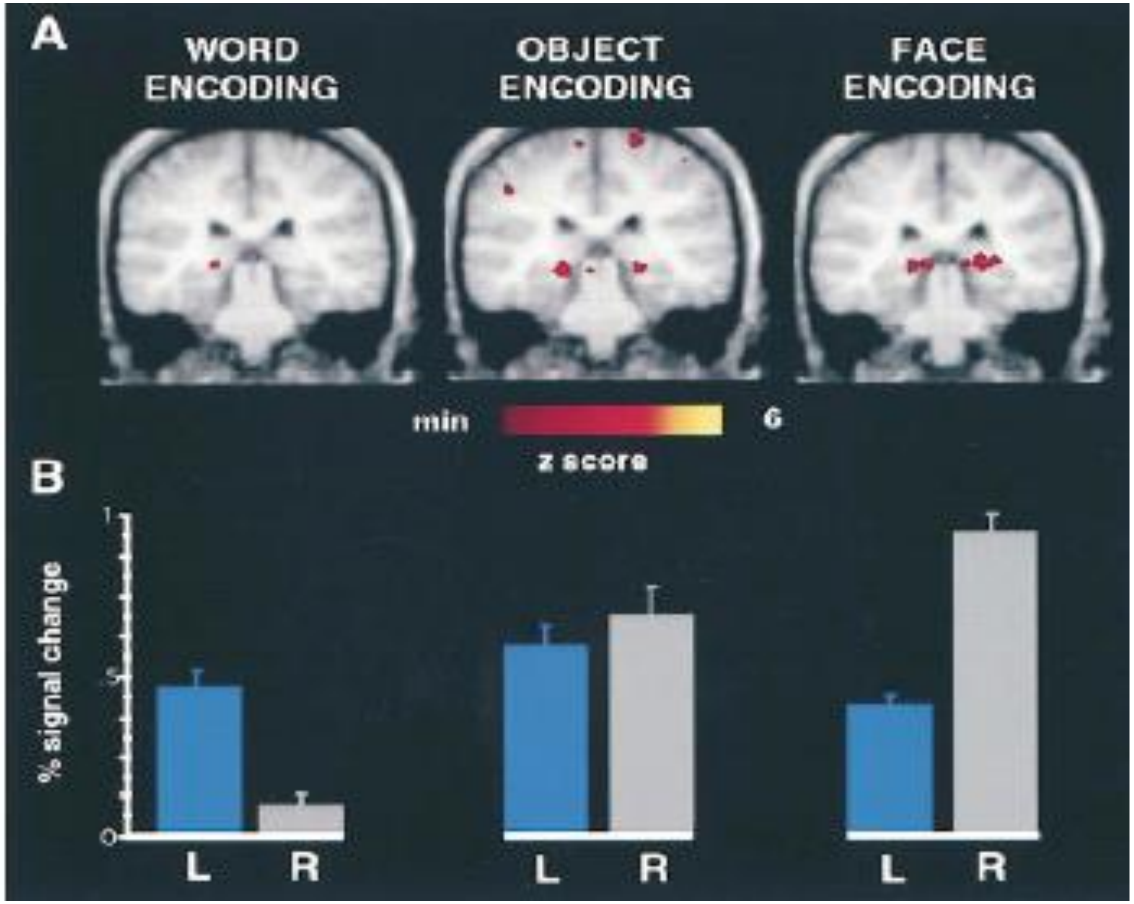
Brain. 2001 Sep;124(Pt 9):1841-54

Material-specific lateralization in the medial temporal lobe and prefrontal cortex during memory encoding

Golby AJ, Poldrack RA, Brewer JB, Spencer D, Desmond JE, Aron AP, Gabrieli JD



Hippocampal role



Hippocampal Lateralization & type of encoded material

Kelley et al. Neuron 98, 20: 927-936

Hippocampal role

Anteroposterior axis?

HIPPOCAMPUS 8:313–322 (1998)

RAPID COMMUNICATION

Hippocampal PET Activations of Memory Encoding and Retrieval: The HIPER Model

Martin Lepage,* Reza Habib, and Endel Tulving

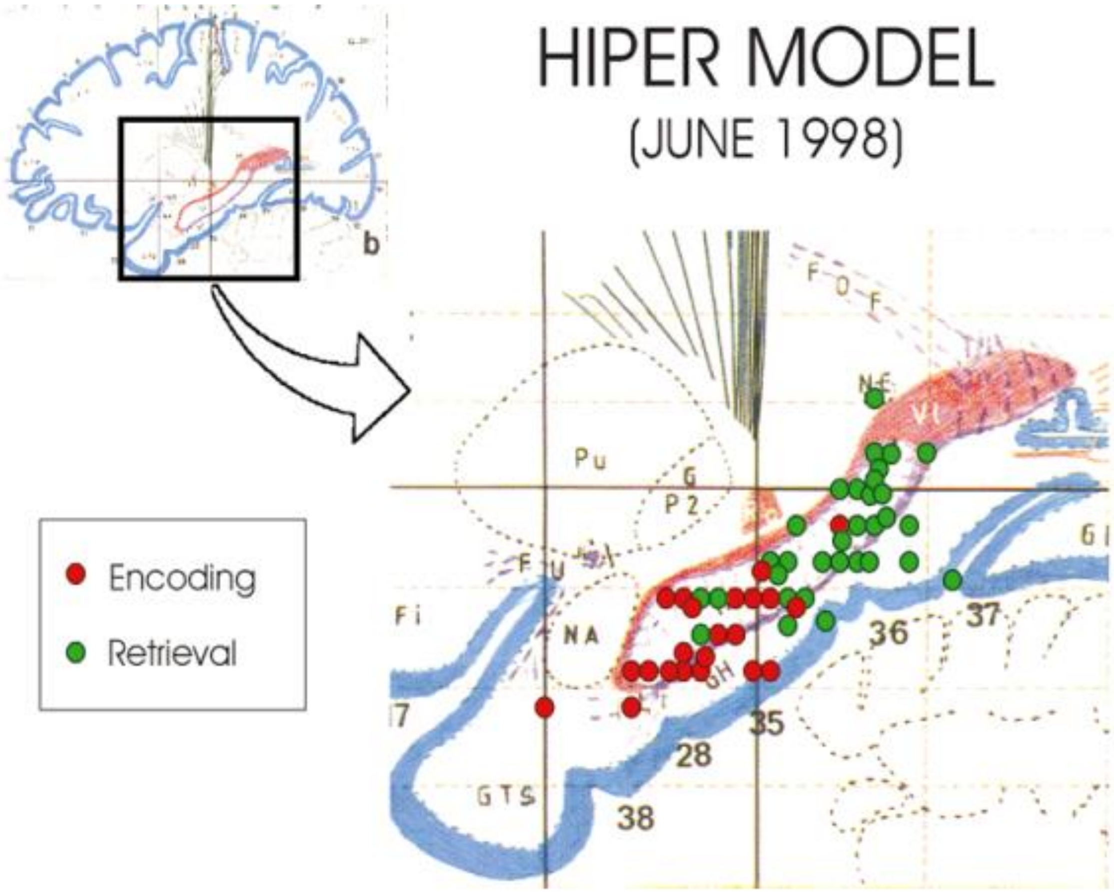


FIGURE 1. Schematic representation of 22 encoding and 32 retrieval activations in the hippocampal regions. Data from the left and the right hemisphere were pooled and projected onto a single sagittal slice (25 mm laterally from the midline) of the Talairach and Tournoux (1988) stereotaxic atlas. Overlapping activations were slightly moved.

A meta-analysis of PET studies studies: HIPER model

- ✓ episodic encoding: anterior activation
- ✓ episodic recollection: posterior activation
- ✓ Why?

Hippocampal role

Anteroposterior axis?

HIPPOCAMPUS 25:500–510 (2015)

Encoding and Retrieval Along the Long Axis of the Hippocampus and Their Relationships With Dorsal Attention and Default Mode Networks: The HERNET Model

Hongkeun Kim*

2 networks undergoing external & internal attention processes

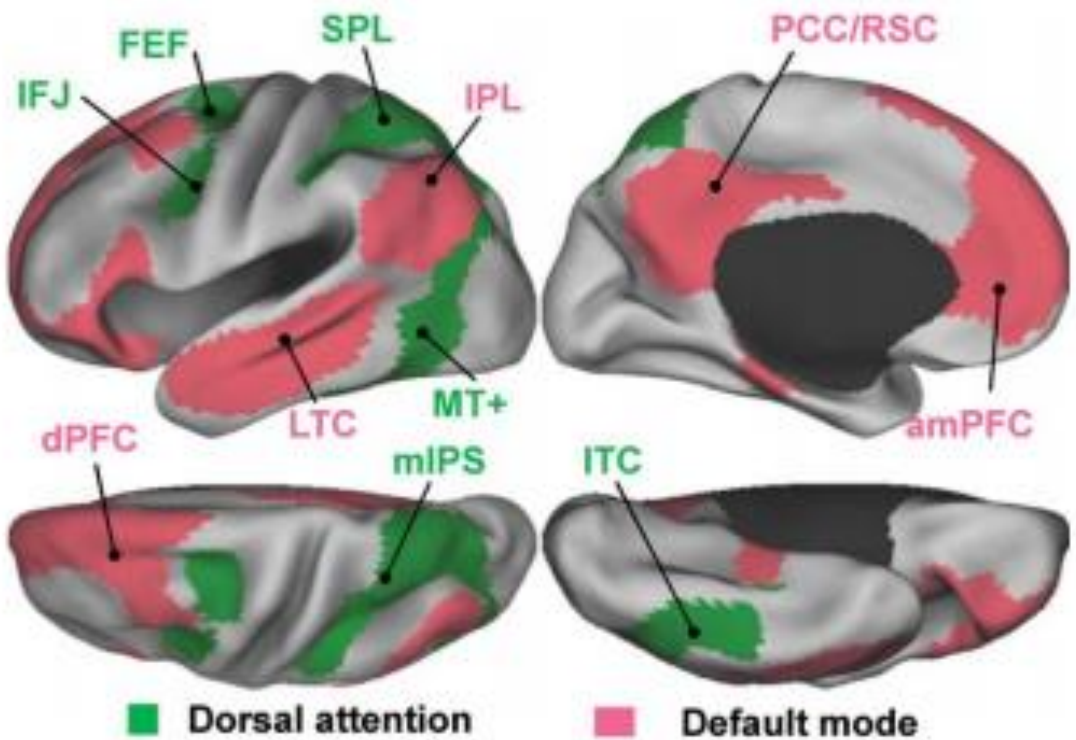


FIGURE 1. Estimates of the dorsal attention network (shown in green) and the default mode network (red). The estimates were

Hippocampal role

Anteroposterior axis?

HIPPOCAMPUS 25:500–510 (2015)

Encoding and Retrieval Along the Long Axis of the Hippocampus and Their Relationships With Dorsal Attention and Default Mode Networks: The HERNET Model

Hongkeun Kim*

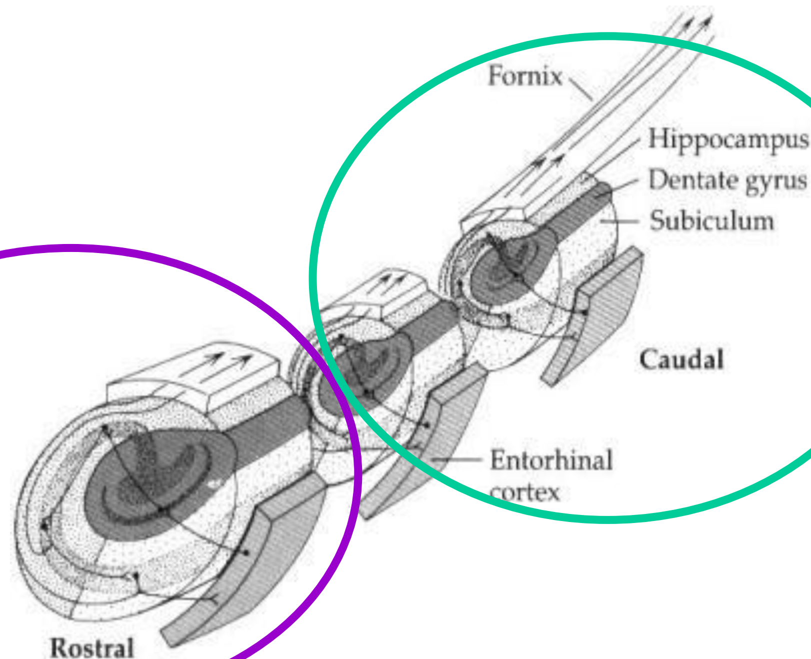
HERNET model

Reminder is related to internal attention processes (DMN)

Posterior part of the hippocampus

Encoding of sensory inputs is related to external attention processes

Hippocampal anterior part



meta-analysis: 167 individual studies with 2,856 participants: model HERNET valid and extends to amygdala for previous hippocampal activations

Hippocampal role

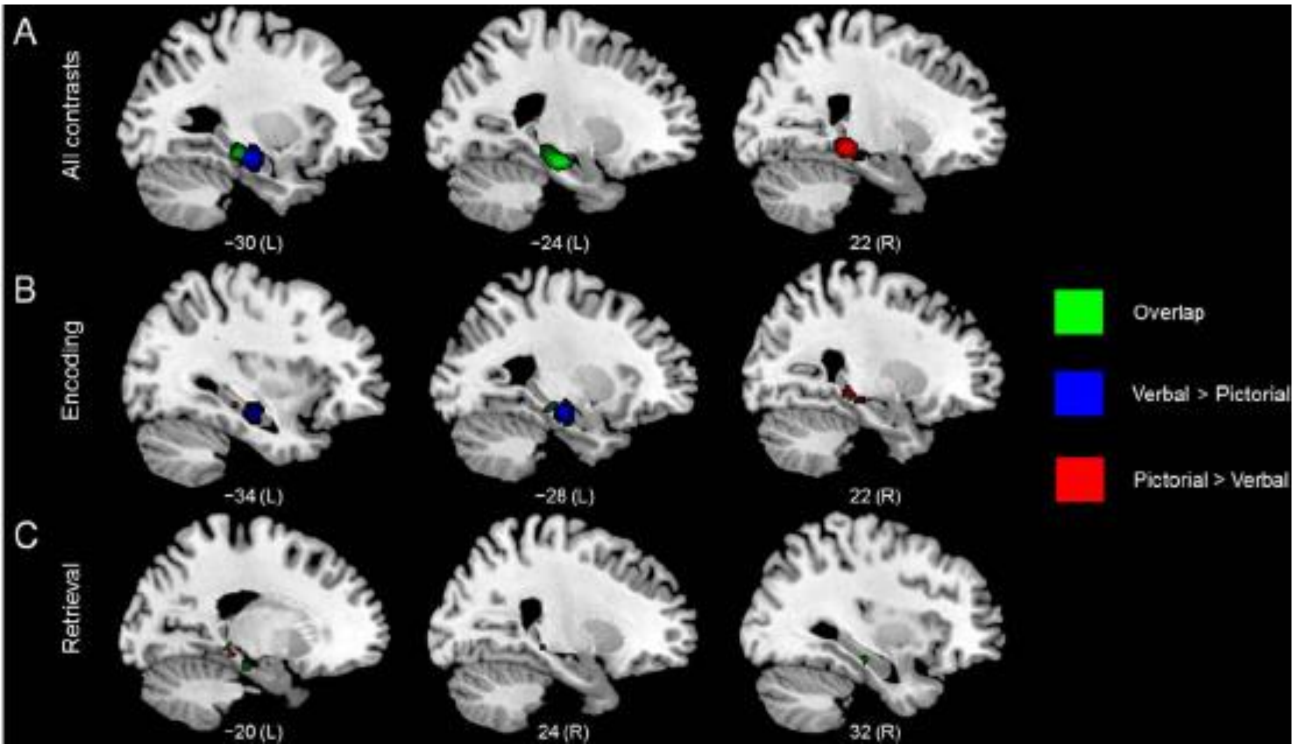
Anteroposterior axis?

Why?

HIPPOCAMPUS 25:1614–1631 (2015)

Hippocampal Hemispheric and Long-Axis Differentiation of Stimulus Content During Episodic Memory Encoding and Retrieval: An Activation Likelihood Estimation meta-Analysis

Jonas Persson* and Hedvig Söderlund



Meta-analysis of 94 studies

Localisation according tne anteroposterior axis will depend of the type of material that must be encoded:

Verbal: anterior activation

Non verbal: posterior activation

Less evident during recollection

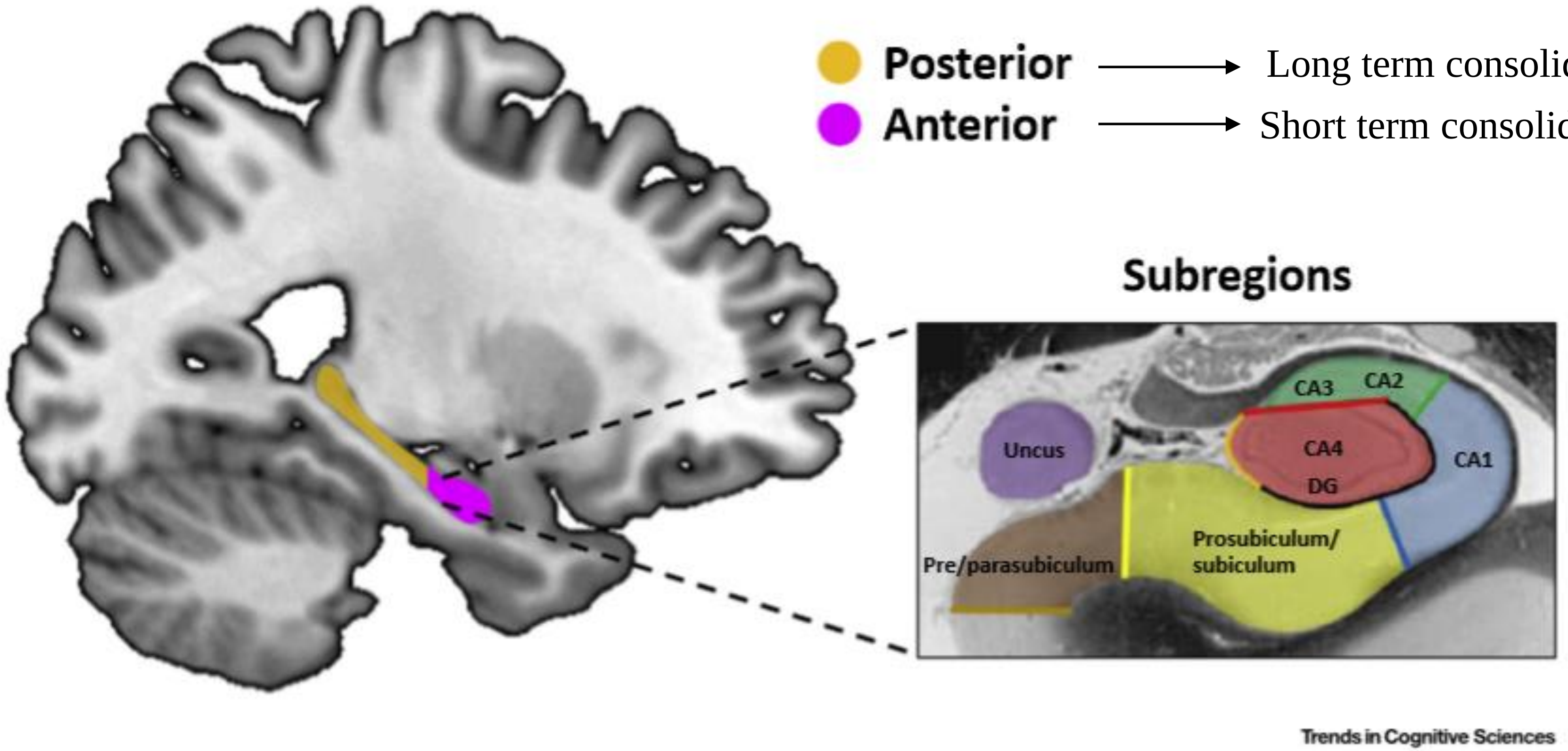
Hippocampal role

Anteroposterior axis?

Trends in Cognitive Sciences
CellPress REVIEWS
Opinion

Remote Memory and the Hippocampus: A Constructive Critique

Daniel N. Barry[1] and Eleanor A. Maguire[1,*]



Posterior → Long term consolidation

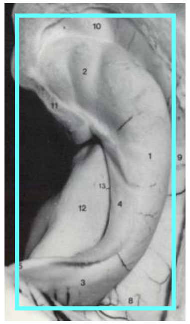
Anterior → Short term consolidation

Hippocampal role

Anteroposterior axis?

Yes but different hypotheses

- *Involvement of internal ou external attention processes*
- *Type of material*
- *Long term consolidation vs short term consolidation*



Hippocampal role

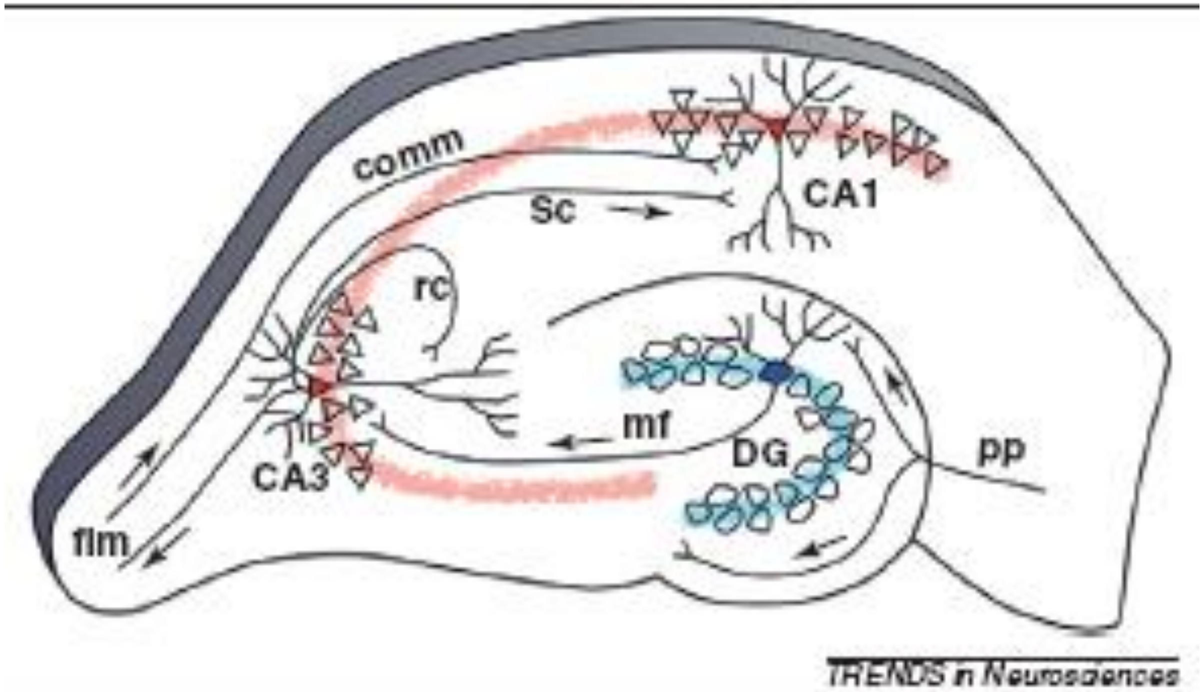
among hippocampal fields

Review

Special Issue: Hippocampus and Memory

Pattern separation in the hippocampus

Michael A. Yassa[1] and Craig E.L. Stark[2]



Trisynaptic circuit:

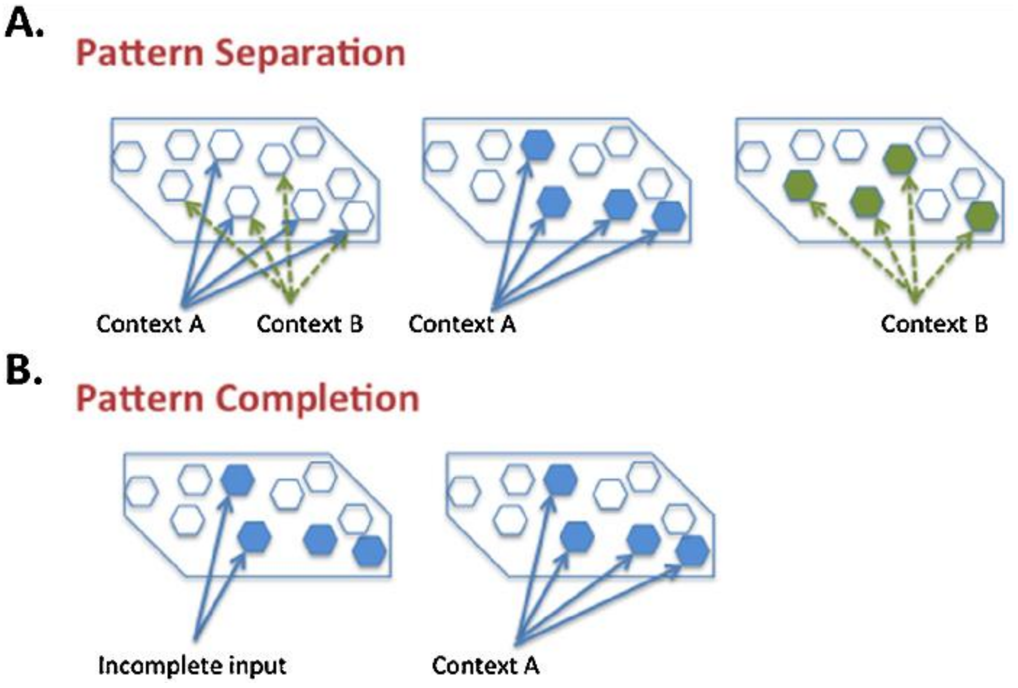
1. EC Neurons Project on DG / Perforating Pathway (PP)
2. DG projects on CA3: Mossy fiber channel (mf)
3. CA3 projects on itself / collateral recurring (rc) and on CA1 / Schaeffer collateral (sc)
4. CA1 sort / fornix & fimbria (fim) & also receives by this same way commissural afferences (comm) of the contralateral hippocampus

Hippocampal role

Pattern completion

- Ability to recall a whole memory from a partial cue

- Theoretical models of hippocampal function in memory posit that hippocampal pattern completion may be necessary to reactivate, or bring back to mind, the details associated with a past experience and that hippocampal pattern completion may, thus, mediate cortical reinstatement



Hippocampal role

Pattern completion

Task delay between encoding & retrieval

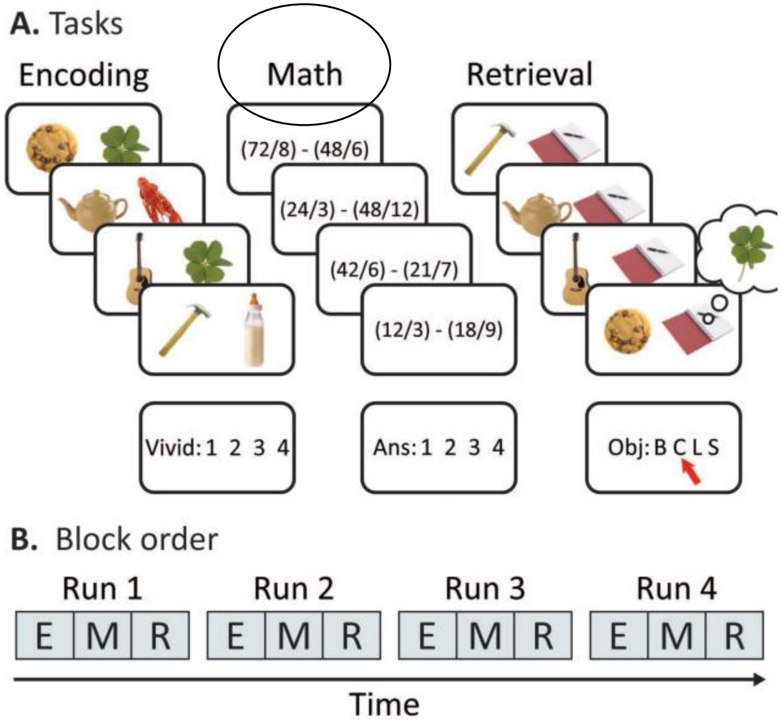


Figure 1. Experiment design

A. An overview of the experiment design. Participants completed blocks of encoding, math, and retrieval, preceded by one baseline block of math. During encoding, participants imagined two objects interacting, and later performed cued recall by choosing the associate (baby bottle, clover, lobster, or scissors) originally presented with each cue. Between each encoding and retrieval block, participants solved math problems. The math blocks were used as a filler task to incorporate a delay between encoding and retrieval.

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Author manuscript

Hippocampus. Author manuscript; available in PMC 2017 August 01.

Published in final edited form as:

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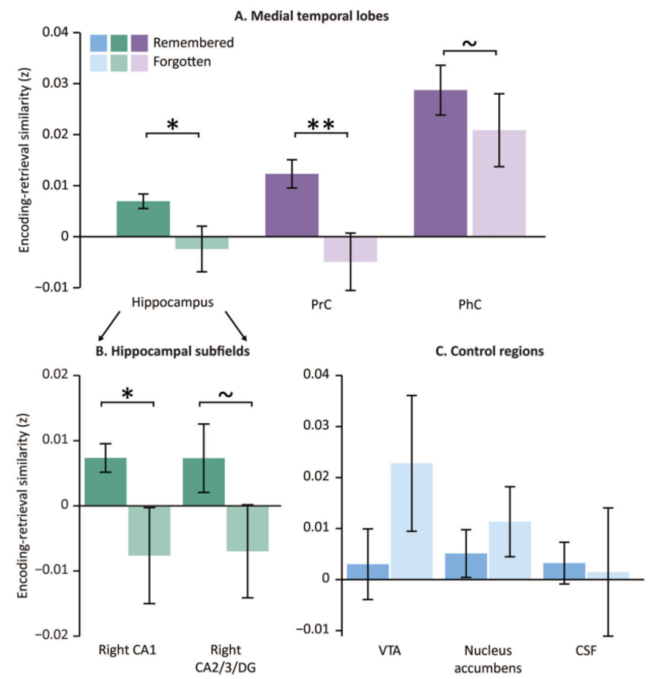
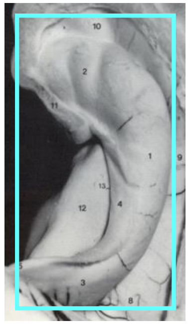
High-resolution investigation of memory-specific reinstatement in the hippocampus and perirhinal cortex

Alexa Tompary[1], **Katherine Duncan**[2], and **Lila Davachi**[1,3]



Successful memory for unique episodic events is reflected by neural reinstatement of patterns of activity in the hippocampus, particularly in right CA1 .



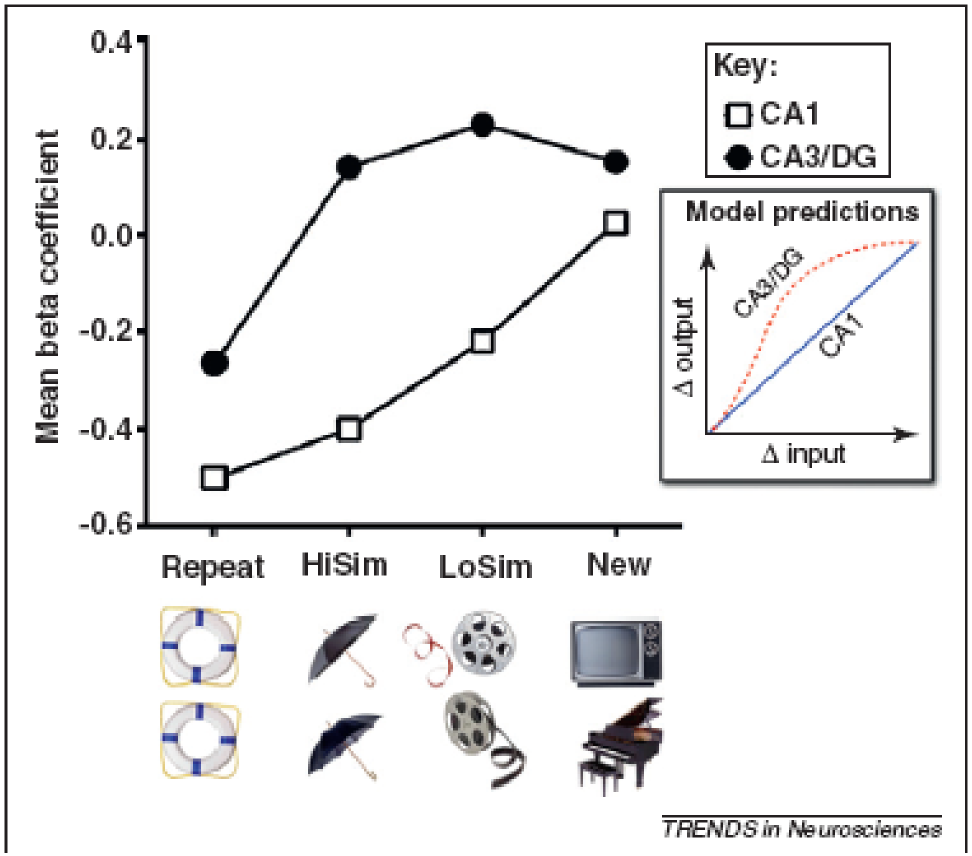
Pattern separation

Review

Special Issue: Hippocampus and Memory

Pattern separation in the hippocampus

Michael A. Yassa[1] and Craig E.L. Stark[2]

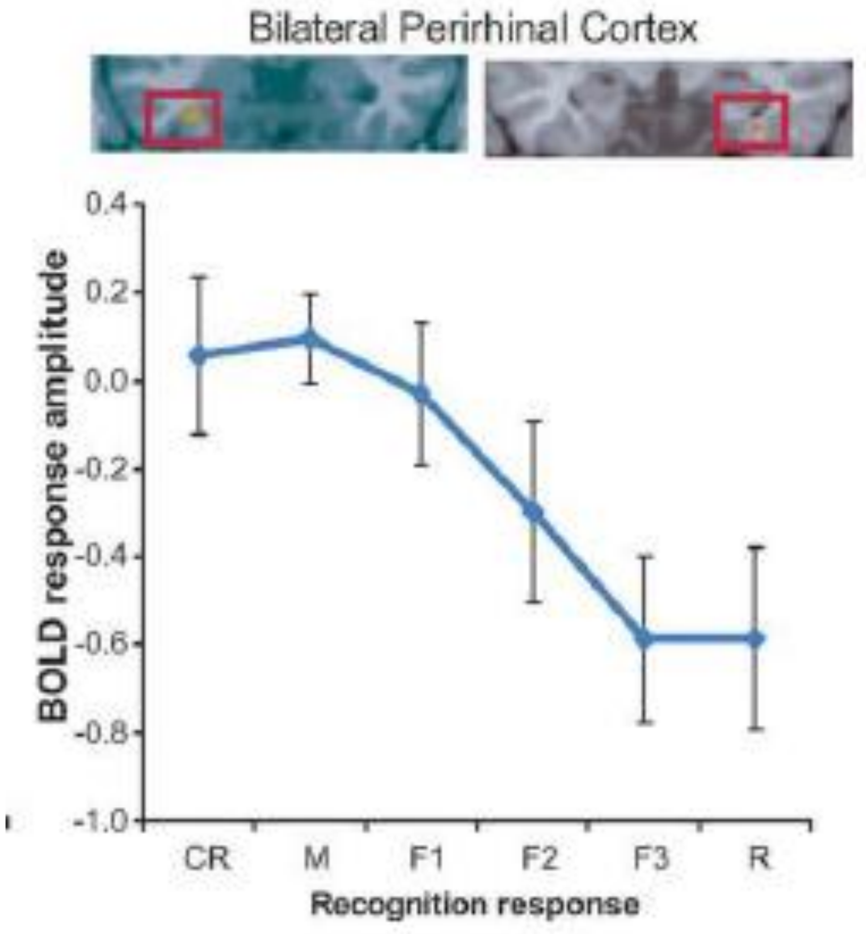


FMRI encoding Decision category "inside" or "outside" for objects

Different bold activations for CA1 & CA3 / DG

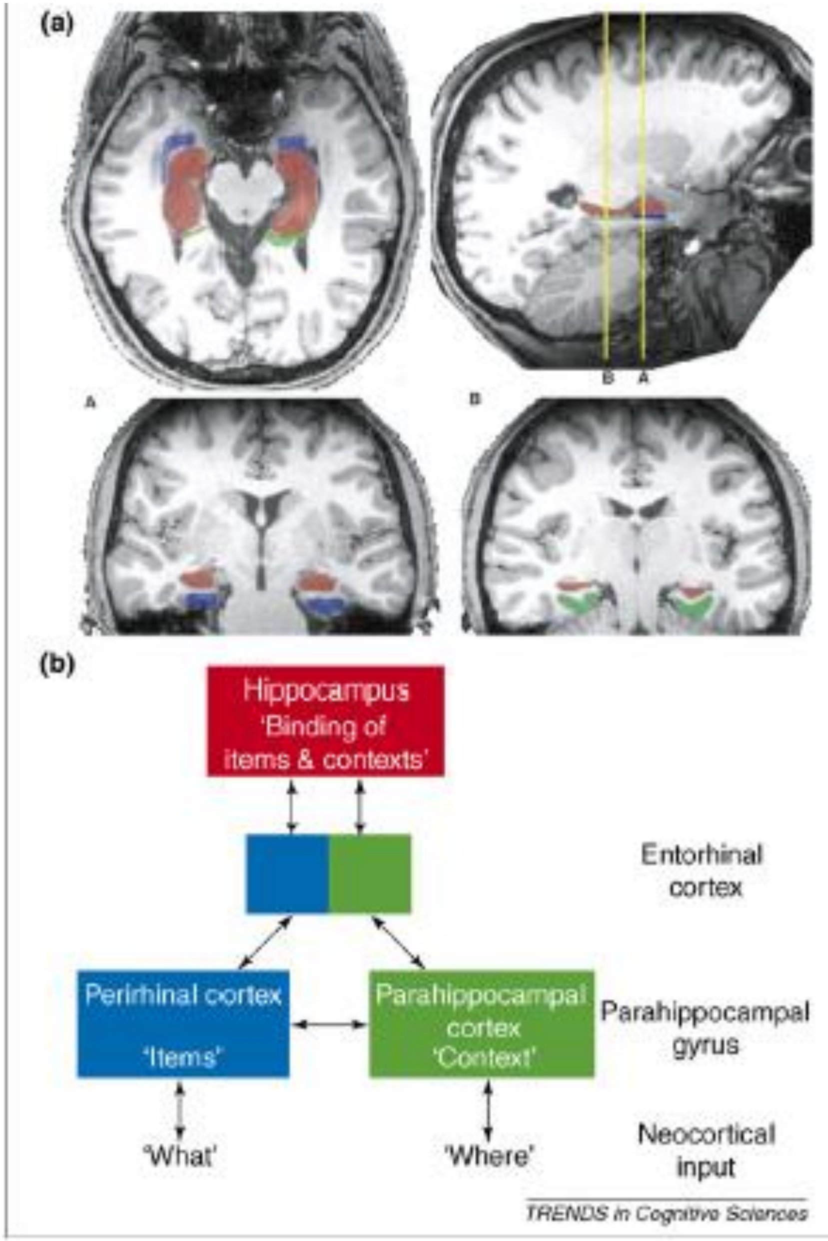
Role of the perirhinal cortex

1. Familiarity detection (Know)



Montaldi, 2006

Role of the perirhinal cortex



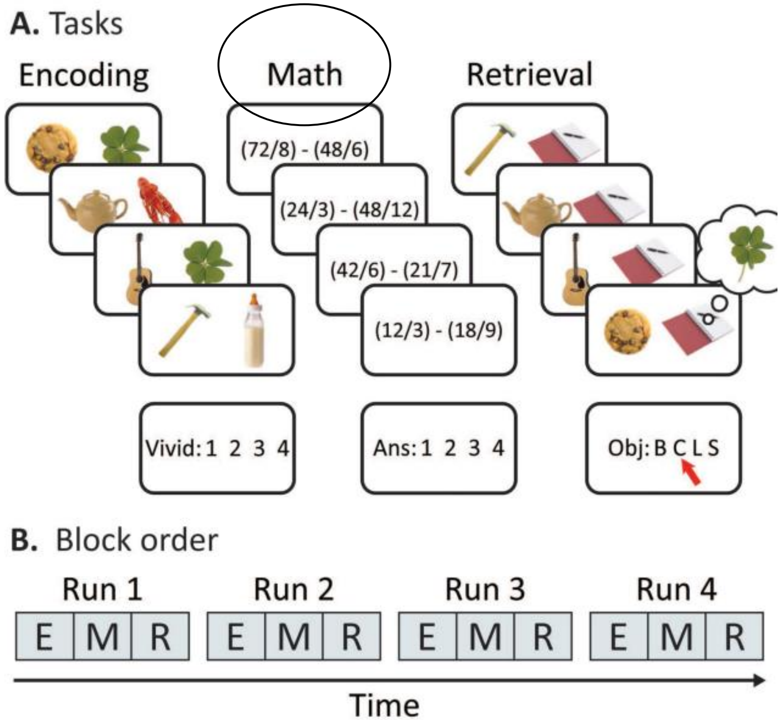
2. Encoding physical traits items

Diana, 2007

Role of the perirhinal cortex

3.Pattern completion

Task delay between encoding & retrieval



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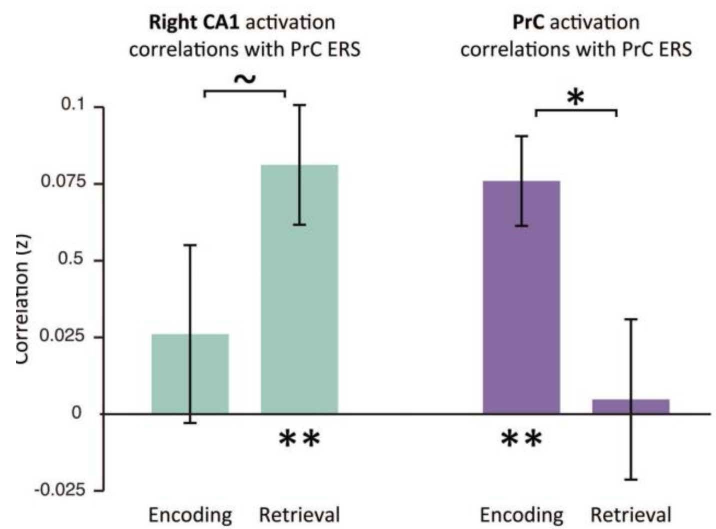


Successful memory for unique episodic events is reflected by neural reinstatement of patterns of activity in the hippocampus, particularly in right CA1 **and in the perirhinal cortex**

Role of the entorhinal cortex

Current Biology Vol 16 No 16
R644

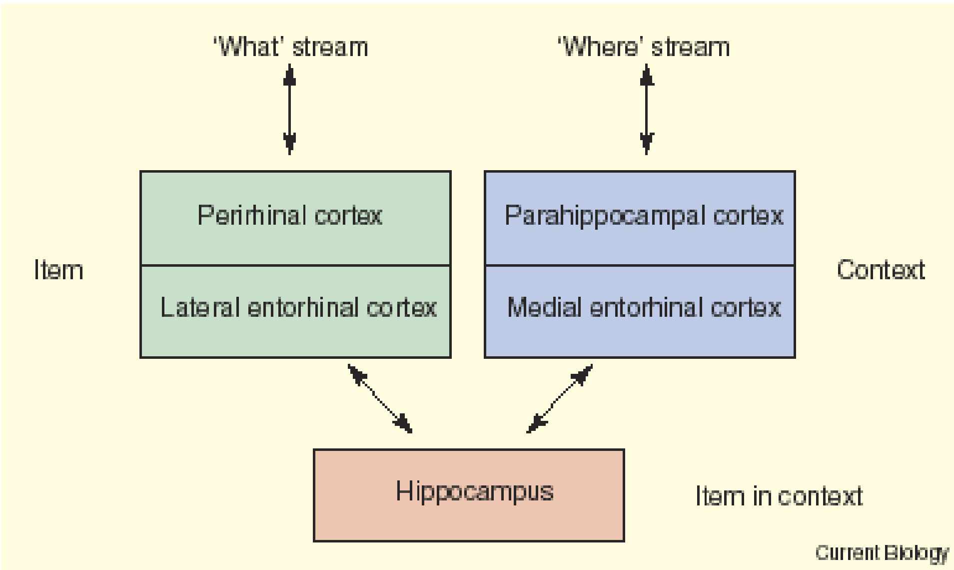
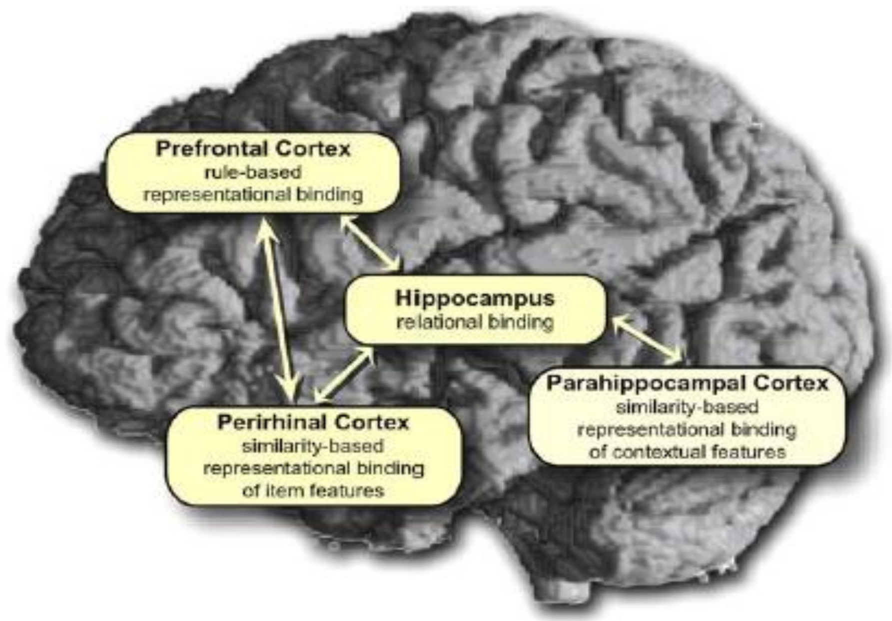


Figure 1. A hypothetical functional organization of the medial temporal lobe memory system.

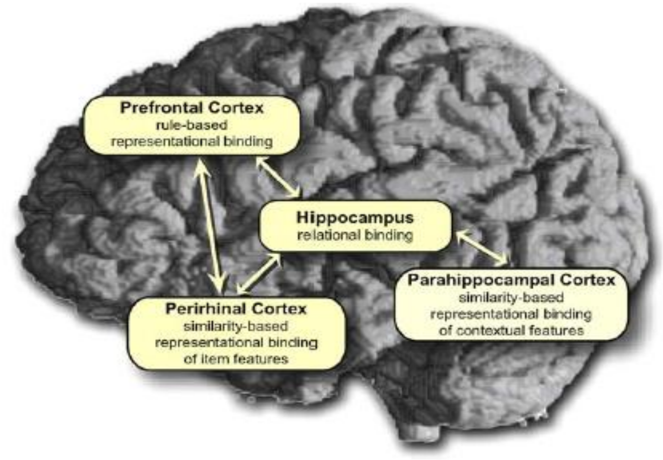


Gateway to the hippocampus

Specific role?

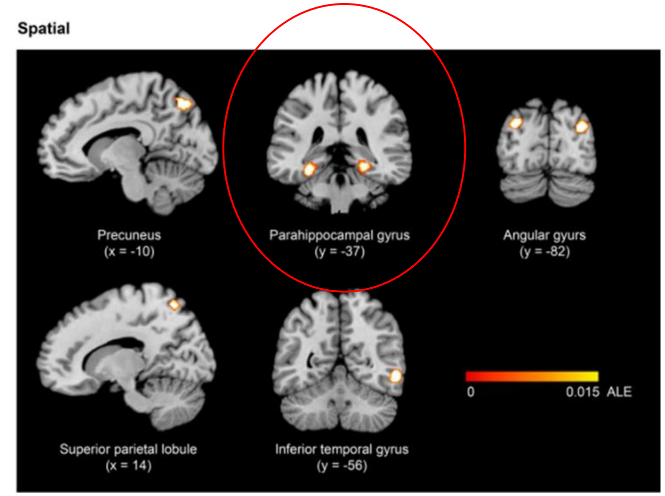
Role of the parahippocampal cortex

1. Contextual encoding



2. Help to spatial context retrieval

Meta-analysis (18 studies)



Cognitive, Afective, & Behavioral Neuroscience-2023-
https://doi.org/10.3758/s13415-023-01140-1

Role of the prefrontal cortex

The role of prefrontal cortex during tests of episodic memory

Scott F. Nolde, Marcia K. Johnson and Carol L. Raye

Recent studies of episodic memory using functional neuroimaging techniques indicate that right prefrontal cortex (PFC) is activated while people remember events. Our review suggests that left PFC is also activated during remembering, depending on the reflective demands of the task. As more, or more complex, reflective processes are required (e.g. when criteria for evaluation have to be established and maintained, when the complexity of the evaluation required increases, and when retrieval of additional information is required beyond that activated by an initial cue), left PFC activity is more likely to occur. Our 'cortical asymmetry of reflective activity' (CARA) hypothesis summarizes available findings and suggests directions for future research.

Role of the prefrontal cortex

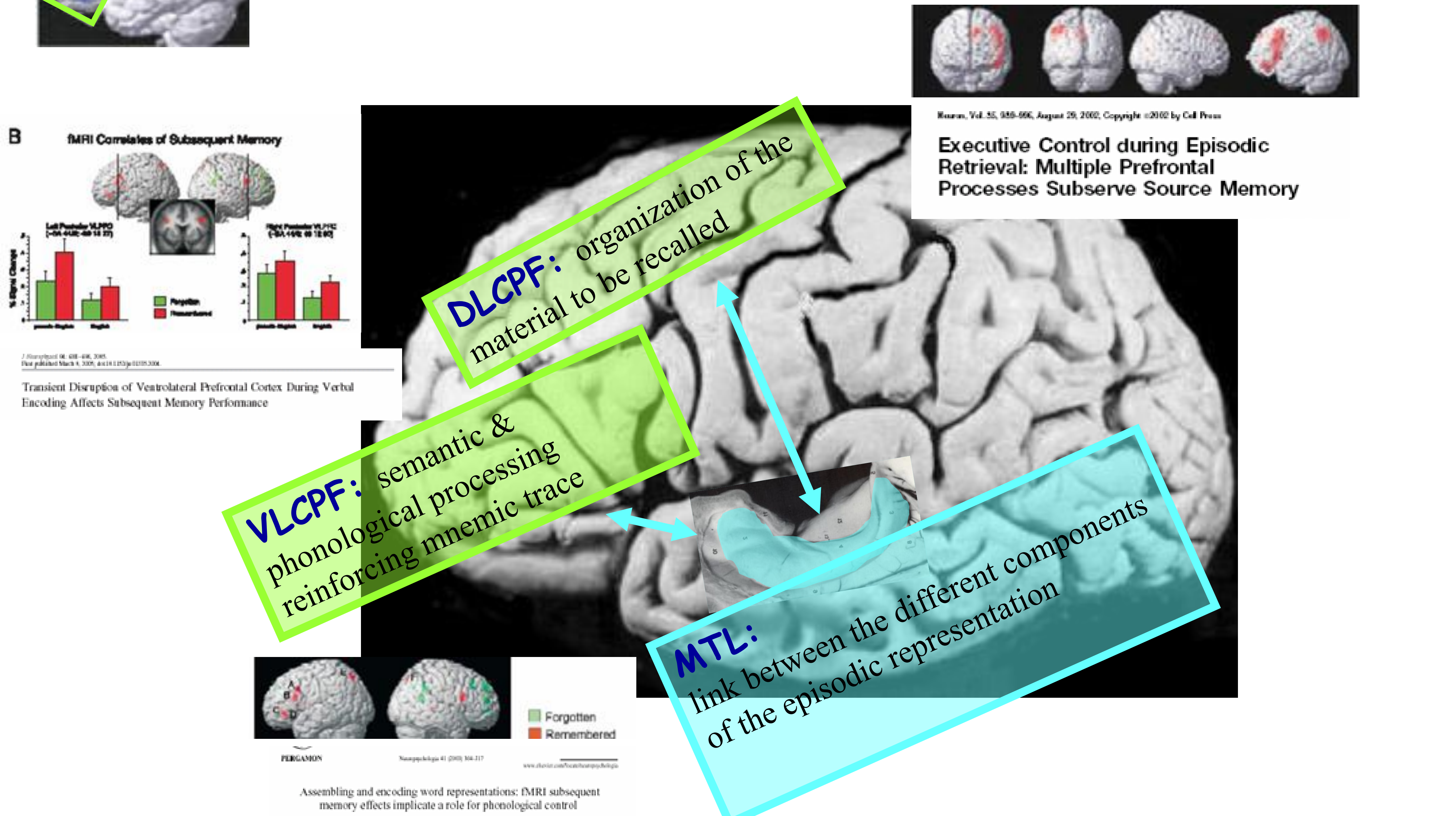
-ventrolateral cortex: maintaining and updating information

- dorsolateral cortex: selection, manipulation and control of information

- lateral frontal pole: selections of processes, objectives to be achieved and how to achieve them

Fletcher and Henson, 2001

Interactions between hippocampus and prefrontal cortex during encoding



Interactions between hippocampus and prefrontal cortex during consolidation

HHS Public Access

Author manuscript

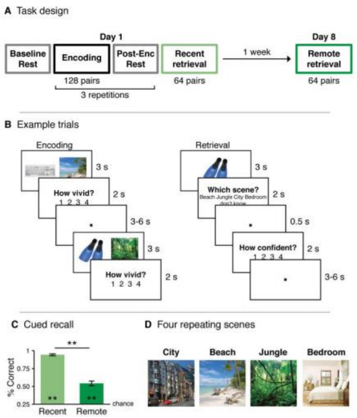
Neuron. Author manuscript; available in PMC 2018 September 27.

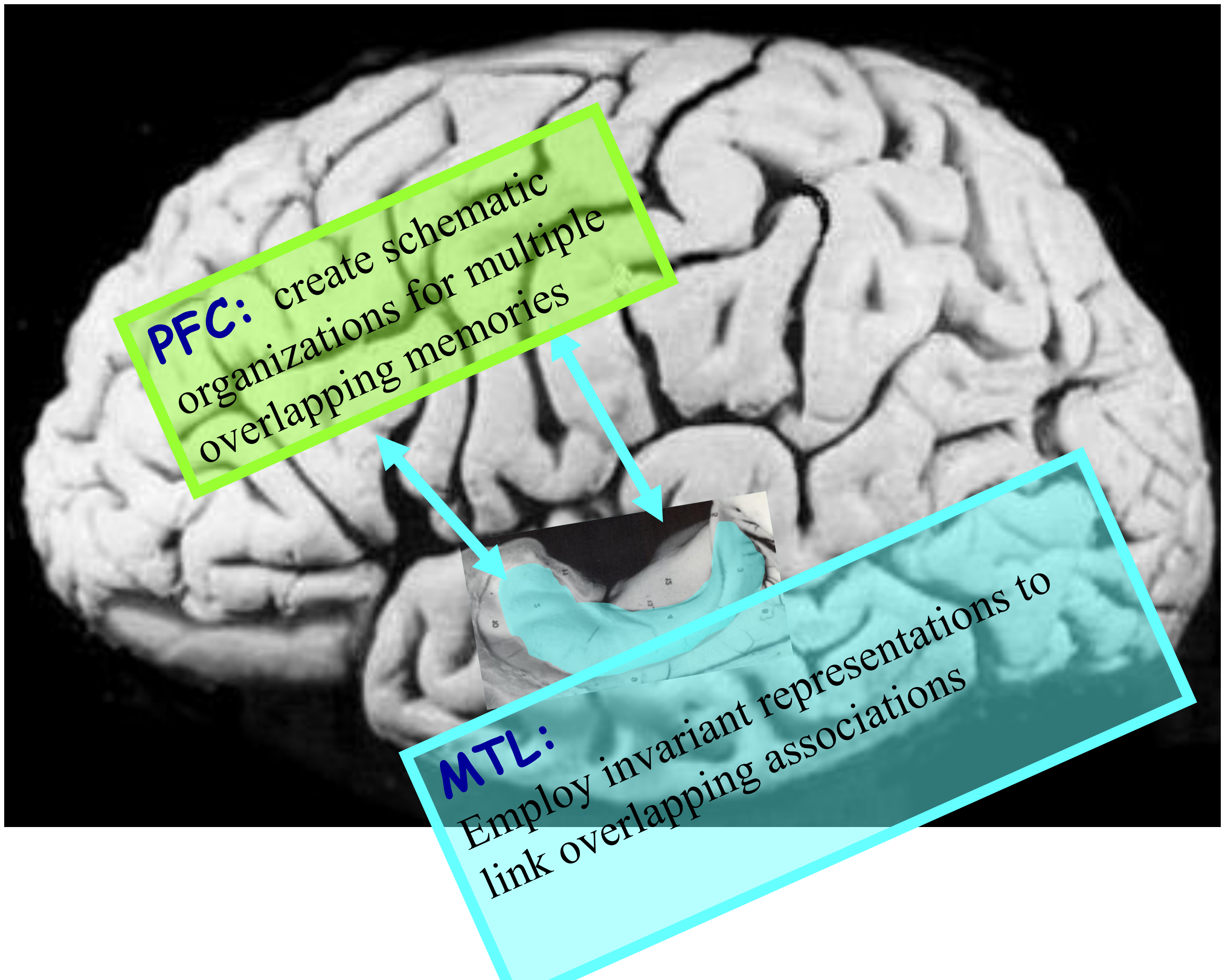
Published in final edited form as:

Neuron. 2017 September 27; 96(1): 228–241.e5. doi:10.1016/j.neuron.2017.09.005.

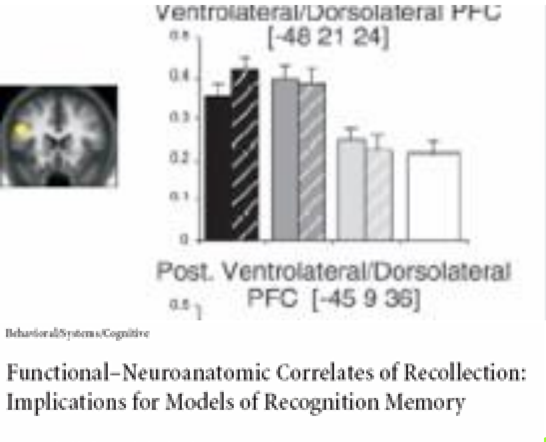
Consolidation promotes the emergence of representational overlap in the hippocampus and medial prefrontal cortex

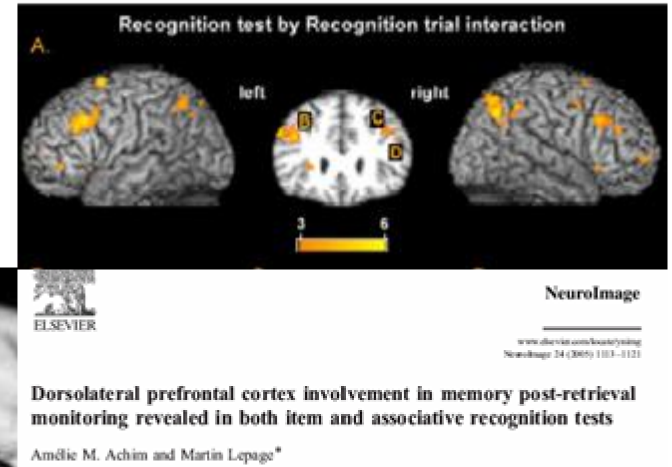
Alexa Tompary[1] and **Lila Davachi**[1,2]





Interactions between hippocampus and prefrontal cortex during recollection





Role of the prefrontal cortex

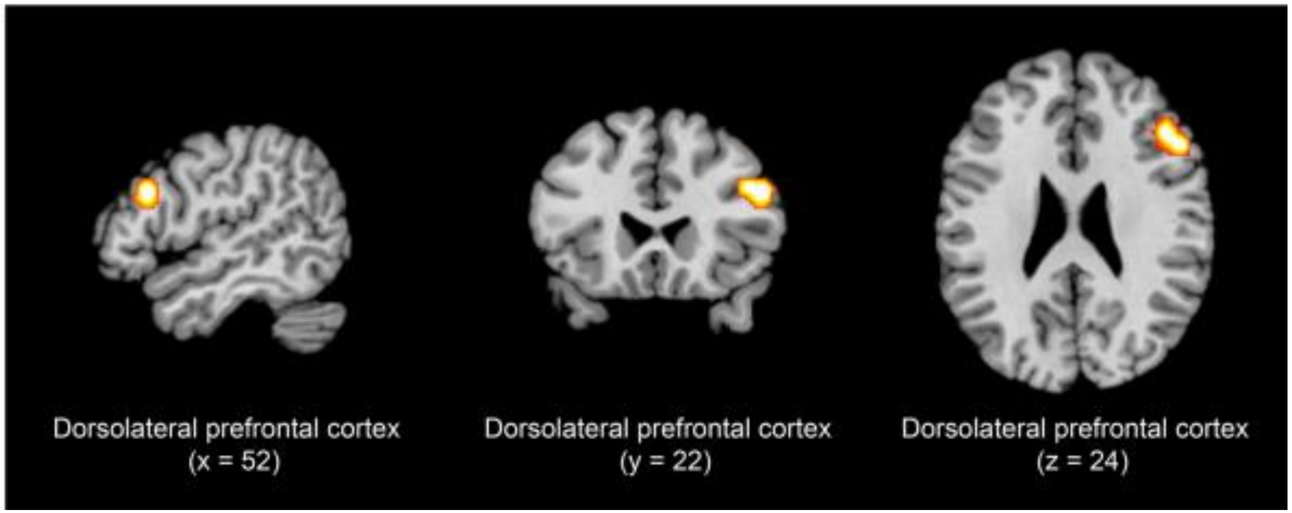
Cognitive, Affective, & Behavioral Neuroscience
https://doi.org/10.3758/s13415-023-01140-1

THEORETICAL REVIEW

Brain representations of space and time in episodic memory: A systematic review and meta-analysis

César Torres-Morales[1] · Selene Cansino[1]

Temporal



18 studies
264 participants

Temporal context retrieval is supported by the dorsolateral prefrontal cortex

Current Biology 23, R764–R773, September 9, 2013 http://dx.doi.org/10.1016/j.cub.2013.05.041

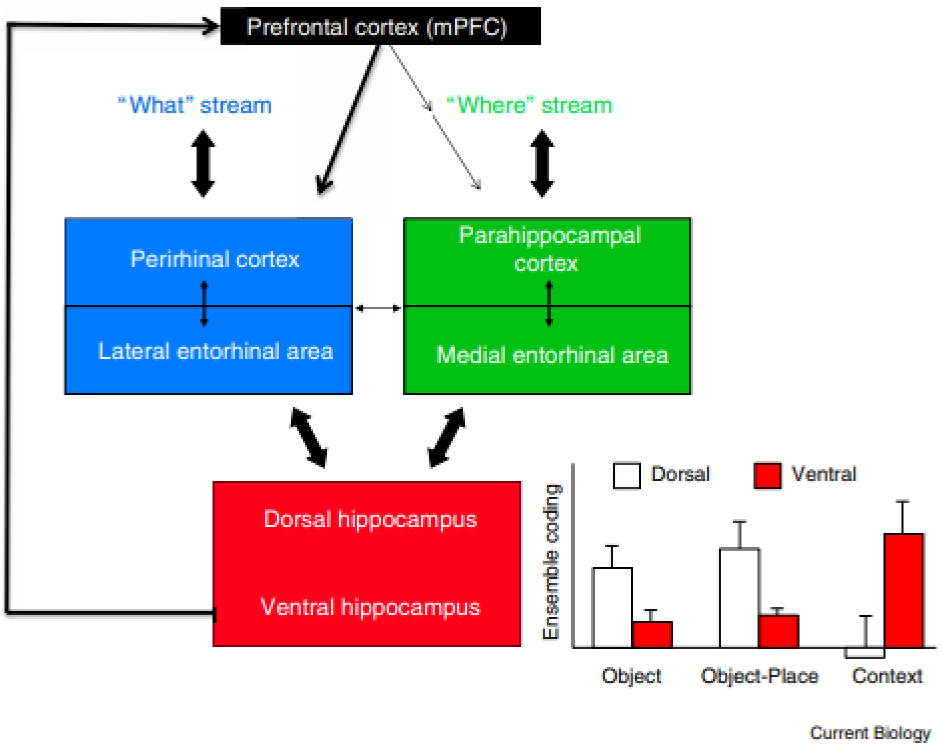
Interplay of Hippocampus and Prefrontal Cortex in Memory

Review

-in summary-

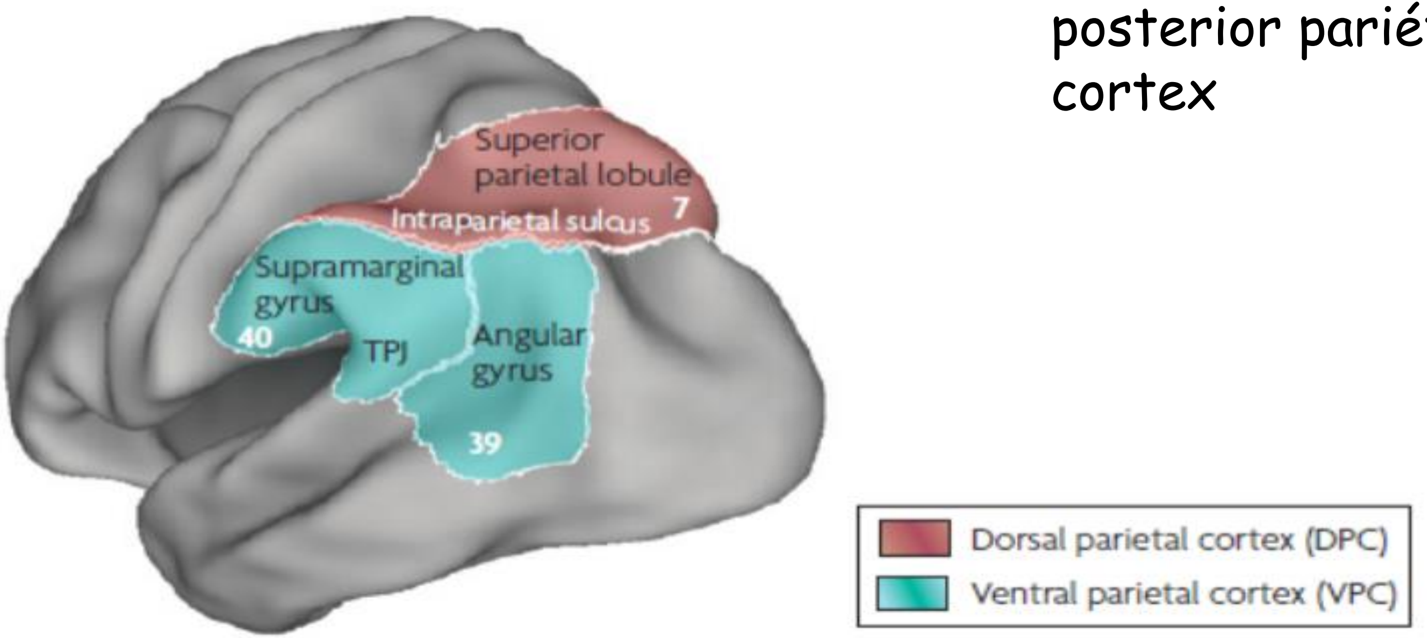
Table 1. Roles of the hippocampus (HPC) and prefrontal cortex (PFC) in successive stages of memory processing.

	Learning	Consolidation	Expression
HPC	Represent links between elements of new associations	Employ invariant representations to link overlapping associations in specific neocortical areas	Retrieve links between directly and indirectly related associations according to PFC-selected schema
PFC	Reconcile new associations with existing ones whose elements overlap	Create schematic organizations for multiple overlapping memories	Select correct schema for current situation



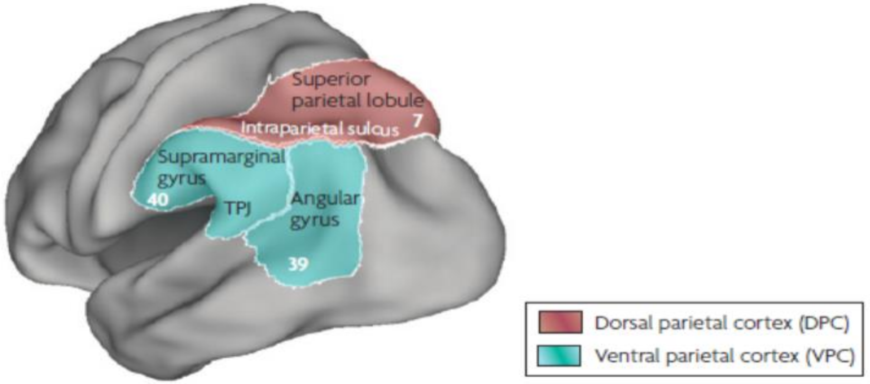
Role of the parietal cortex

Focus on the posterior pariétal cortex



Supplemental Figure 8. The posterior parietal cortex and its division into dorsal (*red*) and ventral (*aqua*) regions. Figure used with permission from Cabeza et al. (2012). Abbreviation: TPJ, temporal parietal junction.

Role of the parietal cortex



Supplemental Figure 8. The posterior parietal cortex and its division into dorsal (*red*) and ventral (*aqua*) regions. Figure used with permission from Cabeza et al. (2012). Abbreviation: TPJ, temporal parietal junction.

Role of the VPC +++

VPC associated with
Effective recollection
Source monitoring
High degree of confidence in the answers

DPC associated with
Familiarity
Low degree of confidence in the answers

Role of the parietal cortex

Available online at www.sciencedirect.com
SCIENCE DIRECT
NeuroImage
NeuroImage 20 (2003) 1934–1943
www.elsevier.com/locate/ynimg

Isolating the retrieval of imagined pictures during episodic memory: activation of the left precuneus and left prefrontal cortex

Brian Nils Lundstrom,[a,b] Karl Magnus Petersson,[a,c,d] Jesper Andersson,[a] Mikael Johansson,[e] Peter Fransson,[a] and Martin Ingvar[a,*]

[a] *Department of Clinical Neuroscience, Karolinska Institutet, Stockholm, Sweden*
[b] *Medical Scientist Training Program, University of Washington, Seattle, Washington, USA*
[c] *Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands*
[d] *F.C. Donders Centre for Cognitive Neuroimaging, Katholieke Universiteit Nijmegen, The Netherlands*
[e] *Department of Psychology, Lund University; Lund, Sweden*

Received 14 April 2003; revised 20 July 2003; accepted 23 July 2003

parietal cortex involvement in establishing contextual links helping to recollection

Role of the parietal cortex

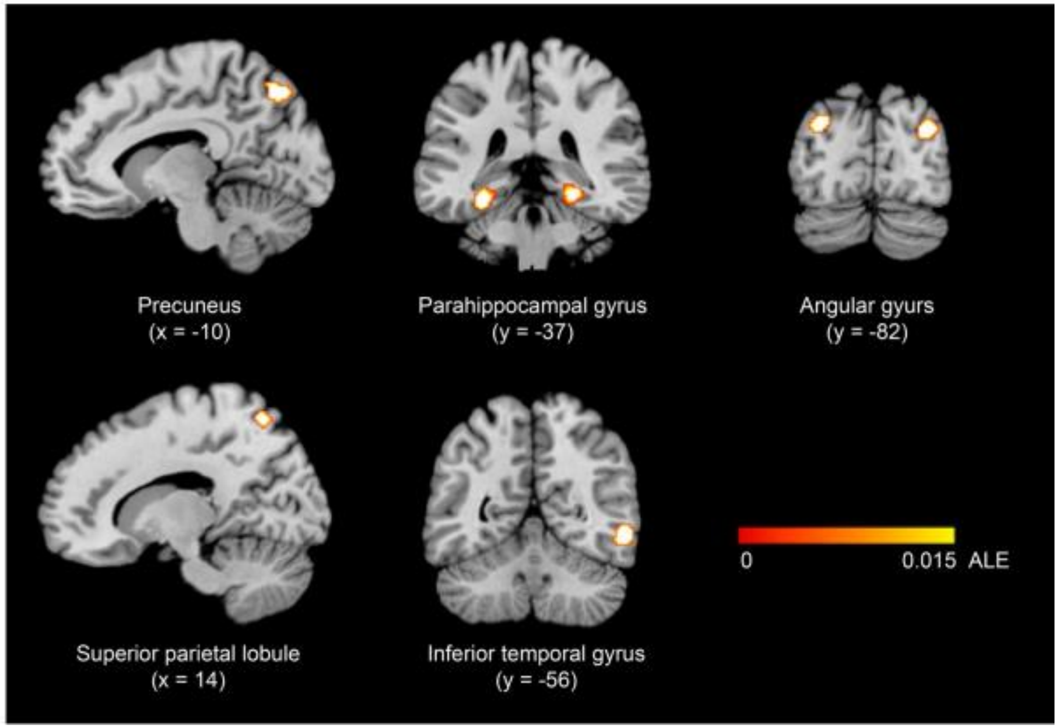
Cognitive, Affective, & Behavioral Neuroscience
https://doi.org/10.3758/s13415-023-01140-1

THEORETICAL REVIEW

Brain representations of space and time in episodic memory: A systematic review and meta-analysis

César Torres-Morales[1] · Selene Cansino[1]

Spatial



18 studies
369 participants

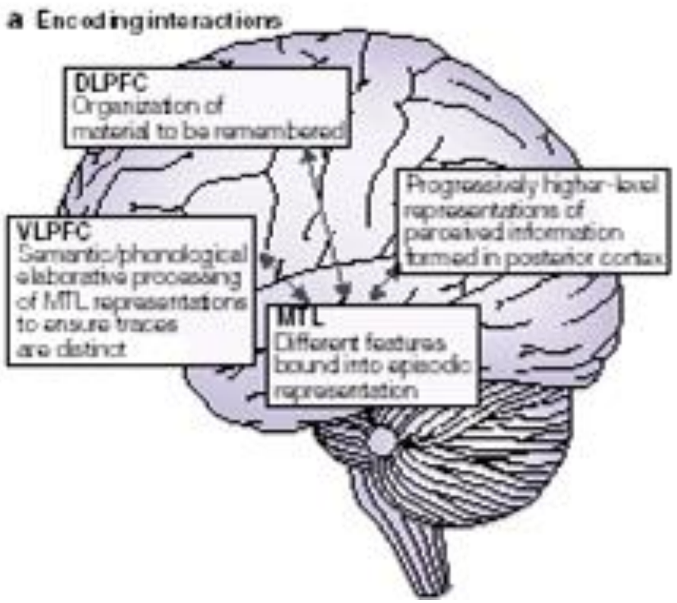
- ✓ the superior parietal lobule employs top-down attention to search internally for relevant cues
- ✓ the angular gyrus engages bottom-up attention guided by spontaneous recovery cues, performs executive functions to recover, integrate and mentally maintain the episodic representation, and conducts binding to integrate the spatial context dispersed across the neocortex
- ✓ the precuneus mentally reestablishes the spatial contextual environment.

Spatial context retrieval is mainly supported by the parietal cortex

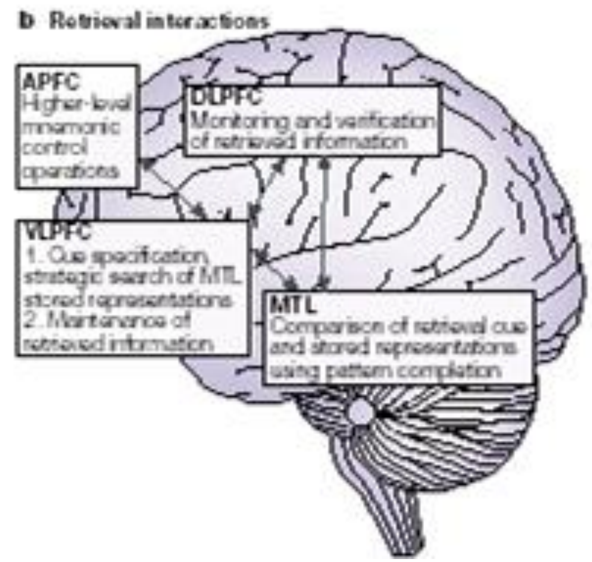
STORAGE

ENCODING-BINDING

RECOLLECTION



Consolidation (LTP/SLEEP)



In summary……………..

Intercurrents processes?

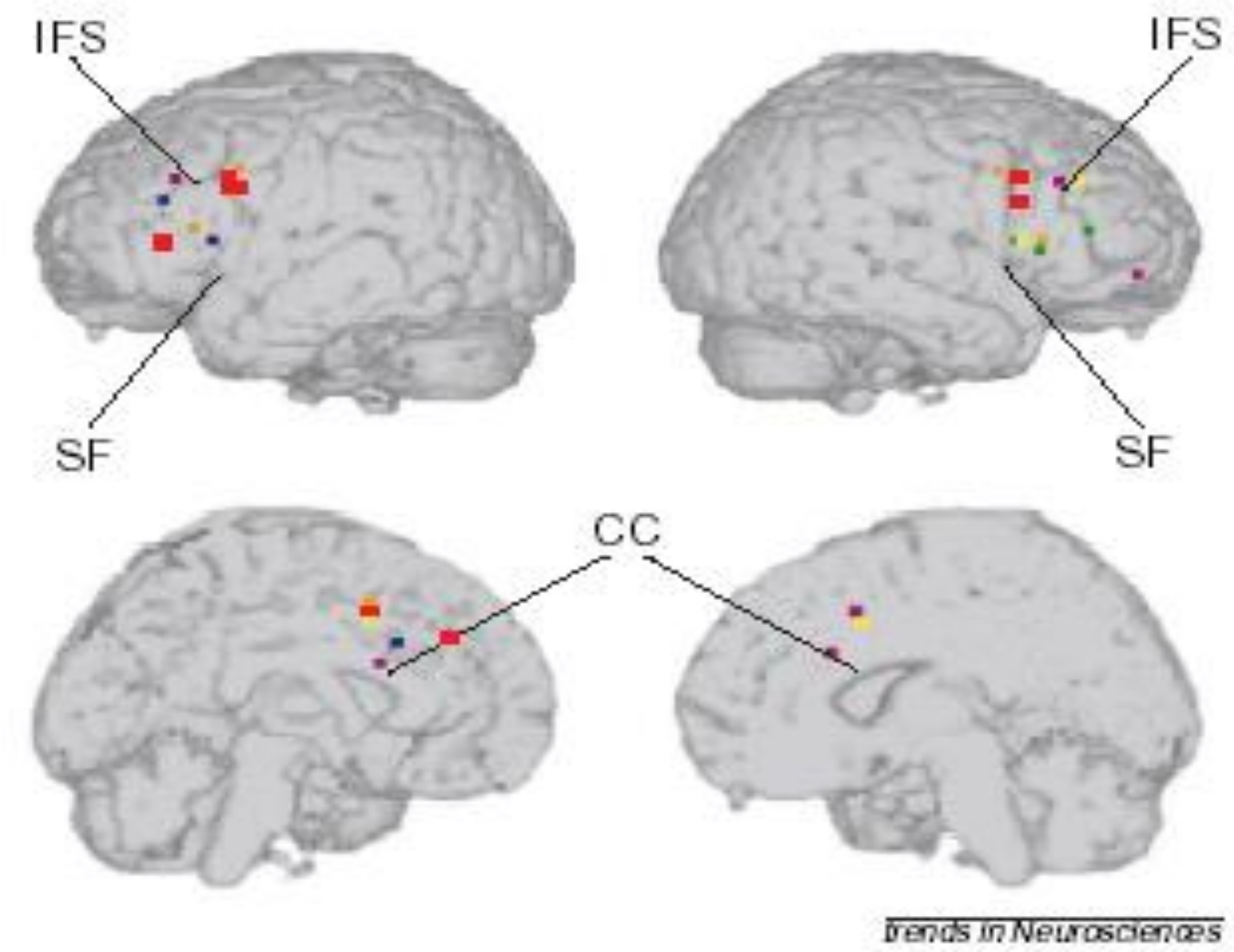
Common regions of the human frontal lobe recruited by diverse cognitive demands

John Duncan and Adrian M. Owen

Though many neuroscientific methods have been brought to bear in the search for functional specializations within prefrontal cortex, little consensus has emerged. To assess the contribution of functional neuroimaging, this article reviews patterns of frontal-lobe activation associated with a broad range of different cognitive demands, including aspects of perception, response selection, executive control, working memory, episodic memory and problem solving. The results show a striking regularity: for many demands, there is a similar recruitment of mid-dorsolateral, mid-ventrolateral and dorsal anterior cingulate cortex. Much of the remainder of frontal cortex, including most of the medial and orbital surfaces, is largely insensitive to these demands. Undoubtedly, these results provide strong evidence for regional specialization of function within prefrontal cortex. This specialization, however, takes an unexpected form: a specific frontal-lobe network that is consistently recruited for solution of diverse cognitive problems.

Trends Neurosci. (2000) 23, 475–483

Intercurrents processes?



- Auditory Discrimination
- Visual Attention
- Self-managed responses
- switching
- Resolving spatial problems
- Semantic verbal fluency

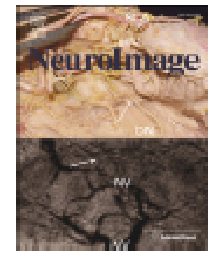
Déactivations?

NeuroImage 84 (2014) 932–938

Contents lists available at ScienceDirect

NeuroImage

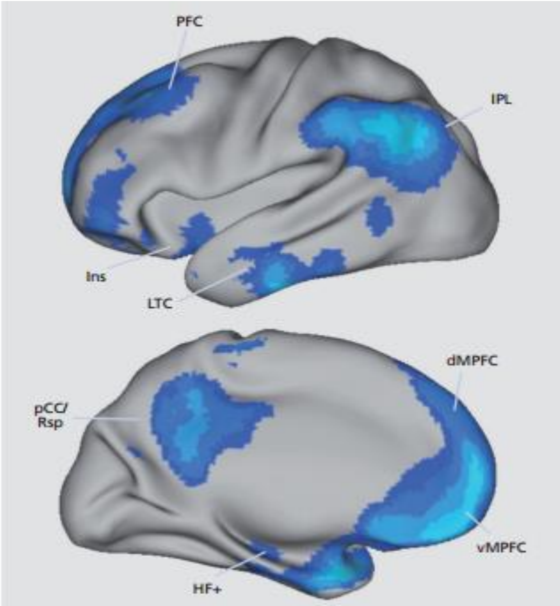
journal homepage: www.elsevier.com/locate/ynimg



Development of deactivation of the default-mode network during episodic memory formation

Xiaoqian J. Chai [a,*,1], Noa Ofen [a,b,1], John D.E. Gabrieli [a,c], Susan Whitfield-Gabrieli [a]

[a] Department of Brain and Cognitive Sciences and McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA, USA
[b] Institute of Gerontology and Department of Pediatrics, Wayne State University, Detroit, MI, USA
[c] Institute for Medical Engineering and Science, MIT, USA



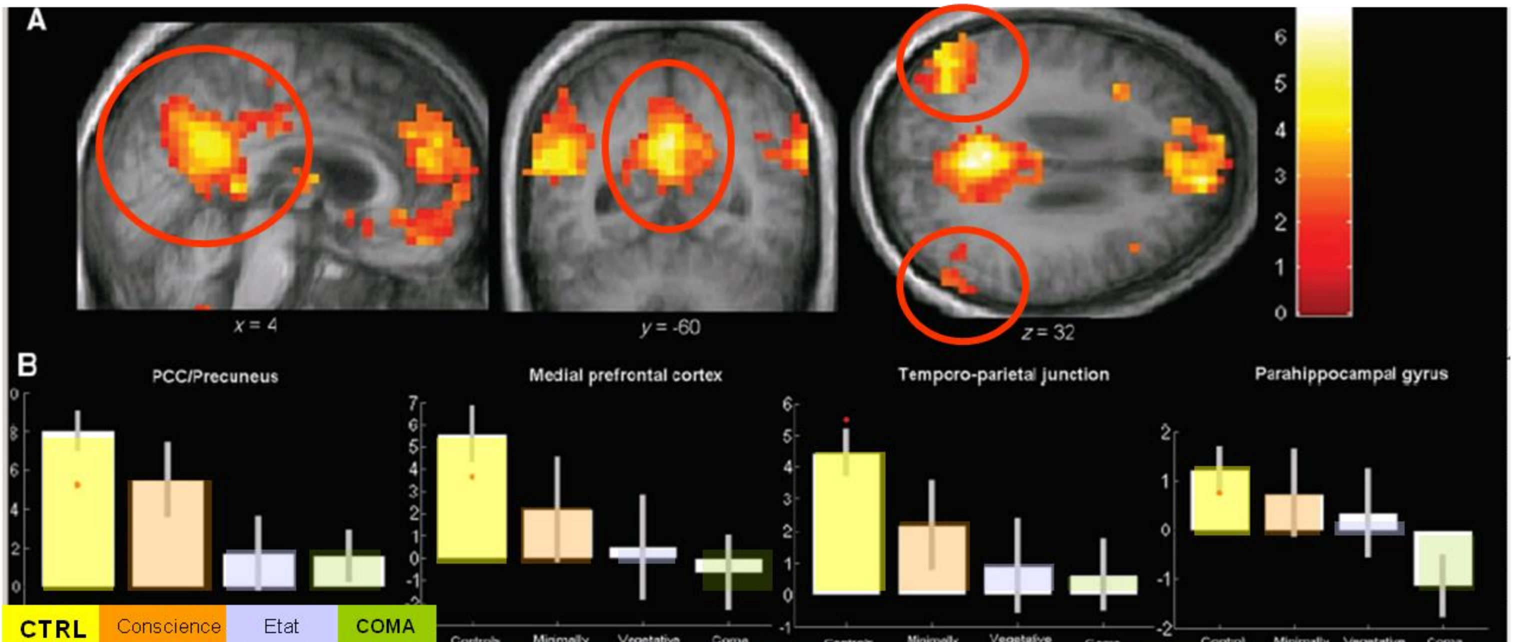
Default mode network

= network of regions activated by "default" in passive condition

doi:10.1093/brain/awp313 Brain 2010: 133; 161–171 | 161
BRAIN A JOURNAL OF NEUROLOGY

Default network connectivity reflects the level of consciousness in non-communicative brain-damaged patients

Default mode network: network underlying consciousness?



CTRL | Conscience minimale | Etat végétatif | COMA

CTRL | Conscience minimale | Etat végétatif | COMA

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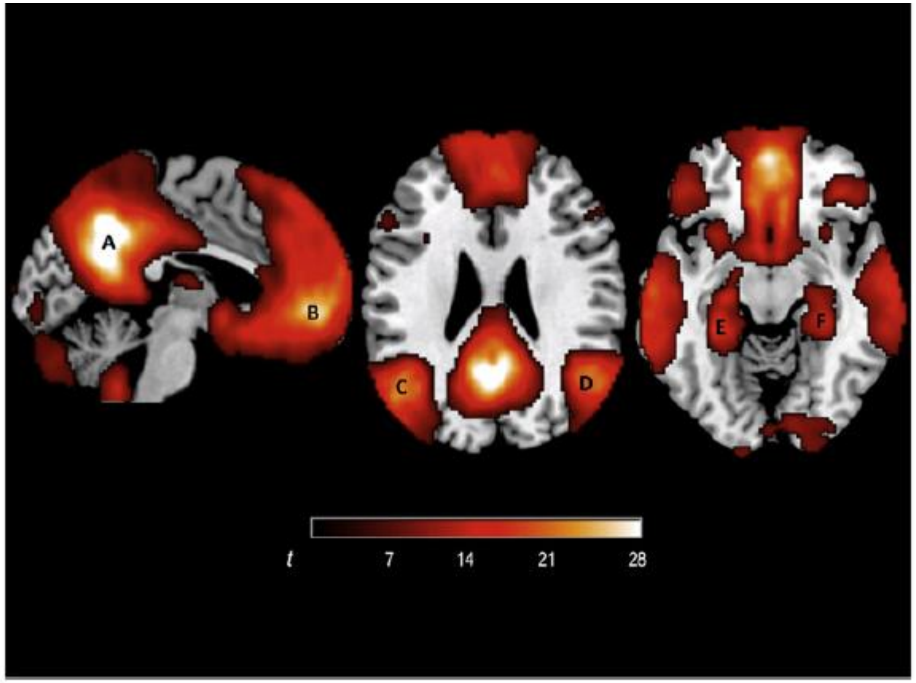


Fig. 1. DMN in 82 participants of 8–24 years of age, defined from resting-state connectivity data in an independent sample of participants. A = PCC; B = MPFC; C = LLP; D = RLP; E = left hippocampal region; and F = right hippocampal region.

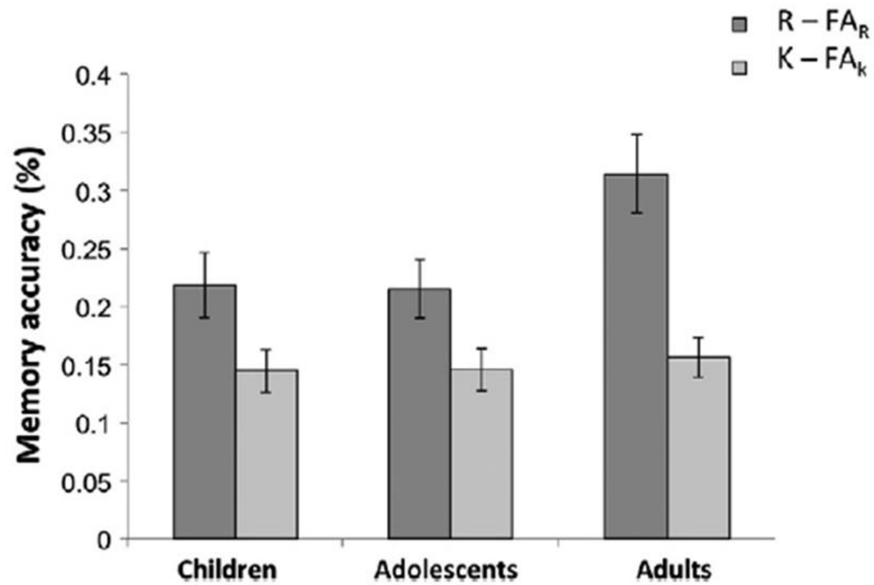


Fig. 2. Recognition memory accuracy. Accuracy for "Remembered" (R) and "Know" (K) trial types was calculated by subtracting the corresponding false alarm rate from the hit rate for R or K trial types (R accuracy: $R - FA_R$; K accuracy: $K / (1 - R) - FA_K$, adjusted for being mathematically constrained by R responses).

3 groups:

- ✓ children
- ✓ teenagers
- ✓ young adults

→ Memory performances improve with age

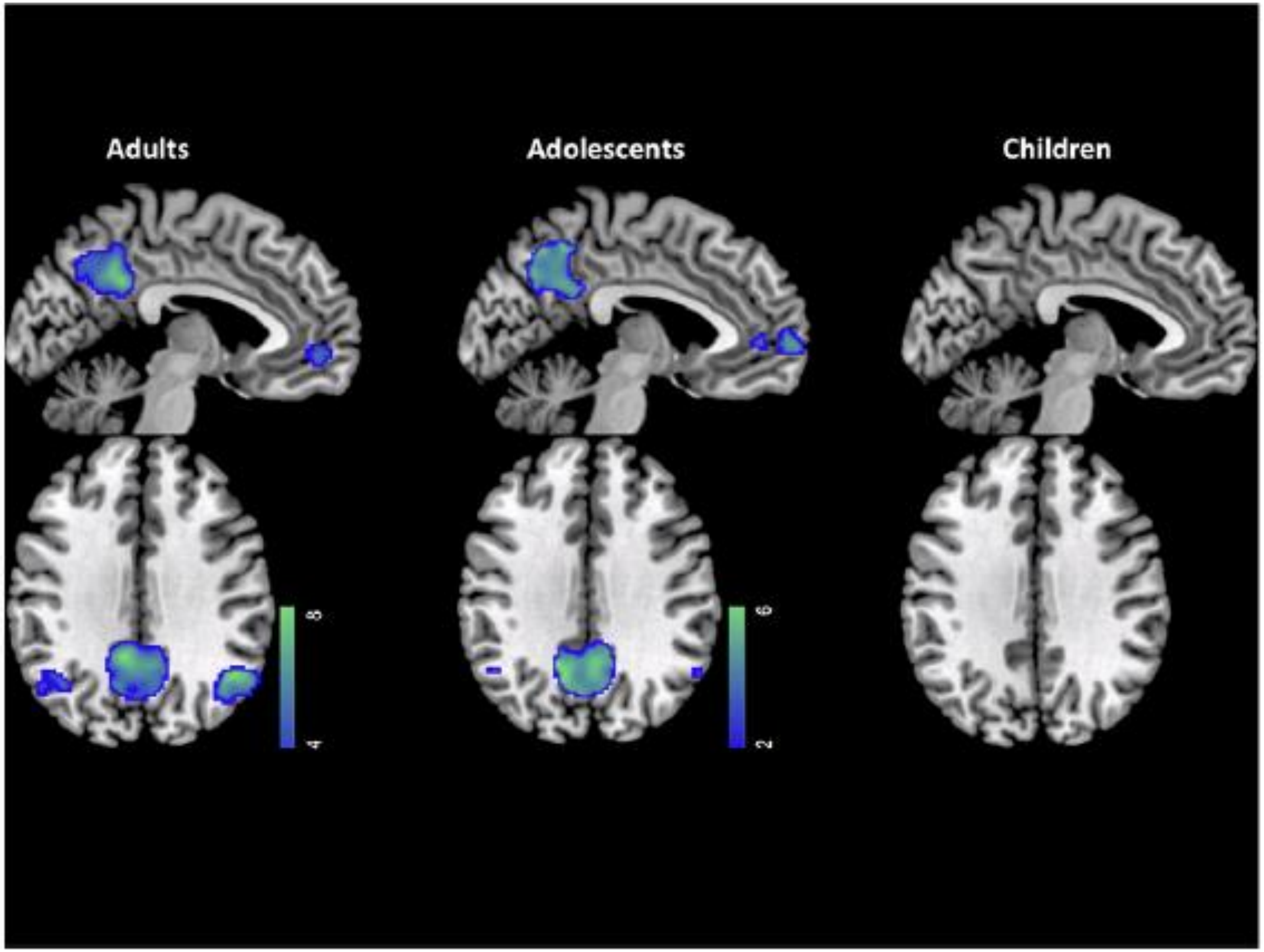


Fig. 4. Regions within DMN ROIs that showed deactivations for remembered trials compared to forgotten trials for each age group.

Hypothesis: Deactivation of DMN allows to refocus attentional resources on success encoding

In adults, good correlation between DMN deactivation and correctly recalled scenes

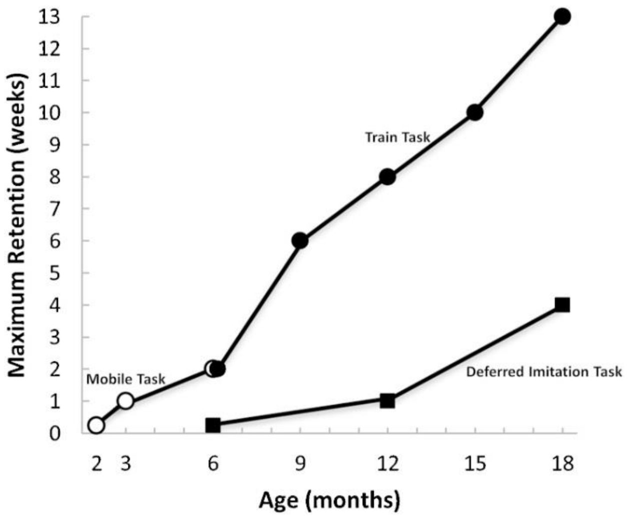
Outstanding issues

- Time window of age?
- Ageing
- Sub-cortical structures?

Time window?

Classically: 9 months

- ✓ Linked to hippocampal circuitry maturation

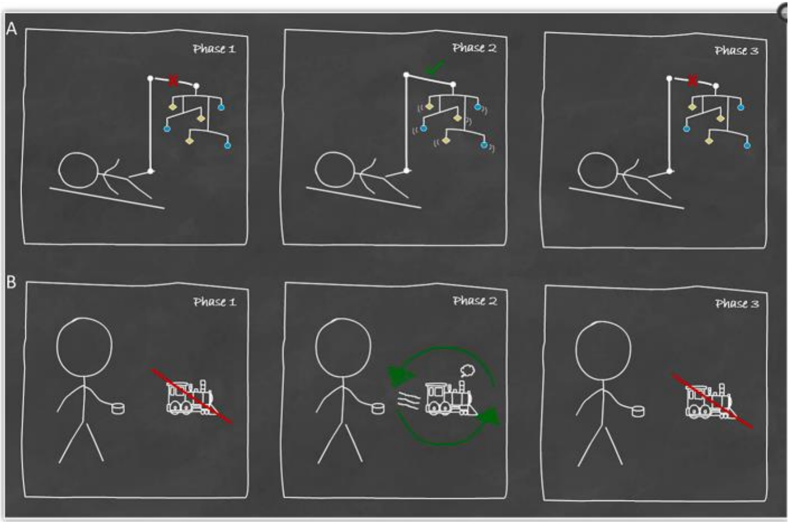


- ✓ Difficulty +++ of adapting paradigms to young children

Developmental Cognitive Neuroscience
ELSEVIER

Learning to remember: The early ontogeny of episodic memory ☆

Sinéad L. Mullally and Eleanor A. Maguire



The operant conditioning paradigms. (A) The mobile conjugate reinforcement paradigm (Rovee-Collier et al., 1980; suitable for use in 2–7 month old infants). The left panel illustrates phase 1: the baseline condition. Here the ankle ribbon is not connected to the mobile so that when the infant kicks they do not move the mobile. The middle panel illustrates phase 2, the acquisition phase, where the ankle ribbon and the mobile are connected so that when the infant kicks, the mobile conjugately moves. The right panel illustrates phase 3, the retention phase. Here, as in phase 1,

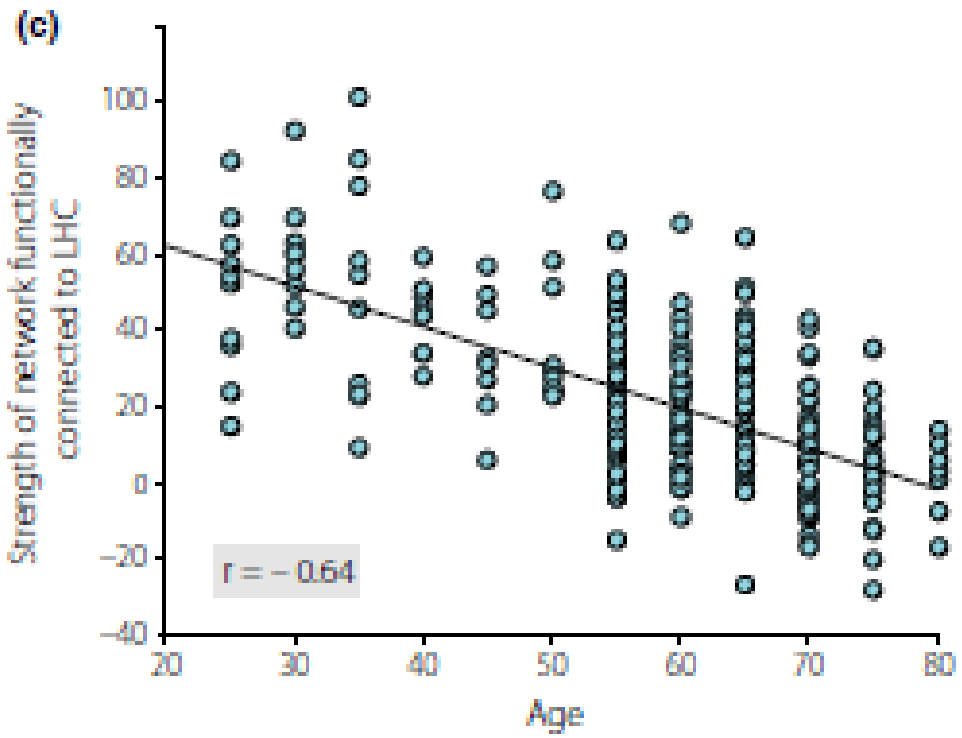
Ageing

Review
Journal of INTERNAL MEDICINE
doi: 10.1111/joim.12533

Functional brain imaging of episodic memory decline in ageing

L. Nyberg

From the Departments of Radiation Sciences and Integrative Medical Biology, Umeå University and Umeå Center for Functional Brain Imaging (UFBI), Umeå University, Umeå, Sweden



the degree of connectivity decreased as a function of age

Link between age-related episodic memory decline and the hippocampus during active mnemonic processing,

Alterations in hippocampus–neocortex connectivity occurring with age contribute to impaired episodic memory.

Ageing

Cerebral Cortex Advance Access published July 30, 2013
Cerebral Cortex
doi:10.1093/cercor/bht188

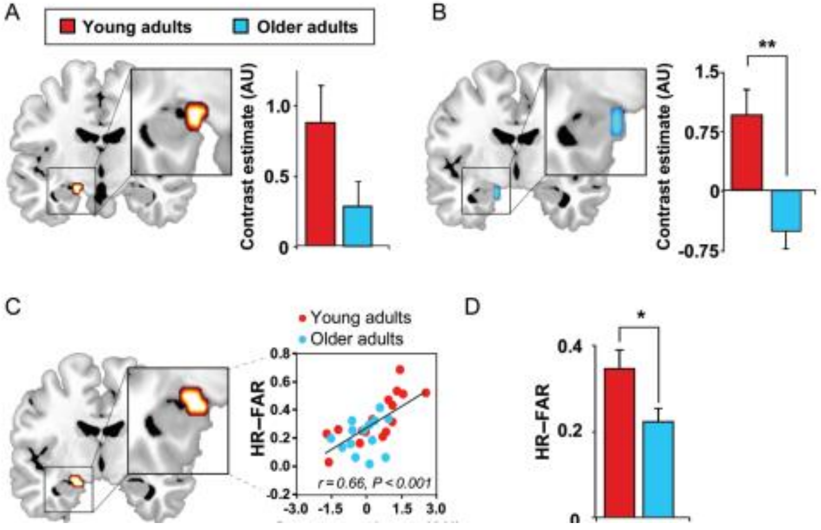
Impaired Prefrontal Sleep Spindle Regulation of Hippocampal-Dependent Learning in Older Adults

Bryce A. Mander[1], Vikram Rao[1], Brandon Lu[5], Jared M. Saletin[1], Sonia Ancoli-Israel[6], William J. Jagust[2,4] and Matthew P. Walker[1,2,3]

Recently acquired information is strengthened and consolidated during sleep.

For hippocampus-dependent memory, this process is assumed to occur mainly during slow wave sleep.

Changes in sleep patterns in older adults can contribute to the disruption of the consolidation process during sleep and thus lead to cognitive impairment.



Subcortical structures

Hippocampal efferents to subcortical structures depend completely or predominantly on the fornix

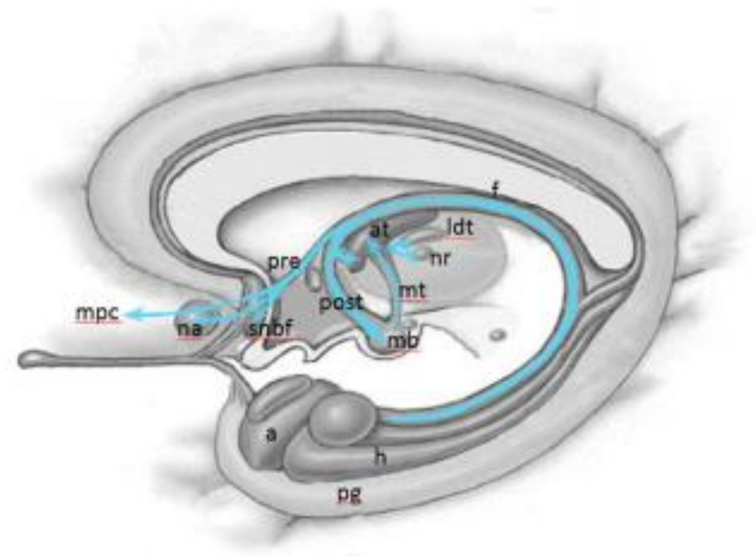


Figure 3 Hippocampal efferents coursing through the fornix (f). Targets include the mammillary bodies (mb) through the postcommissural tracts (post), the septal nuclei and basal forebrain (snbf), nucleus accumbens (na), and medial prefrontal cortex (mpc) through the precommissural tracts (pre) and direct projections to the anterior thalamic nuclei (at), lateral dorsal thalamic nucleus (ldt), and nucleus reuniens (nr). a, Amygdala; h, hippocampus; mt, mammillothalamic tracts; pg, parahippocampal gyrus. (Color version of figure is available online.)

Interactions with subcortical structures

Neuron
Perspective

The Cognitive Architecture of Spatial Navigation: Hippocampal and Striatal Contributions

Fabian Chersi[1,*] and Neil Burgess[1,*]
[1]Institute of Cognitive Neuroscience & Institute of Neurology, University College London, 17 Queen Square, London, WC1N 3AZ, UK
*Correspondence: f.chersi@ucl.ac.uk (F.C.), n.burgess@ucl.ac.uk (N.B.)
http://dx.doi.org/10.1016/j.neuron.2015.09.021

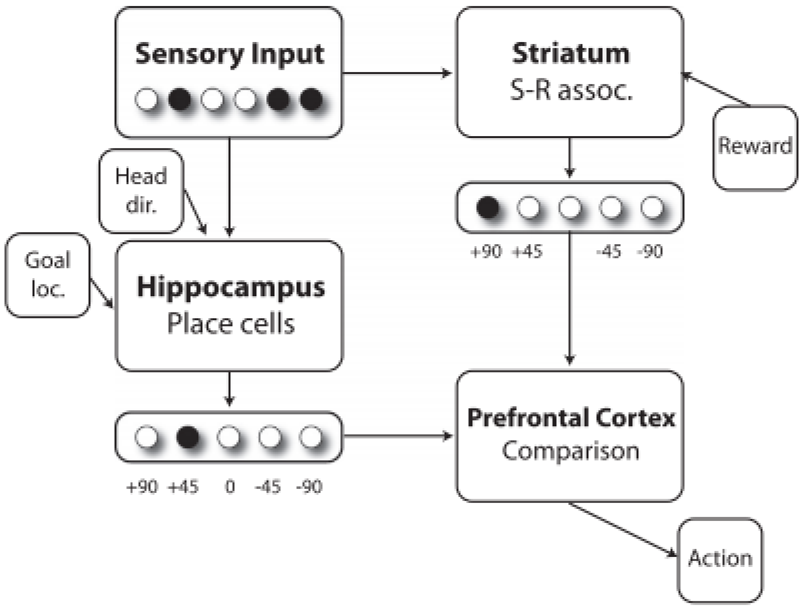
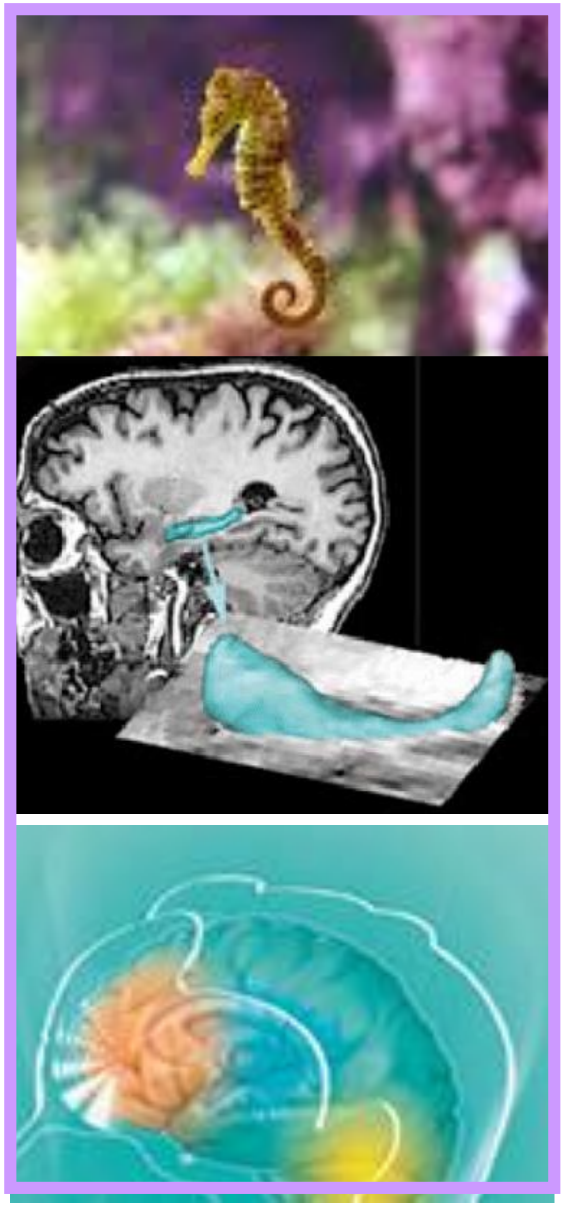


Figure 4. A Minimal Cognitive Architecture for Spatial Navigation
Schematic representation of a minimal circuit for two of the main mechanisms that guide spatial navigation: the hippocampus, providing the "cognitive map" with information about locations for goal-directed decision making, and the striatum that learns stimulus-response associations. Note that the same sensory input is used in different ways by the two systems. Basic sensory inputs reach both the striatum and the hippocampus: the former learns only when a reward signal is provided (there is no flexible goal); the latter receives additional information about the head direction and a learning signal when an important location (e.g., a goal) has been reached. Each area outputs the estimated optimal action (i.e., the turning angle), which is then compared and chosen by the prefrontal cortex.

Box 2. Future Directions

- How do the hippocampal and striatal systems influence each other during learning, and do both contribute to the calculation of a single prediction error?
- Does efficient navigation in complex environments require combinations of memory-based and reinforcement-based representations?
- What is the nature of the neural representation in the striatum and parietal cortex that support landmark-related and response learning?
- What is the exact role of "forward sweeps" of place cell activity and how do they contribute to planning?
- Are the representations of places and distances distorted by the frequency with which a route is taken, and could this problem be solved by the intrinsic regularity of grid cells?
- How is fast incidental learning implemented at a neuronal level? What determines which information is stored and which is discarded, and what role does temporal structure play?



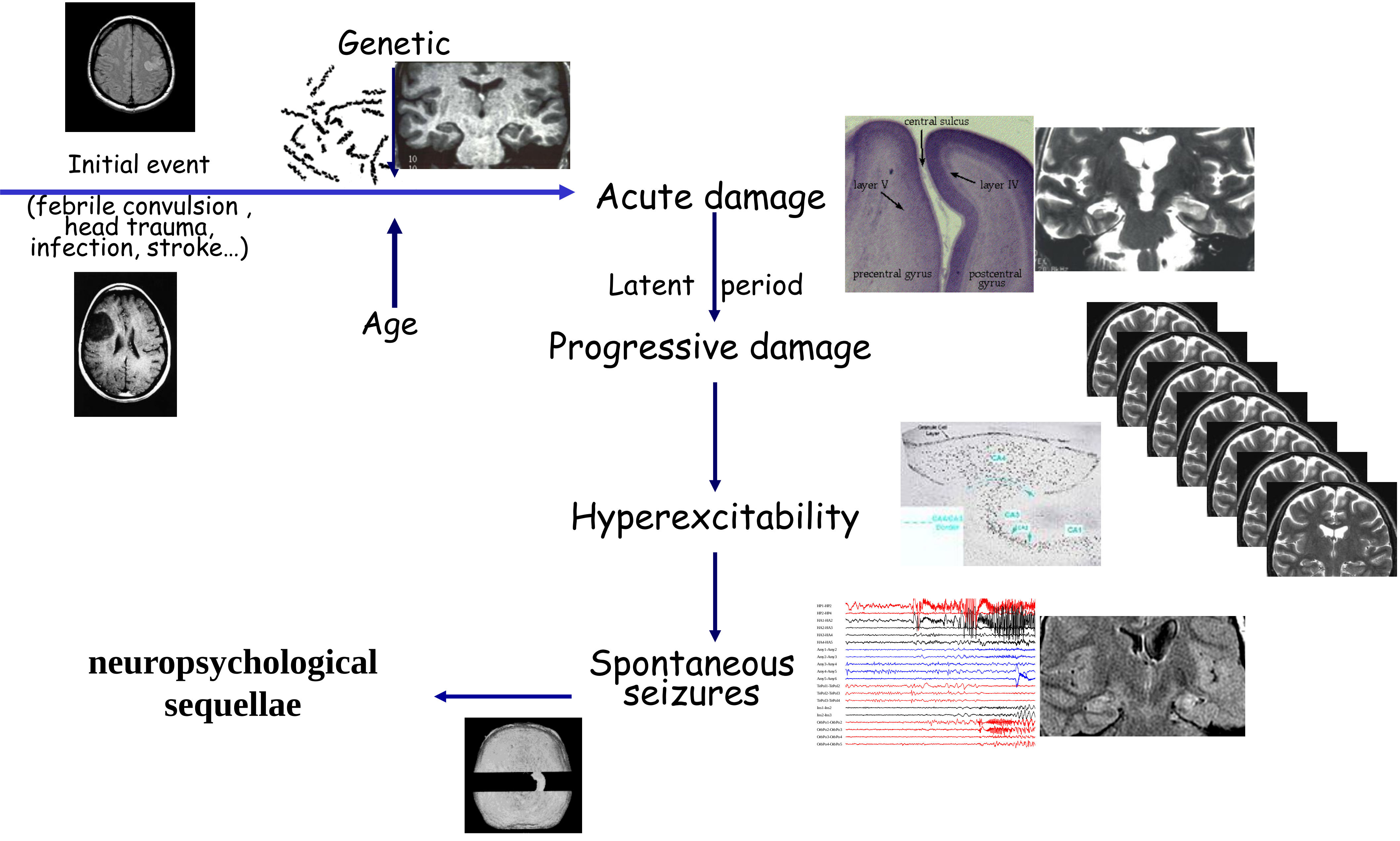
Definitions

Traditional approach

Neuroimaging

Insights from pathology

Human model: MTLE with hippocampal sclerosis



Predicting potential postoperative memory deficits

Indépendant evaluation of hippocampal function

Arch Clin Neuropsychol. 1995 Oct;10(5):413-32

Hippocampal adequacy versus functional reserve: predicting memory functions following temporal lobectomy

Chelune GJ

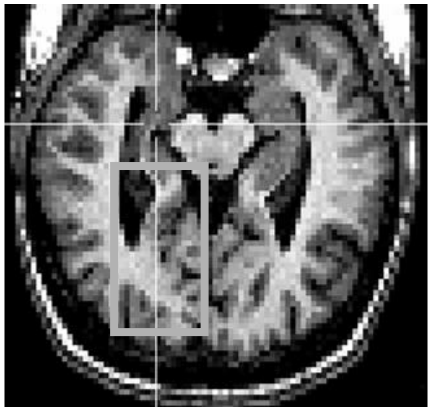
1) Hippocampal adequacy:

less is good

2) Functional reserve:

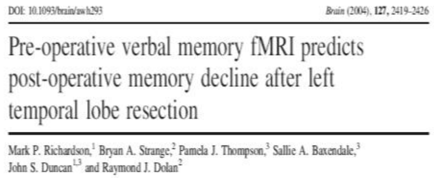
brain plasticity

Hippocampal adequacy



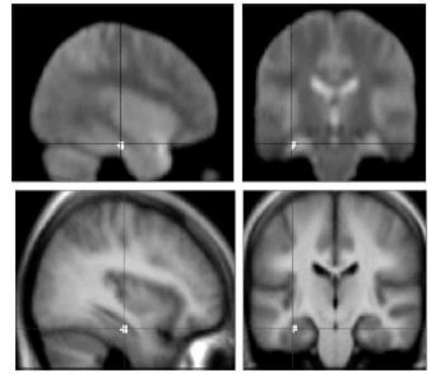
Activation ipsilateral to the seizure focus = bad Prognosis

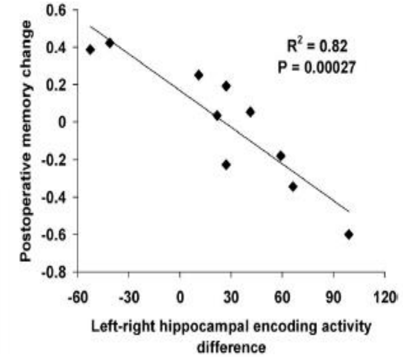
Reduced activation ipsilateral to the seizure focus = good prognosis

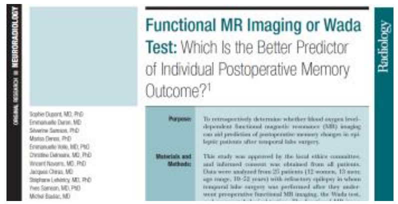

DOI: 10.1093/brain/awh293 — Brain (2004), 127, 2419–2426

Pre-operative verbal memory fMRI predicts post-operative memory decline after left temporal lobe resection

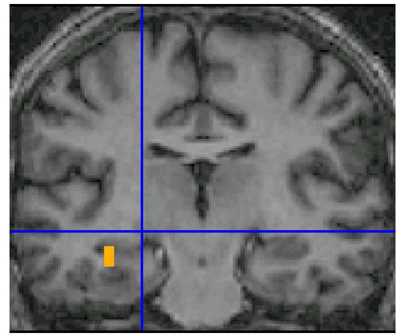
Mark P. Richardson,[1] Bryan A. Strange,[2] Pamela J. Thompson,[3] Sallie A. Baxendale,[3] John S. Duncan[1,3] and Raymond J. Dolan[2]

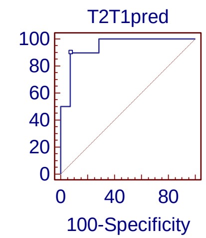





Functional MR Imaging or Wada Test: Which Is the Better Predictor of Individual Postoperative Memory Outcome?[1]

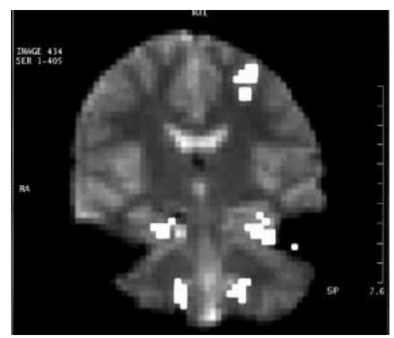
Radiology

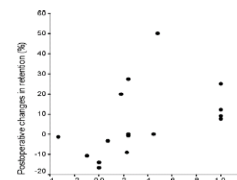




T2T1 verbal = 7.62 + 7.25*LDR – 5.65*SIDE – 0.58*T1verbal

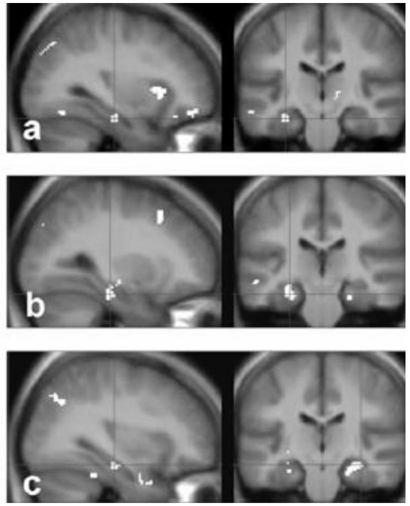

Functional MRI Predicts Memory Performance after Right Mesiotemporal Epilepsy Surgery





Functional reserve

Important but not crucial



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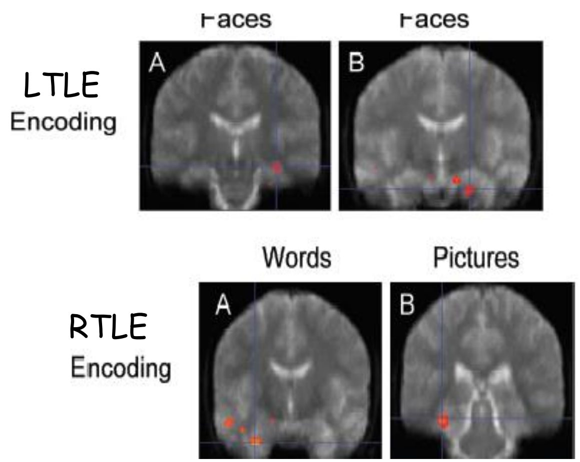
NeuroImage
NeuroImage 20 (2003) S112–S119
www.elsevier.com/locate/ynimg

Preserved verbal memory function in left medial temporal pathology involves reorganisation of function to right medial temporal lobe

Mark P. Richardson,[a,*] Bryan A. Strange,[b] John S. Duncan,[a] and Raymond J. Dolan[b]

[a] Department of Clinical and Experimental Epilepsy, Institute of Neurology, Queen Square, London WC1N 3BG, UK
[b] Wellcome Department of Imaging Neuroscience, Institute of Neurology, Queen Square, London WC1N 3BG, UK



Epilepsia, 48(8):1512–1525, 2007
Blackwell Publishing, Inc.

Reorganization of Verbal and Nonverbal Memory in Temporal Lobe Epilepsy Due to Unilateral Hippocampal Sclerosis

*H. W. Robert Powell, †Mark P. Richardson, *Mark R. Symms, *Philip A. Boulby, *Pam J. Thompson, *John S. Duncan, and *Matthias J. Koepp

Conclusion: our findings suggest that memory function in unilateral TLE is betetr sustained by activation within the damaged hippocampus and that reorganization to the undamaged MTL is an uneefficient process, incapable of preserving memory function

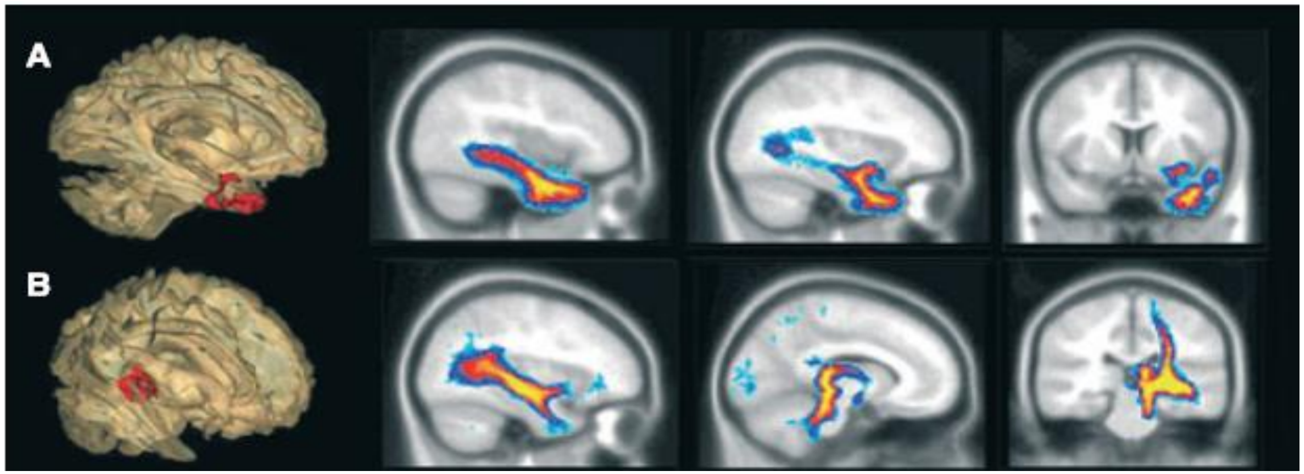
New predictors: DTI

Epilepsia, 51(4):536–545, 2010
doi: 10.1111/j.1528-1167.2009.02508.x

FULL-LENGTH ORIGINAL RESEARCH

Altered white matter integrity in temporal lobe epilepsy: Association with cognitive and clinical profiles

*Jeffrey D. Riley, †David L. Franklin, *Vicky Choi, *‡Ronald C. Kim, §¶Devin K. Binder, *¶Steven C. Cramer, and *Jack J. Lin



Positive correlation between FA and delayed memory in the anterior MTL

Positive correlation between FA and immediate memory in the whole TL

New predictors: connectivity

Epilepsia, 54(5):809–818, 2013
doi: 10.1111/epi.12098

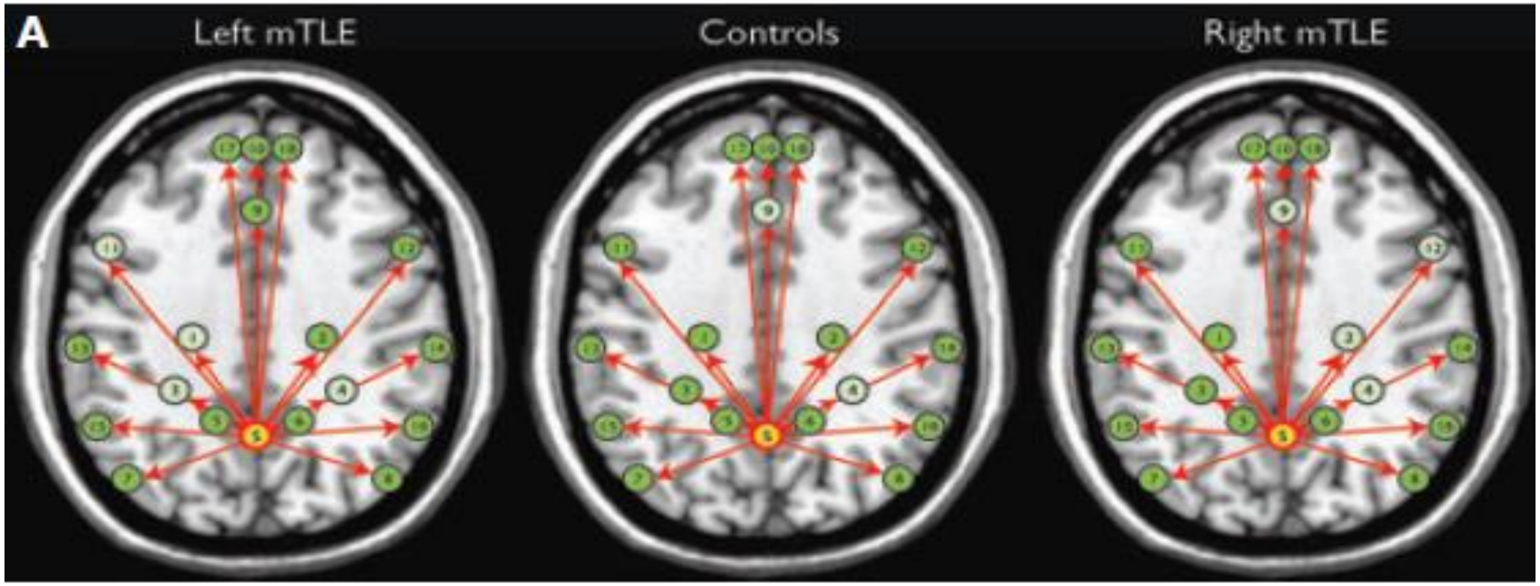
FULL-LENGTH ORIGINAL RESEARCH

Default mode network connectivity indicates episodic memory capacity in mesial temporal lobe epilepsy

*†Cornelia McCormick, *Maher Quraan, *‡Melanie Cohn, *§Taufik A. Valiante, and *†‡Mary Pat McAndrews

*Krembil Neuroscience Center & Toronto Western Research Institute, University Health Network, Toronto, Ontario, Canada; †Institute of Medical Sciences, University of Toronto, Toronto, Ontario, Canada; Departments of ‡Psychology and §Neurosurgery, University of Toronto, Toronto, Ontario, Canada

20 right MTLE, 18 left MTLE



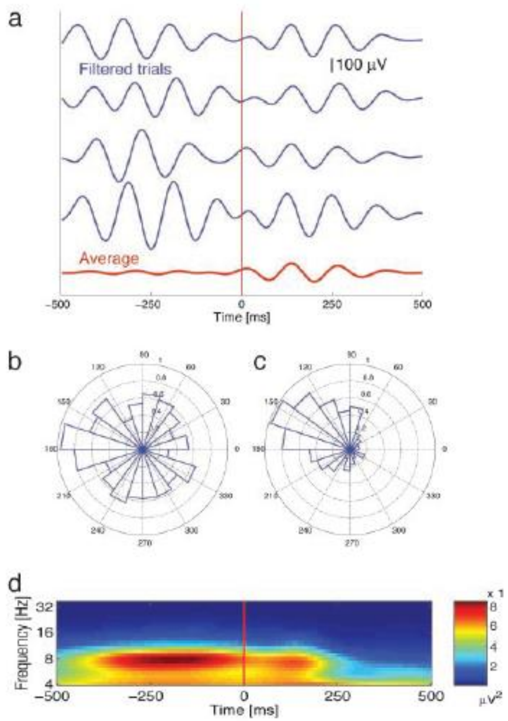
1. ⇩ functional connectivity between the posterior congulate cortex and the epileptic hippocampus
   a. Good Connectivity = good pre operative memory
   b. Good Connectivity = bad postoperative memory
2. ⇧ functional connectivity between the posterior congulate cortex and the contralateral hippocampus
   a. Reinforcement Connectivity = best postoperative memory outcome

SEEG

J of Neurosciences, 2003 (23): 10809-10814

Theta and gamma oscillations during encoding oredict subsequent recall

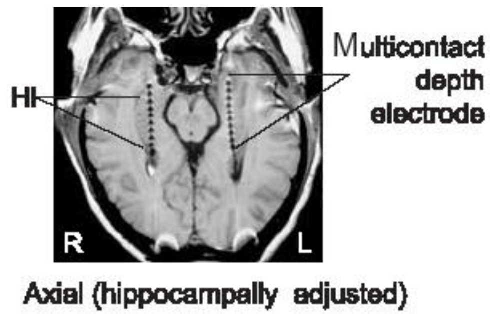
Sederberg et al.

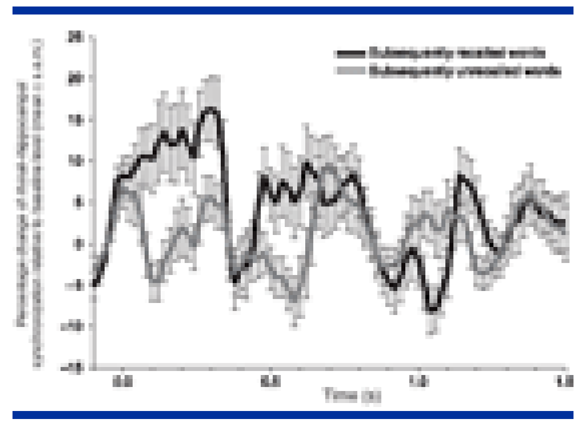


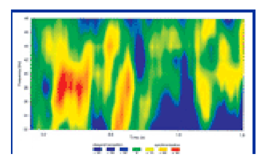
Nature Neurosciences, 2001 (4): 1259-1264

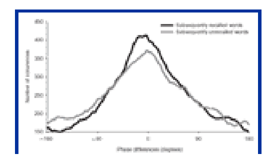
Human memory is accompanied by rhinal-hippocampal coupling and decoupling

Fell et al.

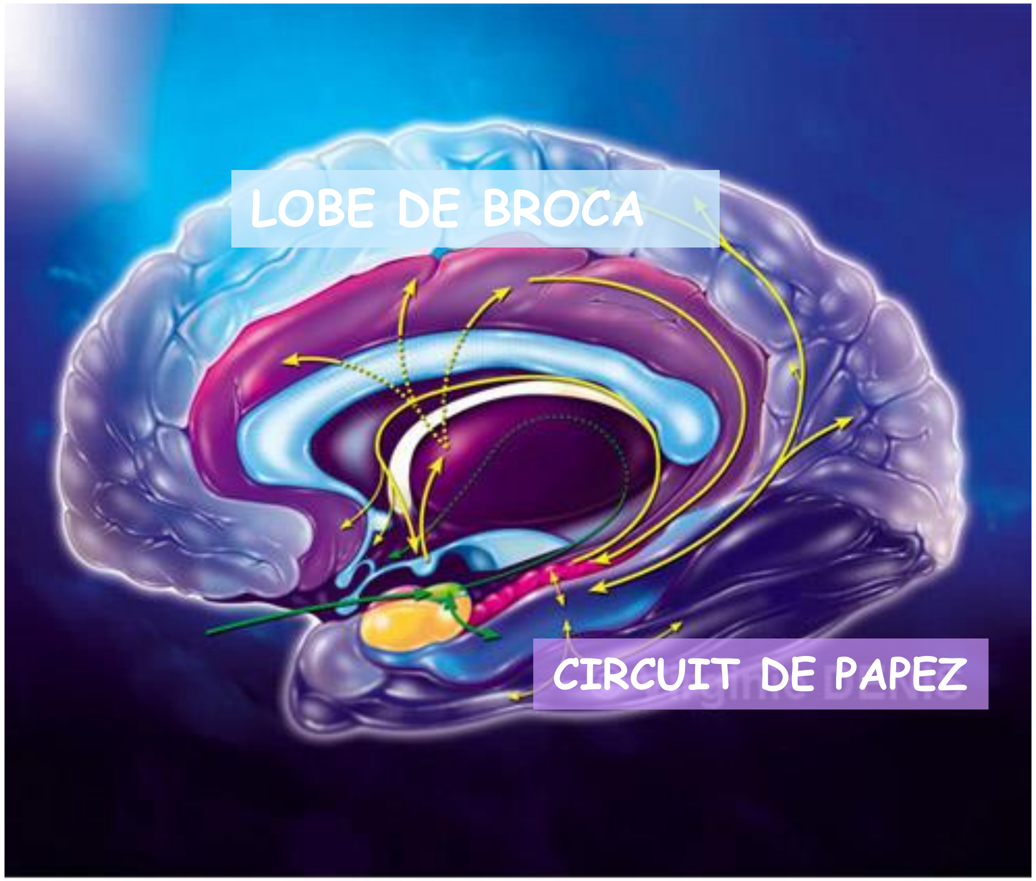








Conclusion



The functional neuroanatomy of episodic memory

P.C. Fletcher, C.D. Frith and M.D. Rugg

Functional neuroimaging studies have revealed that effective encoding in episodic memory is associated with enhanced activity in left prefrontal cortex, whereas retrieval is accompanied by the enhancement of predominantly right-sided prefrontal activity. The extent of the contribution of prefrontal cortex to episodic memory, and the fact that the encoding and retrieval operations it supports are differentially lateralized, were unexpected on the basis of evidence from lesion studies. Such studies have highlighted the crucial role in episodic memory played by the hippocampus and related medial temporal lobe structures. Neuroimaging studies, however, have had only limited success in elucidating the role of the hippocampus in episodic memory. Refinements in experimental design and improved spatial resolution should promote rapid future progress with respect to this issue.

Trends Neurosci. (1997) 20, 213–218