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# Every individual makes a difference:

A trinity derived from linking individual brain morphometry, connectivity and mentalising ability

人类大脑形态学表征、功能连接和心智化能力中  
三位一体的自涌现

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# PROLOGUE



(Adapted from 12371.cn)

## MAO TSE-TUNG – ON CONTRADICTION

‘But this general character is contained in every individual character; without individual character there can be no general character. If all individual character were removed, what general character would remain?’




“矛盾的普遍性和矛盾的特殊性的关系，就是矛盾的**共性**和**个性**的关系。其**共性**是矛盾存在与一切过程中，并贯串于一切过程的始终，矛盾即是运动，即是事物，即是过程，也即是思想。否认事物的矛盾就是否认了一切。这是共通的道理，古今中外，概莫能外。所以它是**共性**，是绝对性。然而这种**共性**，即**包含于一切个性之中，无个性即无共性。假如除去一切个性，还有什么共性呢？**”

# BACKGROUND

**Mentalising ability is a pivotal and fundamental component of human social cognition.**



## SELF

-  Feelings
-  Needs
-  Goals
-  Reasons
-  Thoughts

## OTHER

-  Feelings
-  Needs
-  Goals
-  Reasons
-  Thoughts

# BACKGROUND

However, considering the multifaceted nature of mentalising ability <sup>1</sup>, **little research** has focused on characterising individual differences in different mentalising components <sup>2</sup>.

Self-self mentalisation  
(SS, meta-cognition)



Self-other mentalisation  
(SO, perspective-taking)



Other-self mentalisation  
(OS)

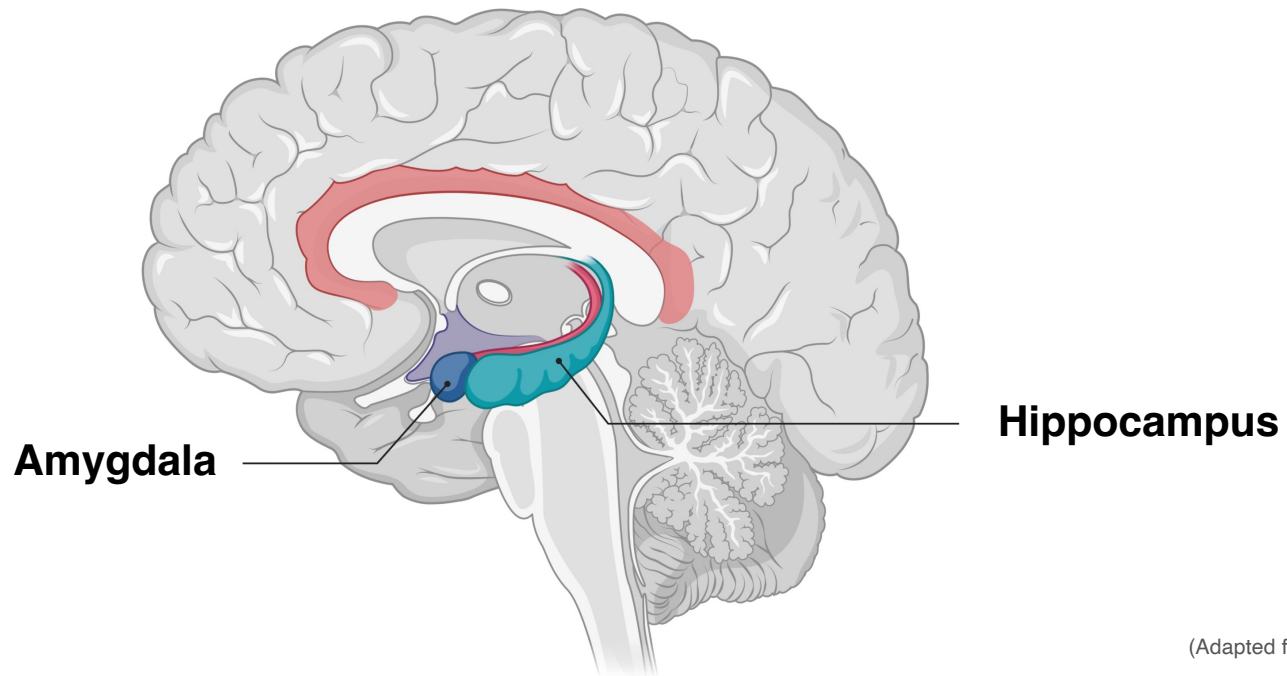


(Adapted from BioRender.com)

1. Wu, H., Liu, X., Hagan, C. C., & Mobbs, D. (2020b). Mentalising during social interaction: A four component model. *Cortex*, 126, 242–252.
2. Wu, H., Fung, B. J., & Mobbs, D. (2022). Mentalising during social interaction: The development and validation of the interactive mentalising questionnaire. *Frontiers in Psychology*, 12.

# BACKGROUND

And **even less research** has been devoted to investigating how the variance in the structural and functional patterns of the amygdala and hippocampus, **two vital subcortical regions of the ‘social brain’**<sup>3, 4</sup>, are related to inter-individual variability in mentalising ability.



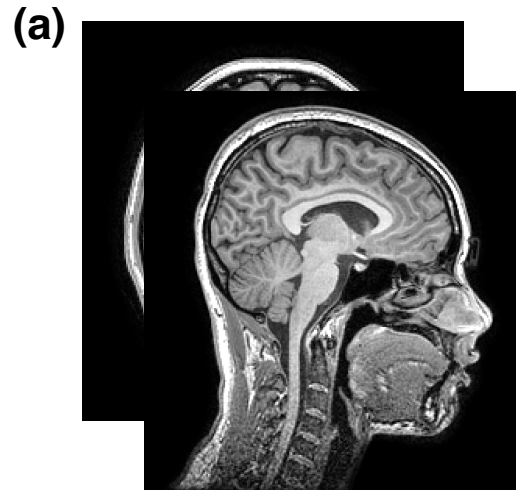
(Adapted from BioRender.com)

3. Bickart, K. C., Dickerson, B. C., & Barrett, L. F. (2014). The amygdala as a hub in brain networks that support social life. *Neuropsychologia*, *63*, 235–248.
4. Montagrin, A., Saiote, C., & Schiller, D. (2018). The social hippocampus. *Hippocampus*, *28*, 672–679.

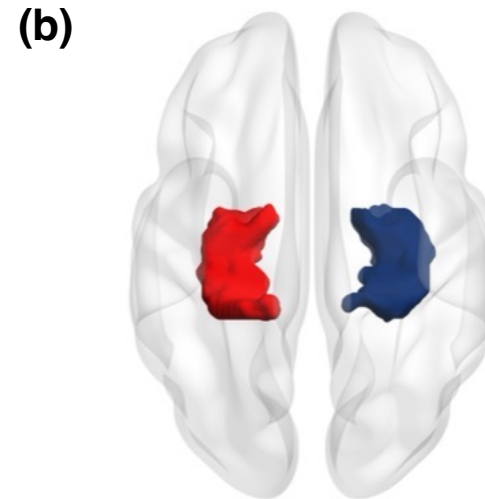
# RESEARCH QUESTION

**Whether inter-individual variability in the structural or functional patterns of the above two brain regions is associated with that in different mentalising components?**

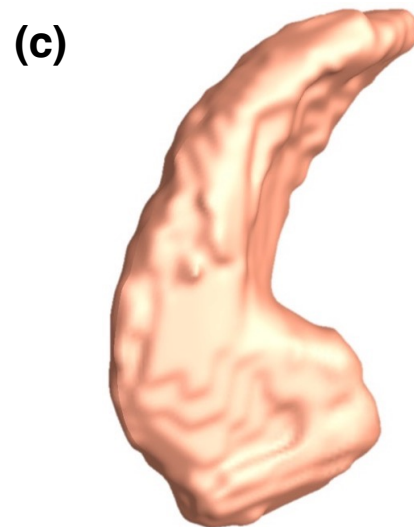
## MMS: Surface-based multivariate morphometry statistics



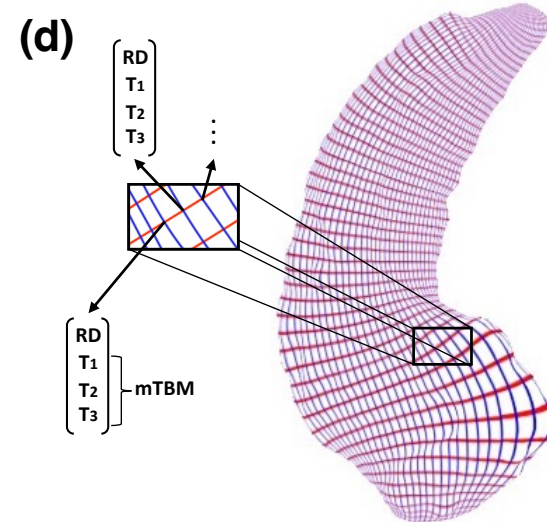
T1-weighted MRI scans



Hippocampal segmentation



Smoothed surface

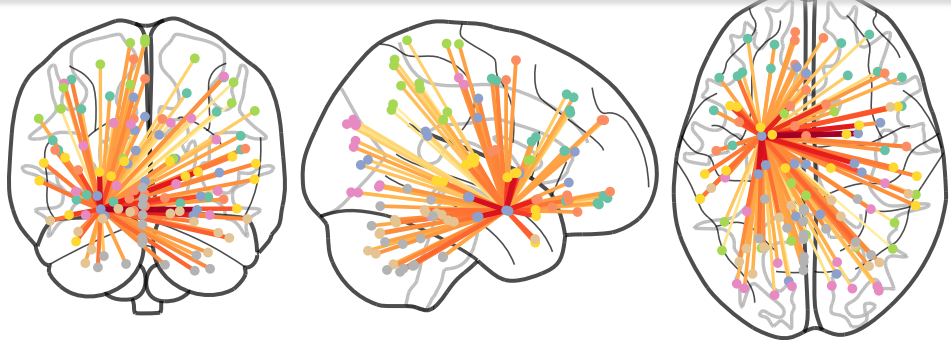


Multivariate morphometry statistics

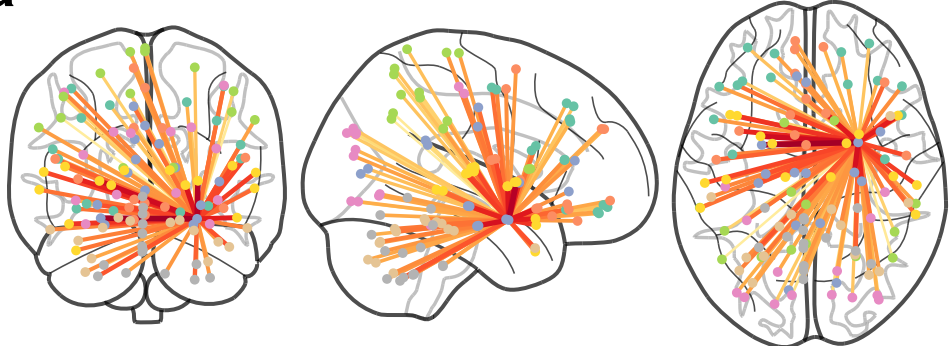
# METHODS

## **Rs-FC: Resting-state functional connectivity**

**Left amygdala**

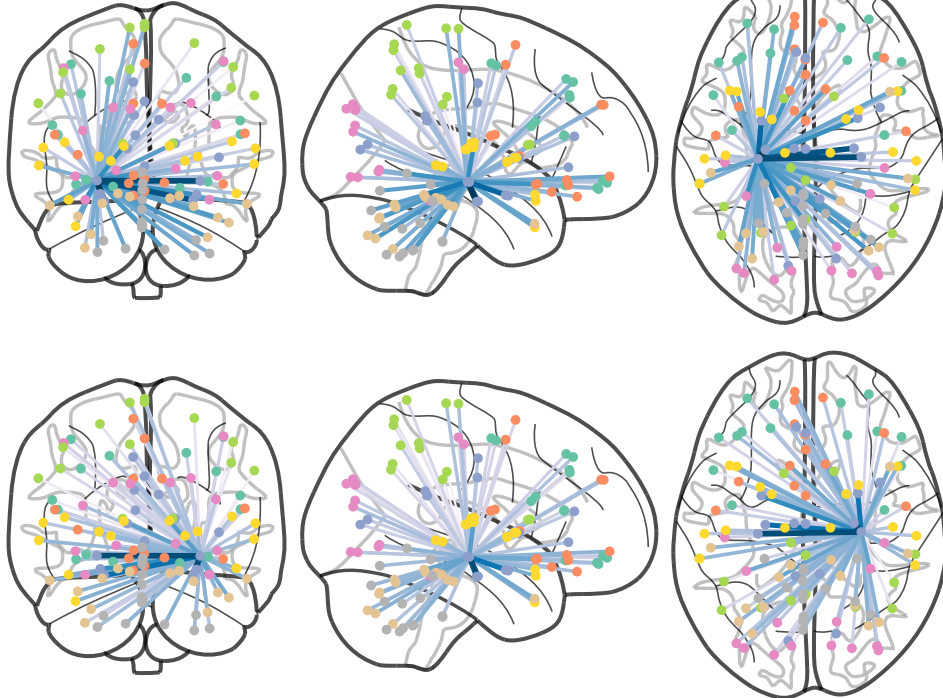
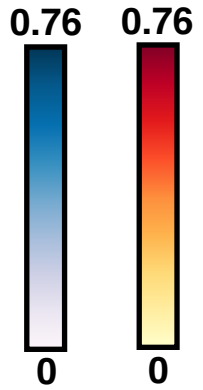


**Right amygdala**



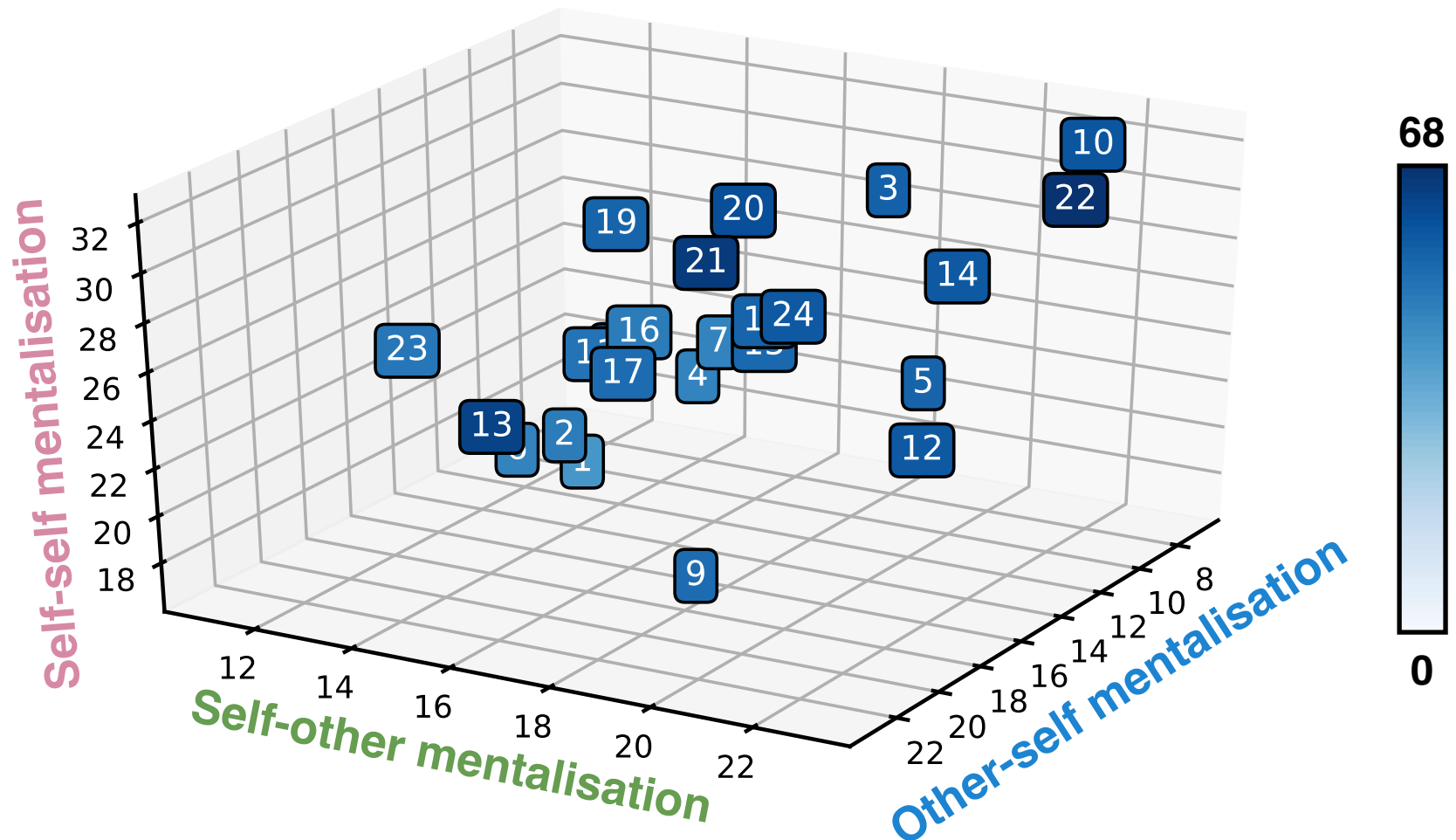
**Left hippocampus**

**Right hippocampus**





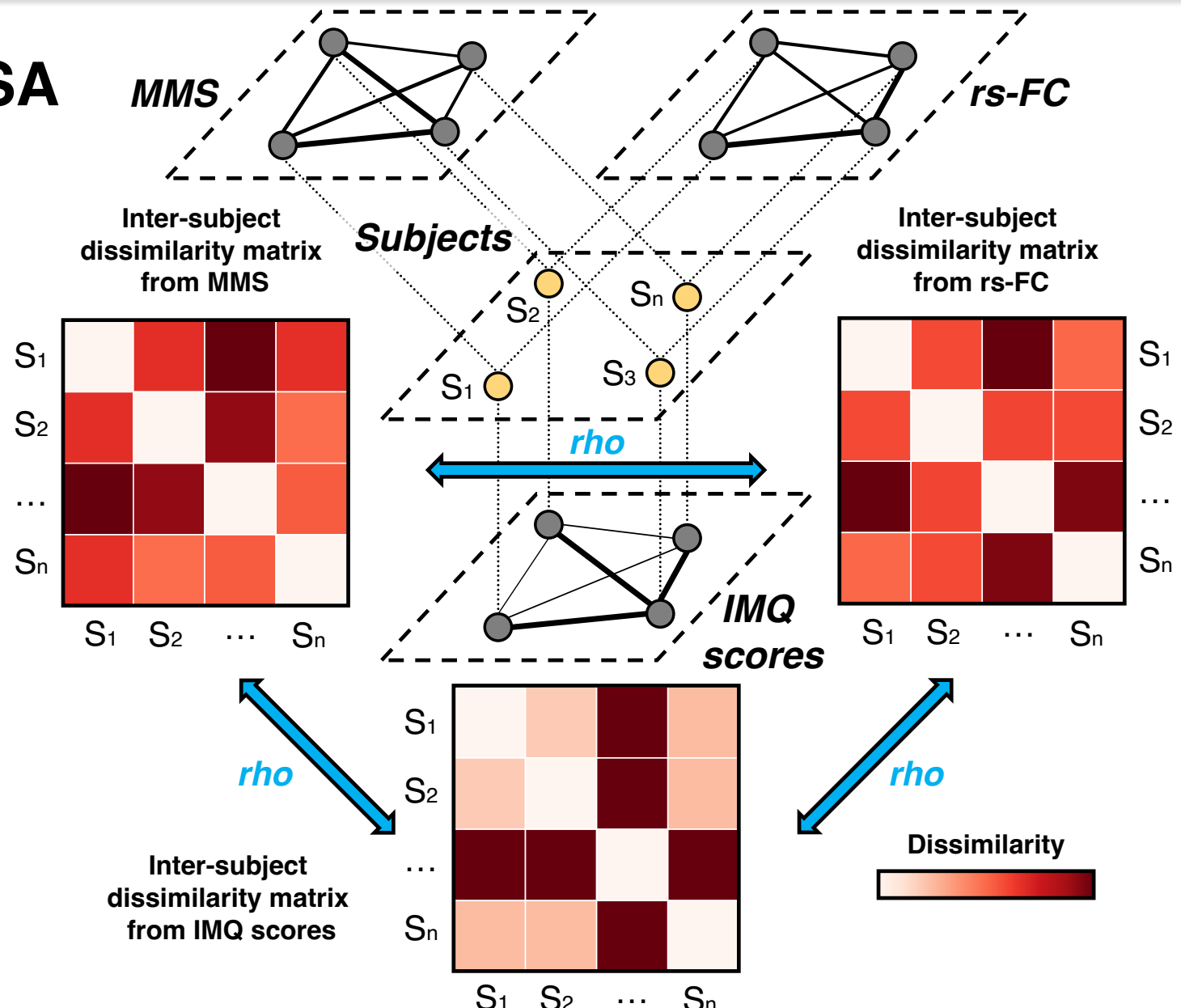
## IMQ: Interactive mentalisation questionnaire <sup>2</sup>



2. Wu, H., Fung, B. J., & Mobbs, D. (2022). Mentalising during social interaction: The development and validation of the interactive mentalising questionnaire. *Frontiers in Psychology*, 12.

# METHODS

## IS-RSA



# HYPOTHESIS 1

We predicted that

- 1) the levels of mentalising ability would **correlate positively** with the dissimilarity in amygdala and hippocampal morphometry and connectivity;
- 2) dissimilarity in functional and structural patterns would **positively covary** with each other.

# HYPOTHESIS 1

Three distinct modalities will **share one essence**, i.e., there is a structure that existed in idiosyncratic patterns of brain morphometry, connectivity and mentalising ability, and we termed it as **'trinity'**.



(Adapted from Wikipedia)

# HYPOTHESIS 2

There will be a **region-related specificity** in associations among different mentalising components and amygdala or hippocampal MMS and rs-FC.

## Self-self mentalisation (SS, meta-cognition)



Allen et al., *Neuroimage*, 2017

Alkan et al., *Schizophr. Bull.*, 2020

Ye et al., *Brain Struct. Funct.*, 2019

Zou & Kwok, *J. Cogn. Neurosci.*, 2022

# HYPOTHESIS 2

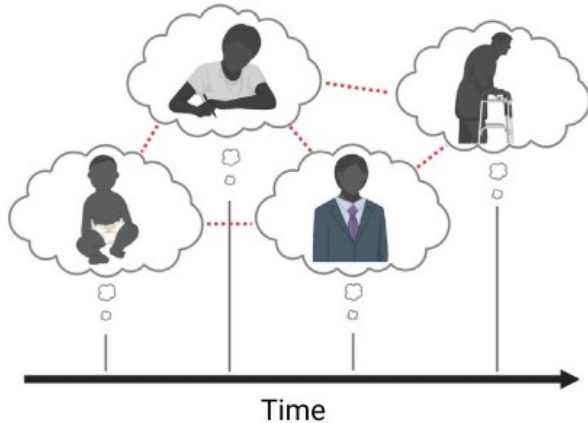
There will be a **region-related specificity** in associations among different mentalising components and amygdala or hippocampal MMS and rs-FC.

## Self-other mentalisation (SO, perspective-taking)

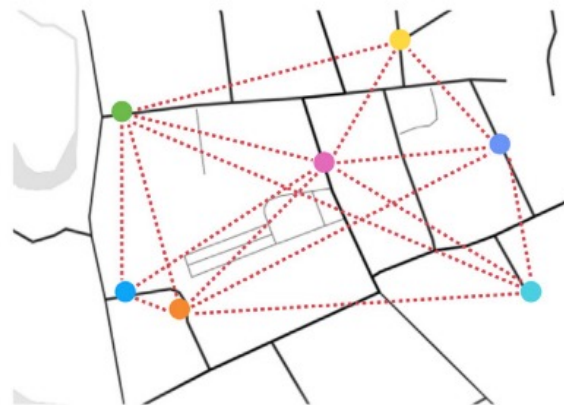
### Relational integration theory

O'Keefe & Nadel, *The hippocampus as a cognitive map*, 1978  
Rubin et al., *Front. Hum. Neurosci.*, 2014

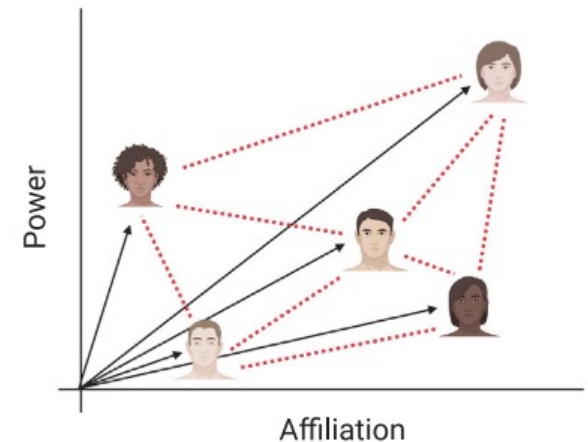
(A) Memories



(B) Physical locations



(C) Social relationships

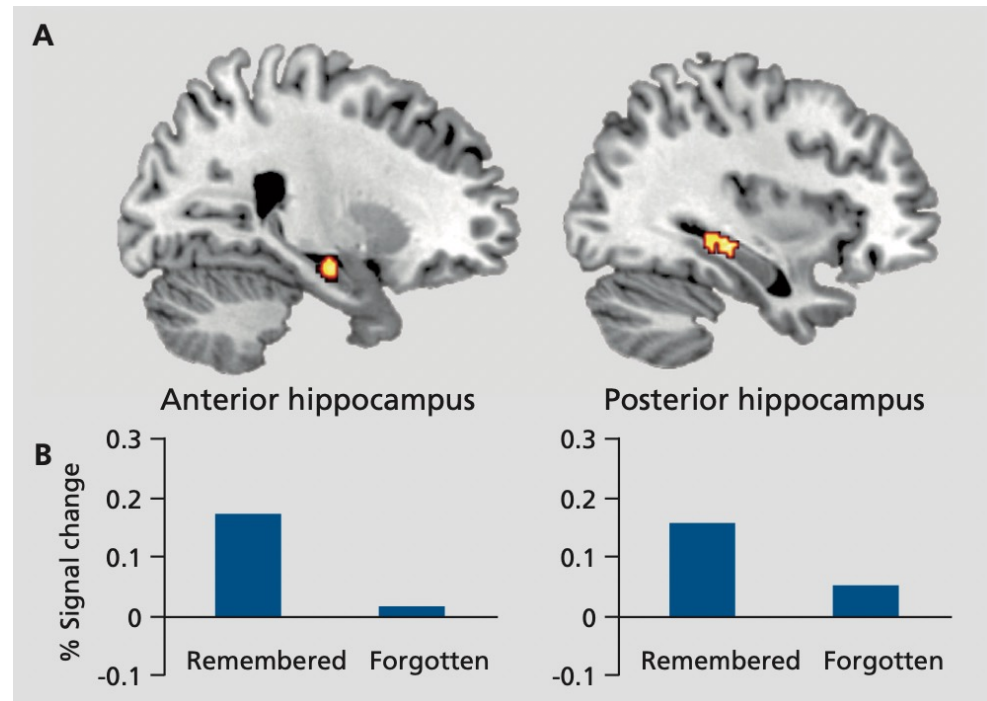


(Adapted from Banker et al., *Trends Neurosci.*, 2021)

# HYPOTHESIS 2

There will be a **region-related specificity** in associations among different mentalising components and amygdala or hippocampal MMS and rs-FC.

## Self-other mentalisation (SO, perspective-taking)



Hippocampal responses to encoding simulations of future events

(Adapted from Schacter, *Am. Psychol.*, 2012)

## Constructive memory theory

Schacter, *Am. Psychol.*, 2012

# HYPOTHESIS 2

There will be a **region-related specificity** in associations among different mentalising components and amygdala or hippocampal MMS and rs-FC.

Other-self mentalisation (OS, the ability to see ‘ourselves from the outside’)

Wu et al., *Front. Psychol.*, 2022

Koscik & Tranel, *Neuropsychologia*, 2011

Haas et al., *Neuroimage*, 2015

Santos et al., *PLoS ONE*, 2016

Eskander et al., *Neural Correlates and Mechanisms of Trust*, 2020

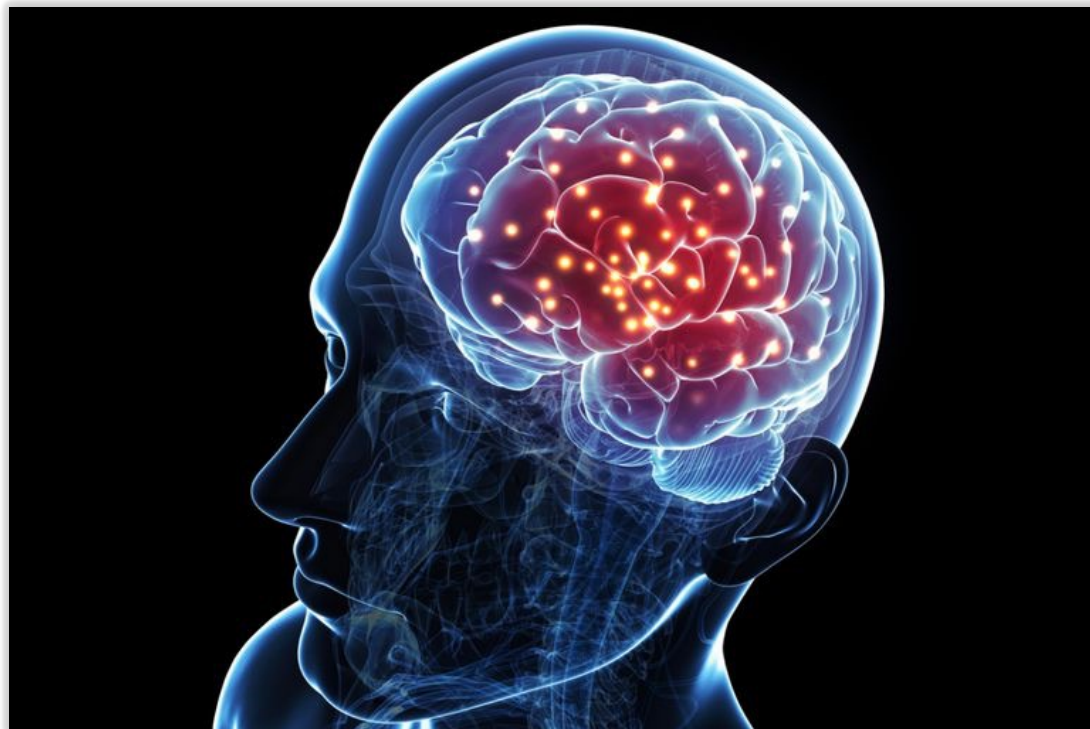




# HYPOTHESIS 3

Subject pairs with **similar hippocampal MMS** will have even **greater SS and SO similarity** if they are also **similar in hippocampal rs-FC**.

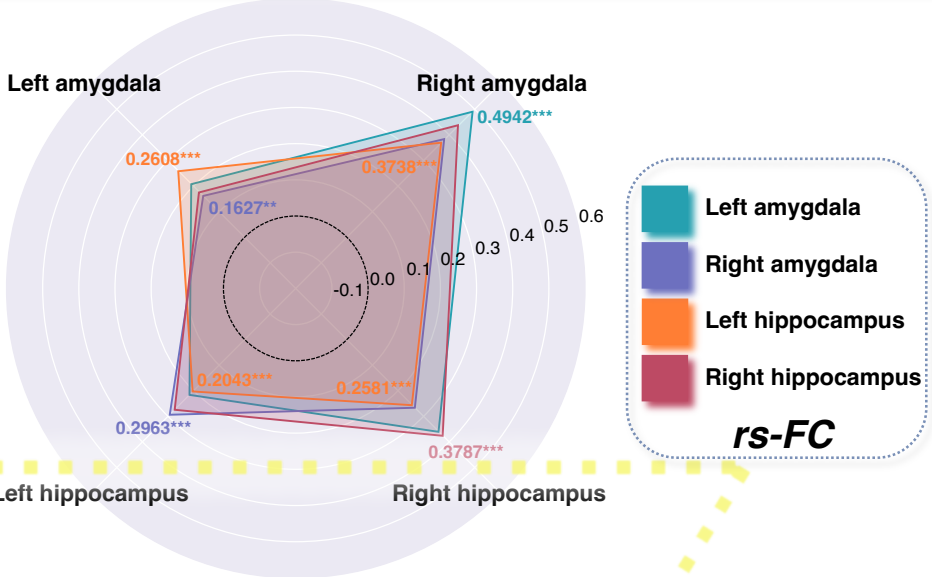
In a similar vein, subject pairs with **similar amygdala MMS** will have even **greater OS similarity** if they are also **similar in amygdala rs-FC**.



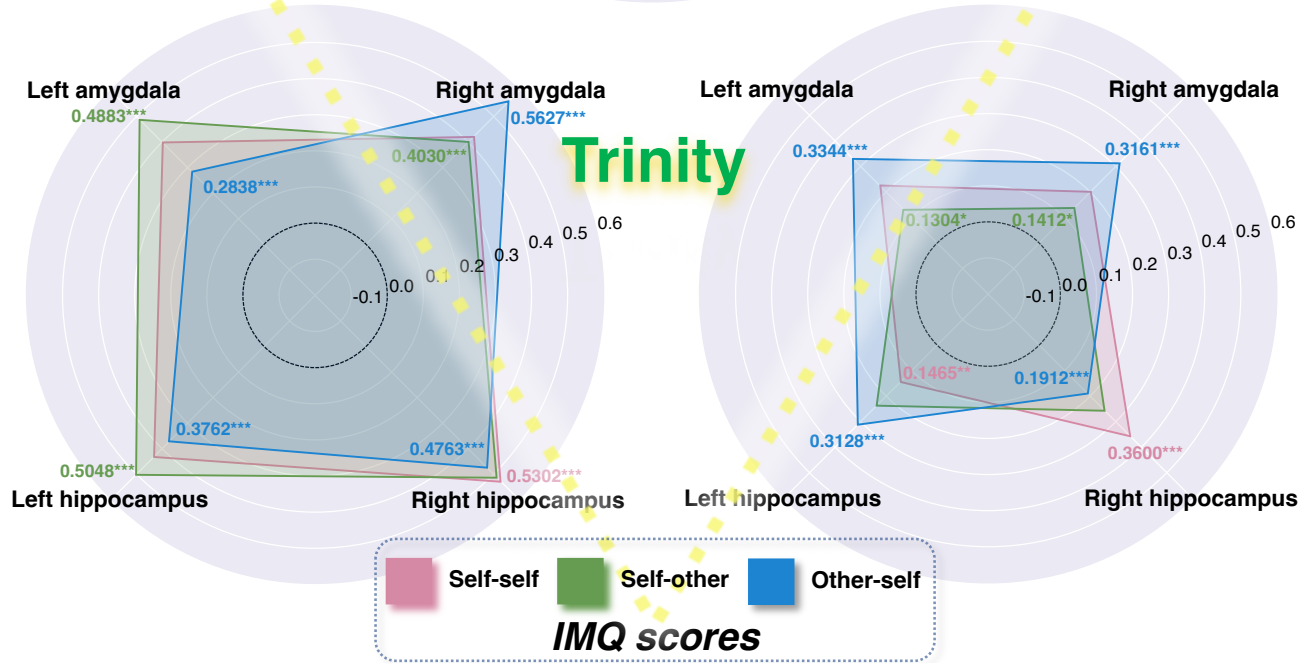
# RESULTS

Three distinct modalities  
**shared one essence**

*MMS*



**Trinity**



# RESULTS

## A region-related mentalising specificity emerged from the trinity

Comb.	<i>rho</i>	Mean (95% CI)	<i>p</i> <sub>FDR</sub>
<b>SS</b>			
LA	0.3981	0.3677 (0.3569-0.3785)	<.001***
RA	0.4228	0.3947 (0.3861-0.4034)	<.001***
LH	0.4347	0.4127 (0.4055-0.4199)	<.001***
<b>RH</b>	0.5302	<b>0.5168 (0.5051-0.5284)</b>	<.001***
<b>SO</b>			
LA	0.4883	0.4607 (0.4478-0.4736)	<.001***
RA	0.4030	0.3821 (0.3751-0.3891)	<.001***
LH	0.5048	0.4678 (0.4601-0.4755)	<.001***
<b>RH</b>	0.5156	<b>0.4766 (0.4657-0.4875)</b>	<.001***
<b>OS</b>			
LA	0.2838	0.2890 (0.2801-0.2980)	<.001***
<b>RA</b>	0.5627	<b>0.5153 (0.5051-0.5255)</b>	<.001***
LH	0.3762	0.3548 (0.3453-0.3643)	<.001***
RH	0.4763	0.4433 (0.4321-0.4544)	<.001***

(a) Results of similarities between IMQ scores and MMS.

Comb.	<i>rho</i>	Mean (95% CI)	<i>p</i> <sub>FDR</sub>
<b>SS</b>			
LA	0.2272	0.2094 (0.1995-0.2194)	<.001***
RA	0.2025	0.1747 (0.1668-0.1826)	<.001***
LH	0.1465	0.1256 (0.1162-0.1350)	.007**
<b>RH</b>	0.3600	<b>0.3434 (0.3348-0.3520)</b>	<.001***
<b>SO</b>			
LA	0.1304	0.1239 (0.1169-0.1310)	.016*
RA	0.1412	0.1359 (0.1266-0.1452)	.010*
LH	0.2383	0.2254 (0.2147-0.2360)	<.001***
<b>RH</b>	0.2580	<b>0.2427 (0.2347-0.2508)</b>	<.001***
<b>OS</b>			
<b>LA</b>	0.3344	<b>0.3164 (0.3078-0.3250)</b>	<.001***
RA	0.3161	0.2890 (0.2788-0.2993)	<.001***
LH	0.3128	0.2861 (0.2742-0.2980)	<.001***
RH	0.1912	0.1682 (0.1538-0.1825)	<.001***

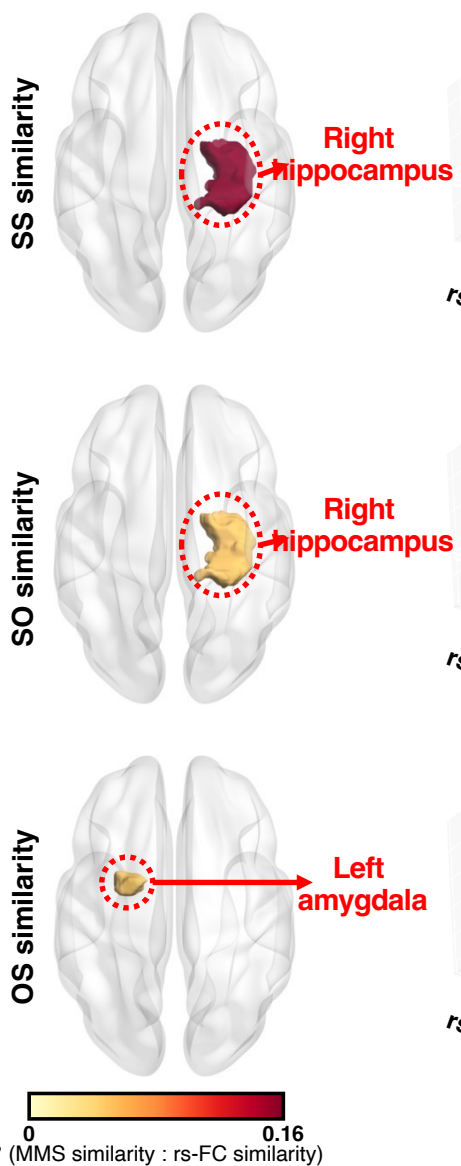
(b) Results of similarities between IMQ scores and rs-FC.

‘LA’ for left amygdala; ‘RA’ for right amygdala; ‘LH’ for left hippocampus; ‘RH’ for right hippocampus

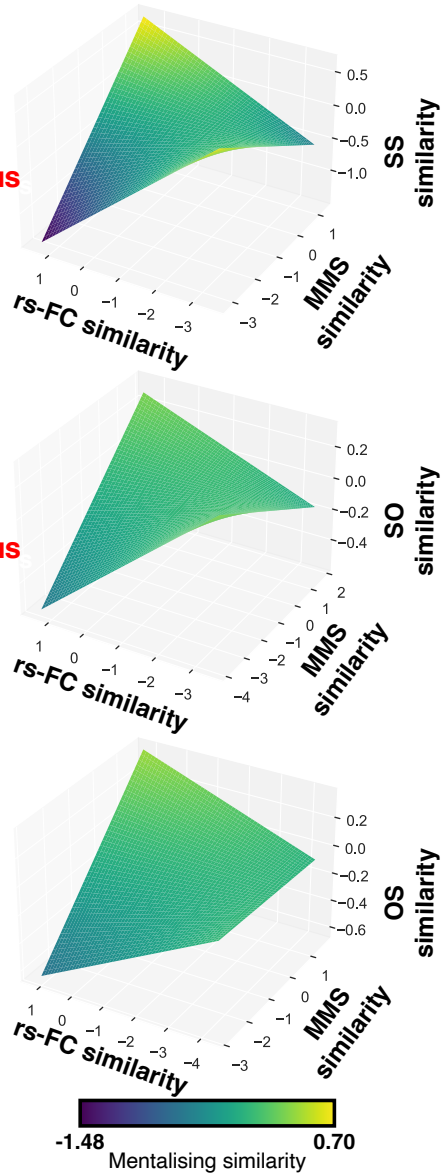
# RESULTS

**Rs-FC gates**  
**the MMS**  
**predicted**  
**similarity in**  
**mentalising**  
**ability**

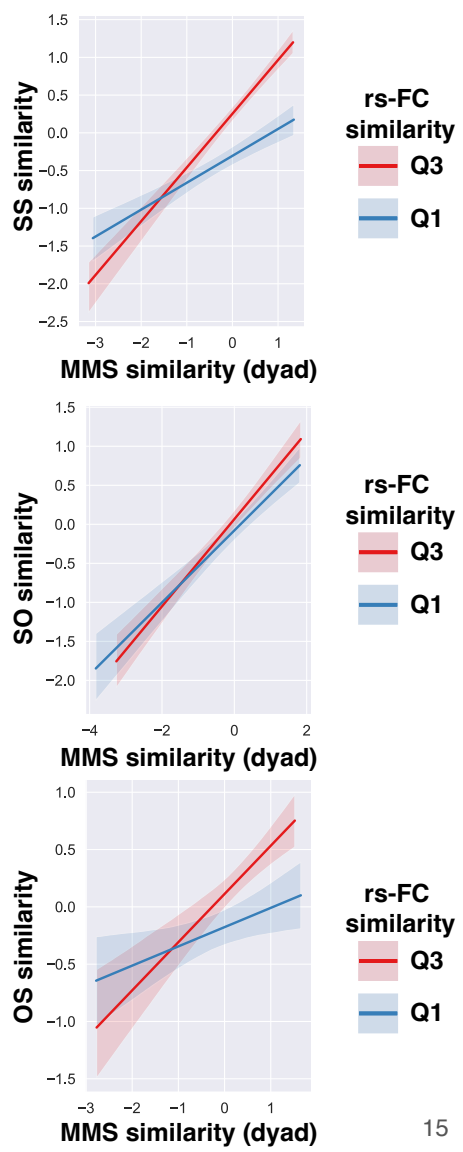
(a) MMS-rs-FC interaction: Significant regions



(b) MMS-rs-FC interaction: Estimated effects



(c) MMS-rs-FC interaction: Marginal effects



# DISCUSSION

- The current work defines an **integrative trinity framework** that provides a testable basis for understanding individual differences in brain morphometry, connectivity and mentalising ability.
- Trinity's finding not only advances our understanding of the neural basis of mentalising but also may further help shed light on the implementational or the physical realisation of **artificial mentalising ability** and thus pave the way for **artificial social intelligence**.
- Our study reveals the existence of a **region-related specificity**: the variation of **SS** and **SO** are more related to individual differences in hippocampal MMS and rs-FC, whereas the variation of **OS** shows a closer link with individual differences in amygdala MMS and rs-FC. Our finding is among the first to present additional evidence on the inter-individual level supporting the different but same pivotal role of the amygdala and hippocampus in rich and complex social life.
- Our data suggest that rs-FC gates the MMS predicted similarity in mentalising ability, revealing the **intertwining role** brain morphometry and connectivity play in social cognition.

# ACKNOWLEDGEMENT & CONTACT



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 [github.com/das-boot](https://github.com/das-boot)

Preprint: <https://doi.org/10.1101/2022.04.11.487870>

The data and code used are available at  
<https://github.com/andlab-um/trinity>

