A neural model of conscious mental imagery and aphantasia

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2026.02

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Mind's eye: "Mental imagery" refers to representations […] of sensory information without a direct external stimulus.

Kossyln et al., 2006

Please imagine an apple…

"vivid"
"blurred"
"perceptual-like"

"Sorry, I don't visualise it"

"Couldn't there be people who could describe a person's features in minute detail from memory […] but who would empathically deny seeing it, […] and people who would find the expression "**I see him before me**" totally inappropriate?"

(Aphantasia and the language of imagination : A Wittgensteinian exploration. Fox-Muraton, 2021)

Is mental imagery a language-game?

Congenital aphantasia

Galton,1880; Zeman et al., 2015; Zeman, 2024
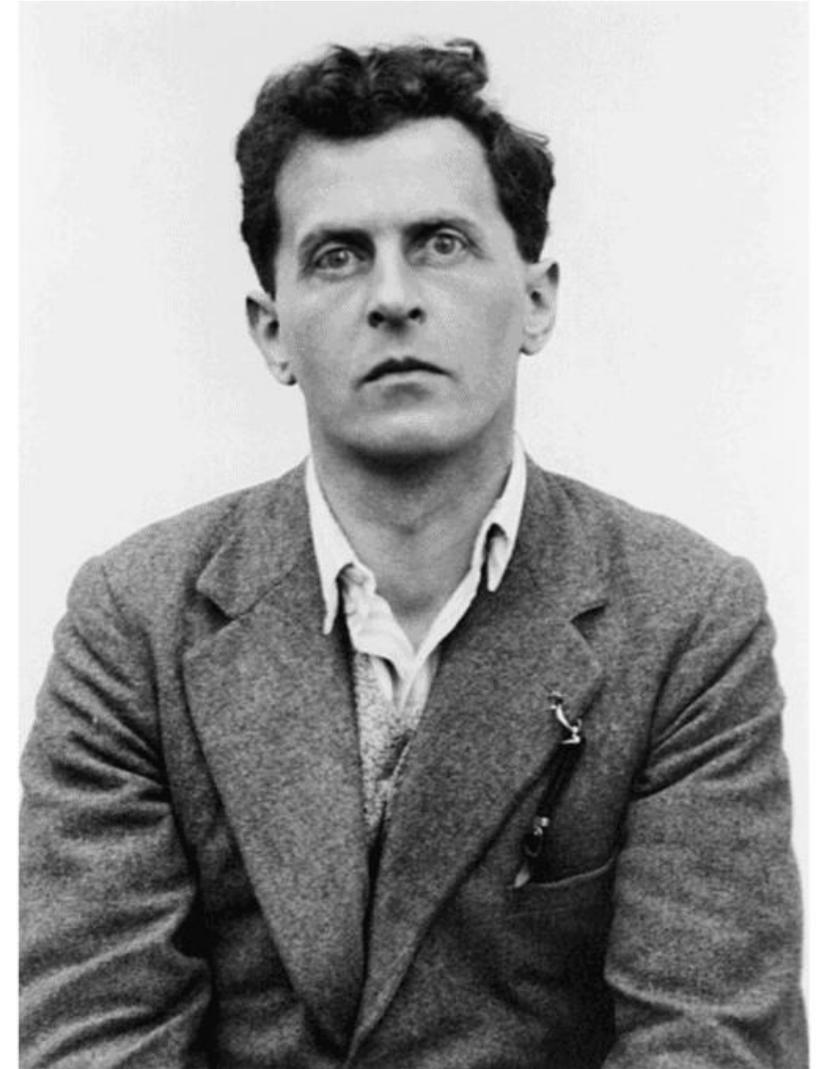
Wittgenstein
(1889-1951)

Introduction: Impaired imagery experience in patients

Lesion-based aphantasia: domain-general or domain-specific loss of visual imagery

Monsieur X

Salpêtrière hospital, Paris
(Charcot and Bernard case, 1883)

"occipital damage is neither necessary nor sufficient to produce imagery deficits. On the other hand, extensive left temporal damage often accompanies imagery deficits for object form or color."
(Bartolomeo, *Cortex*, 2002)

"examination of the lesion sites in this subset of patients implicated a region in the posterior left hemispheres as critical for the image generation process."
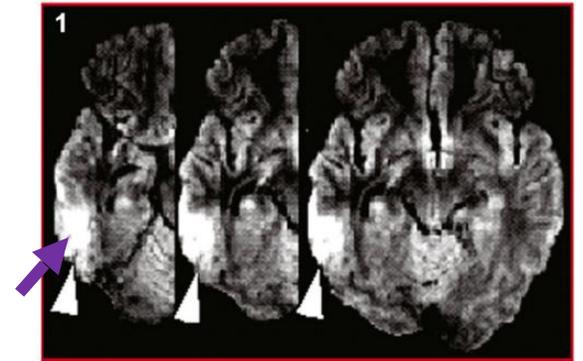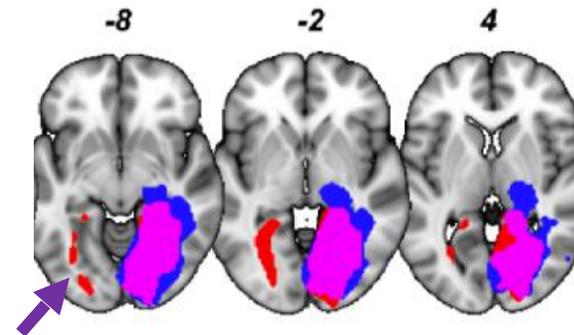(Farah, *Cognition*, 1984)

"Single case studies demonstrate that there are at least five kinds of visual entities whose imagery can be affected independently from each other: shapes of objects, colours of objects, faces, letters and spatial relationships."
(Goldenberg, *Baillieres Clin Neurol.*, 1993)

(Thorudottir et al, *Brain Sci.*, 2020; Moro et al, *Cortex*, 2008)

Neural models of visual mental imagery

Imagery generation as "**vision in reverse**"
1. Initiation of imagery by PFC
2. Retrieval of semantic and episodic information
3. Reactivation of sensory cortices
(Pearson, 2019)

- **Primary visual cortex**: vividness correlated with BOLD signal, decoding, structural volume…(the imagery debate, Kossyln et al., 2006; Cui et al., 2007; Albers et al., 2013; Pearson et al., 2015)
- but see Bartolomeo et al. 2020 (damage to V1, still vivid images)

- **High-level visual cortex**
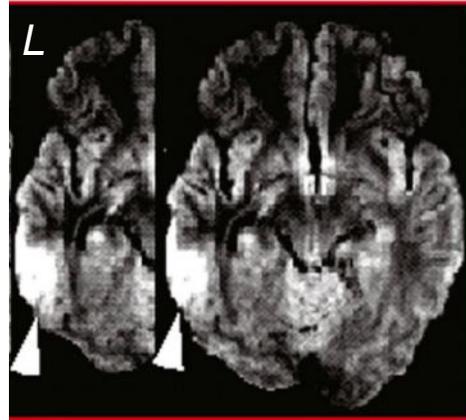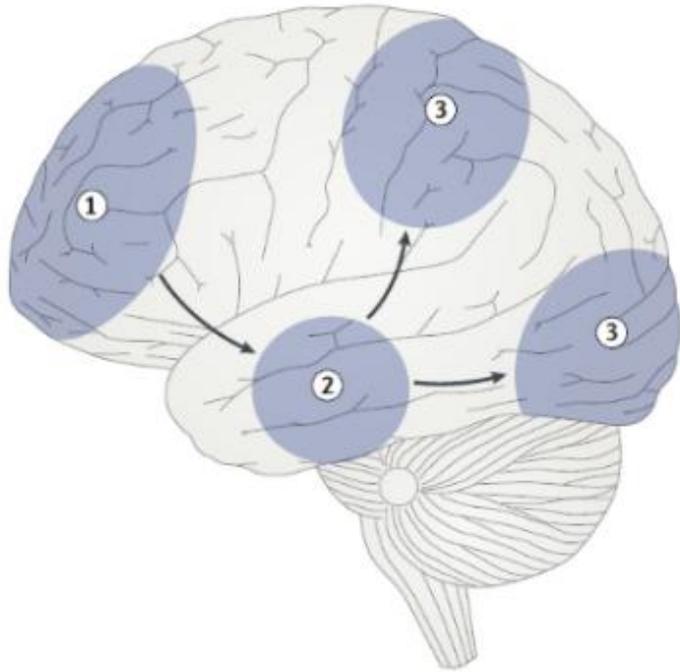
Stroke patients with imagery loss (Moro et al., 2008; Thorudottir et al., 2020)
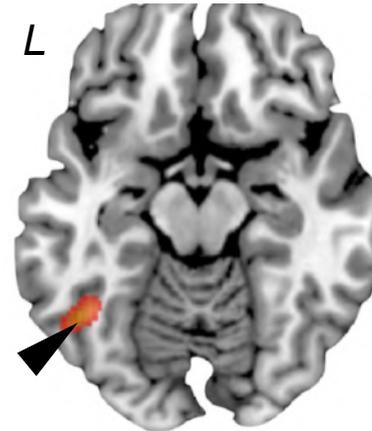
fMRI meta-analysis of 27 studies **Fusiform Imagery Node (FIN)** (Spagna et al., 2021; Bartolomeo et al., 2026)
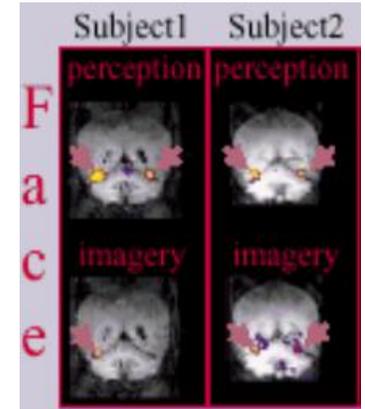
Domain-preferring regions faces, words..(Goldenberg,1993; Bartolomeo, 2002; O'Craven & Kanwisher, 2000)

- Left-hemisphere laterality for voluntary mental imagery (see review, Liu et al., 2022, BSF)
- Patients with brain lesions: errors on specific imagery tasks; no measures of vividness
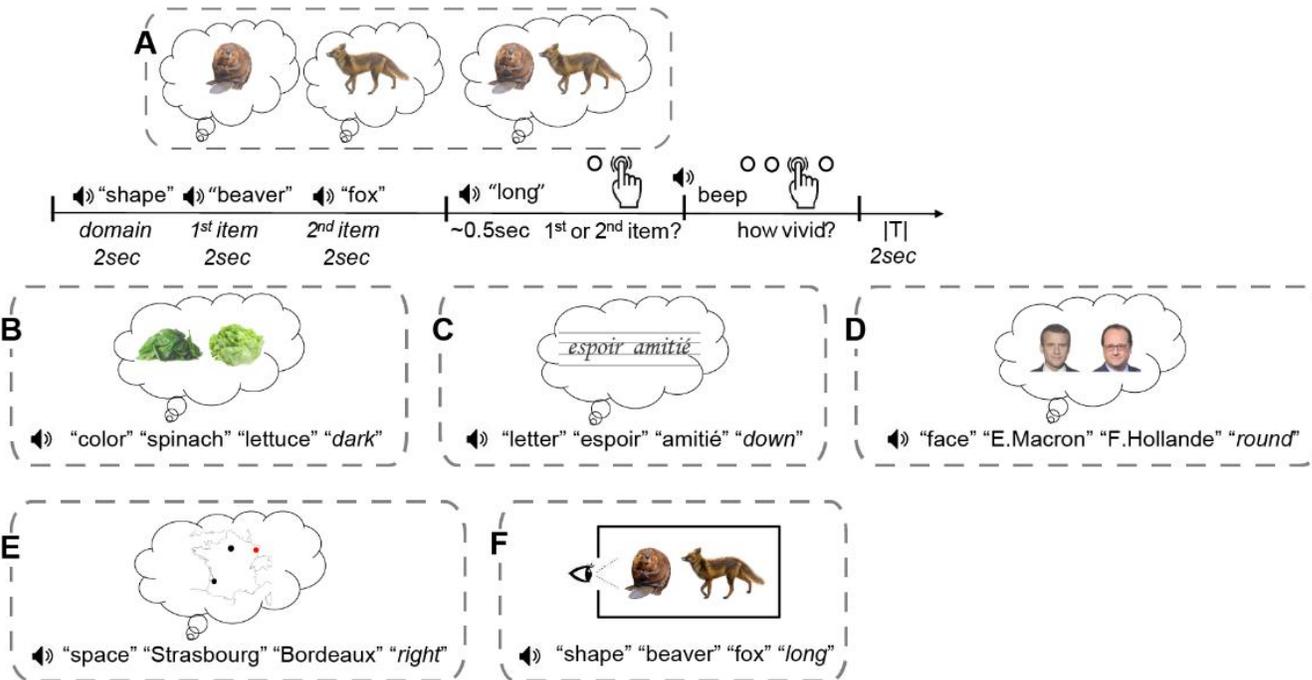
Hypothesis: a domain-general & domain-preferring mechanism for high-level visual cortex?
- Does the FIN exist? If yes, what's its functional properties?
- **How does these regions account for the vividness of imagery (i.e., absence in aphantasia)**
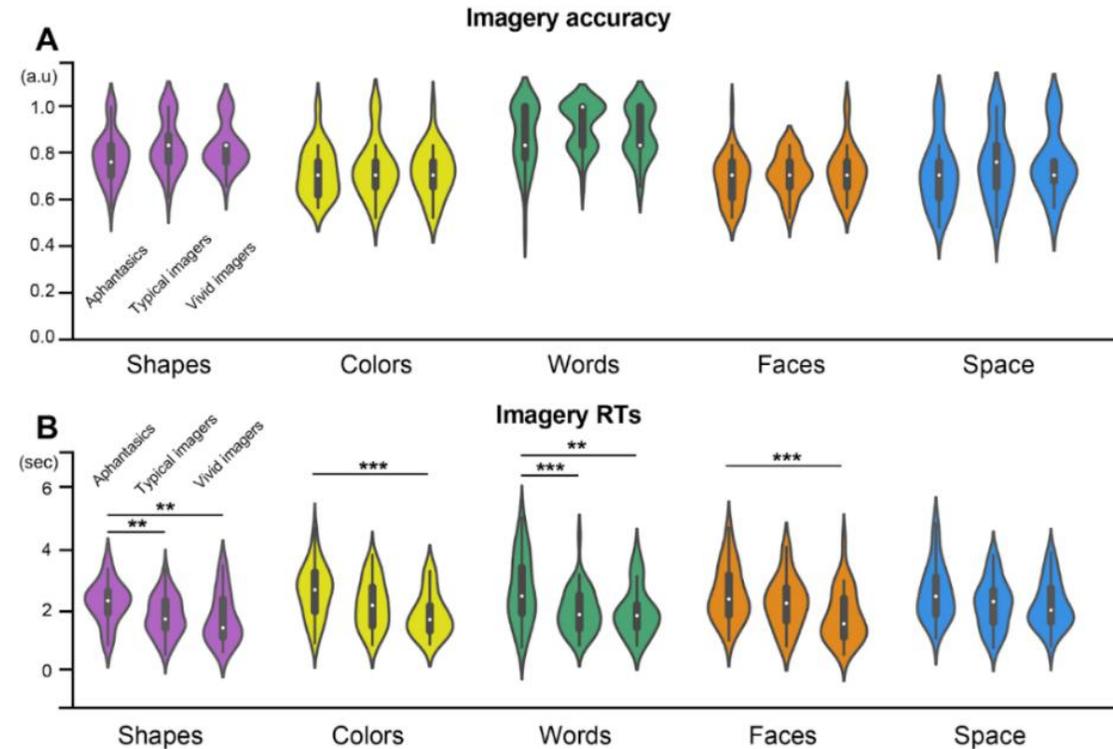
Testing imagery of distinct domains

Across five domains

« Imagine a beaver and a fox, which one is longer? »

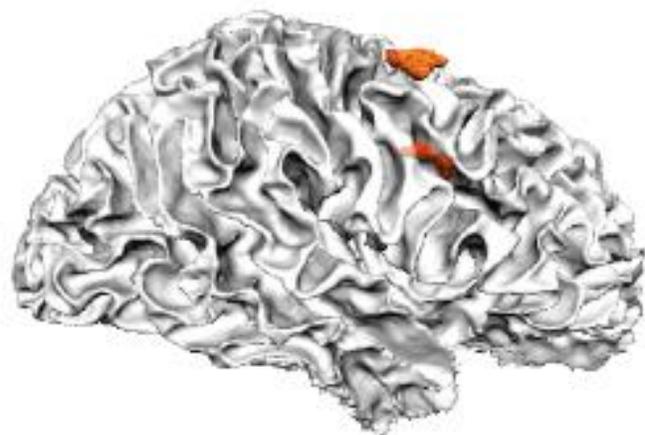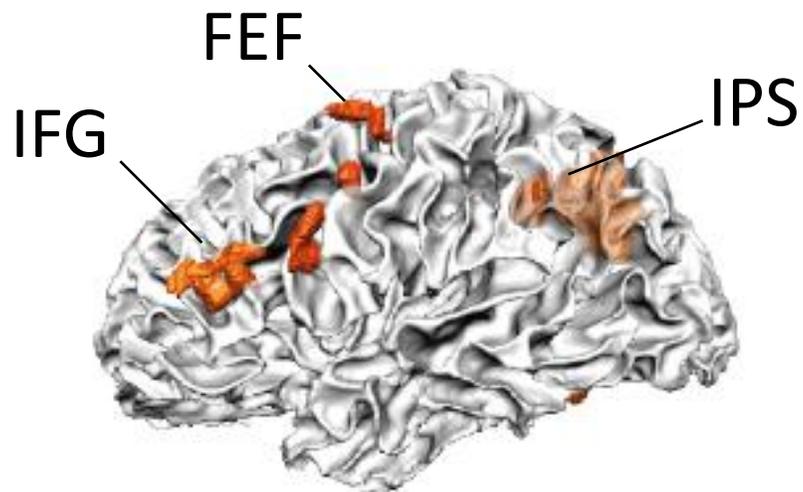Aphantasia: preserved accuracy/cognitive access but slower RTs

-> *Is aphantasia a condition of visual consciousness, like deficits of metacognition?*

Liu & Bartolomeo, 2023, *Cortex*

-> 7T millimetre fMRI

Normal activity in the core imagery network in aphantasia

Left fronto-parietal regions
All imagery domains vs. Abstract words

Fusiform Imagery Node (FIN)
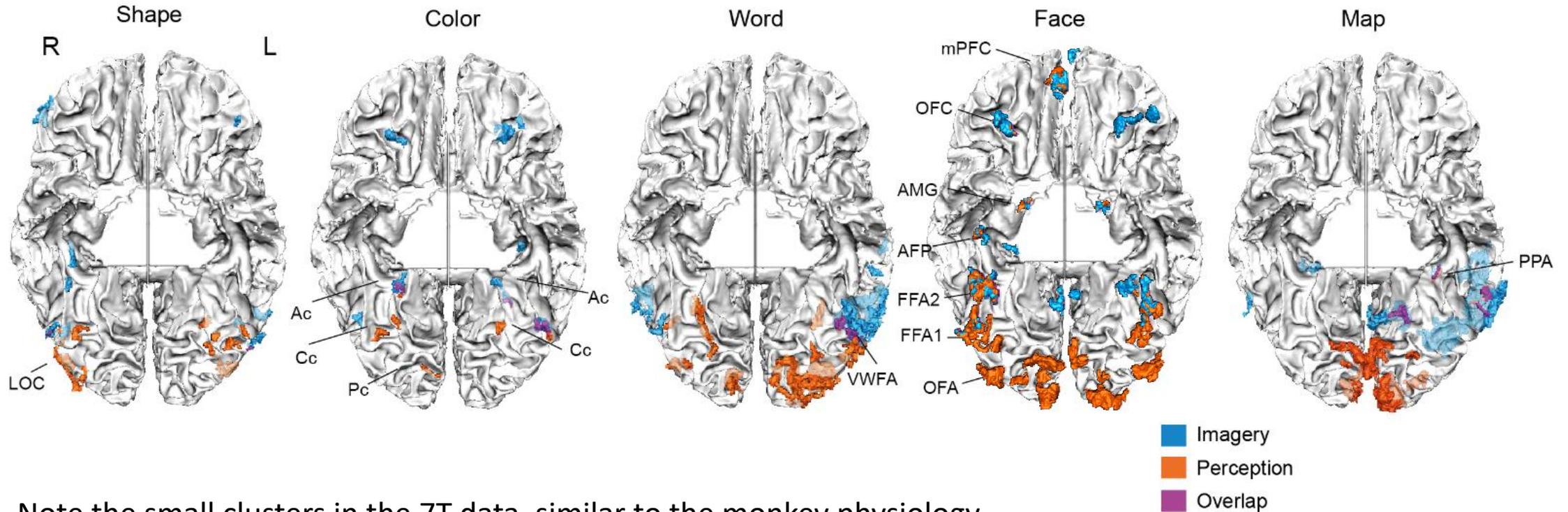

Liu et al, 2025, *Cortex*
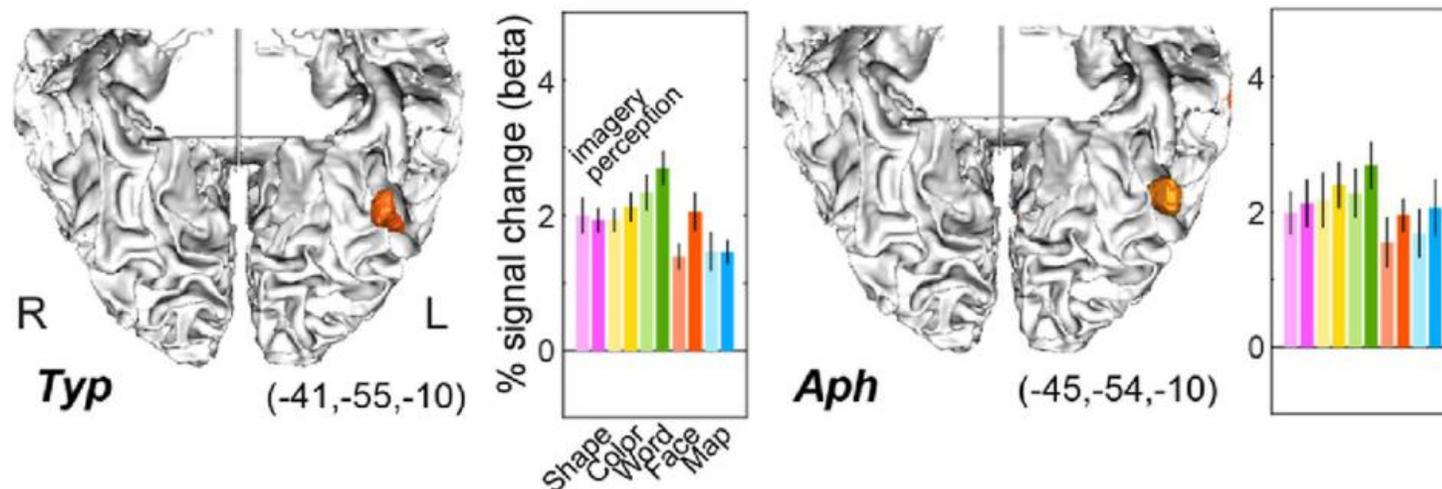
The Fusiform Imagery Node: Where vision meets concepts in the left temporal lobe

Paolo Bartolomeo [a], Jianghao Liu [a,b], Alfredo Spagna [c,d]

Domain-preferring regions
One domains vs. Other domains (representative participants)
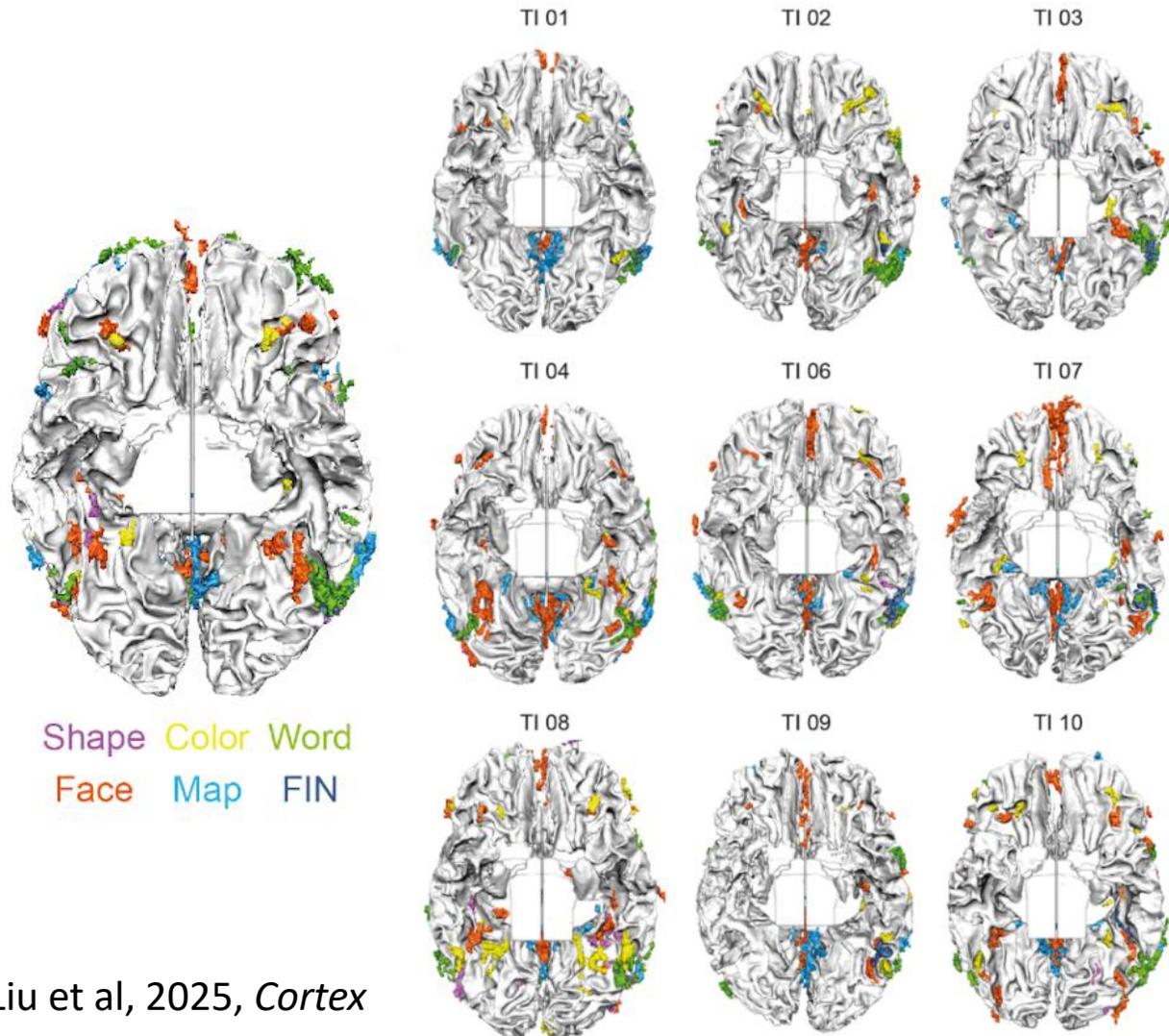
Imagery activation overlaps partially with perceptual activation in high-level visual areas

Note the small clusters in the 7T data, similar to the monkey physiology.

Liu et al, 2025, *Cortex*

The power of 7T fMRI: identify individual domain-preferring imagery network

Typical imager individuals

Aphantasic individuals
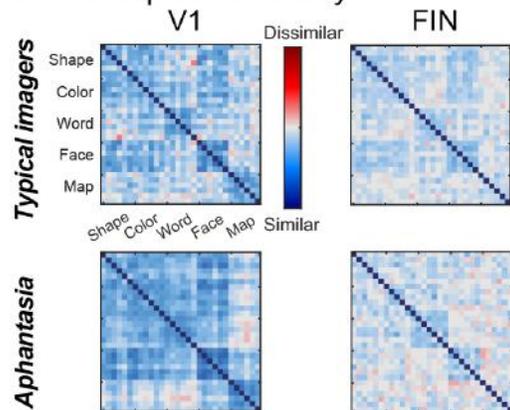

Shape Color Word
Face Map FIN

Liu et al, 2025, *Cortex*
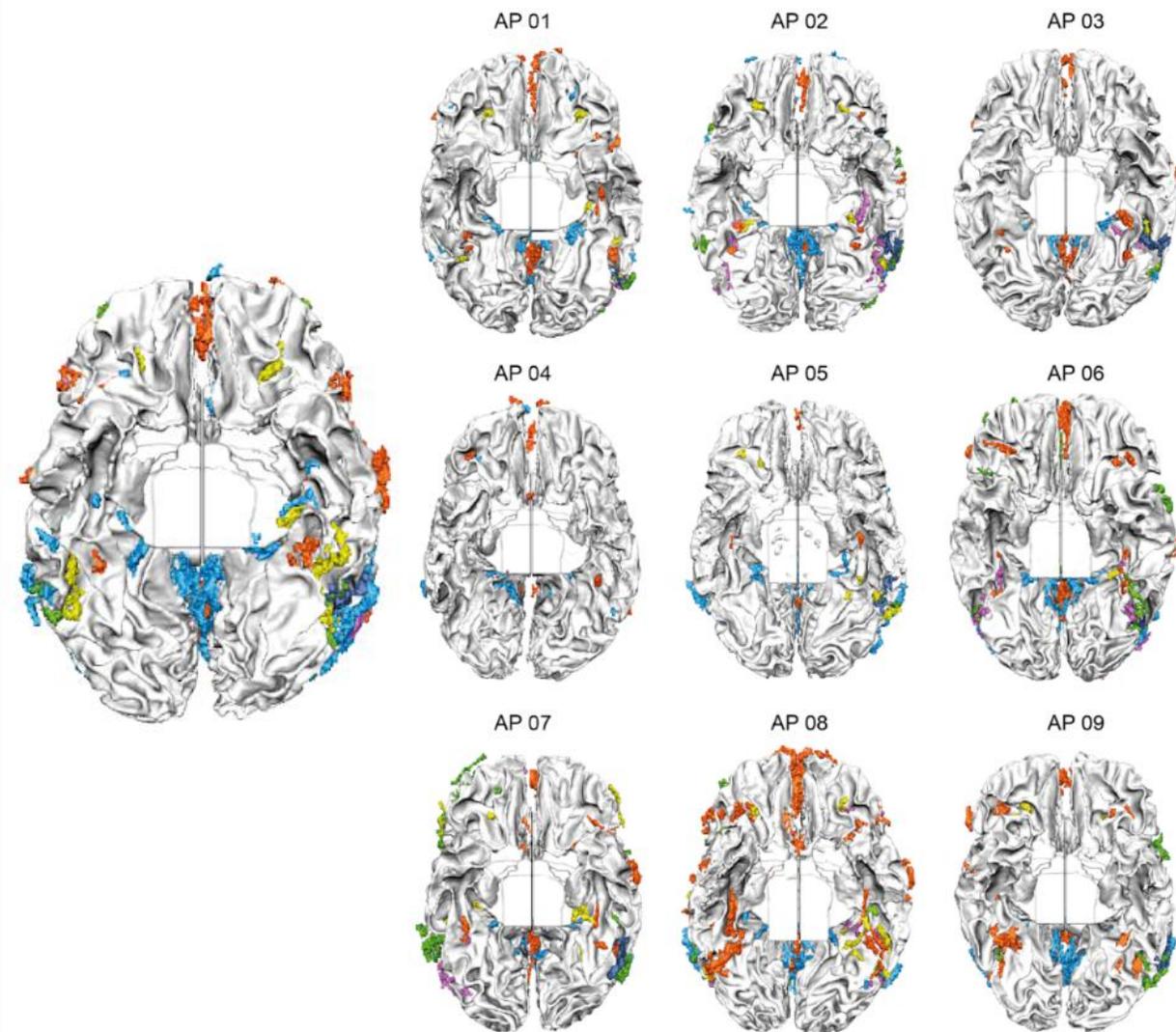
(1) Absence of shared imagery and perceptual representation in aphantasics

Representational content

In the FIN

A Perceptual similarity

Typical imagers / Aphantasia — V1, FIN (Shape, Color, Word, Face, Map)

Dissimilar / Similar

B Imagery similarity

Typical imagers / Aphantasia — V1, FIN (Shape, Color, Word, Face, Map)

Dissimilar / Similar

(not decodable)

Typ

normalized VVIQ (a.u.)

Pearson r = .82
BF = 14.04**

imagery/perception overlap r

BF = 8.15*

imagery/perception r

Aph   Typ

Liu et al, 2025, *Cortex*
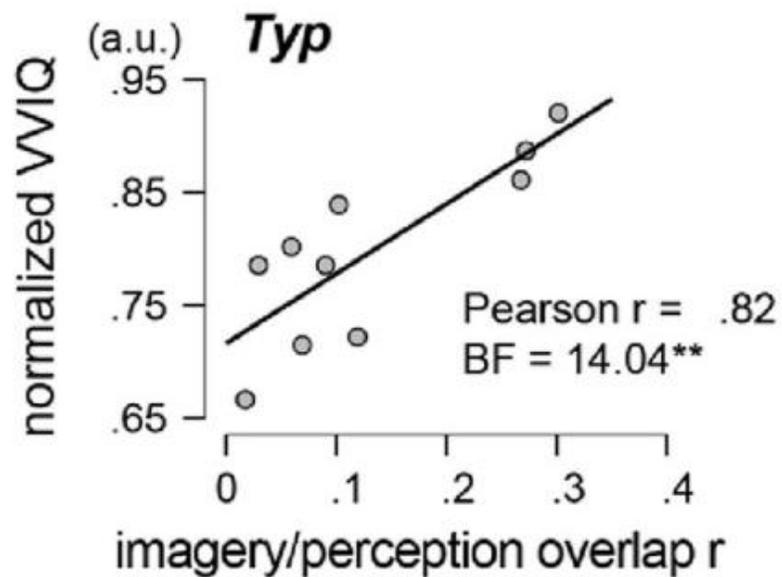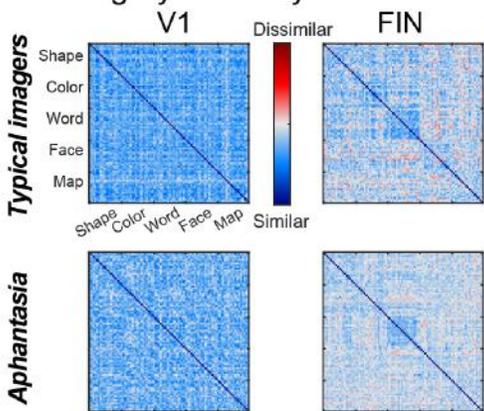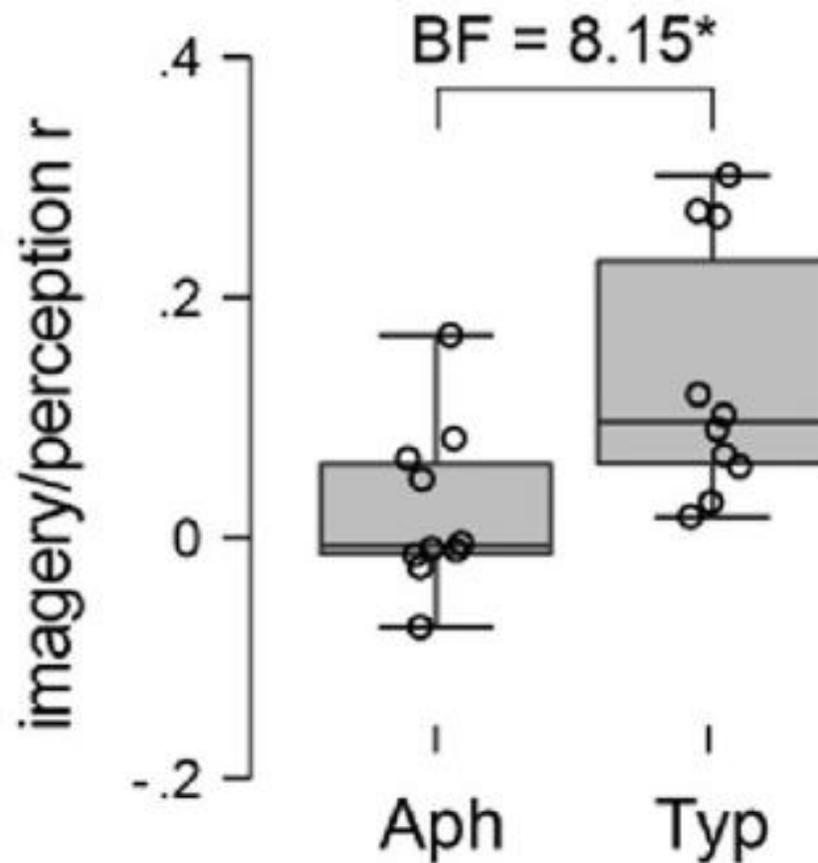
(2) Reduced FIN-PFC functional connectivity in aphantasics

Psychophysiological interaction (PPI)

Left FEF

Left aPFC

C   PPI - all Imagery versus Abstract words (seed: FIN)

Typ > Aph

Liu et al, 2025, *Cortex*

(3) Abnormal activation of ventral attention network in aphantasics

all Imagery Aph > Typ

IPS

TPJ

rIFG

24.65

10.22
F(1,18)

C

all Perception Aph > Typ

24.65

10.22
F(1,18)

Dorsal attention network

FEF

IPS/SPL

IFG/MFG

Ventral attention network

(Corbetta et al. 2008)
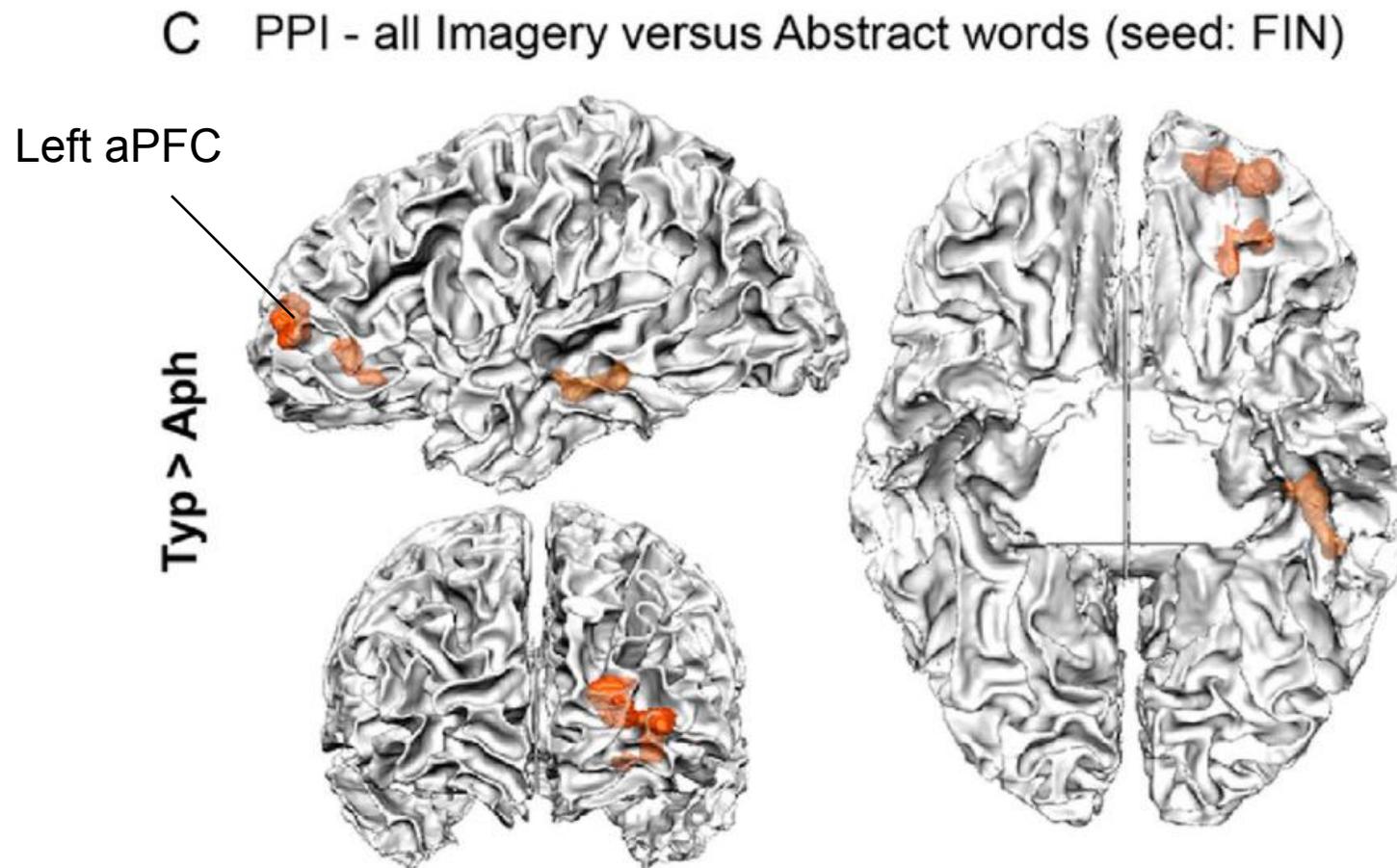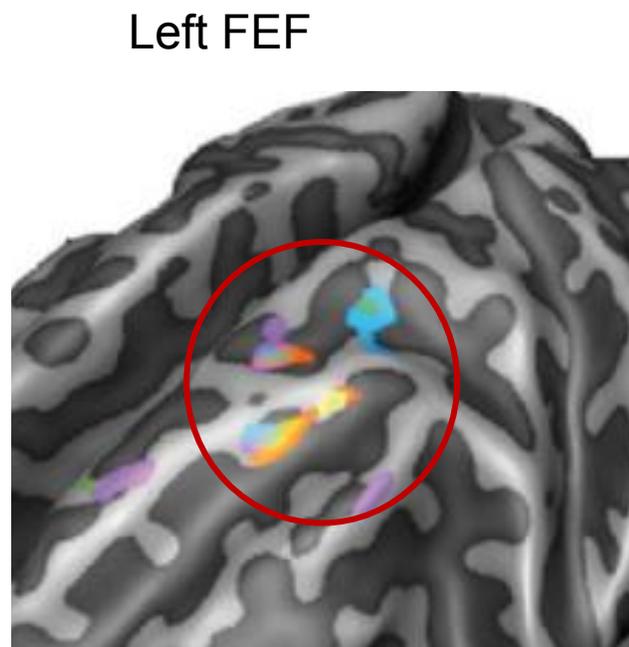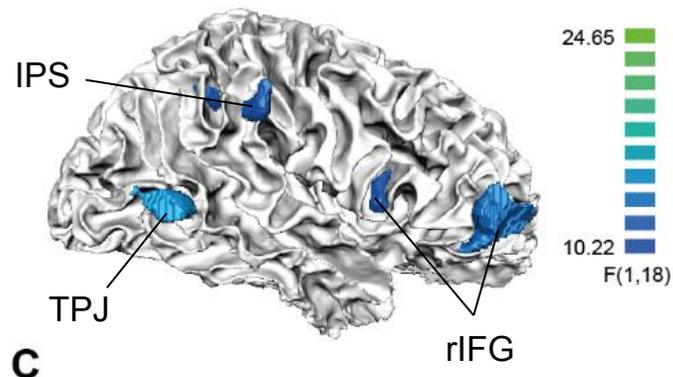
PPI - all Perception vs Abstract words in Aph

Left FEF

Semantic network

8.82

3.69
t(9)

FG

foveal V1
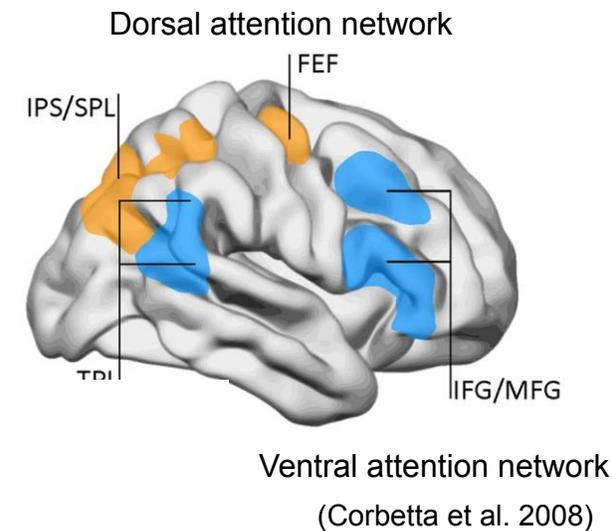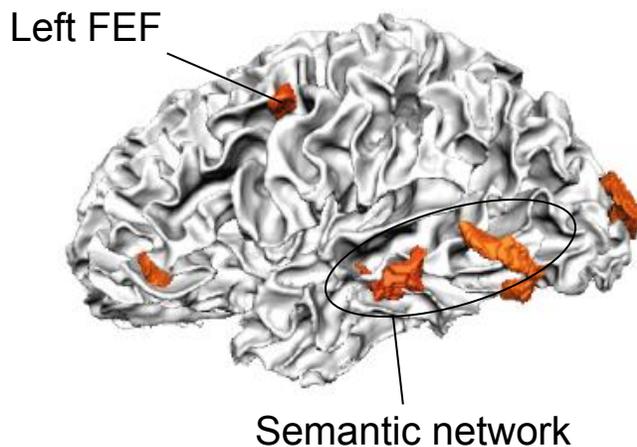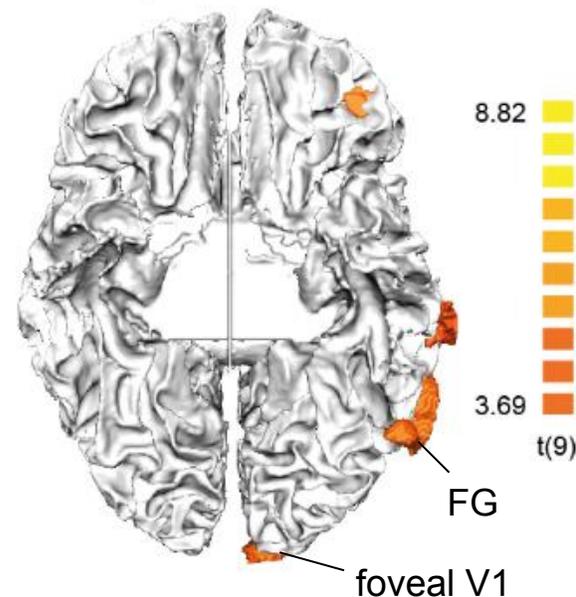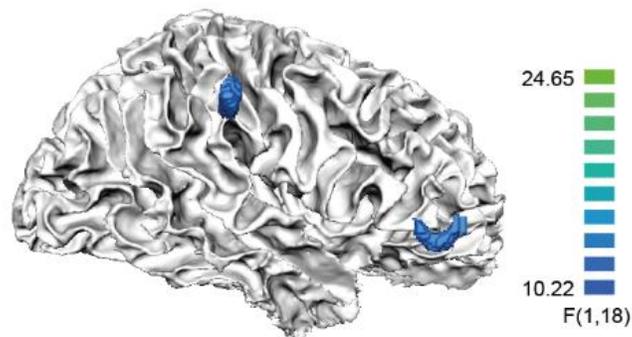
In aphantasia, ventral attention network disrupt left-hemisphere imagery generation, via
- inefficient inhibition of perceptual distractors (v1)?
- over-inhibition of the dorsal attention and imagery network (FEF and/or FG)

Liu et al, 2025, *Cortex*

(4) Absence of representational overlap and reduced OFC-anterior temporal connectivity

Absence of Img./Per. overlap in anterior patches
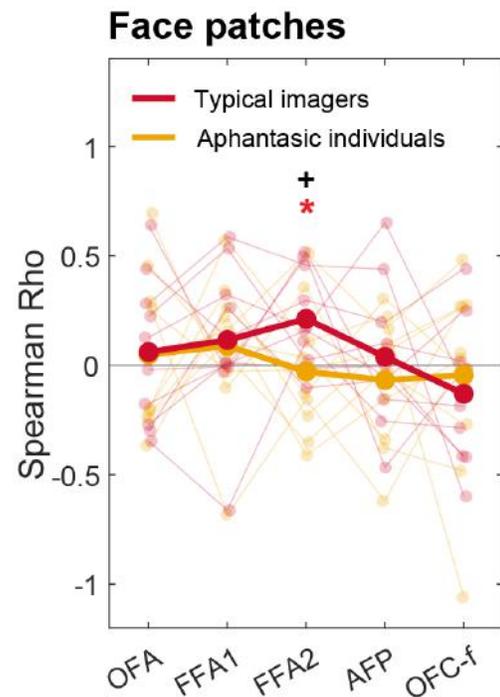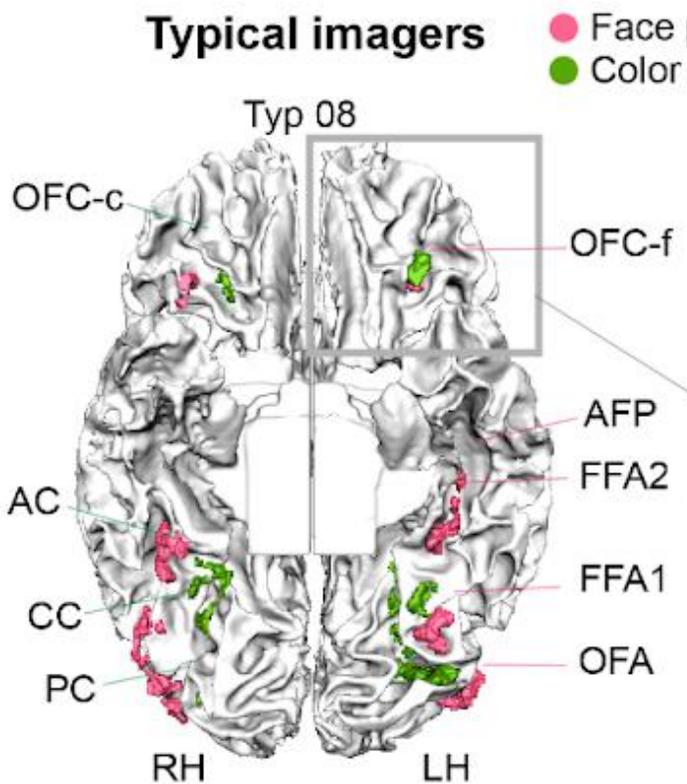
Reduced OFC-anterior temporal patches
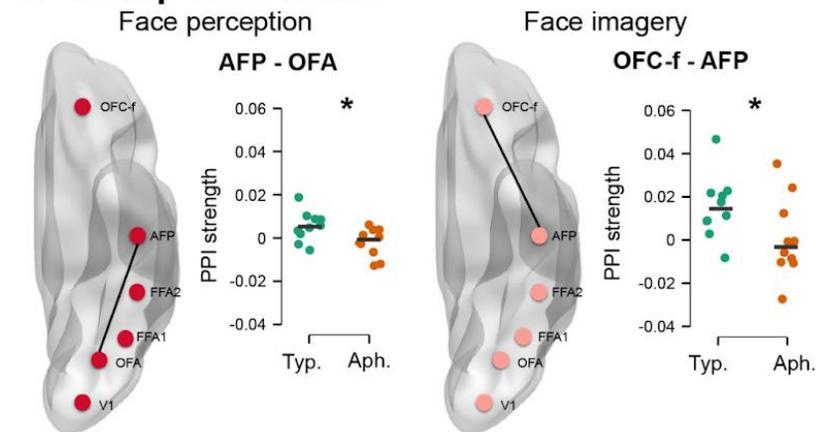
Liu et al. (bioRxiv) Face-, color-, and word-specific patches in the human orbitofrontal cortex

- Normal activity in the imagery network (left FP, the FIN and domain-preferring systems), except more deactivation in the foveal V1.
- Presence of stimulus-specific content but **absence of representational overlap** in the visual system
- However, **functional disconnection** between temporal areas (FIN, anterior patches) and FP networks, related to conscious access
- Abnormal activity in the **ventral attention network** and in its interaction with **dorsal attention networks** (e.g., left FEF) and visual system

This retained representation of visual content alongside functional disconnection, may explain how people with aphantasia can still have **cognitive access to visual knowledge despite lacking phenomenal consciousness**.

## Aphantasia as a functional disconnection

Liu et al. 2025
Hauw et al. 2024
Del Cul et al. 2009
FIN
Trends in Cognitive Sciences
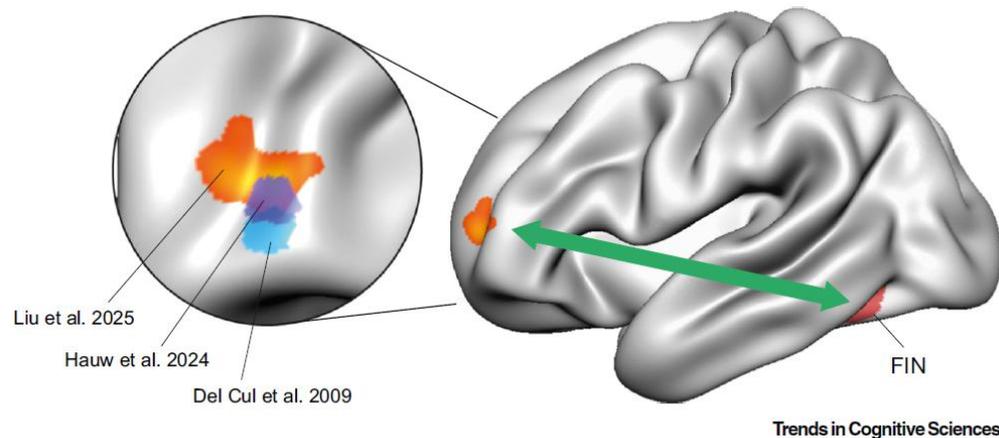
Liu & Bartolomeo (2025) TiCS

Open questions:

1. Does this suggest that aphantasia have imagery, but just to be unconscious?

2. Aphantasia: deficits of top-down modulation rather than pure local visual deficits. How does higher-order networks control for conscious imagery?

The aphantasia paradox: preserved cognitive abilities without imagery experience

Unconscious mental imagery

Bence Nanay ✉

Published: 14 December 2020 | https://doi.org/10.1098/rstb.2019.0689

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Aphantasia as imagery blindsight

Matthias Michel [1,2] · Jorge Morales [3,4] · Ned Block [2] · Hakwan Lau [5,6,7] ✉

Affiliations & Notes ∨   Article Info ∨

Full Length Article

Aphantasia and the unconscious imagery hypothesis

Andy Mckilliam [a,b,*,1], Manuela Kirberg [b]

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Are there unconscious visual images in aphantasia? Development of an implicit priming paradigm

Rudy Purkart [a b 1], Maël Delem [b 1], Virginie Ranson [b], Charlotte Andrey [b], Rémy Versace [b], Eddy Cavalli [b 2], Gaën Plancher [b c 2] ✉

- Mental imagery is **perceptual** processing/representation that is not triggered directly by sensory input (Kosslyn et al., 2006)

- Unconscious imagery is the **perceptual** processing associated with mental imagery, without imagery experience (Nanay, 2020).
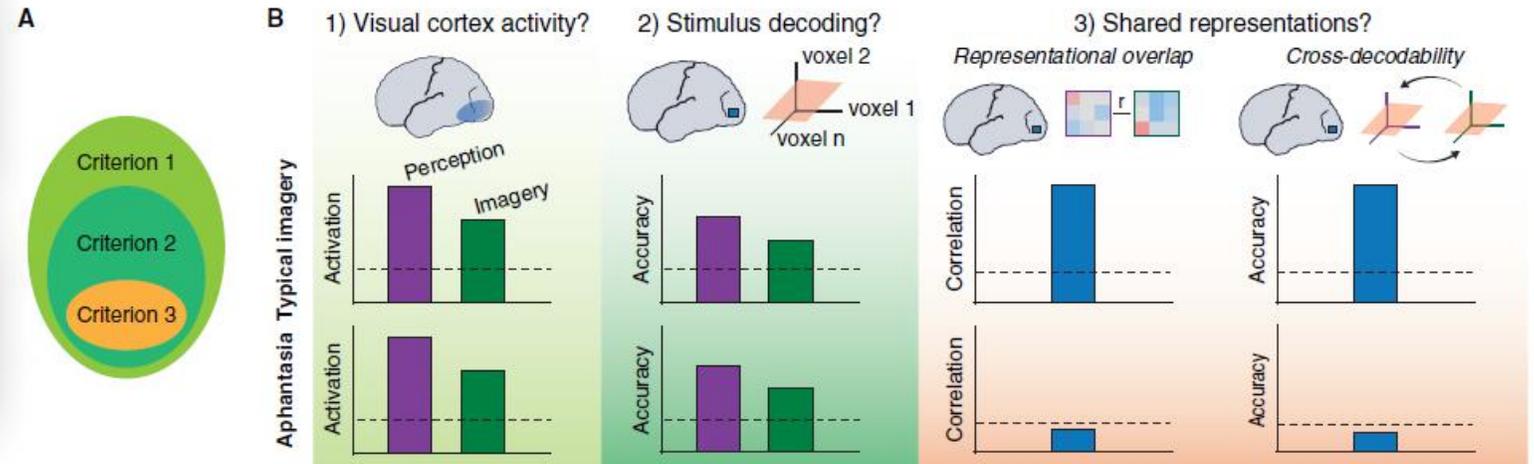
We propose that aphantasics have unconscious visual representation rather than unconscious imagery, due to absence of perceptual-like format.

Scholz, Monzel, Liu* (2025) *Curr. Biol.*

Not enough…We need a theory…

Are we aware of neural activity in imagination?
        Attempting a neural model of conscious mental imagery
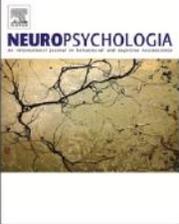
A neural model of conscious mental imagery and aphantasia

Jianghao Liu [a,b]

[a] Sorbonne Université, Institut du Cerveau - Paris Brain Institute - ICM, Inserm, CNRS, AP-HP, Hôpital de la Pitié-Salpêtrière, F-75013, Paris, France
[b] Corporate Research, Dassault Systèmes, Vélizy-Villacoublay, 78140, France

Implicit assumption:
reactivation of the visual cortex ("visual buffer") in imagery generation is...**sufficient** for imagery experience.
Kossyln, 1985, *Image and brain*
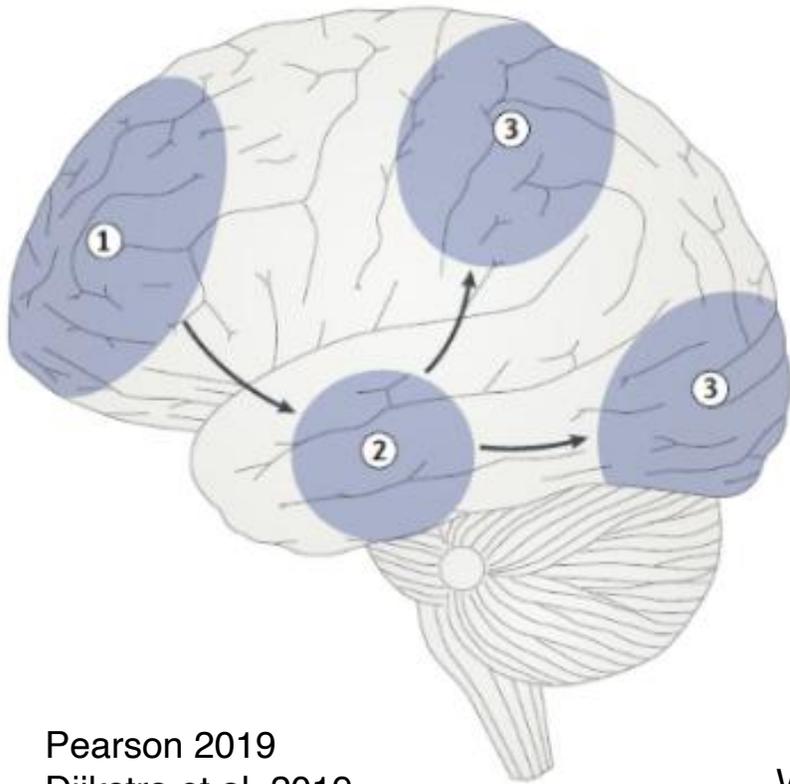
- Aphantasia: successful reactivation of sensory cortices during imagery.
- In visualizers, spontaneous activity is often unconscious (spontaneous activity, hippocalpal-cortical replay during rest or sleep)

Imagery experience is rich and diverse:
- Voluntary imagery (driven by top-down reactivation)
- Spontaneous imagery (visual dreams, hallucinations, deprivation-induced images; engagement of visual system but driven by bottom-up emerged signal).

Pearson 2019
Dijkstra et al. 2019
Spagna et al. 2021,2024

What are additional, as-yet-unspecified, processes required for ***conscious access to*** imagined content?

Theories of consciousness: Global Neuronal Workspace Theory

A **Perception**
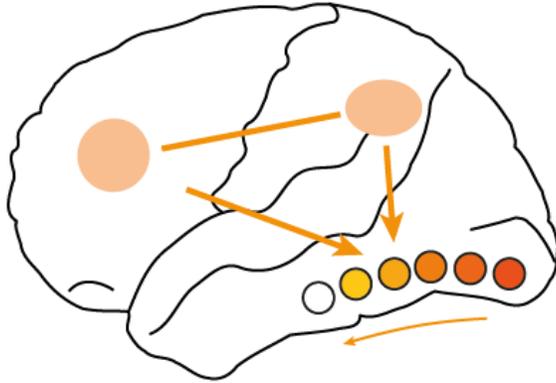
i) subliminal
- little or feedforward activation
- depth of processing depends on task set and attention
- no durable frontoparietal (FP) activity
- no reportability
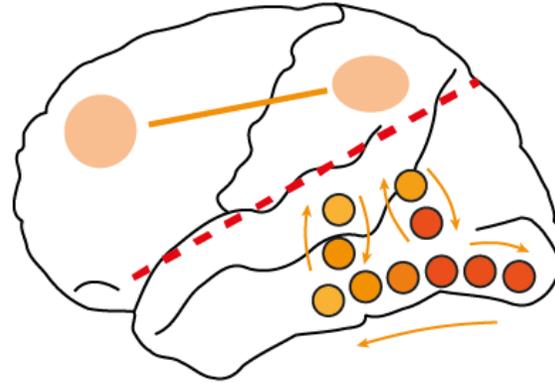
ii) preconscious
- intense activation confined to visual areas
- occipito-temporal loops and local synchrony
- no reportability when attention is elsewhere
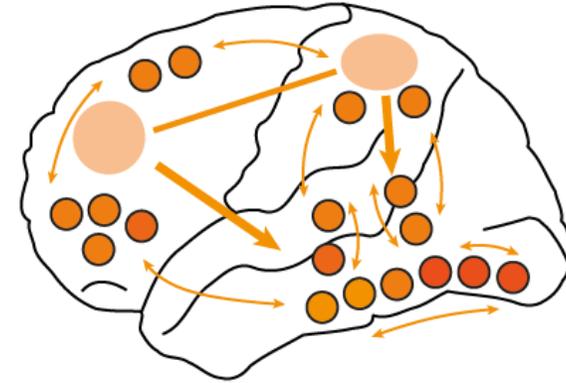
iii) conscious
- top-down attentional amplification to visual areas
- intense activation spreading to FP networks
- long-distance loops and global synchrony
- durable and maintained activation
- reportability of perceptual experience

Dehaene et al. 2001, 2006
Dehaene & Naccache, 2001
Mashour et al., 2020

No clear theory for conscious **imagery**...

Hypothesis: shared conscious access to internal/external signals, through a **threshold** mechanism

Is the access to conscious experience shared between external and internal signals?
1. shared/overlapping neural substrates for perception and imagery (FP networks, high-level visual areas; Liu et al., 2025; Dijkstra et al., 2019)
2. shared **global workspace** for different modules (e.g., language, sensory, emotion...)
3. common **reverberate/recurrent loops** and conscious threshold for external signal and spontaneous activity (Moutard et al., 2015)
4. shared threshold for **report** signals originating from external reality and internal imagination (anterior insula and FIN; Dijkstra et al., 2025)

The role of (supra-modality) attention in conscious visual experience (mostly studied in conscious perception)
1. early attentional orienting inward and **preparatory states** (Bartolomeo & Liu, 2025, *TiCS*)
2. **feature binding** (e.g., combine elements into objects; Treisman & Gelade, 1980)
3. **attentional ignition/amplification for weak visual signals** (Dehaene et al., 2006; Moutard et al., 2015).

How? *Weaker* signal in imagery than perception.
- An neuronal excitatory-inhibition mechanism in attention networks (Liu et al., 2023, *Comm. Biol.*)
- Only *attended* stimuli give rise to top-down predictions/experience (Westerberg & Roelfsema, 2025)
- much implication of attention networks in absence of imagery in aphantasics (Liu et al., 2025)

Liu (2026) Neuropsychologia

Successive processes for conscious imagery

B Voluntary imagery (top-down)
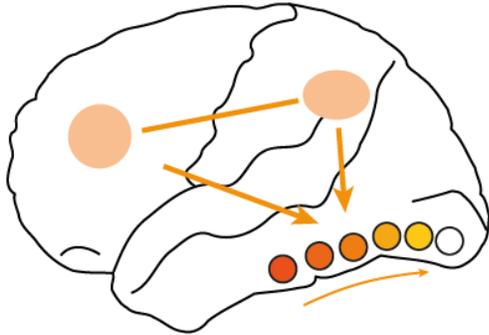
i) subliminal (generation)
- imagery generation by FP networks, with semantic and memory retrieval
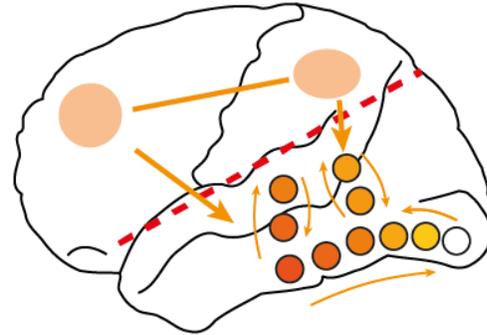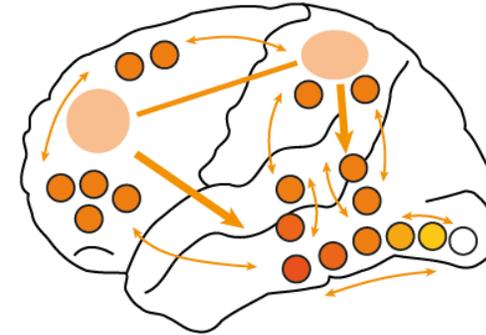- weak feedback sweep of visual areas
- reportability of conceptual knowledge

ii) preconscious (integration)
- integrating concepts with visual features, and shaping perceptual-like representations
- intense activation confined to visual areas
- temporo-occipital loops and local synchrony
- reportability of visual knowledge

iii) conscious (amplification)
- top-down attentional amplification to visual areas
- intense activation spreading to FP networks
- long-distance loops and global synchrony
- durable and maintained activation
- reportability of imagery experience

**1. Generation** (Reactivation of the sensory cortices from semantic & episodic retrieval)

2. Integration (Visual feature binding and tuning of perceptual-like representation)
- support a continuous spectrum of subjective vividness

3. Amplification (ignition/recurrent loops for conscious access)
- binary / thresholded / bifurcation

Liu (2026) Neuropsychologia

C **Spontaneous imagery (bottom-up)**
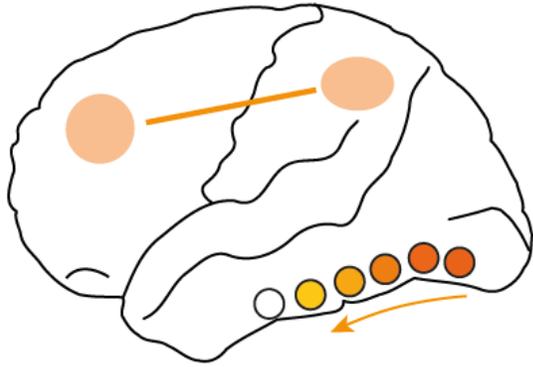
i) subliminal (emergence)
- reduced inhibition control
- spontaneous visual activity emerges and spread forward the visual hierarchy
- no reportability
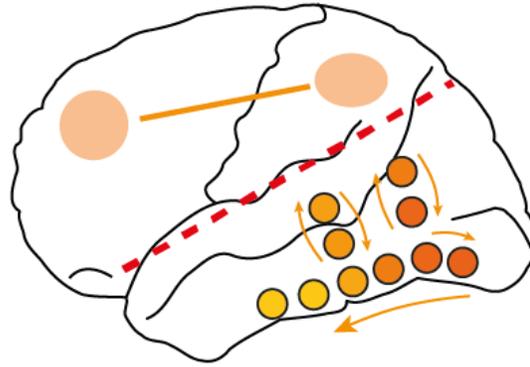
ii) preconscious (integration)
- uncontrolled integration of visual features
- intense visual activity forms local synchrony
- attempting to capture bottom-up attention
- no reportability
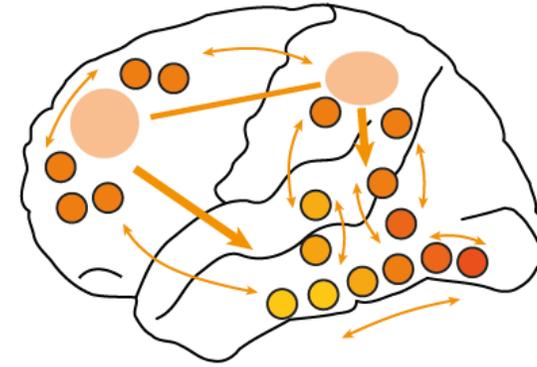
iii) conscious (amplification)
- top-down attentional amplification to visual areas
- long-distance loops and global synchrony
- reportability of hallucinations or "flashes of imagery"

Frontoparieto-fusiform network shape conscious imagery experience

A

domain-preferring regions

B

Salience Network
- transitions between internal and external attention
- regulating conscious access

Dorsal attention network
- hierarchical processing of imagery: generation, integration, amplification

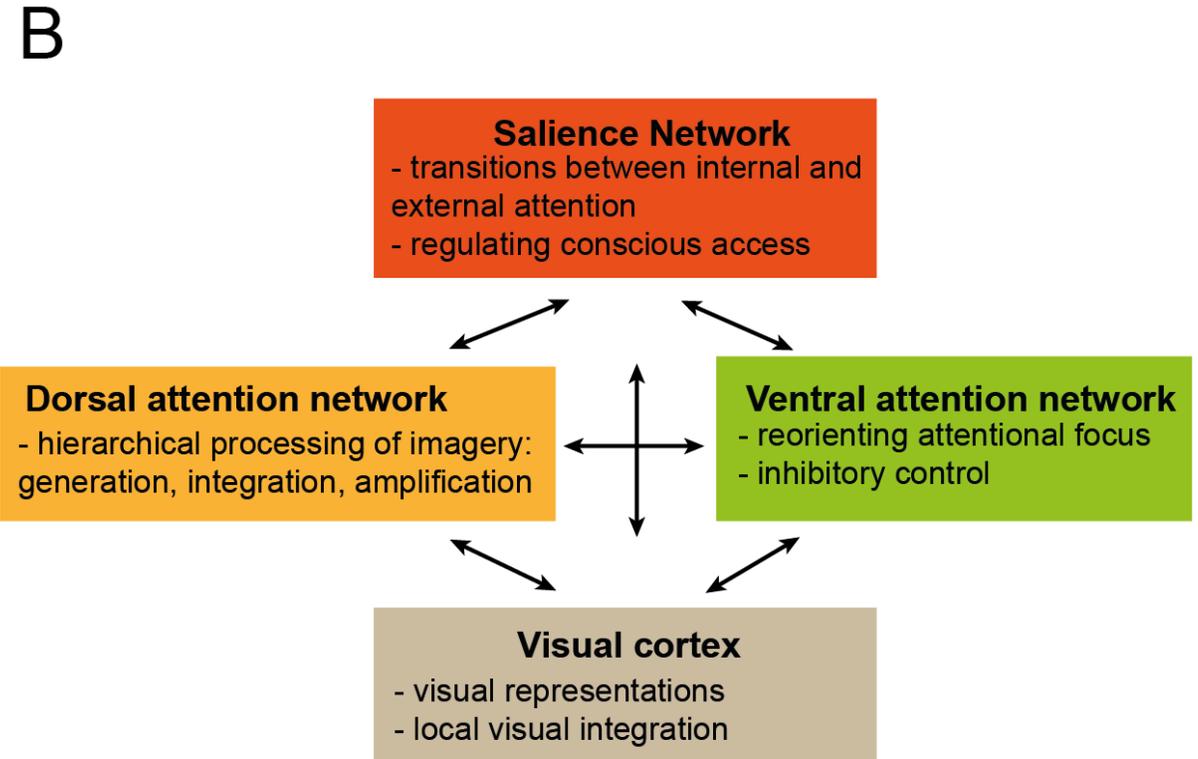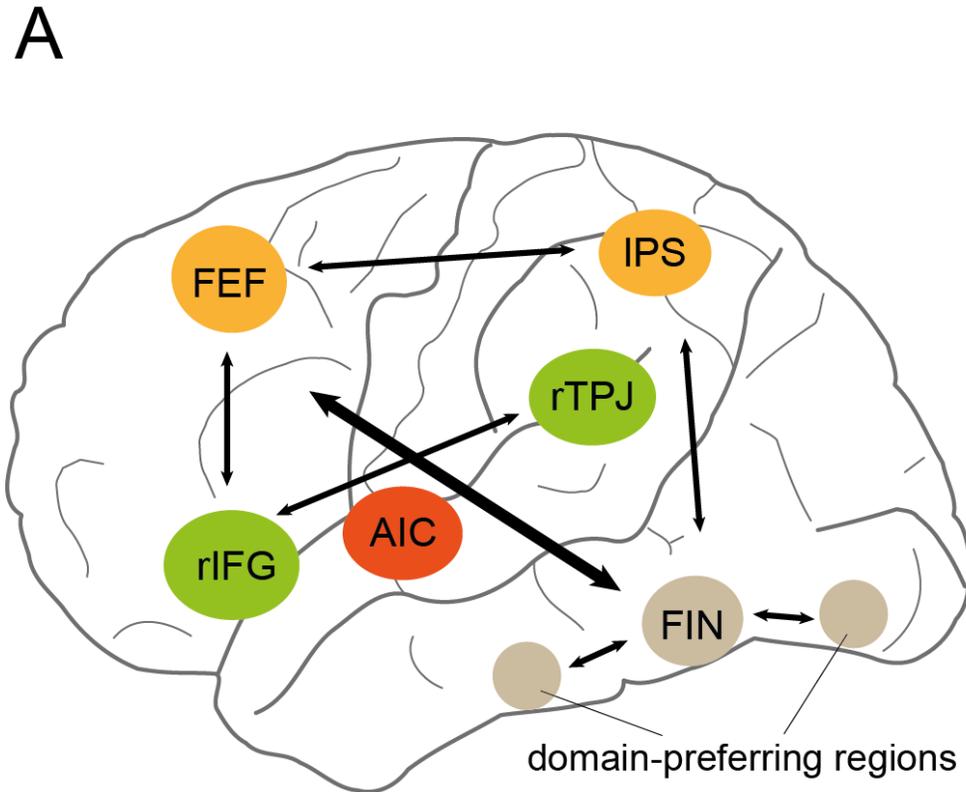**Ventral attention network**
- reorienting attentional focus
- inhibitory control

Visual cortex
- visual representations
- local visual integration

Anterior insular cortex (AIC; gatekeeper for conscious visual experience)
1) identifying and prioritising salient stimuli in the stream of continuous sensory information
2) modulating large-scale network activity (e.g., default mode network, frontoparietal network)

Liu (2026) Neuropsychologia

Aphantasia is a deficit of top-down modulation, not pure visual deficit

A Hierarchical processing during imagery attempts in aphantasia

i) generation ii) integration iii) amplification
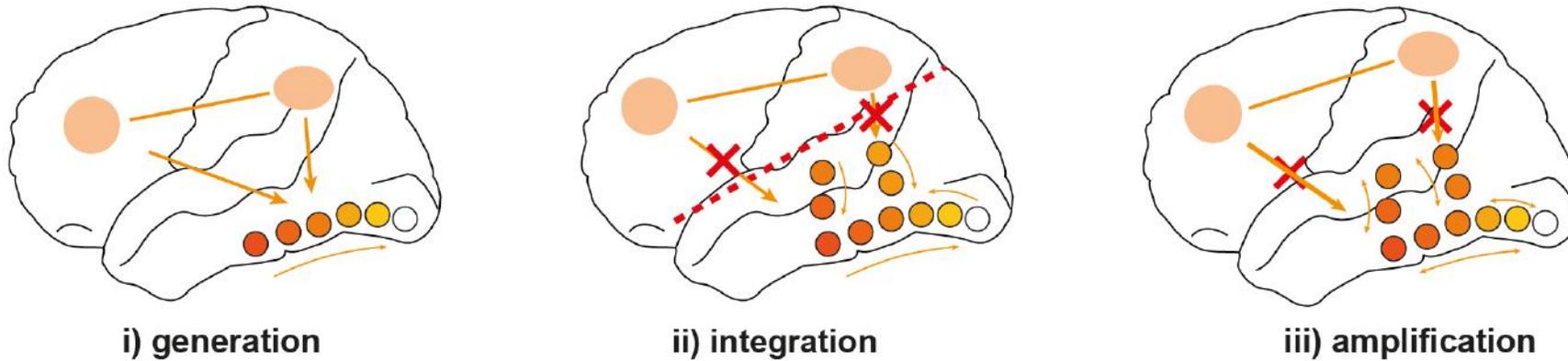
Note that a dissociation between weak imagers (ii, inefficient integration) vs. Aphantasia (due to ii or iii, deficit of amplification)
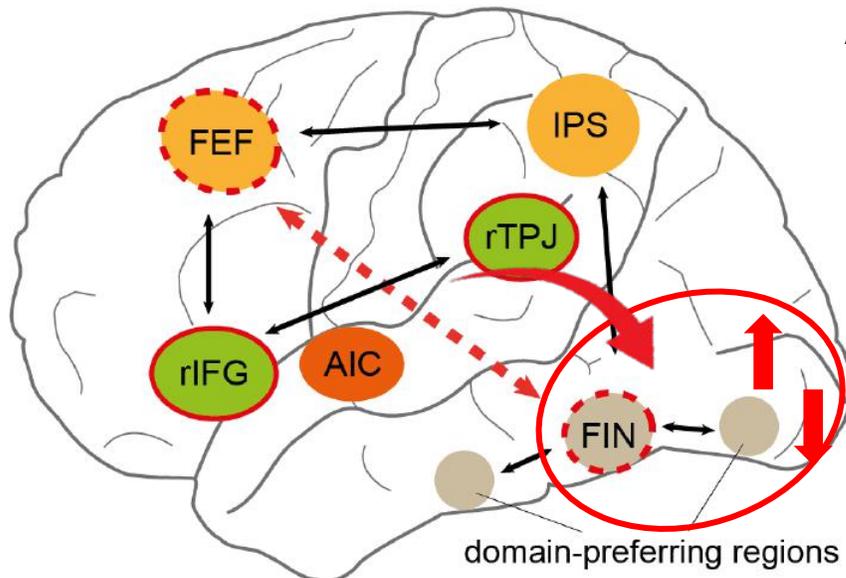
Abnormal visual activities ((e.g., early visual areas) could be explained by an unbalanced excitatory-inhibitory mechanism led by attention networks.

Liu (2026) Neuropsychologia

Aphantasia as a window into unconscious internal processing

- A neuro-mechanistic model bridging research on **imagery** and **consciousness**
- Conscious imagery arises from **generation**, **integration**, and **amplification** processes
- **Attention** appears to be necessary, though not sufficient
- A **frontoparieto-fusiform circuit** for conscious imagery
- **Aphantasia** involves impaired top-down modulation but unconscious visual processing

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Implication
- Imagery should be a conscious process -> specifying steps for unconscious internal processing
- Theory of consciousness -> extending unconscious perception to unconscious internal processing

New challenges
- masking for unconscious external stimuli -> how to create "masked" internal signals?
- dissociating stages of processing requires high temporal-resolution techniques (sensory vs. P3 signals)

And elicited more questions….
e.g., how to distinguish signals from subjective perception and imagery ('threshold')? the role of attention?

Liu (in press) Behavioral and Brain Sciences

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NEWS FEATURE | 03 February 2026

Many people have no mental imagery. What's going on in their brains?

People with aphantasia are offering a window into consciousness.

By Elizabeth Quill

Symposium "Aphantasia and Consciousness"

- Jianghao Liu (ICM, Chair)
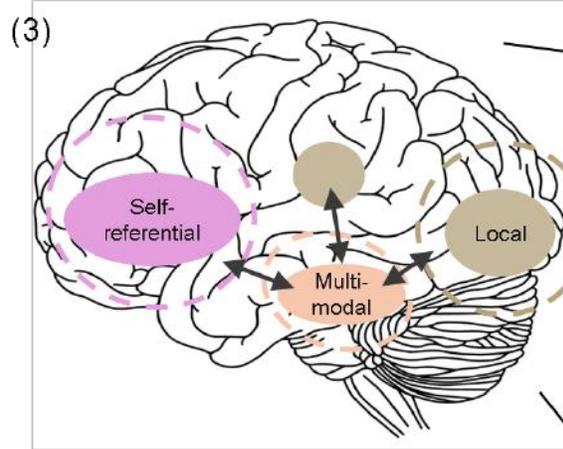- Matthias Michel (MIT)
- Giulia Cabbai (UCL)
- Lu Teng (ANU)

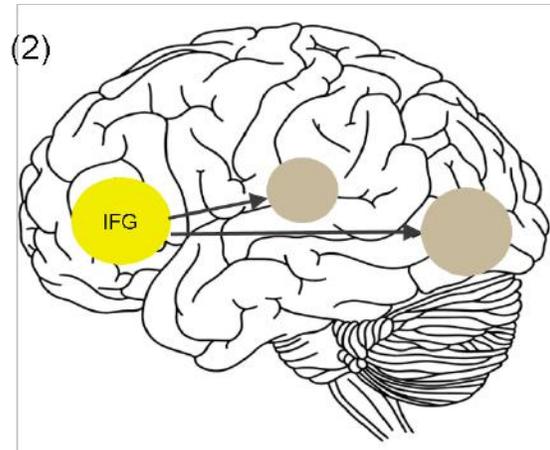**How does this model inspire new research?**

Three lines of ongoing studies…

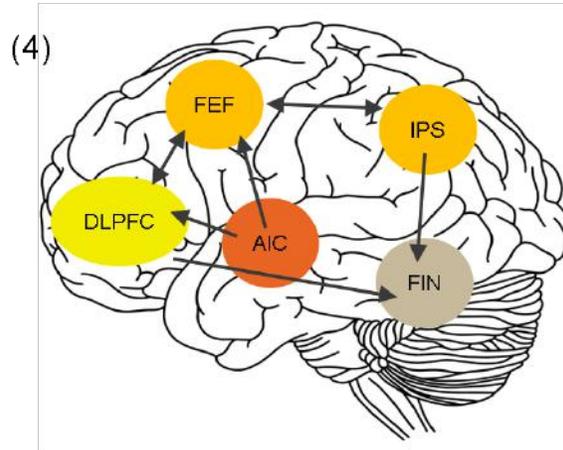# Expanding **integration**: towards a multi-level, dual-stream attention-interoception processing of imagery

Unconscious mental imagery or **"Sensory precursor"** ?
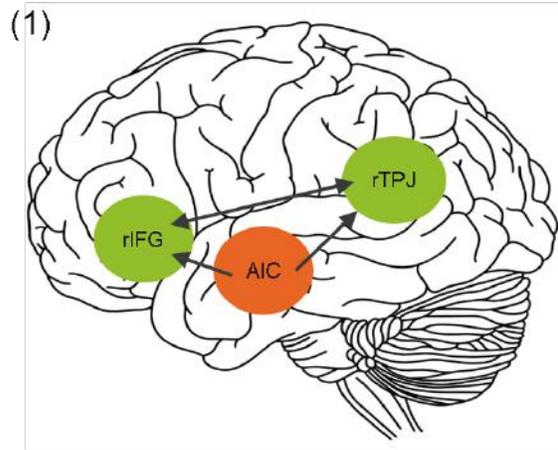
(1) Stage 1, attention shifts inward (AIC + VAN)

(2) Stage 2, generation: IFG reactivates sensory precursors (e.g. visual and auditory cortex)

(3) Stage 3, integration across three levels

(4) Stage 4, amplification: AIC triggers DAN which ignites the integrated representation
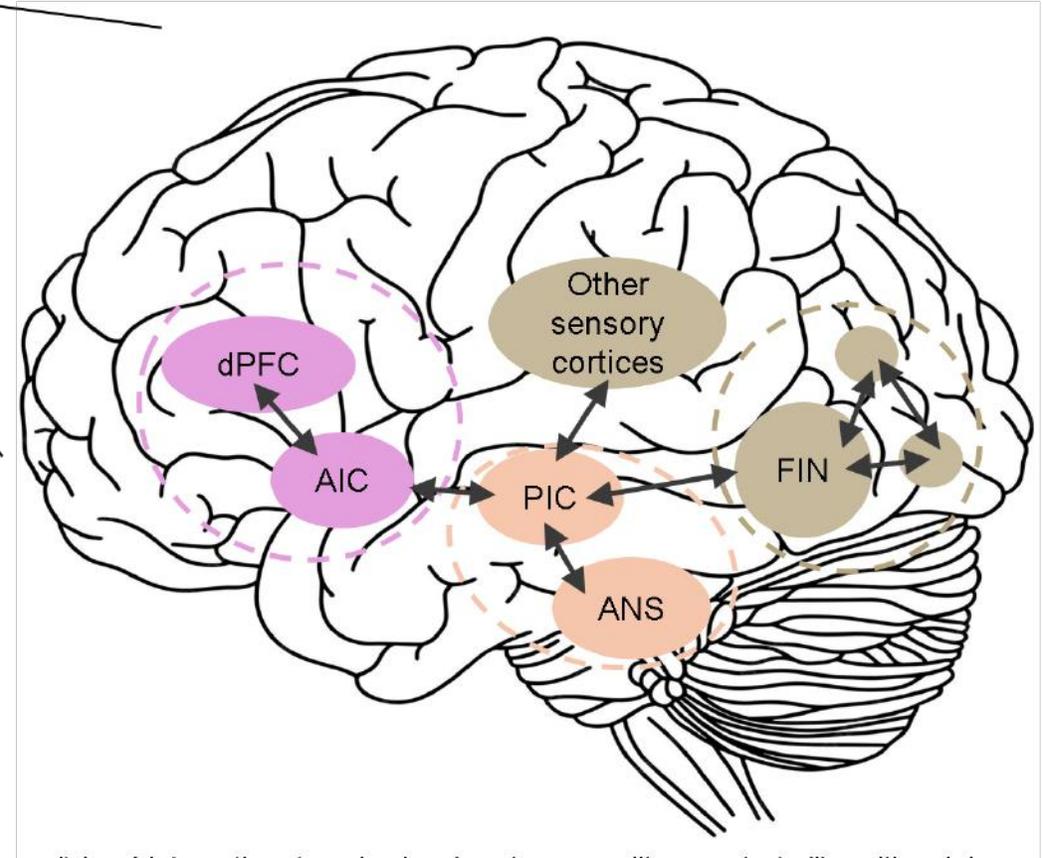
i) local integration (e.g. in visual cortex or auditory cortex); ii) multimodal integration (PIC and ANS); and iii) self-referential integration (AIC and dPFC)

Scholz,…, **Liu***, Silvanto* (2026) Neuropsychologia

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…

Thank you !

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With Christian O. Scholz (Ruhr-Universität Bochum)

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Deadline for abstract submission: **17/04/2026**
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