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Every individual makes a difference:
A trinity derived from linking individual brain morphometry, connectivity and mentalising ability

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Prologue

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？[1]

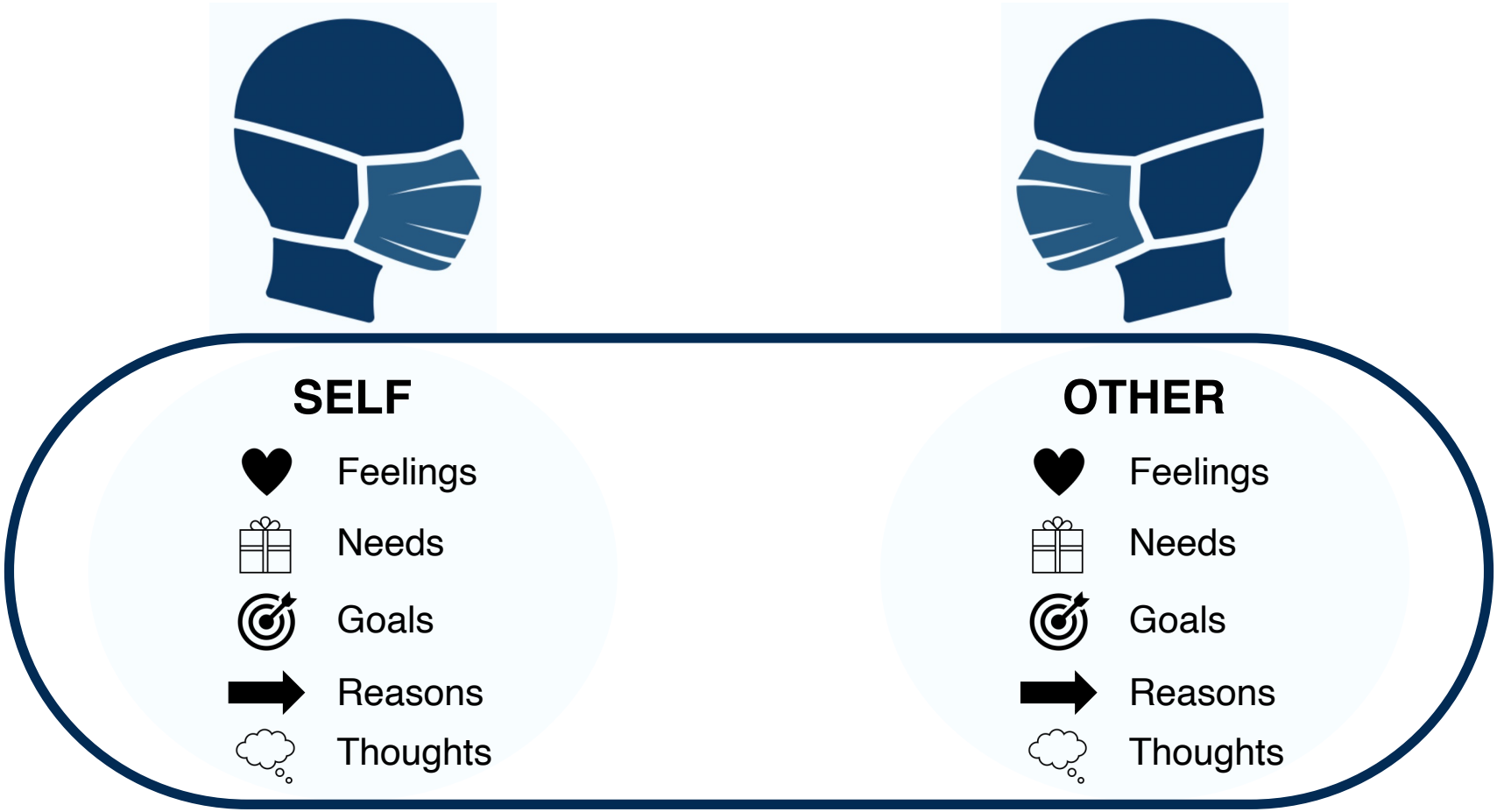
1936年，毛泽东在保安

(Adapted from 12371.cn)

1. Tse-Tung, M. (1937). On contradiction.

Background

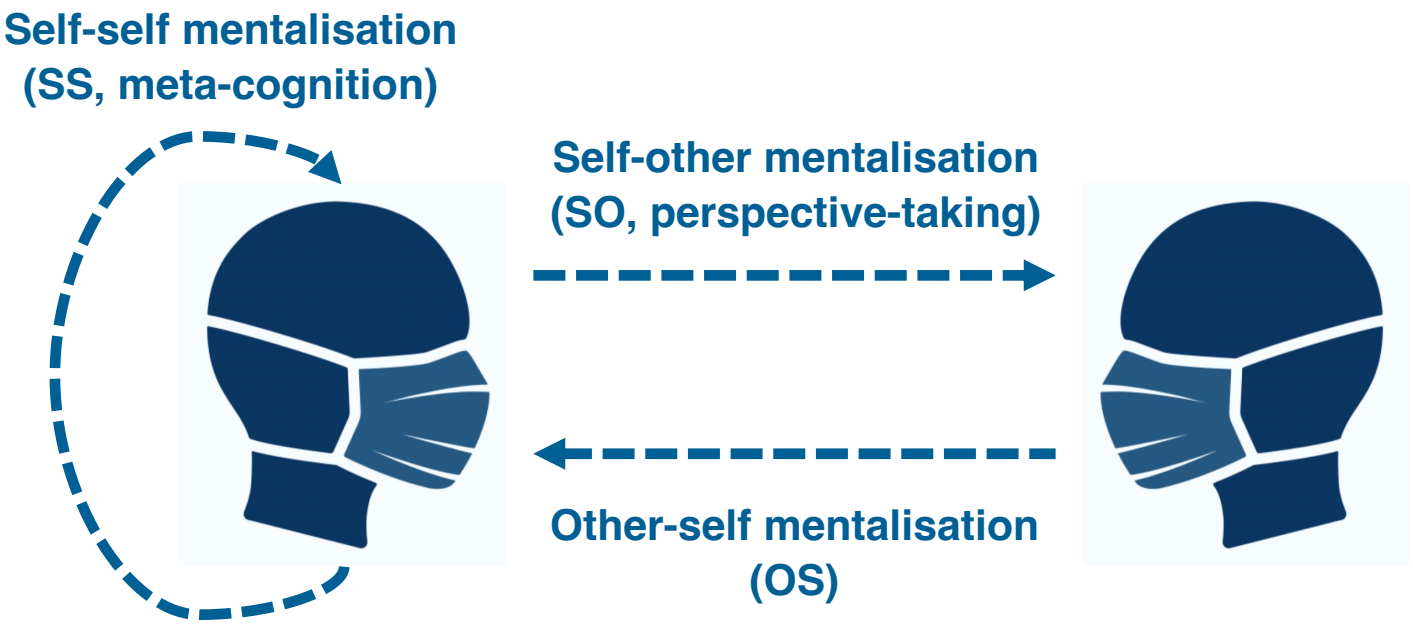
Mentalising ability is a pivotal and fundamental component of human social cognition.



(Adapted from BioRender.com)

Background

However, considering the multifaceted nature of mentalising ability [2], little research has focused on characterising individual differences in different mentalising components [3].

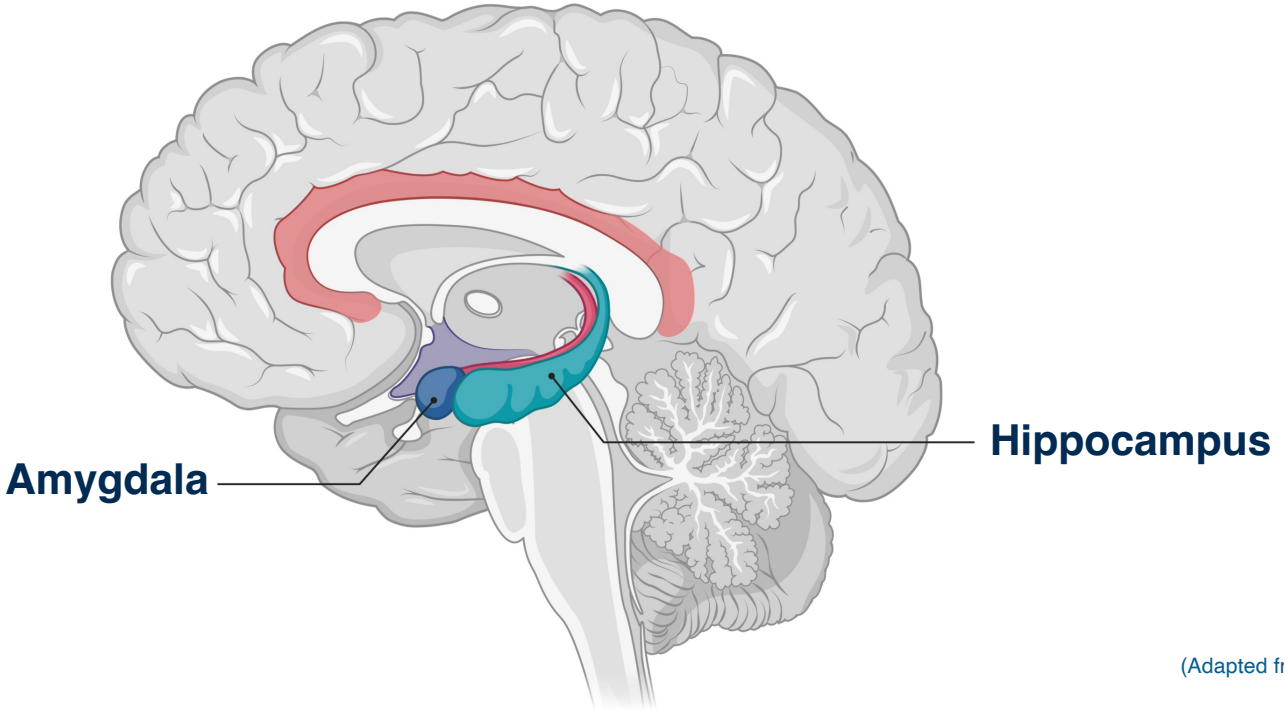


(Adapted from BioRender.com)

2. Wu, H., Liu, X., Hagan, C. C., & Mobbs, D. (2020b). Mentalising during social interaction: A four component model. *Cortex*, *126*, 242–252.
3. 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' [4, 5], are related to inter-individual variability in mentalising ability.



(Adapted from BioRender.com)

4. 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.
5. Montagrin, A., Saiote, C., & Schiller, D. (2018). The social hippocampus. *Hippocampus*, *28*, 672–679.

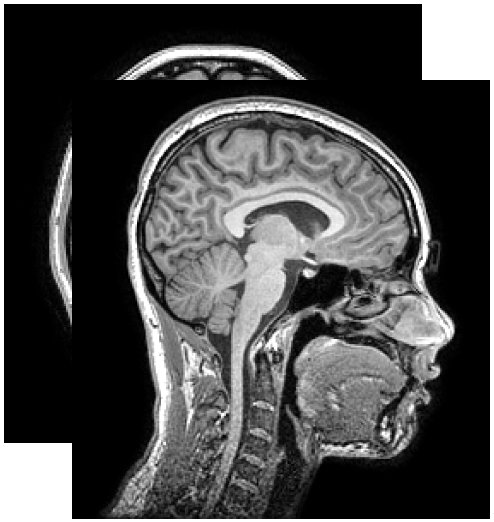
Research question

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

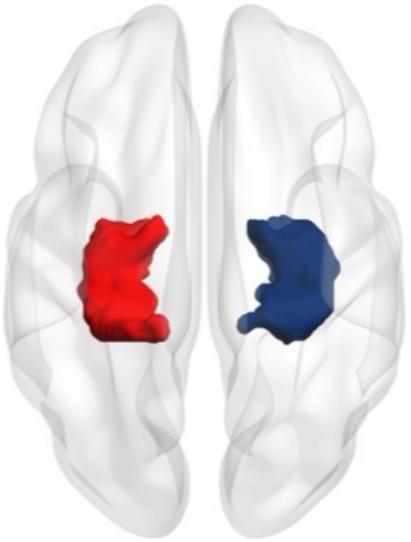
Processing pipeline of hippocampal morphometry data

(a)



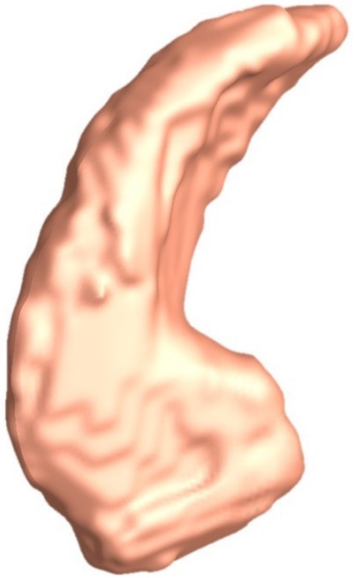
T1-weighted MRI scans

(b)



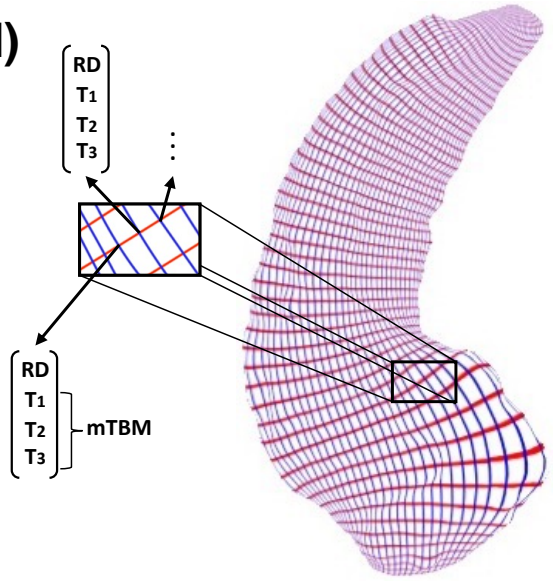
Hippocampal segmentation

(c)



Smoothed surface

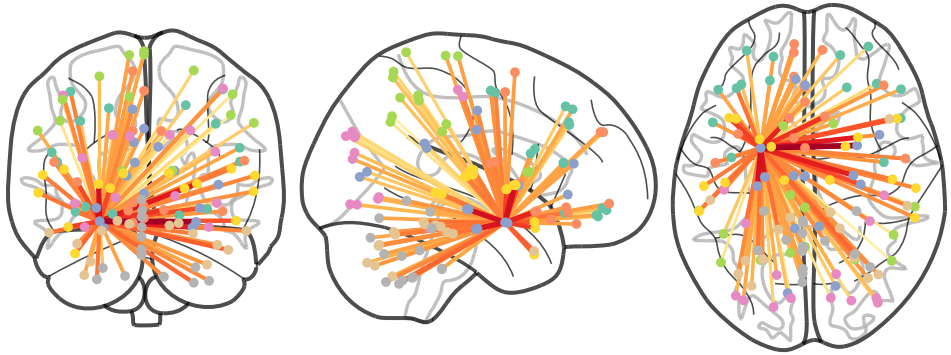
(d)



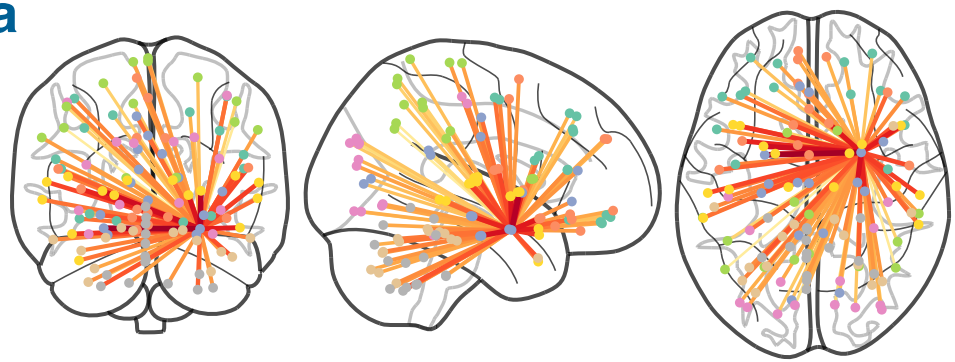
Multivariate morphometry statistics

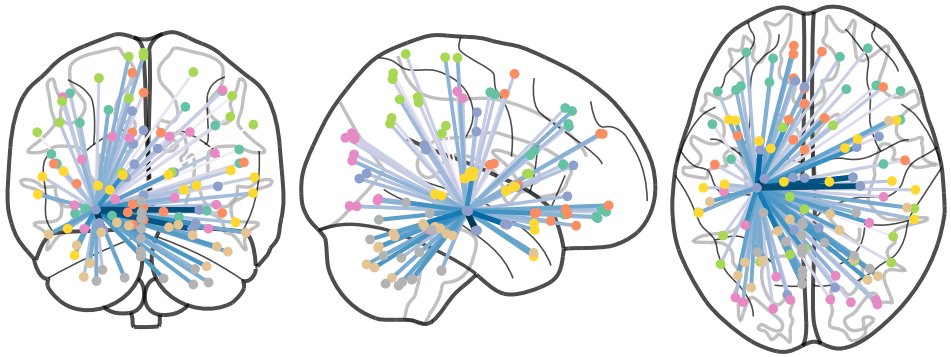
Rs-FC: Resting-state functional connectivity

Left amygdala

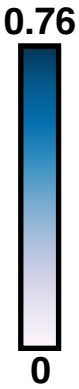


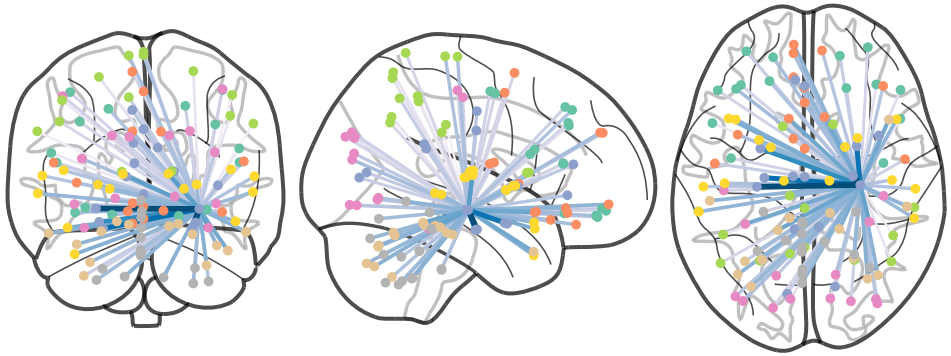
Right amygdala





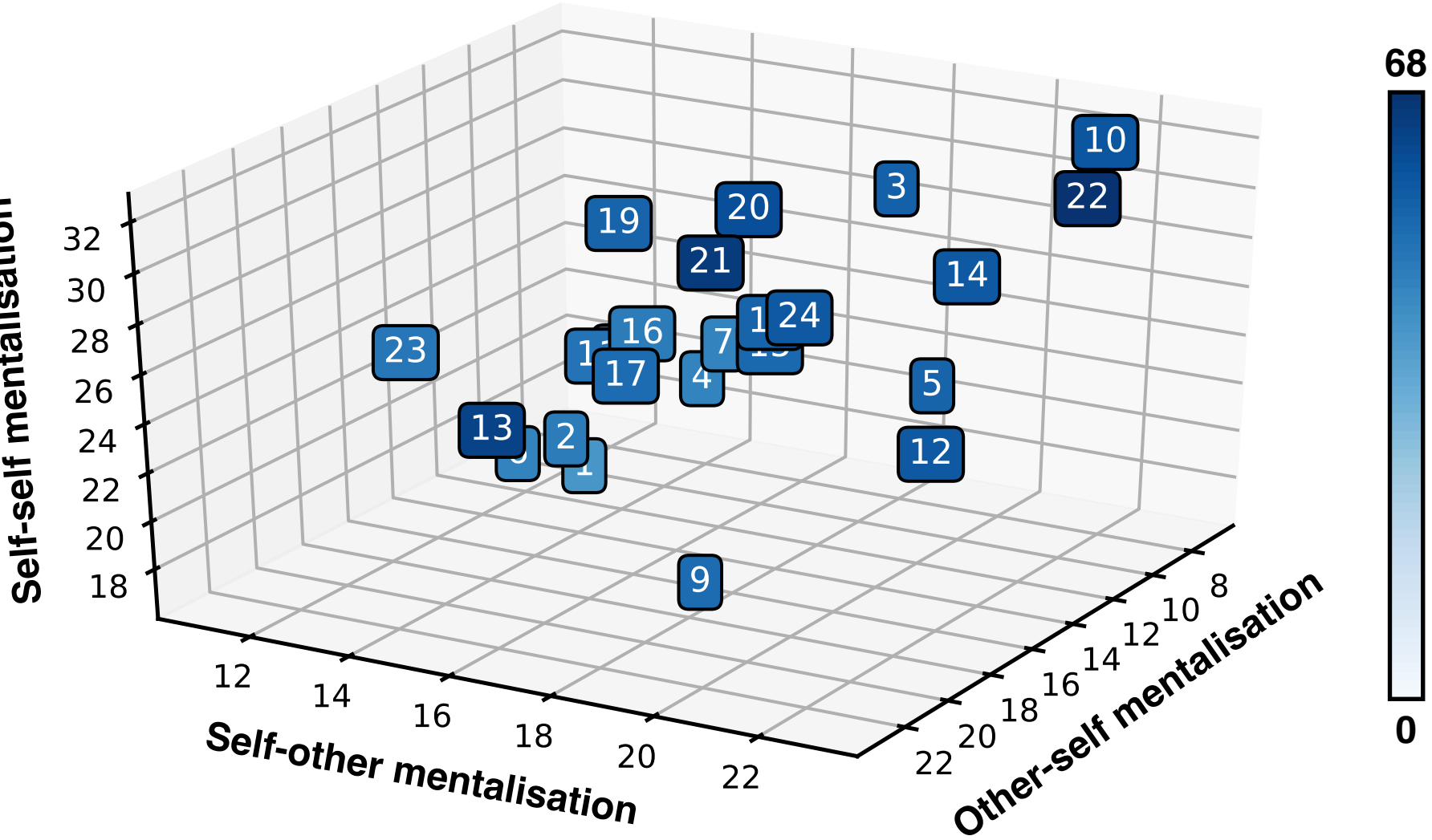
Left hippocampus





Right hippocampus

IMQ: Interactive mentalisation questionnaire [1, 2]



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*.

IMQ: Interactive mentalisation questionnaire [1, 2]

Different versions of IMQ are available at https://github.com/andlab-um/IMQ

IMQ (interactive mentalization questionnaire)

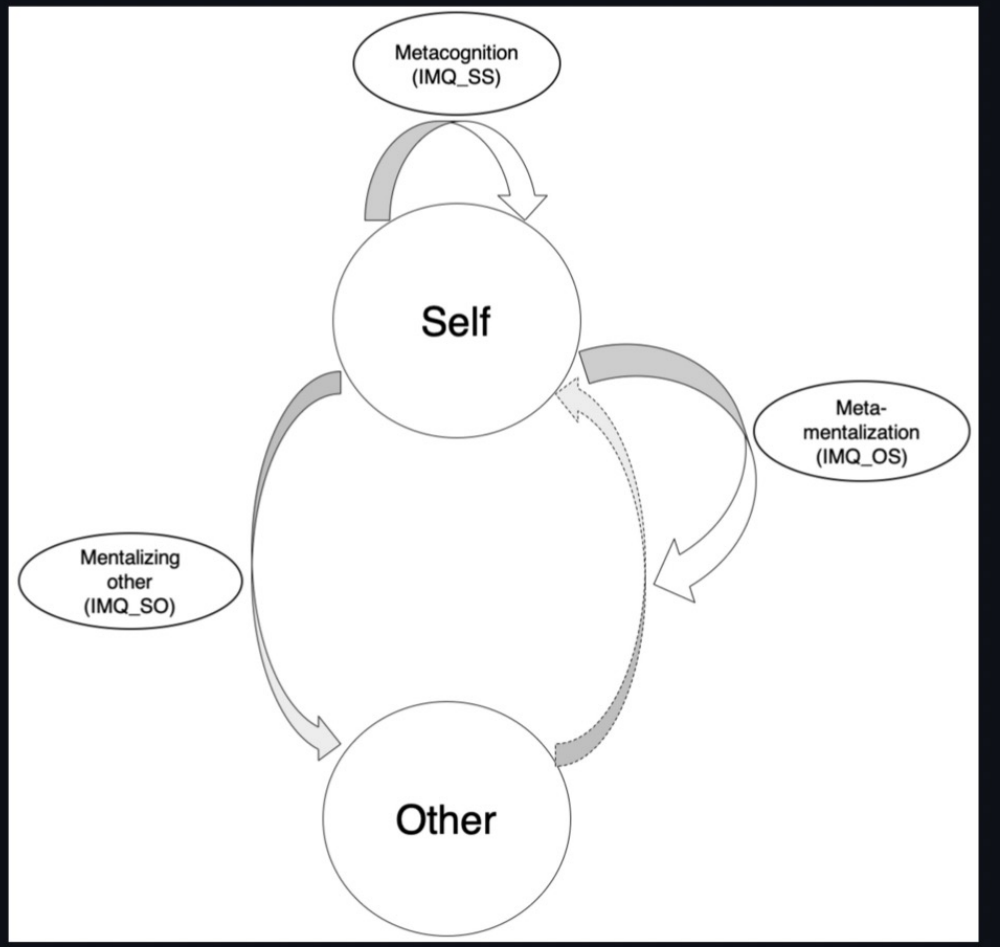
repo size 423 kB

DOI 10.3389/fpsyg.2021.791835

@ANDlab3 @lizhn7

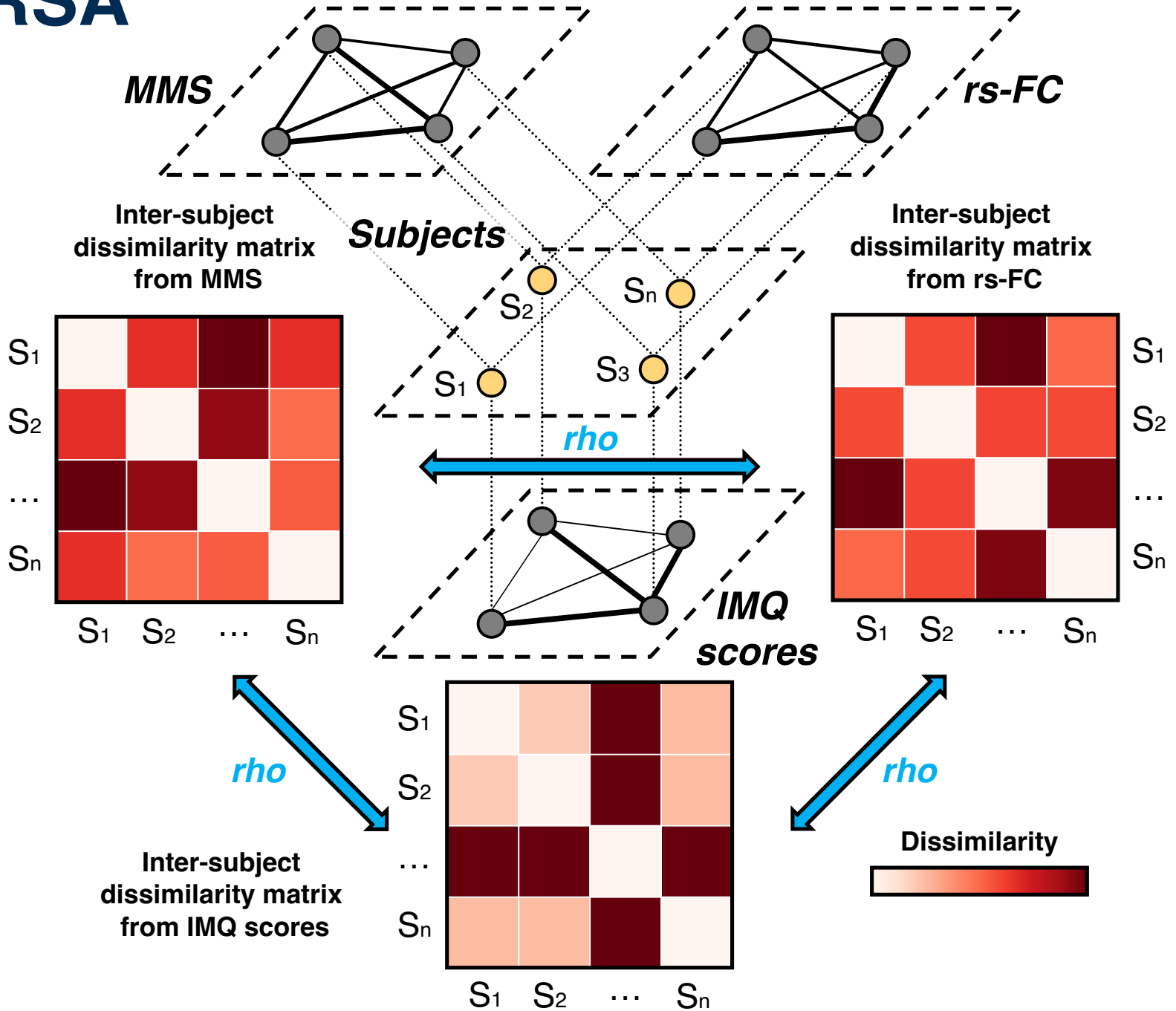
For different versions of IMQ:

Wu, H., Fung, B. J., & Mobbs, D. (2022). Mentalizing during social interaction: the development and validation of the interactive mentalizing questionnaire. *Frontiers in psychology*, *12*. DOI: 10.3389/fpsyg.2021.791835.



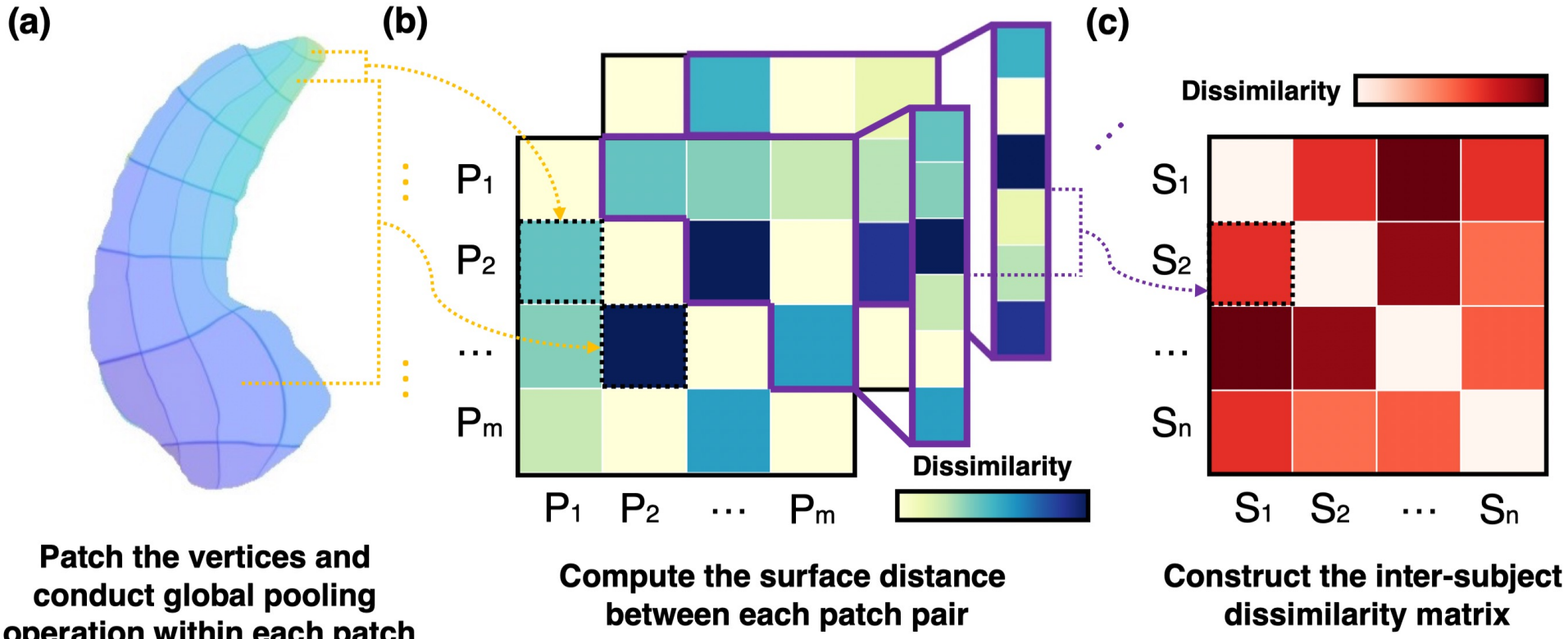
IS-RSA: Inter-subject representational similarity analysis

IS-RSA


MMS
rs-FC
Inter-subject dissimilarity matrix from MMS
Subjects
Inter-subject dissimilarity matrix from rs-FC
S1
S2
Sn
S3
rho
IMQ scores
S1 S2 … Sn
rho
rho
Inter-subject dissimilarity matrix from IMQ scores
Dissimilarity

CPP-SD: Computing patching and pooling operations-based surface distance

The pipeline of constructing inter-subject dissimilarity matrix (IDM) for hippocampal MMS data



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.

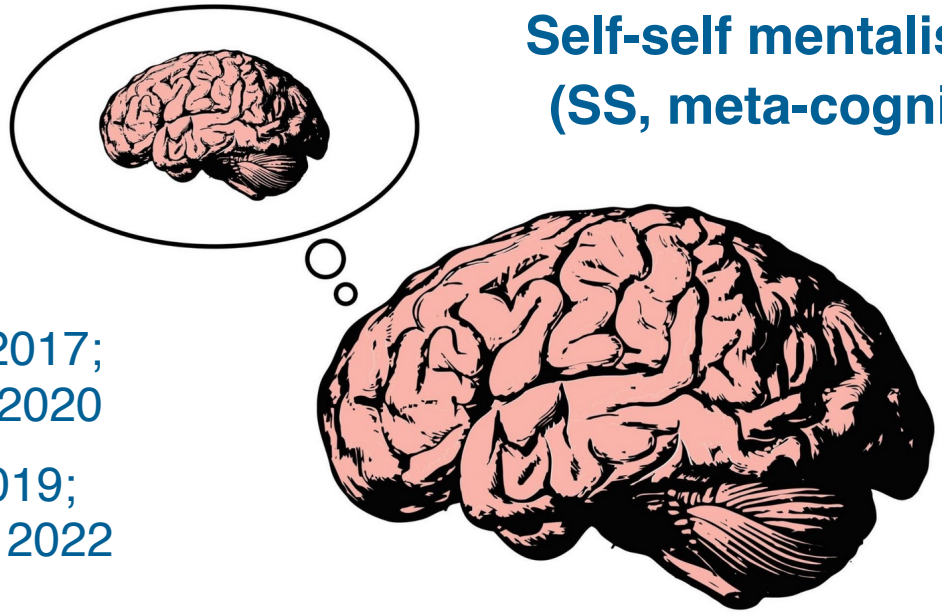
Hypothesis 1

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., 2017;
Alkan et al., 2020

Ye et al., 2019;
Zou & Kwok, 2022

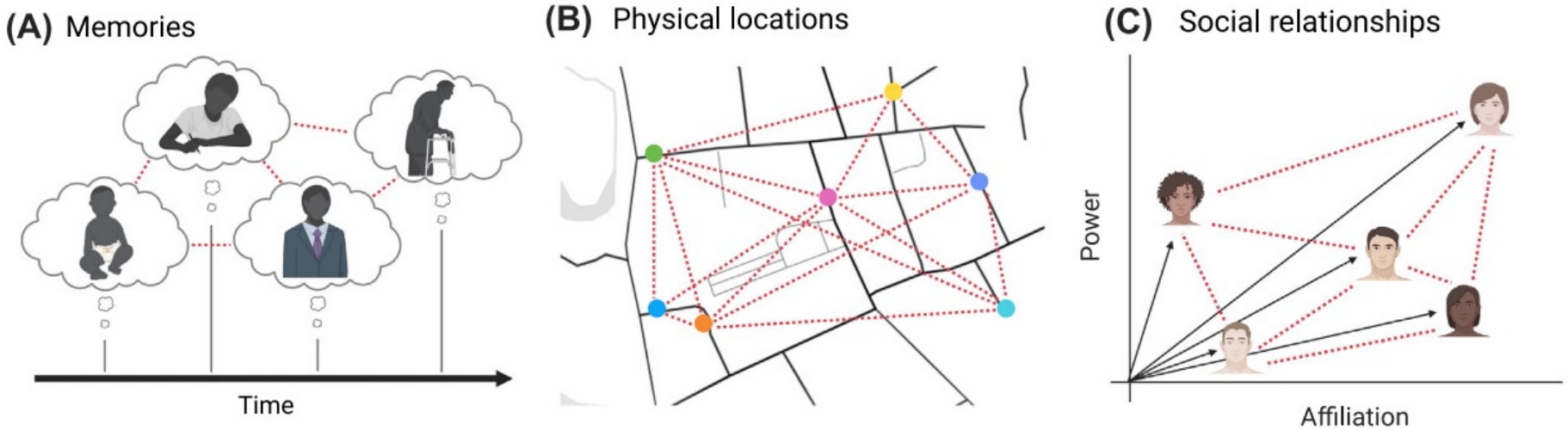
(Adapted from PriMed)

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, 1978; Rubin et al., 2014)



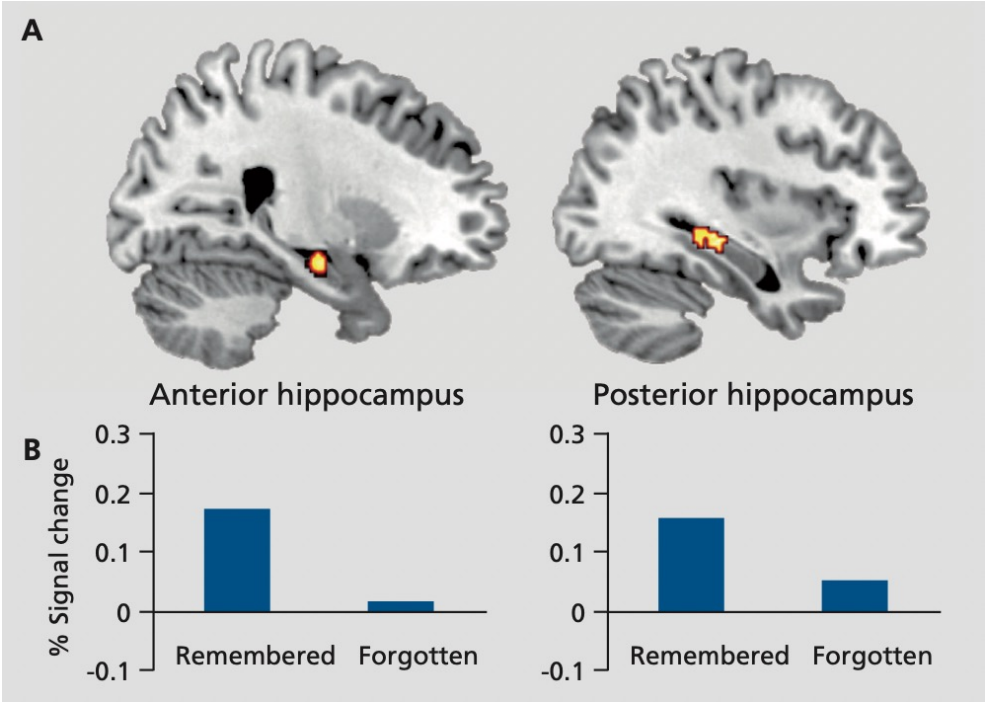
(Adapted from Banker et al., 2021)

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)

Constructive memory theory (Schacter, 2012)



Hippocampal responses to encoding simulations of future events

(Adapted from Schacter, 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., 2022

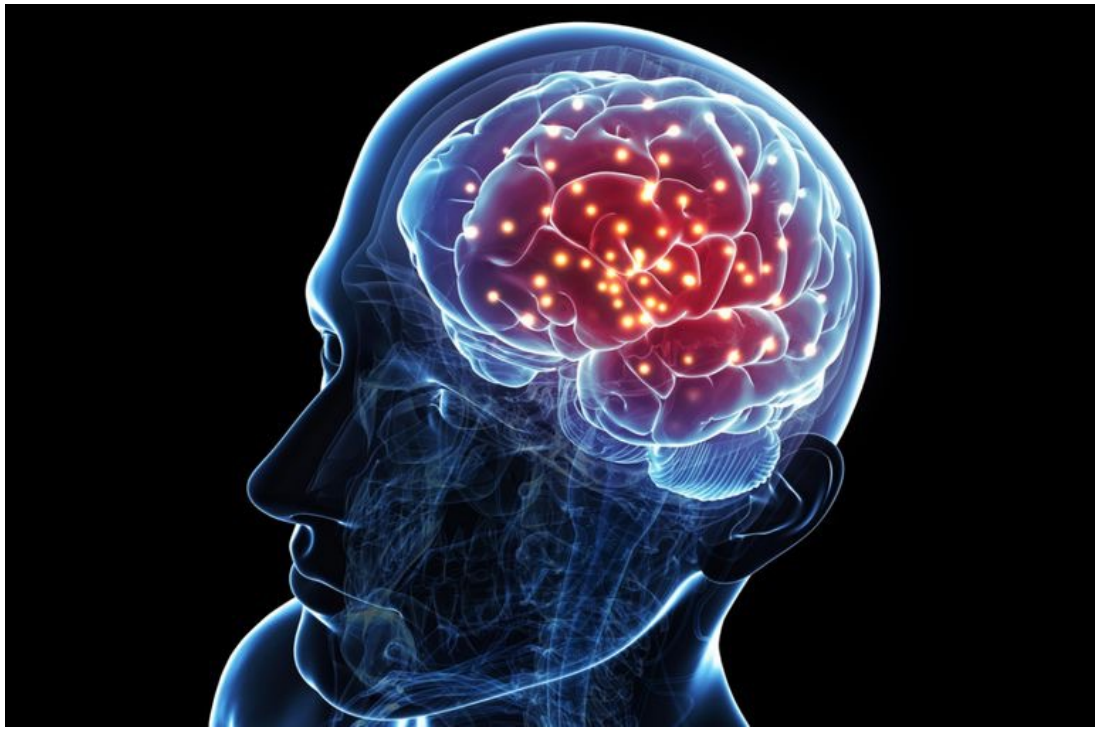
Koscik & Tranel, 2011; Haas et al., 2015; Santos et al., 2016; Eskander et al., 2020

(Adapted from Earth.com)

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.

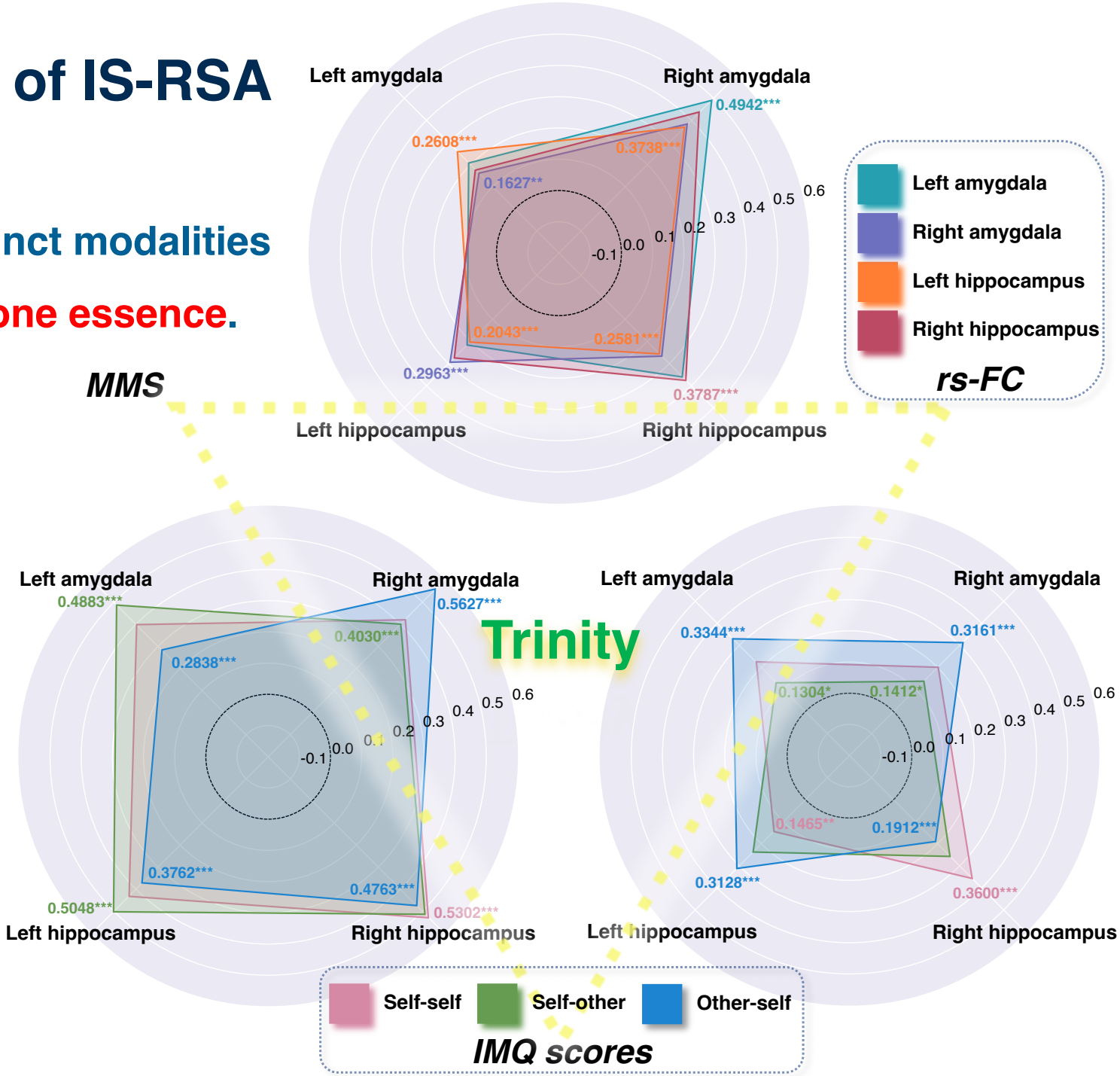


(Adapted from thoughtco.com)

Results of IS-RSA

Three distinct modalities

shared one essence.



Results of IS-RSA

A region-related mentalising specificity emerged from the trinity.

Comb.	*rho*	Mean (*95% CI*)	p_{FDR}
SS			
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***
RH	0.5302	0.5168 (0.5051-0.5284)	<.001***
SO			
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***
RH	0.5156	0.4766 (0.4657-0.4875)	<.001***
OS			
LA	0.2838	0.2890 (0.2801-0.2980)	<.001***
RA	0.5627	0.5153 (0.5051-0.5255)	<.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.

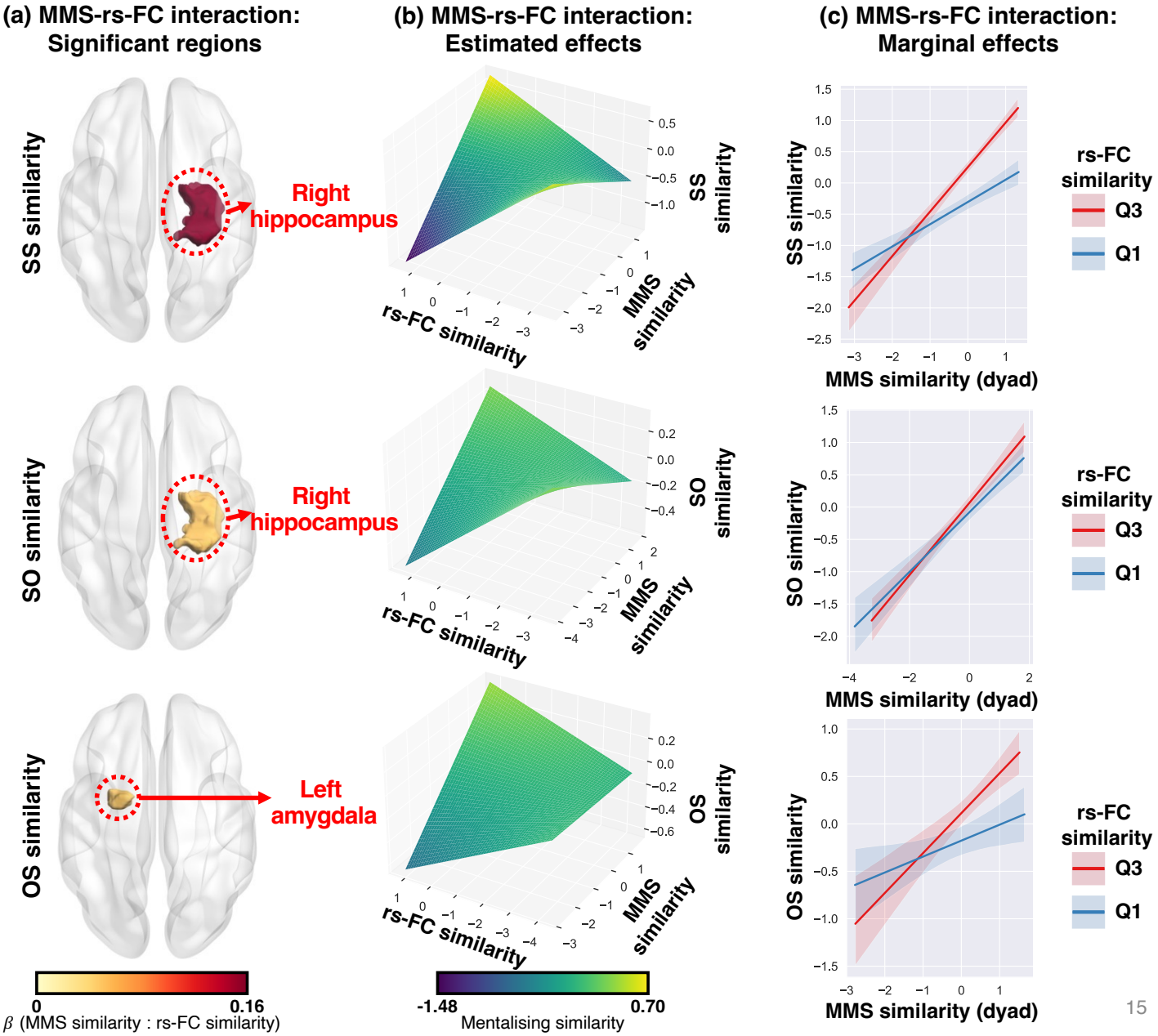
Comb.	*rho*	Mean (*95% CI*)	p_{FDR}
SS			
LA	0.2272	0.2094 (0.1995-0.2194)	<.001***
RA	0.2025	0.1747 (0.1668-0.1826)	<.001***
LH	0.1465	0.1256 (0.1162-0.1350)	.007**
RH	0.3600	0.3434 (0.3348-0.3520)	<.001***
SO			
LA	0.1304	0.1239 (0.1169-0.1310)	.016*
RA	0.1412	0.1359 (0.1266-0.1452)	.010*
LH	0.2383	0.2254 (0.2147-0.2360)	<.001***
RH	0.2580	0.2427 (0.2347-0.2508)	<.001***
OS			
LA	0.3344	0.3164 (0.3078-0.3250)	<.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 of dyadic regression analysis

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



Summary

1. **The current work defines an integrative trinity framework that provides a testable basis for understanding individual differences in brain morphometry, connectivity and mentalising ability.**

2. **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.**

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