# What is the role of the human thalamus? Insights from functional neuroimaging.

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Symposium

In this symposium, we will highlight recent advances in the imaging of the thalamus that elucidate its central role in driving/determining whole brain activity and connectivity, both at rest and on task. Our diverse group of expert speakers will summarize work incorporating studies from an array of sub-fields, including functional MRI, electrophysiology, network analysis, neuroanatomy, computational modeling, neuropsychology, cognition, and non-human animal models. Attendees will receive an up-to-date snap-shot of cutting edge initiatives in the imaging of the thalamus and its interactions with the rest of the brain, along with an appreciation of a number of open-questions that form the basis of ongoing work and inspire future studies.

## Objective

* Participants will develop a strong foundational understanding of the functional neuroanatomy of the thalamus, and also of it's many connections to other cortical and subcortical systems.
* Participants will learn the challenges and benefits of neuroimaging the thalamus using a variety of different neuroimaging techniques and analysis methods, including structural and functional MRI, as well as electrophysiology.
* Participants will receive an update on a rapidly-developing field, along with insights into key open questions and issues relating to corticothalamic imaging.

## Target Audience

Presentations will be aimed towards graduate students and post-docs, although interested scientists from all stages will likely benefit from the blend of functional neuroanatomy, advanced neuroimaging and cognitive neuroscience techniques employed by the four speakers.

# Presentations

## The role of the thalamus in shaping whole-brain functional connectivity

In this talk, I will provide an overview of the functional neuroanatomy of the thalamus. I will review a diverse neuroanatomical literature to highlight the cytoarchitectonic organization of the thalamus, along with its intrinsic and extrinsic patterns of connectivity. I will highlight key hypothetical frameworks that have demonstrated the relevance of thalamic activity and connectivity to a wide-range of different behaviours, including perception, attention, movement, decision-making and affect. Finally, I will highlight recent neuroimaging and modeling work that has helped to clarify the relationship between the thalamus and whole-brain functional modes. Overall, an appreciation of how this highly conserved structure may constrain and augment functional processing in the cortex will aid in the interpretation of whole-brain imaging and large-scale modeling of the human brain.

### Presenter

*James Shine*, The University of Sydney
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## When the thalamus fluctuates, the brain integrates

The study of moment-to-moment brain signal variability continues to gain momentum in cognitive neuroscience, often revealing that higher variability is typical of better performing adults. Although such temporal variability exists at every level of neural organization, several recent lines of work support the emergence of the thalamus as a key region for understanding temporal variability in the brain. First, inspired by animal work demonstrating that "local" temporal variability may reflect synaptic input rather than locally-generated noise, we used publicly-available high-temporal-resolution resting-state fMRI data to show that individuals (N=100 adults) with higher local temporal variability indeed had a more integrated (lower dimensional) network fingerprint, with temporal variability in the thalamus providing the strongest prediction of whole-brain network integration. Second, although our past work has shown that dopamine may be a crucial neurotransmitter enabling modulation of brain signal variability under cognitive load, we know little of how dopamine confers variability-based advantages for brain function at local or network levels, and how it may relate to the central role of the thalamus. Using data from the COgnition, BRain, and Aging (COBRA) study (dopamine D2 binding (PET), fMRI during n-back; N = 162, 64-68 yrs), we show that greater working memory load-related increases in BOLD signal variability within regions of the striato-thalamic system reflect: (1) elevated dopamine, (2) faster working memory performance, and (3) heightened load-related striato-thalamic functional integration. We further show that striato-thalamic functional integration accounted for load-related shifts in BOLD variability in all other networks examined. Overall, our work supports the increasingly central role of the thalamus for understanding how/why the brain fluctuates and communicates across moments, both at rest and on task.

### Presenter

*Douglas Garrett*, Max Planck UCL Centre for Computational Psychiatry and Ageing Research Berlin, Germany
Germany

## Network properties and cognitive functions of the human thalamus

In a series of studies, we examined how network properties of the human thalamocortical system constrain behavior and cognition. We first conducted graph-theoretic analyses on thalamocortical functional connectivity and found that many thalamic subdivisions display strong “hub” like connectivity with multiple cortical networks, suggesting an involvement in global, integrative, and diverse cognitive functions. This result predicts that damage to the thalamus can impair cognitive functions depending on the lesion site’s connectivity profile. We tested this prediction in 21 patients with focal thalamic lesions and 61 patients from a lesion comparison group, both received comprehensive neuropsychological tests. We found that deficits in executive and memory functions can be accurately predicted by thalamic lesion location, and patients with lesions to thalamic hubs exhibit global, unspecific deficits across multiple domains. Finally, we compared the task-evoked structure of thalamocortical functional connectivity across multiple task states, and found pronounced task-specific patterns deviating from a task-general pattern, which was significantly different from the resting-state. Altogether, this converging evidence suggests that the human thalamus plays a broad role in cognition and contributes to multiple specific functions through its distinctive connectivity profile.

### Presenter

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## Thalamic control of arousal states and large-scale cortical dynamics

The thalamus plays a key role in coordinating and synchronizing oscillatory dynamics across large-scale brain networks. These dynamics modulate cognition and behavior, and are transformed across states of sleep and wakefulness. We aimed to understand how thalamic activity modulates cortical network function and arousal. Using optogenetic experiments in mice, we found that a specific nucleus of the thalamus can control local and global arousal states in cortical brain networks, and thereby modulates sleep. In human multimodal neuroimaging studies, we then identified how activity in the thalamus shifts across a spectrum of sleep and wake states, and how these dynamics are coordinated with the cortex. Together, this work demonstrates how the thalamus can modulate and control local and global dynamics in cortical networks across arousal states, with profound effects on awareness and behavior.

### Presenter

*Laura Lewis*, Boston University Boston, MA
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