The contribution of thalamic subdivisions to learning is linked to the inter-individual variability in memory performance

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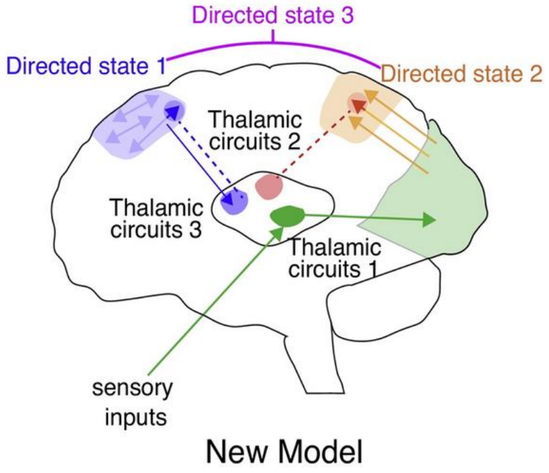
I Research Background - *The role of the thalamus in cognition*

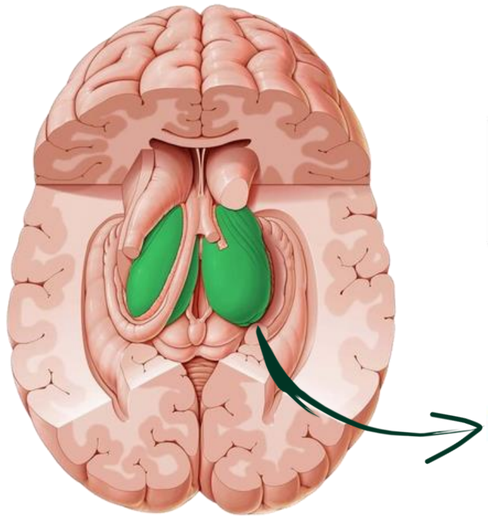
Thalamus actively regulates the information transmitted to cortical areas (Nakajima & Halassa, 2017; Nakajima et al., 2019; Ouhaz et al., 2018; Sherman, 2016)

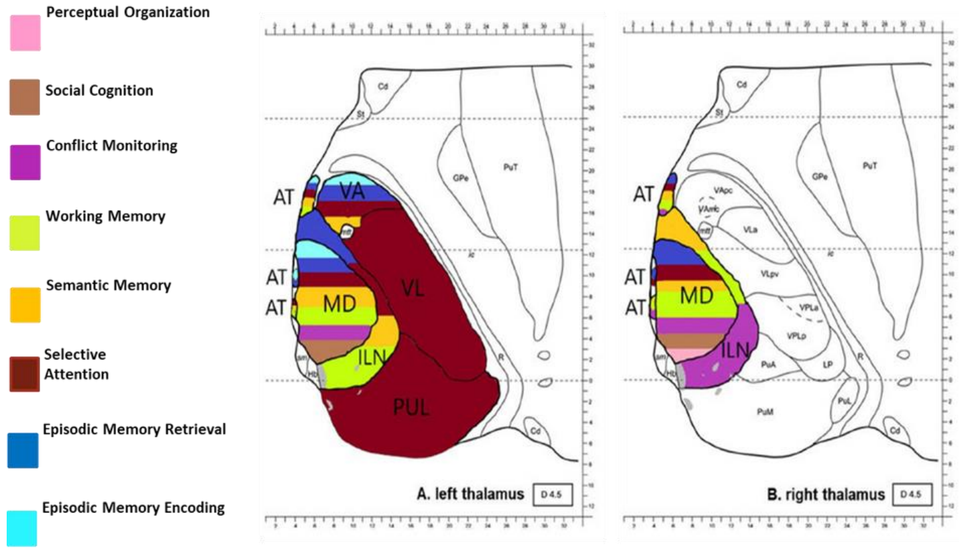
This regulation influences **cortical activity** (Purushothaman et al., 2012; Saalmann & Kastner, 2011; Theyel et al., 2010), and, in turn, impacts **behavioral changes** (Bradfield et al., 2013; Jankowski et al., 2013; Mitchell & Chakraborty, 2013).



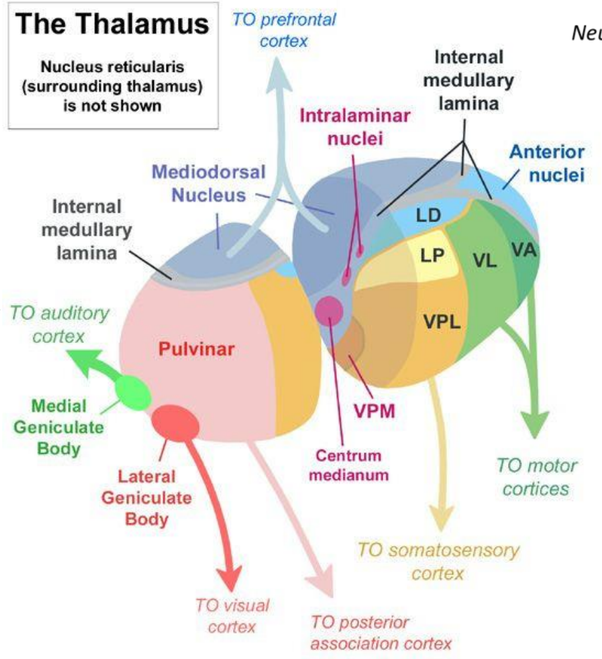
Nakajima & Halassa, 2017
Current opinion in Neurobiology

The diverse cytoarchitecture of thalamic nuclei implies that different thalamic nuclei may specialize in **distinct cognitive domains**, while others serve multiple cognitive processes





Antonucci, Penzel, et al., 2021
Neuroscience and Biobehavioural Reviews

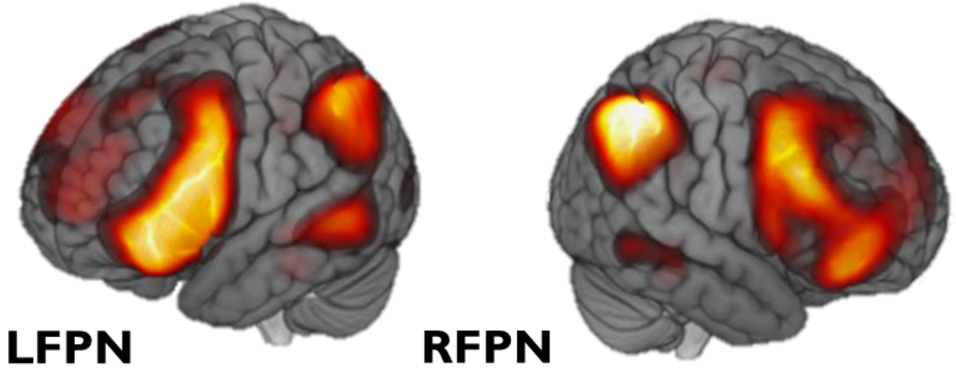


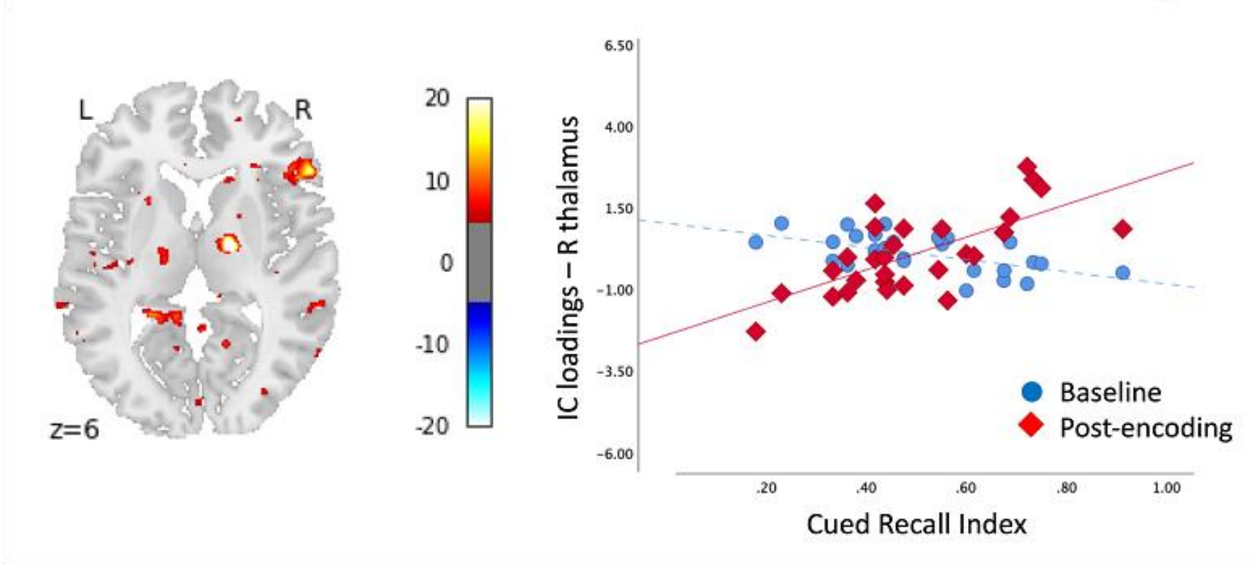
Research Background - *Thalamic functional connectivity and memory*

Recent studies have shown **thalamic functional connectivity (FC) flexibility with a fronto-parietal network** across baseline and post-encoding resting-state (Passiatore et al., 2021)

Thalamic FC with the right fronto-parietal network varied across sessions as a function of **individual memory performance**, with the **medial subdivision** preferentially engaged during the **baseline**, while shifting in the opposite direction after the memory task

The medial subdivision may improve **cortical network efficiency** during **highly demanding cognitive tasks**, possibly by **regulating cognition-related activity in the fronto-parietal network** (Antonucci et al., 2021; Halassa & Sherman, 2019; Mitchell, 2015; Pergola et al., 2018).





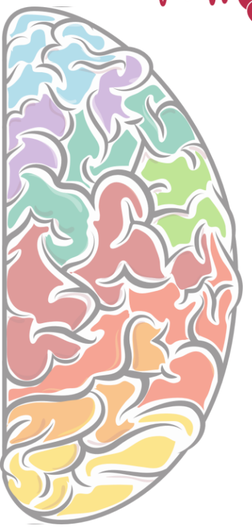
Individual spatial map in which right thalamus shows variations in FC between pre- and post-encoding resting state (Passiatore et al., 2021)

Each individual is unique in their learning process

Core hypothesis

Considering the multitude of thalamocortical connections observed across thalamic nuclei

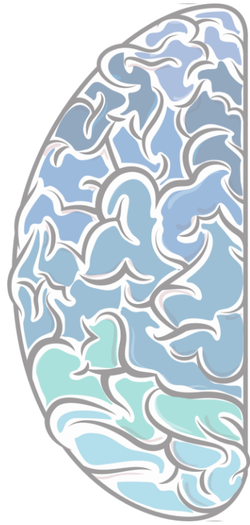
Inter-individual variation of the thalamic recruitment within cortical brain networks



Identifying **individual differences in corticothalamic recruitment** by assessing individual thalamic involvement within cortical networks before and after a memory task

Understanding **how individual thalamocortical patterns relate to learning success** through their association with **memory performance** measures

Determining **how the neural activity during memory task performance mediates thalamocortical configurations** during post-encoding resting state



- **Participants**

- **Discovery sample:** 29 heatlhy adults from Ruhr-Universität Bochum (RUB)
- **Replication sample:** 40 healthy adults from University of Bari Aldo Moro (UNIBA)
- **Indipendent sample:** 74 healthy adults from University of Bari Aldo Moro (UNIBA)

Sample	Age mean±SD (range)	Gender ratio (M:F)	HANDEDNESS mean±SD
Bochum N=29	26 ± 3 (22-29) years	9:20	0.8 ± 0.11
UNIBA – R N=40	27 ± 8 (19-61) years	17:23	0.6 ± 0.41
UNIBA – S N=74	29 ± 8 (18-59) years	37:37	0.6 ± 0.39

- **Experiment Design**

Multi-session fMRI

Resting state sessions preceeding and following an **episodic memory task**

- **Scanning protocols**

RUB

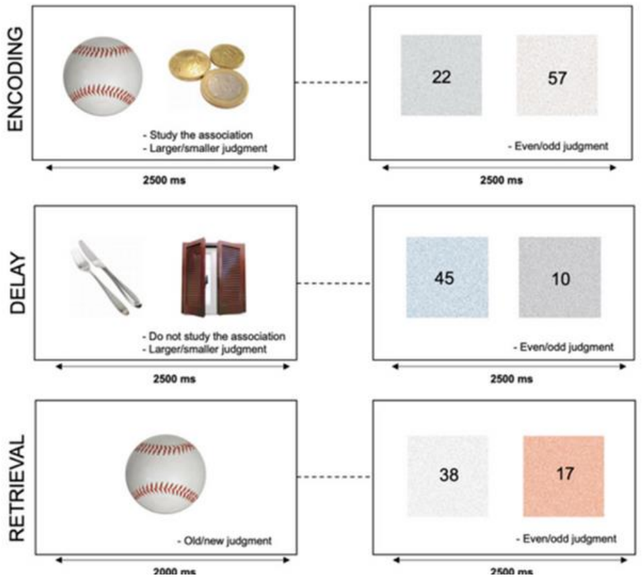
- T1 0.83x0.83x0.9 mm
- Resting state fMRI 1.44x1.44x3.2 mm
- Task fMRI 1.5x1.5x2mm

UNIBA

- T1 1x1x1 mm
- Resting state fMRI 3x3x3 mm
- Task fMRI 3x3x3x3.6 mm

- **fMRI episodic memory task**

RUB



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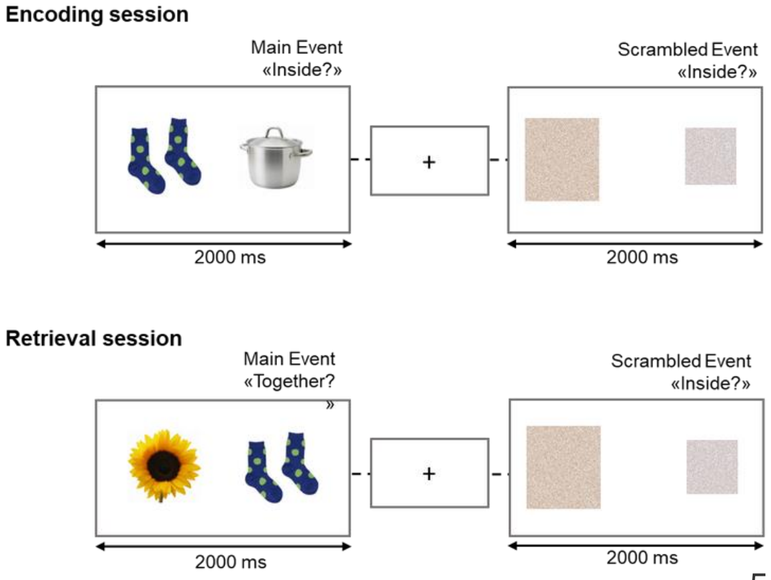
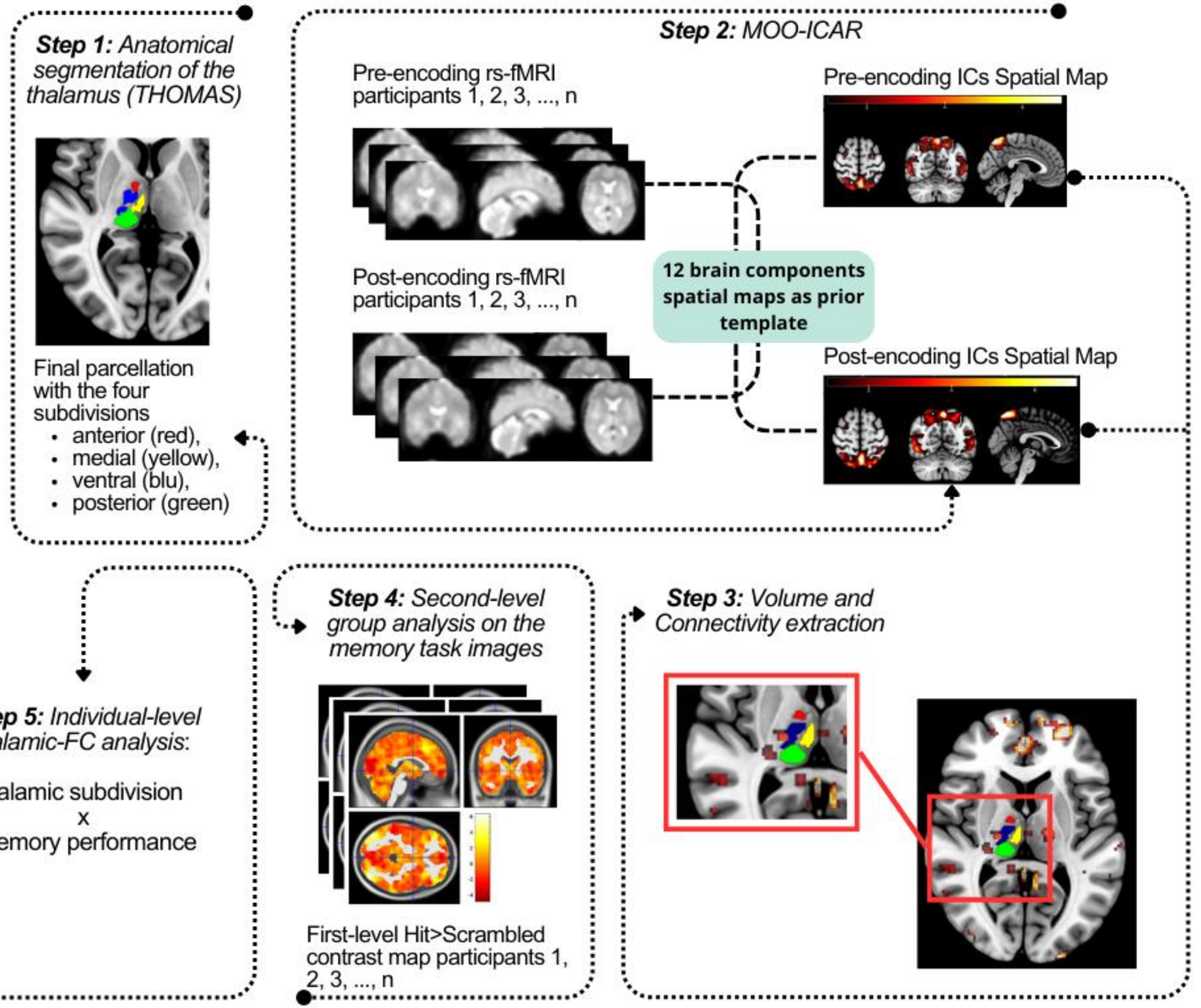
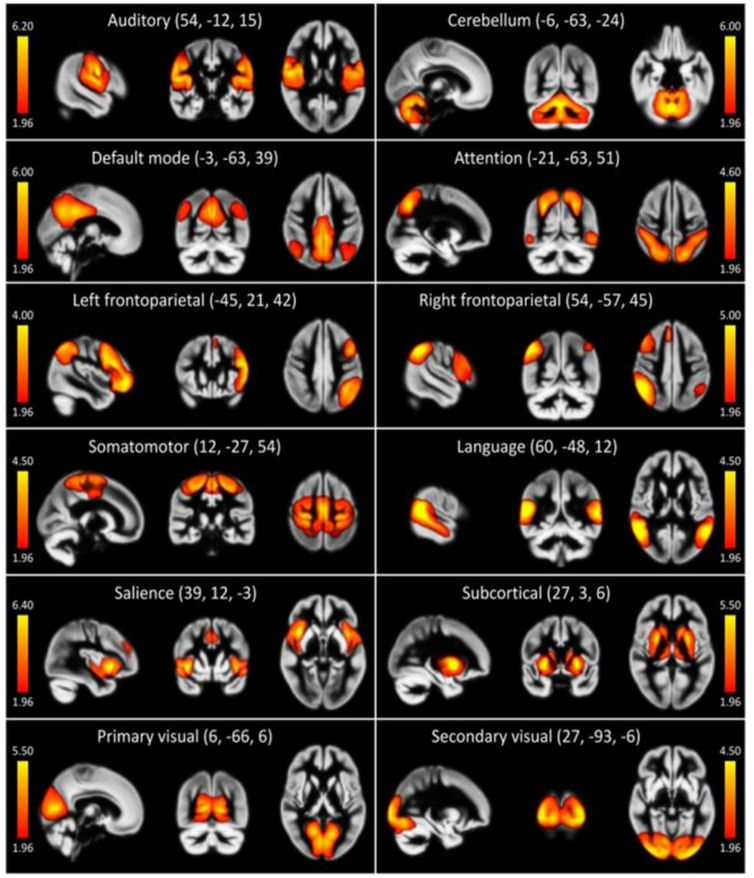






Iraji et al., 2019 *Human Brain Mapping*

IV Results - *Interindividual variability in thalamocortical recruitment*

medial subdivision

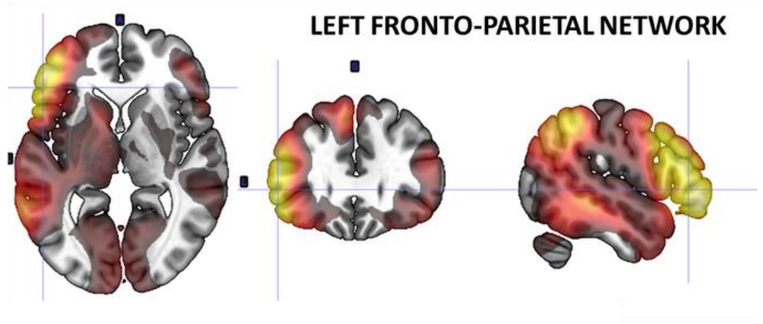
BASELINE - RUB

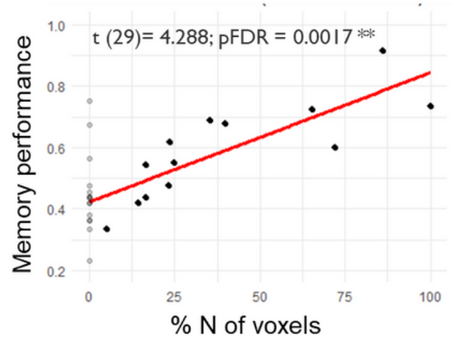
UNIBA-R

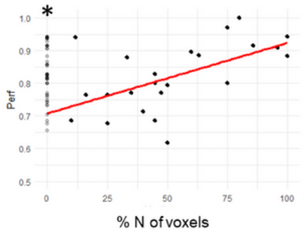
UNIBA-S

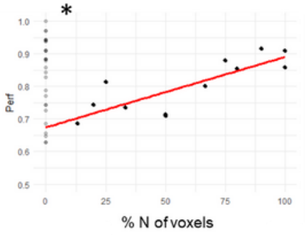
POST-ENCODING

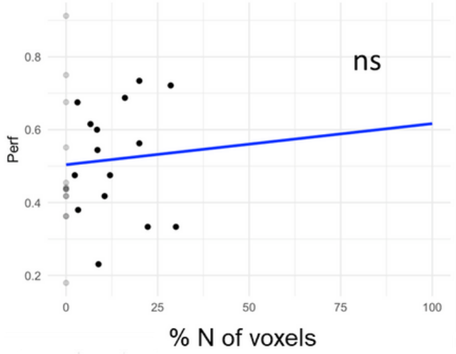
LEFT FRONTO-PARIETAL NETWORK



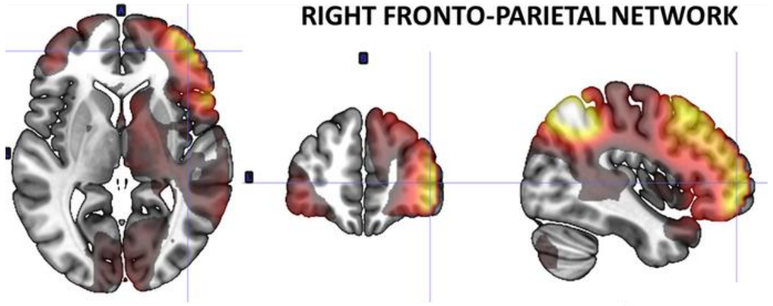


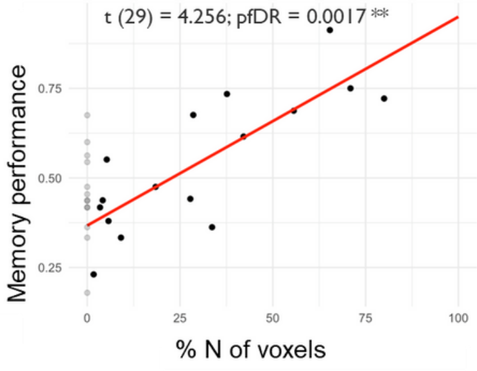


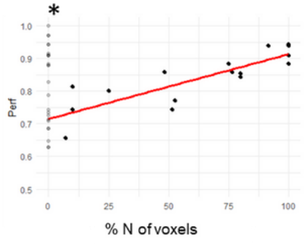


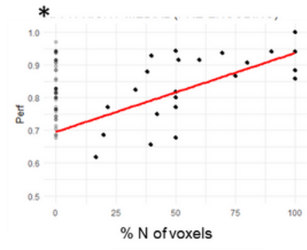


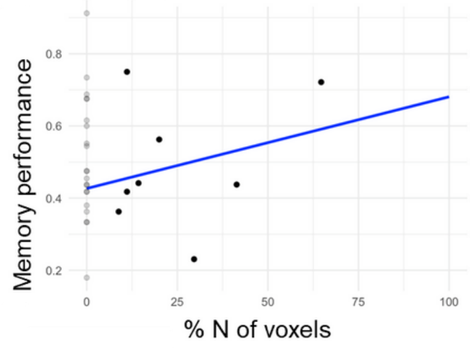
RIGHT FRONTO-PARIETAL NETWORK



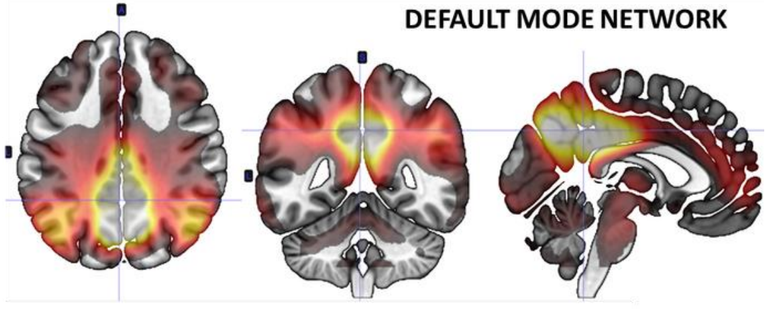


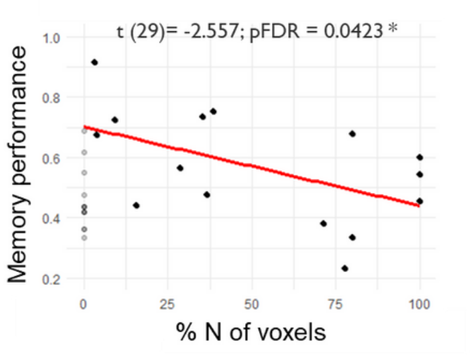


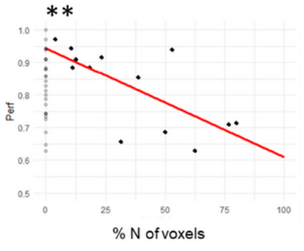


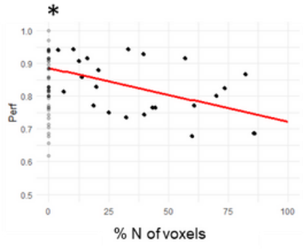


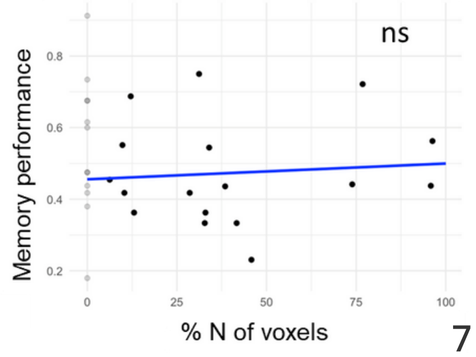
DEFAULT MODE NETWORK









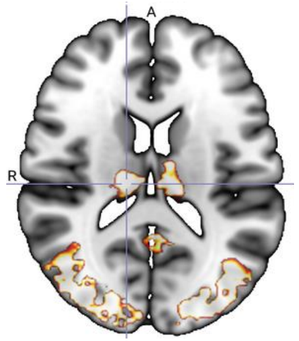


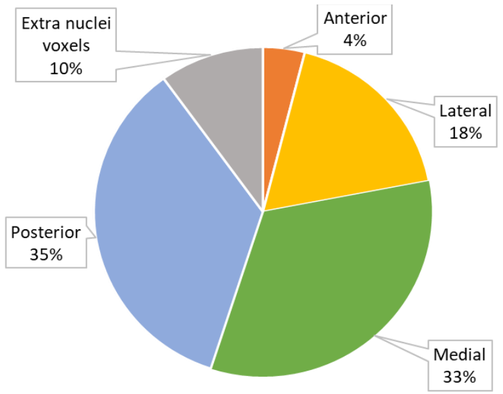
IV Results - *Thalamic involvement across memory stages and mediation of the task activity on thalamocortical configurations during post-encoding resting state*

ENCODING TASK ACTIVITY

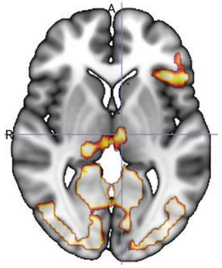
Thalamic involvement during task performance activity overlapped mainly with the **posterior subdivision**

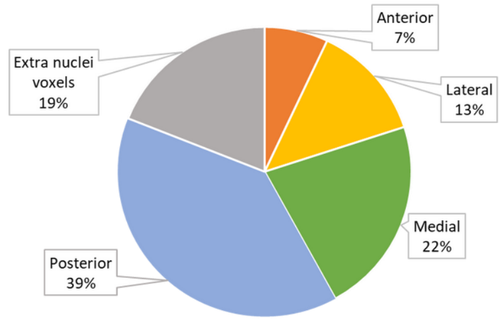
BASELINE - RUB



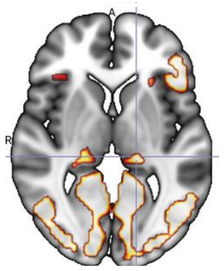


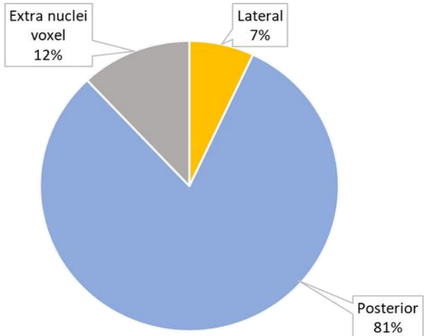
UNIBA-R



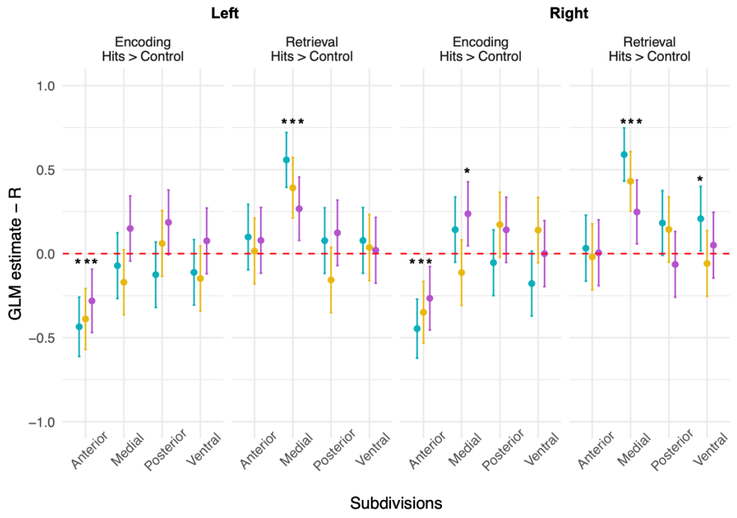


UNIBA-S





TASK ACTIVITY AFFECTS FUNCTIONAL CONFIGURATION AND PERFORMANCE

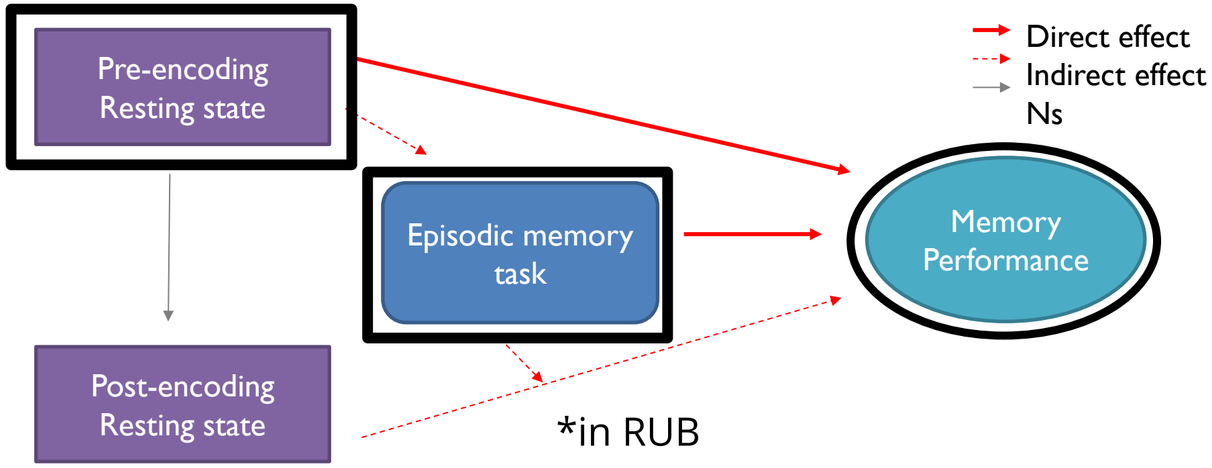


Encoding: Anterior subdivision

Samples
- RUB
- UNIBA–R
- UNIBA–S

Retrieval: Medial subdivision

MEDIATION AND MODERATION EFFECTS



V Conclusion & Discussion

Cortical network changes before and after task execution are associated with memory performance → **Thalamocortical functional connectivity changes as function of memory performance**

Group-level analysis may not always provide insights into the regulation of specific thalamic nuclei and cortical activity supporting learning processes → **Individual-level analysis can reveal differences in thalamic recruitment between the best performers and those with poorer performance**

Different thalamo-cortical circuits differentially support individual memory performance, with the **medial dorsal nucleus** possibly playing a **prominent role** within the **FPNs and DMN**, with a specific function in **learning preparation** → **Individuals with a certain brain functional asset at the pre-encoding resting state perform better or worse in information retention**

Indirect effect of **deactivation of the anterior subdivision** during **encoding** and **activation of the medial subdivision** itself during **retrieval** outlines the dynamic interplay of thalamocortical recruitment during different phases of learning → **Crucial role of the anterior and medial subdivisions during memory task execution in influencing subsequent brain functional configuration during post-encoding resting state**

The identification of distinct connectivity patterns can help establish a baseline for **understanding the physiological functioning** of the brain in healthy individuals and shed light on its relevance to **clinical conditions.**

VI Aknowledgements

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Thank you for listening!

PRESENTED BY
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