## wellcometrust

Fellow

# Oscillatory mechanisms of episodic encoding and retrieval in the human hippocampus

Bernhard Staresina, Ph.D.



### Episodic memory









encoding



encoding





encoding







encoding

'pattern completion'

'pattern separation'

Episodic memory – where to look?





















Intact memory depends on the MTL

### Anatomically distinct subregions



### Anatomically distinct subregions



What is the role of the hippocampus in episodic memory?



Rachel A. Diana<sup>1,2</sup>, Andrew P. Yonelinas<sup>2</sup> and Charan Ranganath<sup>1,2</sup>



### fMRI research has identified a role of the hippocampus both during

### successful associative encoding and retrieval



### Questions

### Questions

What are the hippocampal mechanisms of associative memory when looking 'under the hood' of the BOLD signal?

### Questions

What are the hippocampal mechanisms of associative memory when looking 'under the hood' of the BOLD signal?

What is the neural code distinguishing episodic encoding ('pattern separation') from retrieval ('pattern completion')?

ENCODING



•••



...

•••





Part I: fMRI



### fMRI results



# fMRI activation (parameter estimates)



ENCODING

### fMRI results





### fMRI results





What are the hippocampal mechanisms of associative memory when looking 'under the hood' of the BOLD signal?

What are the hippocampal mechanisms of associative memory when

looking 'under the hood' of the BOLD signal?

### Intracranial EEG (iEEG)

Oscillatory power in different frequency ranges as a proxy for fine-tuned information processing within and across neural assemblies.

### Part II: iEEG



1 hippocampal contact from the healthy hemisphere of each patient.
### Part II: iEEG



1 hippocampal contact from the healthy hemisphere of each patient.



# Part II: iEEG







Part II: iEEG













**A**-

**A+** 

**A**-

**A+** 



Stage Effect Memory Effect **ENC** RET ENC RET 25% 25% 20% 20% 15% 15% 10% 10% 5% 5% 0% 0%







#### time/frequency ranges of interest



#### time/frequency ranges of interest



RET



0%

-5%

**A**-

**A+** 

RET

 $\overrightarrow{}$ 

**A+** 

A+

**A**-

 $\overrightarrow{\mathbf{x}}$ 



RET





direct (inverse) relationship between alpha and gamma:

the more alpha decrease, the more gamma increase for A+ vs. A-



A+ vs. A-, gamma

RET





#### time course analysis, separately for encoding and retrieval

alpha (8-10 Hz)





retrieval







#### retrieval, A+ vs. Aresponse-locked



#### retrieval, A+ vs. Aresponse-locked



# Interim summary

successful associative memory encoding and retrieval are accompanied by relative decreases in alpha power followed by increases in gamma power



successful associative memory encoding and retrieval are accompanied by relative decreases in alpha power followed by increases in gamma power

What is the neural code distinguishing episodic encoding ('pattern

separation') from retrieval ('pattern completion')?

Hippocampal phase coding: CA1 spiking at different phases of the theta cycle as a function of encoding vs. retrieval (Hasselmo et al., 2002)



Are different mnemonic states (encoding vs. retrieval) reflected in different phases of hippocampal oscillations?

1. identify time and frequency where phases are most stable across participants, collapsed across A+ encoding and A+ retrieval

# 1. identify time and frequency where phases are most stable across participants, collapsed across A+ encoding and A+ retrieval



# 1. identify time and frequency where phases are most stable across participants, collapsed across A+ encoding and A+ retrieval



240 ms post-stimulus onset

2-3 Hz



rodent theta  $\leftarrow \rightarrow$  human delta



rstb.royalsocietypublishing.org

Hippocampal theta oscillations are slower in humans than in rodents: implications for models of spatial navigation and memory

Joshua Jacobs

# 2. assess whether phase angles systematically differ between encoding and retrieval






Hippocampal delta phase after stimulus delivery reveals whether a participant is in an encoding- or retrieval state.



## Open questions



### **Open questions**

Are there links with behavior, e.g. more 'typical' phase at stimulus delivery leading to faster response times/greater confidence?



### **Open questions**

Are there links with behavior, e.g. more 'typical' phase at stimulus delivery leading to faster response times/greater confidence?

Is the system capable of switching more rapidly between encoding and retrieval?



### Summary



The hippocampus supports associative memory, shown with fMRI via

increased BOLD responses during successful encoding and retrieval.





## iEEG recordings reveal a decrease in alpha power followed by an increase

in gamma power during successful encoding and retrieval.





Post-stimulus delta phase reflects the mnemonic state, systematically

differing between encoding vs. retrieval of episodic memories.



# Thank you!

Supported by wellcometrust

Juergen Fell Nikolai Axmacher



**Rik Henson** 

MRC Cognition and Brain Sciences Unit Ole Jensen Mathilde Bonnefond



### Anthony Wagner



Dan Schacter





### novel vs. old experiences or encoding vs. retrieval state?





### novel vs. old experiences or encoding vs. retrieval state?



### novel vs. old experiences or encoding vs. retrieval state?







