

Cours 2025-2026:

**Qu'est-ce que la conscience
et quels sont ses mécanismes cérébraux ?**

What is consciousness, and what are its neuronal mechanisms?

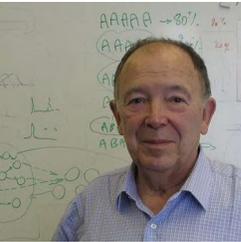
Stanislas Dehaene

Chaire de Psychologie Cognitive Expérimentale

Cours n°3

L'ignition, une signature cérébrale de l'accès à la conscience

Ignition : a cerebral signature of conscious access



Jean-Pierre Changeux

Ignition : a key prediction of the global neuronal workspace (GNW) hypothesis

Dehaene & Changeux, PNAS 1998 ; Dehaene & Naccache, Cognition 2001

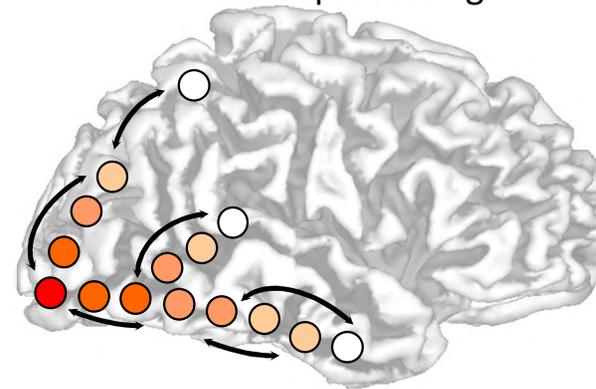


Lionel Naccache

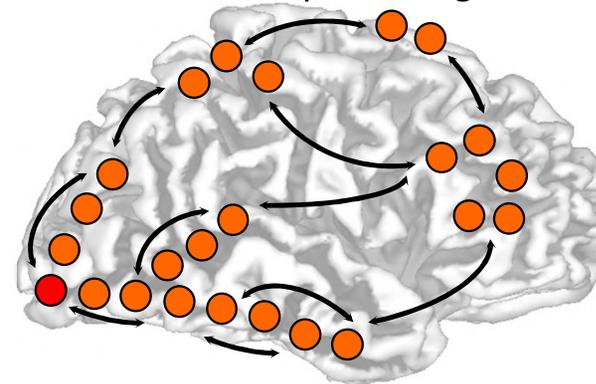
Predictions of the GNW framework : Conscious access is

- A **phase transition**: the sudden “**ignition**” of a **subset** of workspace neurons, **distributed** in prefrontal and other associative cortices, that **broadcast top-down signals** back to all processors.
- A sudden bout of **metastable** activity **lasting at least ~100-200 ms**, which **mobilizes** and **synchronizes** distant processors.
- A **thalamo-cortical** state.
- Not an isotropic state of global activity (which would be epilepsy), but a well-delimited state where **only a subset of neurons** are activated, whose topology (a neural vector) defines the **conscious content**.
- Ignition should be **present whenever we consciously perceive** some piece of information, but it should be prolonged if we need to consciously process it (GNW as a **flexible router**)

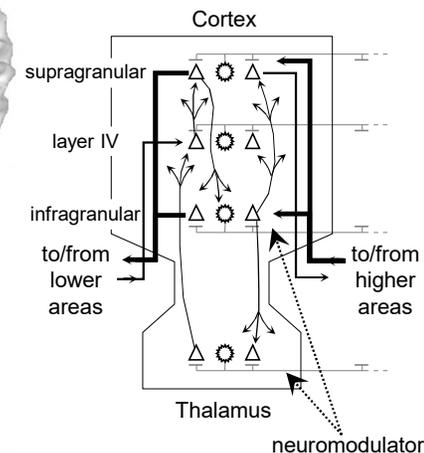
subliminal processing



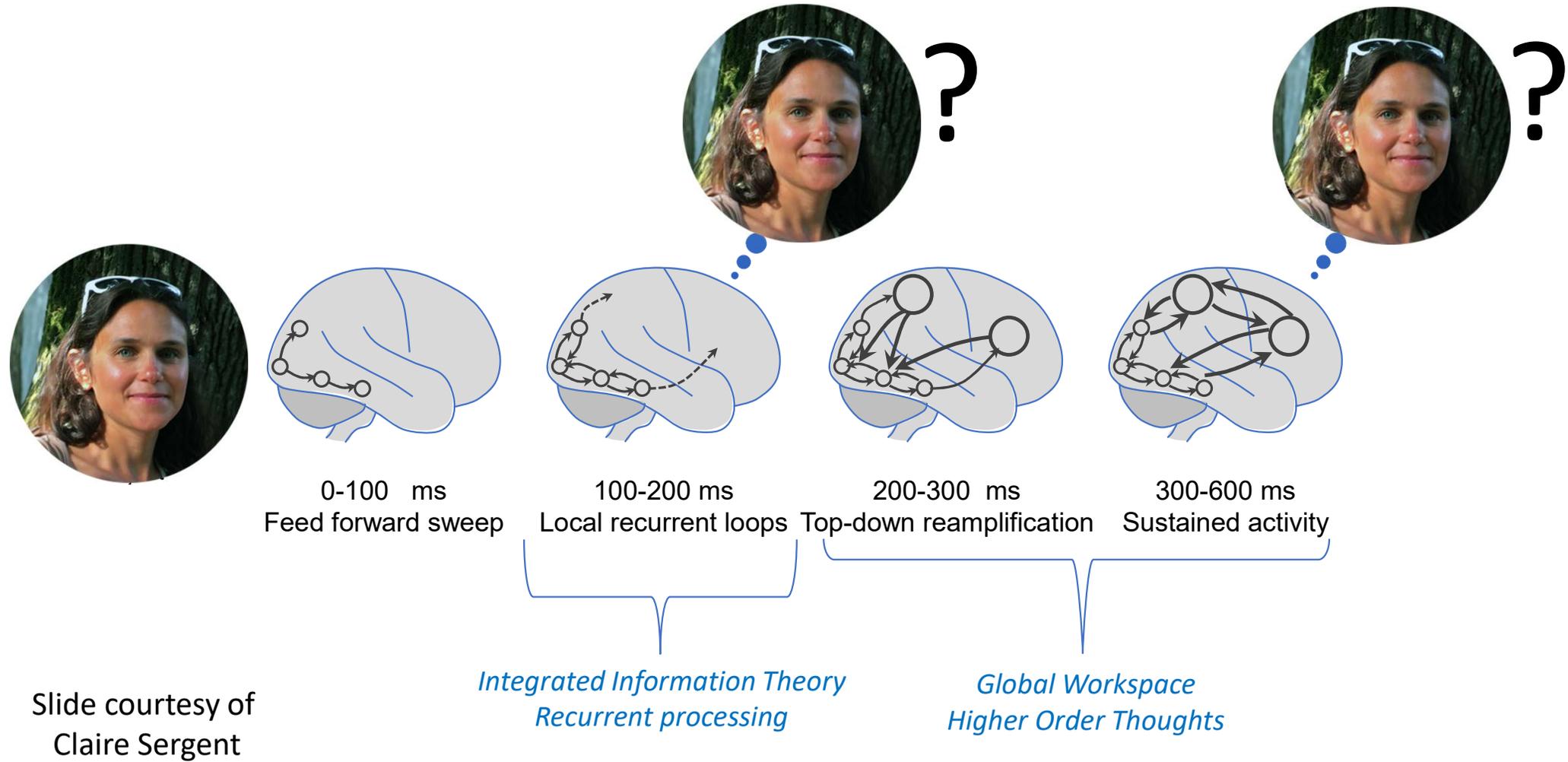
conscious processing



Thalamocortical column

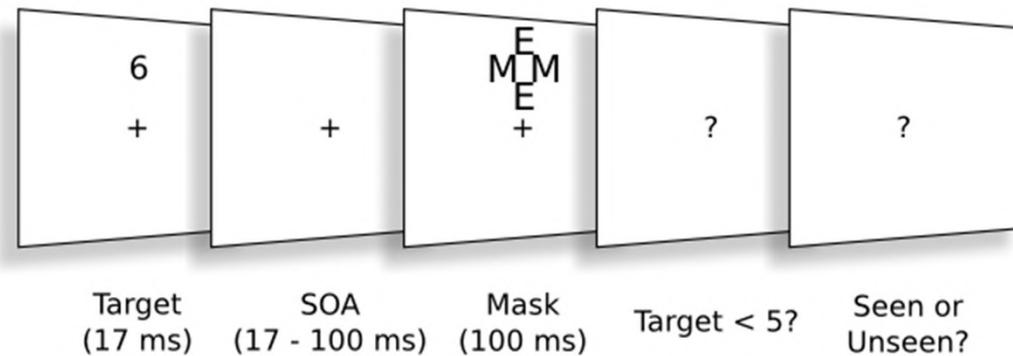


The contemporary debates in a nutshell

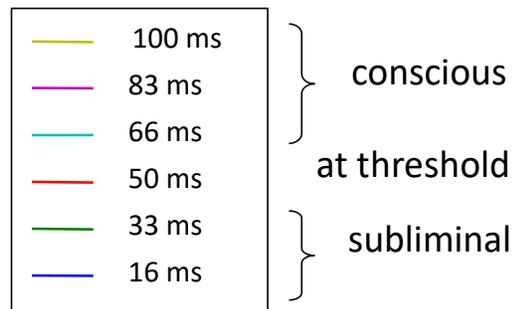


A threshold for consciousness during masking

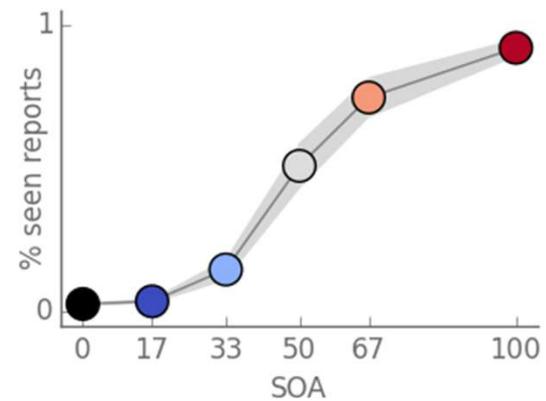
Del Cul, Baillet & Dehaene, *PLOS Biology* 2007



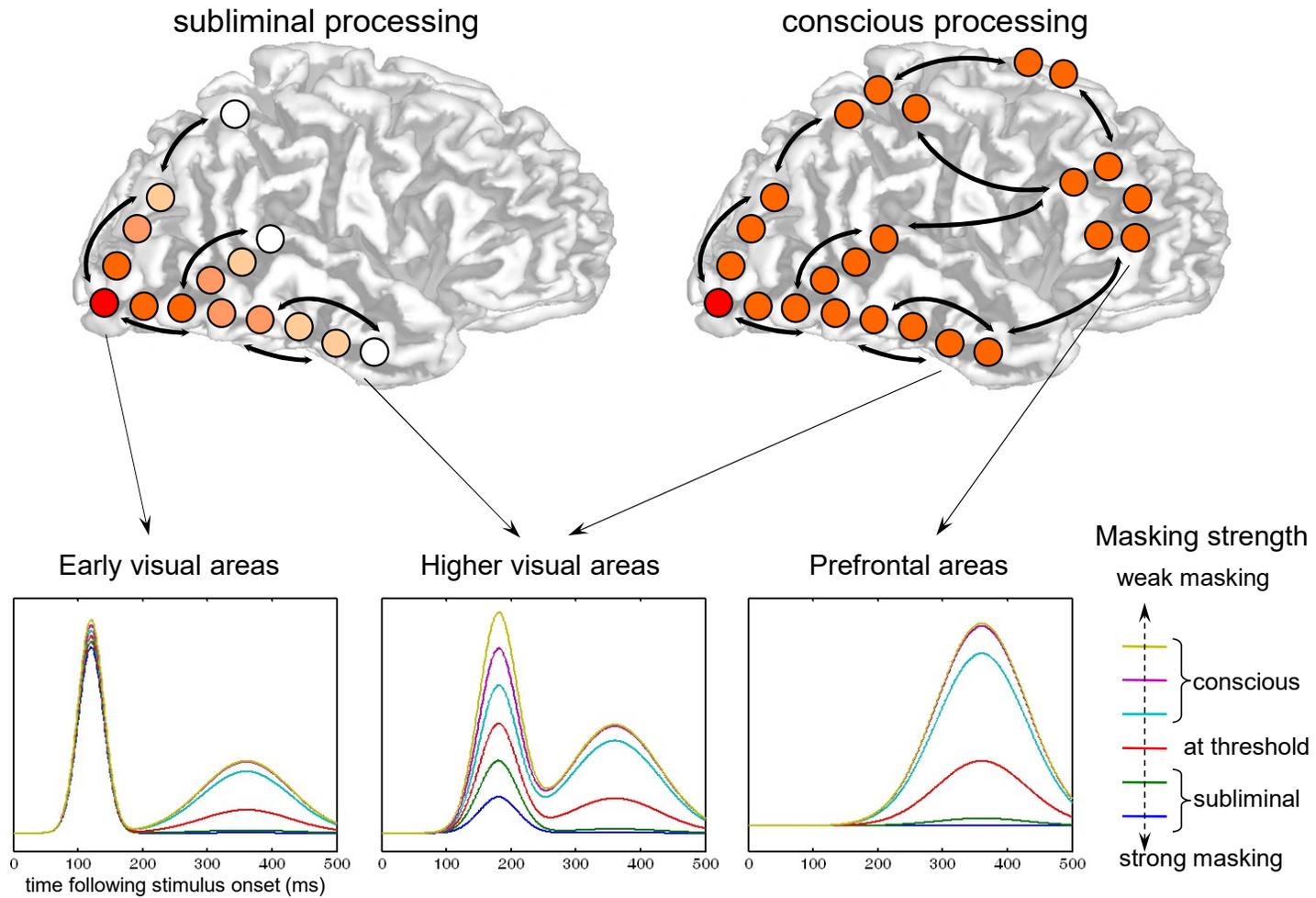
The target-mask delay affects consciousness :



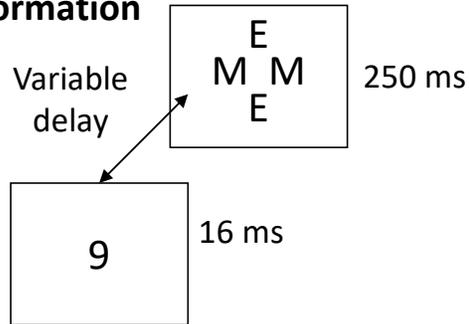
Subjective reports of « seeing »



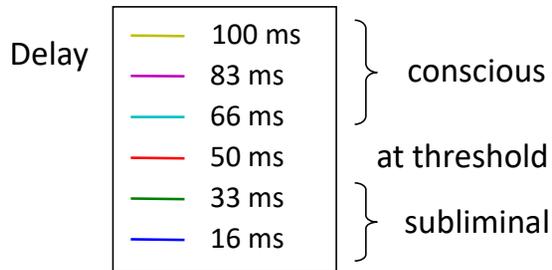
Conscious access according to the global neuronal workspace model



Vary continuously
the amount of
sensory information



Followed by objective and subjective tasks



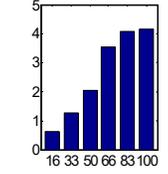
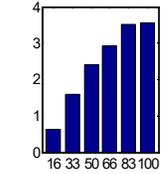
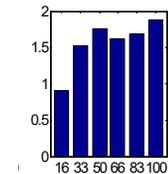
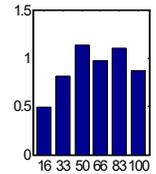
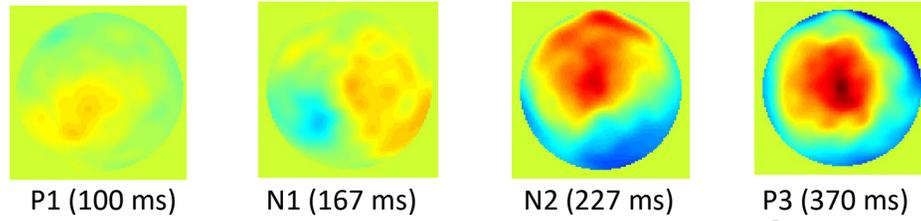
Subtract activation to mask only

- Early accumulation of evidence (linear, nonconscious)
- Late ignition correlating with subjective perception (non-linear, conscious)

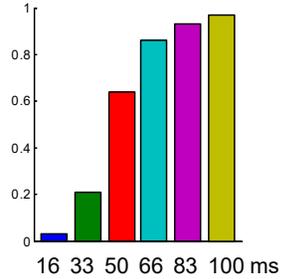
Late non-linear ignition: A signature of conscious access:

Del Cul, Baillet & Dehaene, *PLOS Biology* 2007

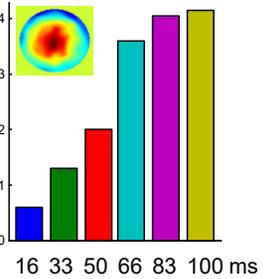
ERPs (evoked by right target)



Fraction of seen digits

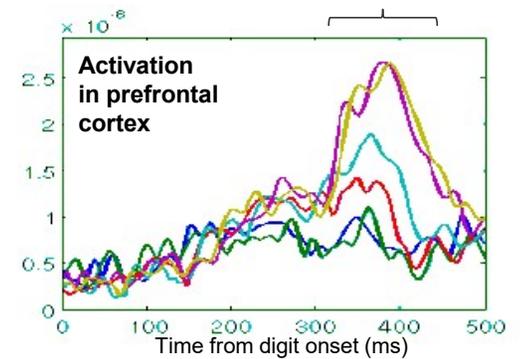
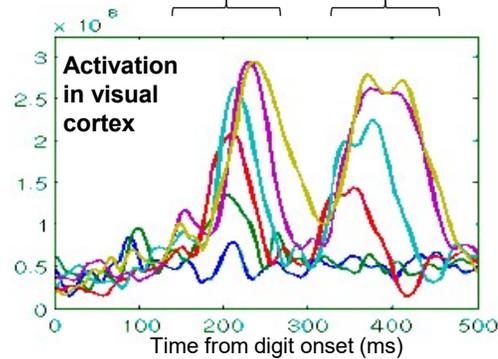


Size of P3 wave



1. Linear accumulation

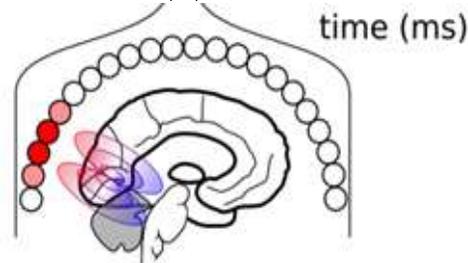
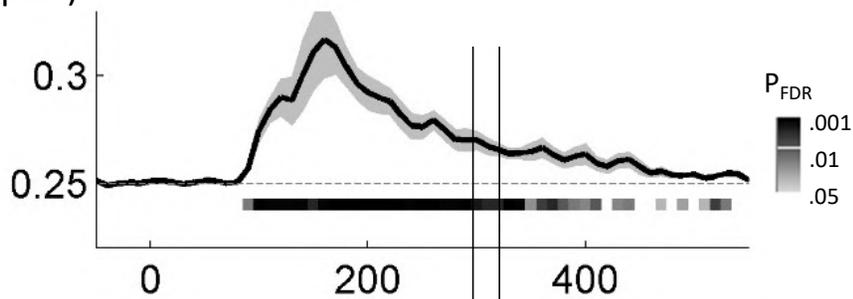
2. All-or-none ignition



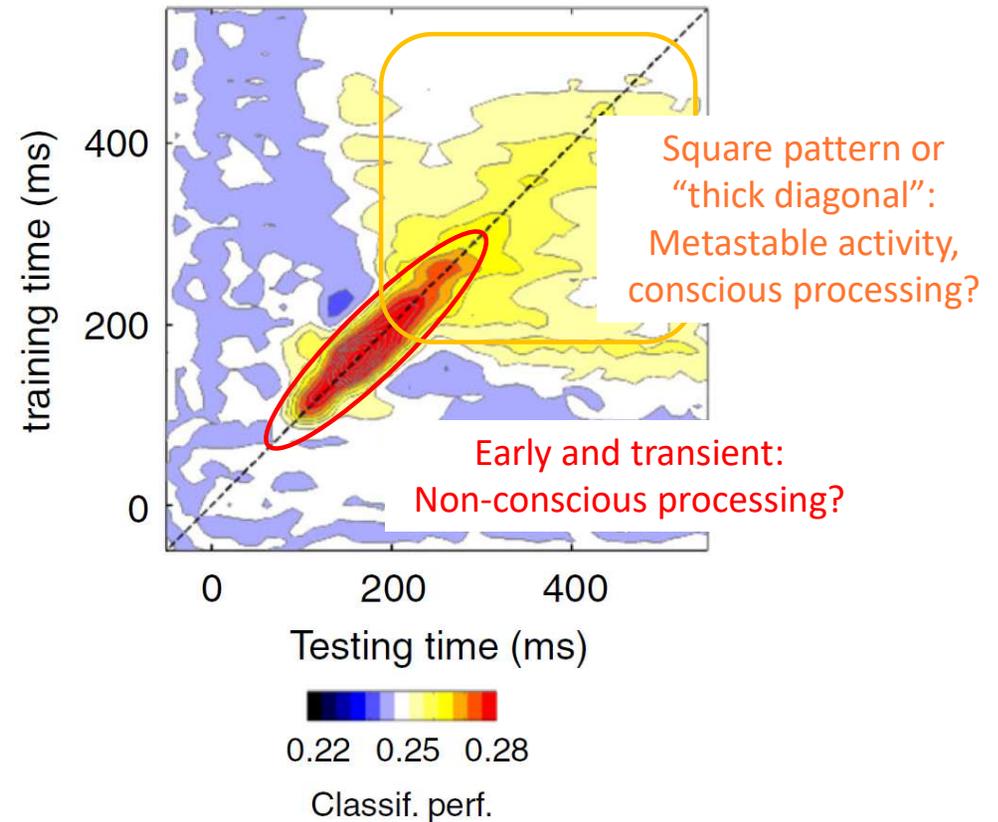
Multivariate decoding unveils the time course of mental representations

King, J.-R., & Dehaene, S. (2014). Characterizing the dynamics of mental representations: the temporal generalization method. *Trends in Cognitive Sciences*, 18(4), 203–210. <https://doi.org/10.1016/j.tics.2014.01.002>

In each time slice, a multivariate decoder can be trained to recover an aspect of the stimulus or the task
Example : decoding an image (face, house, object, or body part)



The generalization across time (GAT) matrix gives information about the stability of representations.



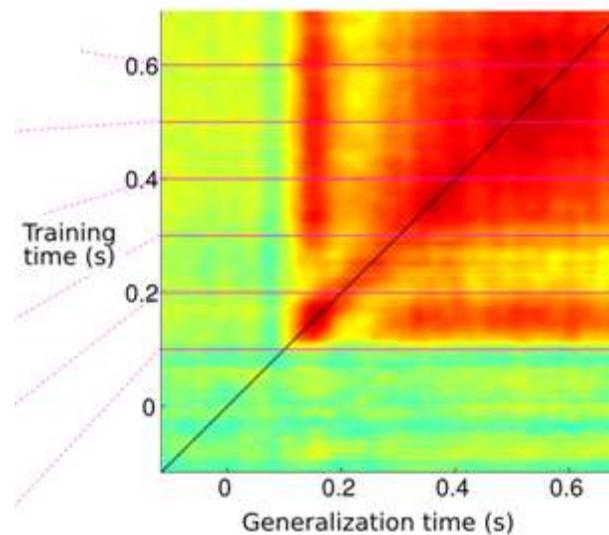
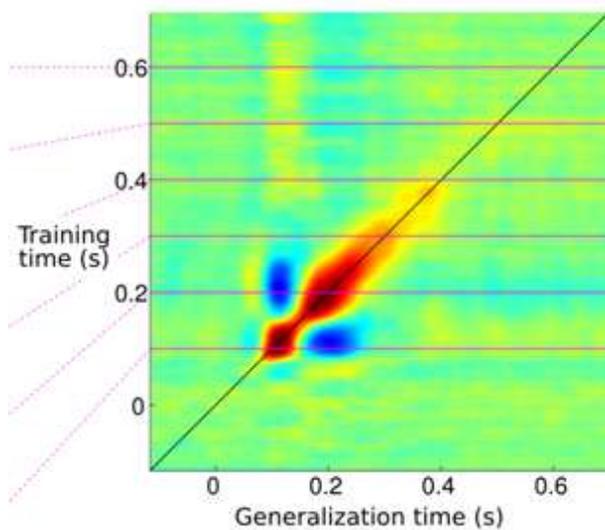
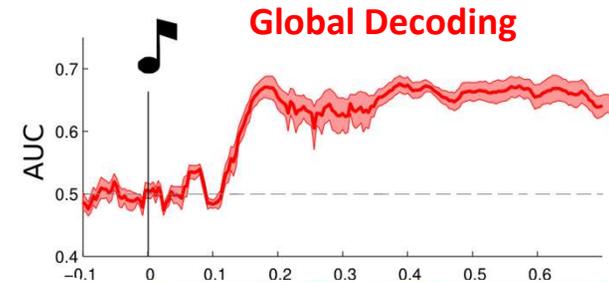
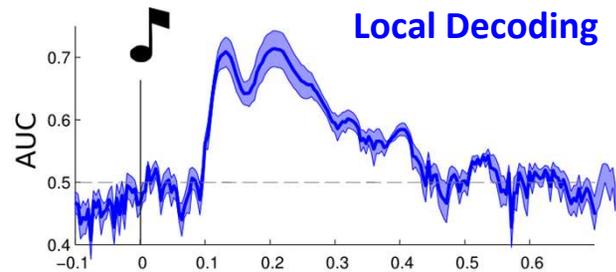
Decoding the local and global effects: different dynamics

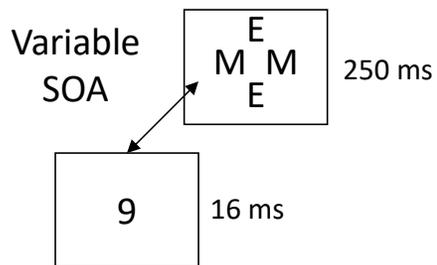
King et al., *NeuroImage* 2013

Decoder trained to discriminate

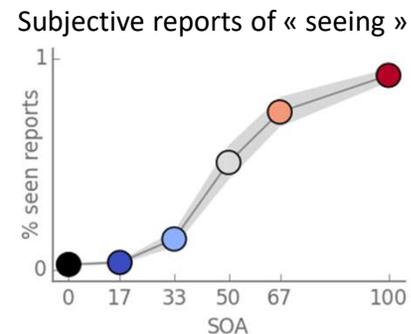


Decoder trained to discriminate
rare versus frequent sequences

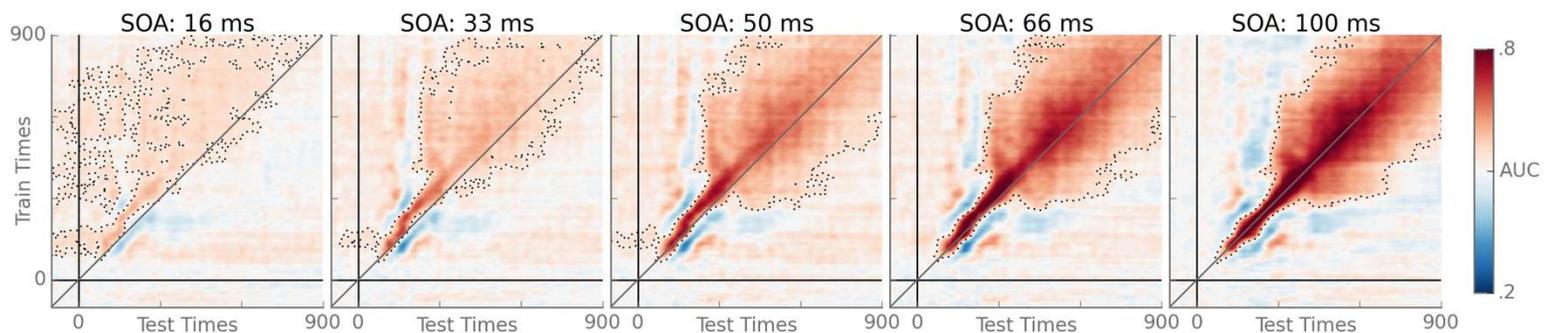




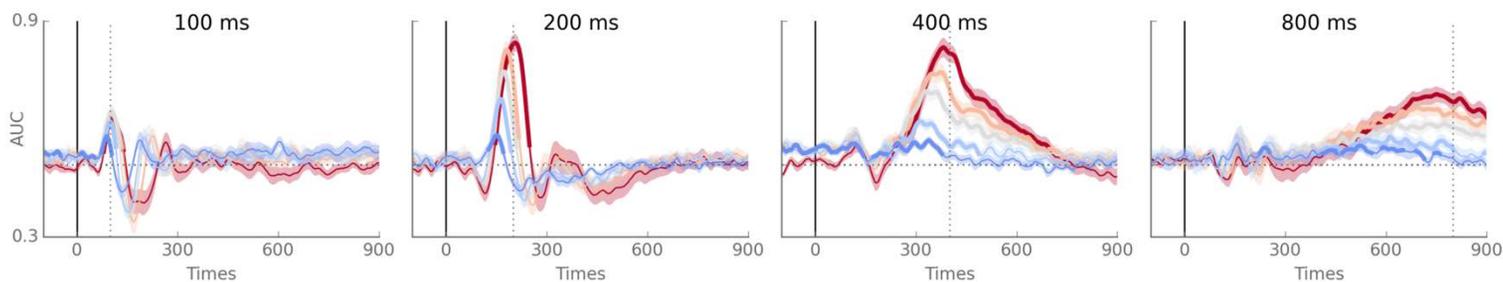
Ignition :
A non-linear transition to a
metastable representation
during conscious access



A decoder can be trained to distinguish target-present versus target-absent trials



Early perceptual activity is linear, only the late activity correlates with conscious reports



Fixed SOA: 50 ms

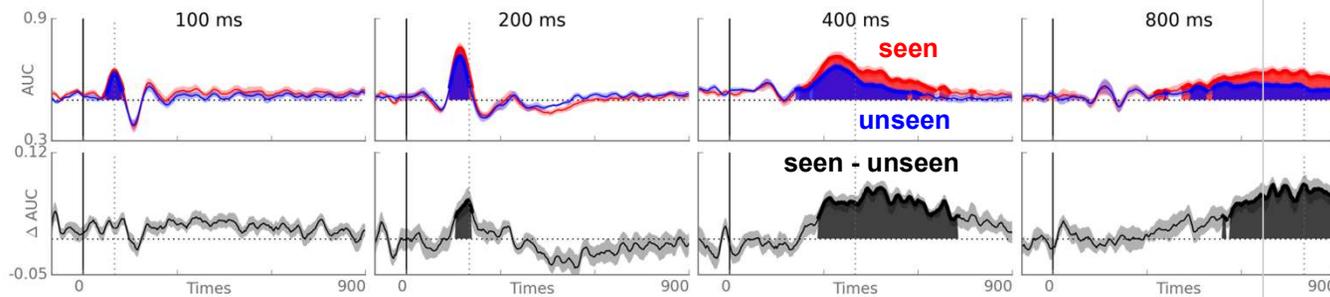
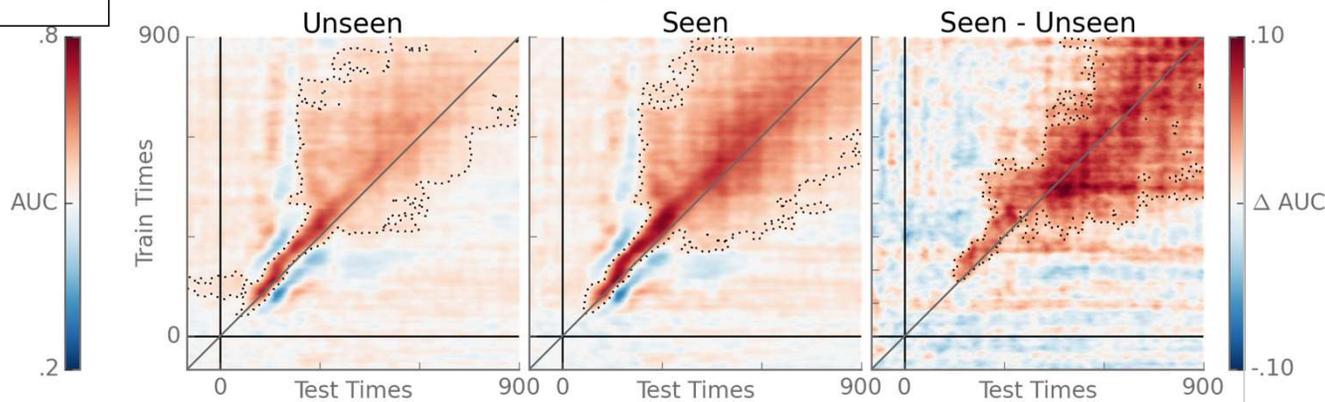
E
 M M
 E

250 ms

9

16 ms

Even when the stimulus is constant, late metastable activity distinguishes conscious from nonconscious trials



Late « metastability » appears as a correlate of conscious perception.

Consciousness stabilizes mental representations: see also Schurger et al., *Science*, 2009; Schurger et al., *PNAS* 2015



Jean-Rémi King

Can we track the **contents** of conscious and nonconscious representations?

King, J.-R., Pescetelli, N., & Dehaene, S. (2016). Brain Mechanisms Underlying the Brief Maintenance of Seen and Unseen Sensory Information. *Neuron*, 92(5), 1122–1134. <https://doi.org/10.1016/j.neuron.2016.10.051>

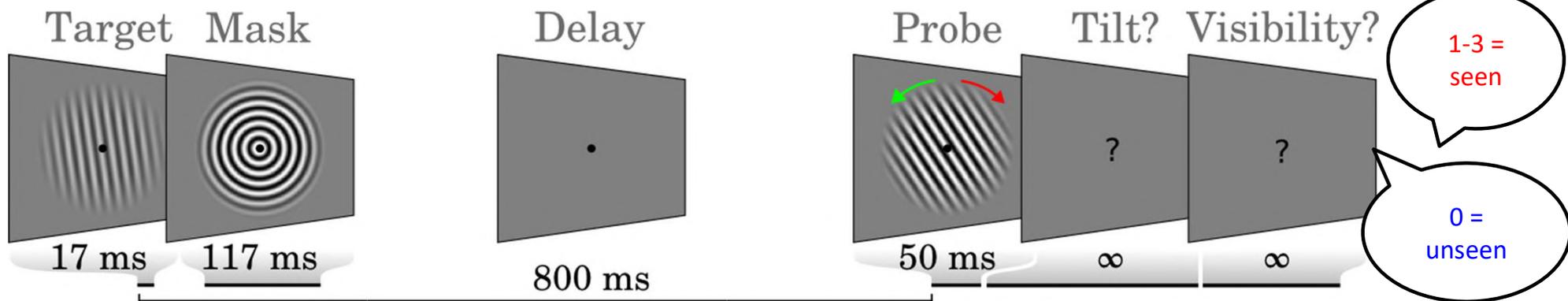
In this MEG experiment, a rich stimulus is presented.

Can we decode its features?

Can we detect an amplification of the task-relevant feature, even on non-conscious trials?

Stimulus = a flashed grid, with variable contrast (hence visibility), orientation and spatial frequency

Only the orientation is task-relevant: subjects must compare it with a subsequent probe.

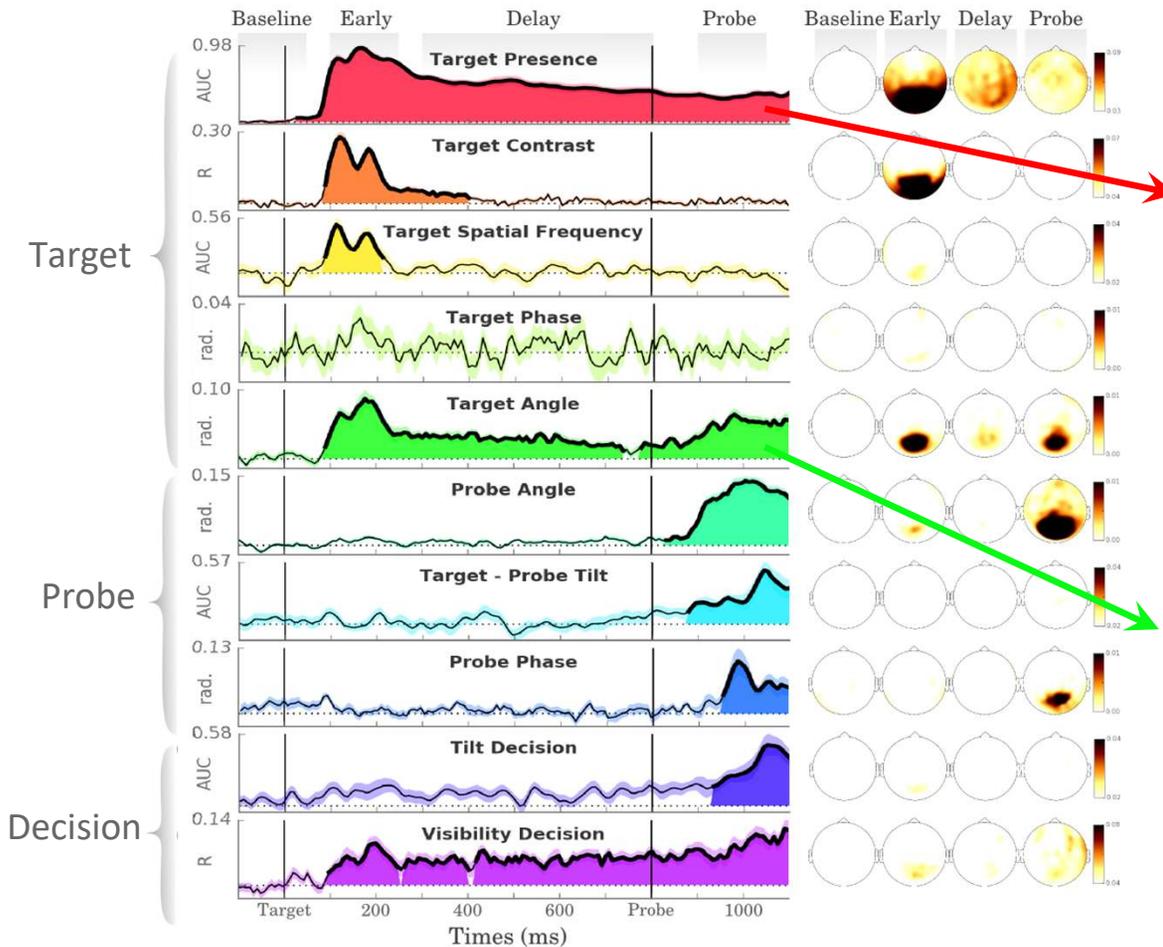


Even on unseen trials, forced-choice performance is significant (58% correct).

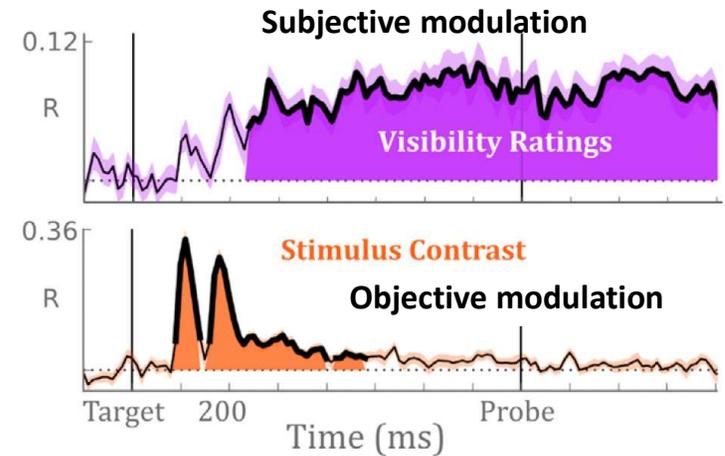
Here the delay is short, but in a later course, we will talk about the reality of non-conscious working memory (or rather short-term memory)

See Trübtscheck et al., *Elife* 2017, *Sci.Rep.* 2019, *PNAS* 2019

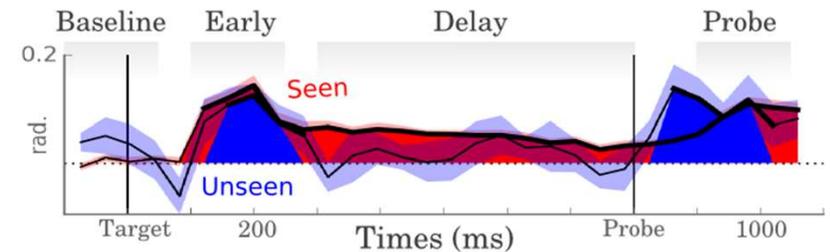
Maintenance of relevant information (angle) and its modulation by conscious visibility



How are these decoders modulated by visibility?



Angle information is selectively maintained on **conscious** trials – and goes dormant on **non-conscious** trials



Visibility ratings can be decoded start around 100 ms and for the entire duration of the trial



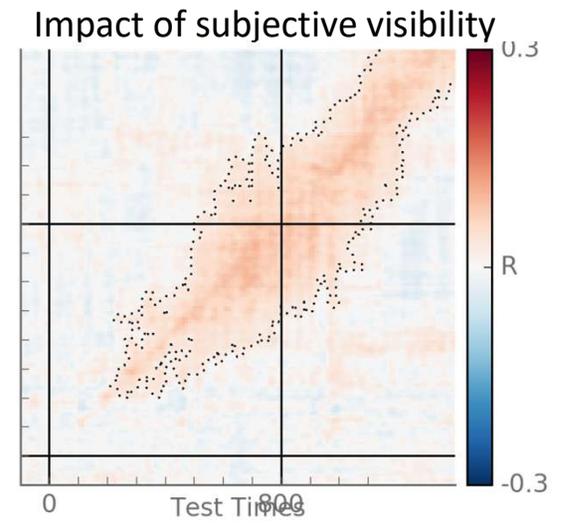
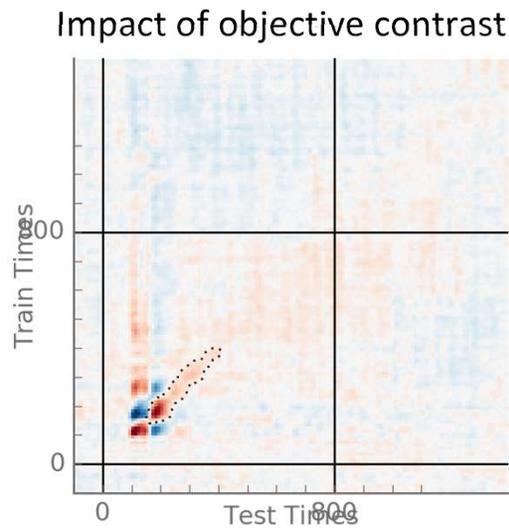
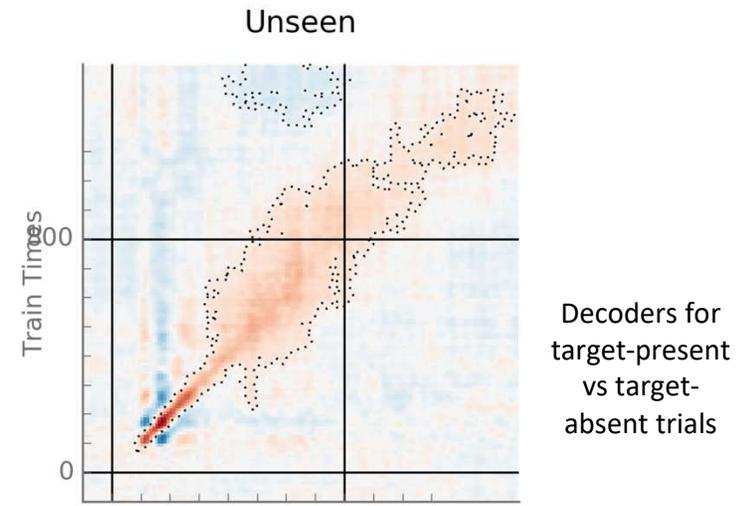
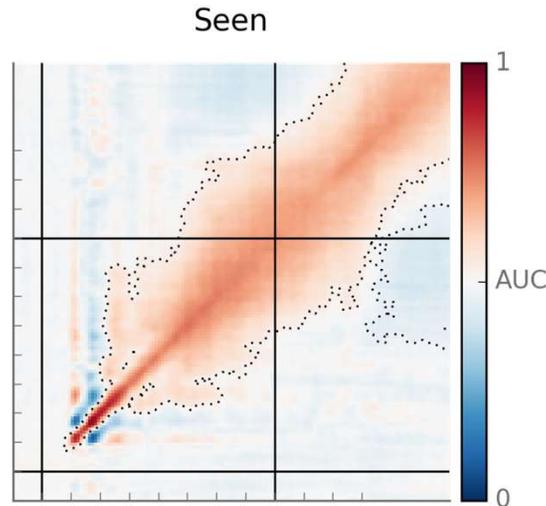
Jean-Rémi King

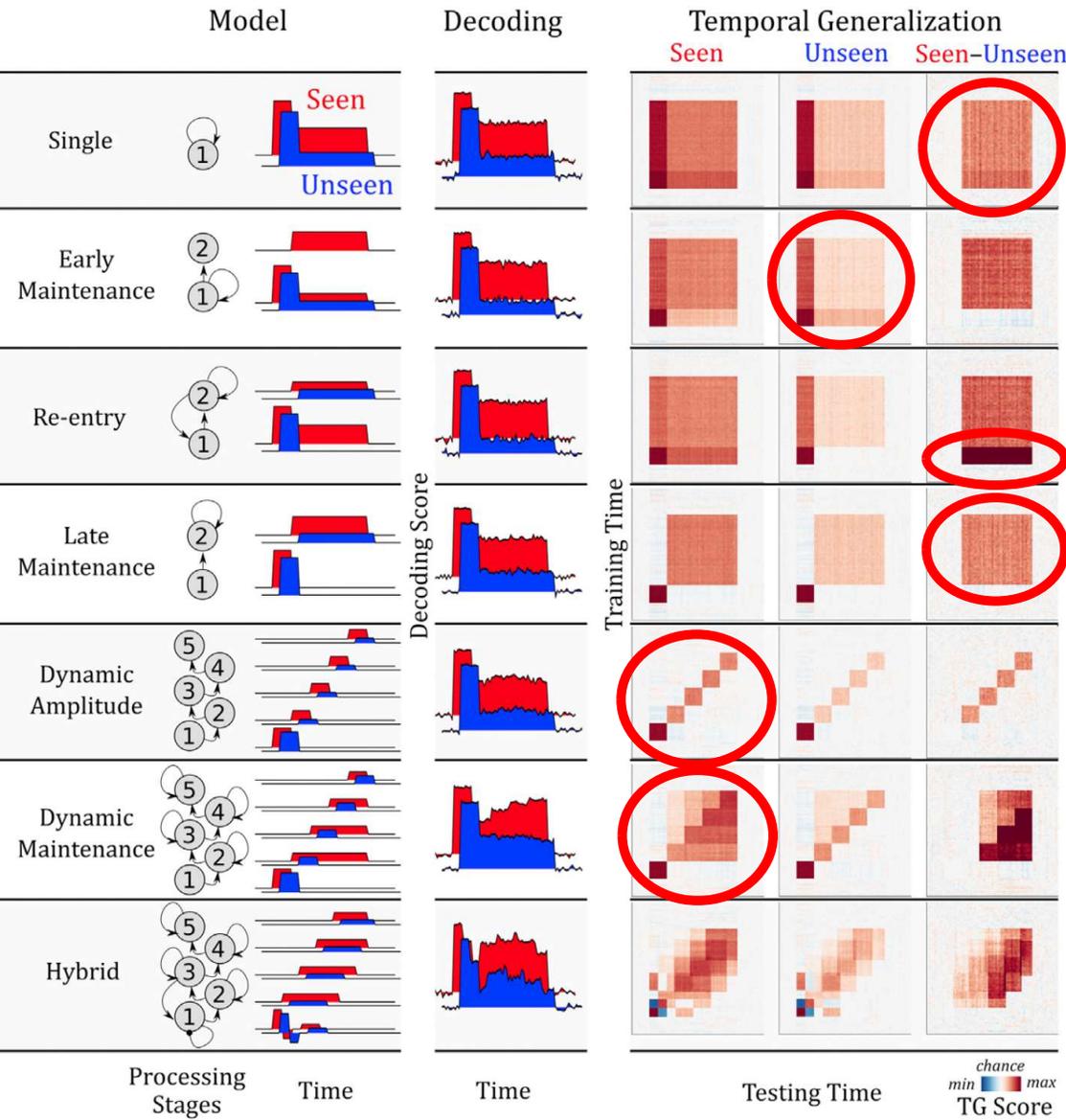
Conscious and nonconscious processing as divergent dynamic trajectories

Both conscious and non-conscious trials evoke a long, complex processing trajectory.

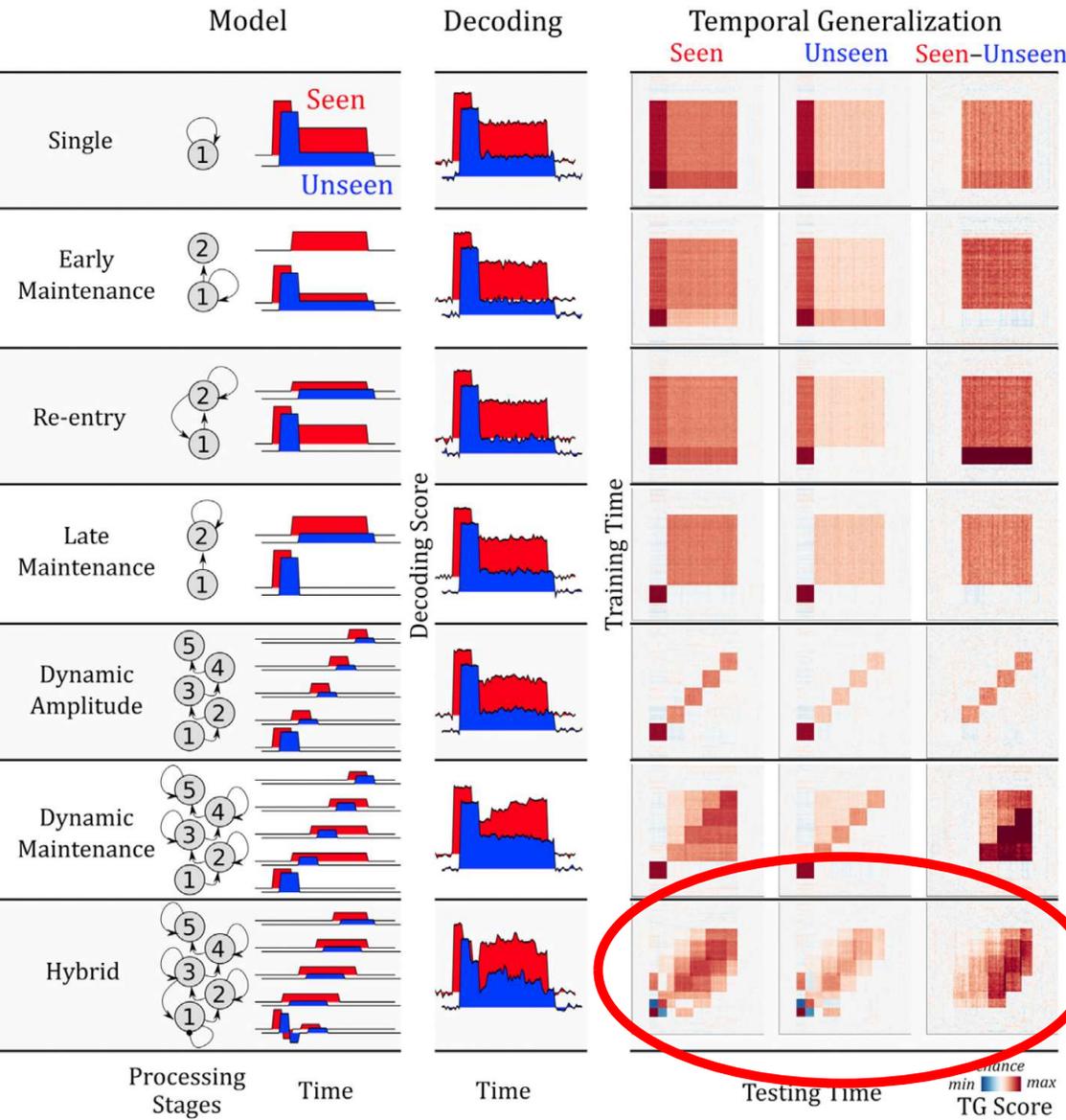
Dissociation between objective and subjective influences.

Subjective visibility is associated with a much more intense and long-lasting trajectory (thicker diagonal) = Conscious ignition



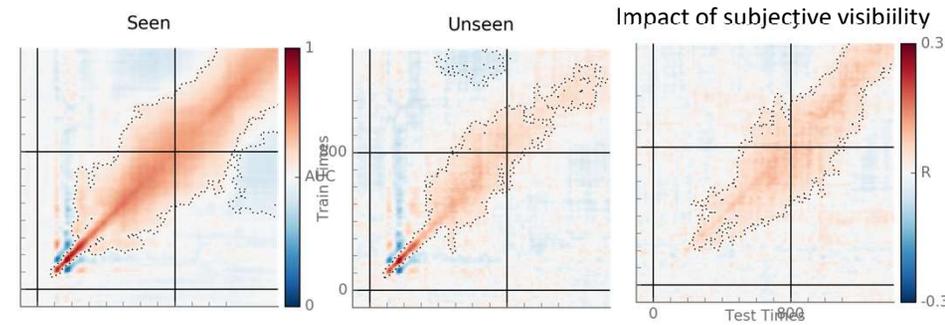


1. **A single processor**, holding the conscious content, is less active on non-conscious trials (e.g. Semir Zeki's **microconsciousness**)
 → Rejected: the data shows a « thick diagonal » pattern
2. Non-conscious processing is confined to early stages; conscious stimuli gain access to a **second stage of processing**.
 → Rejected: the data shows long diagonal decoding on nonconscious trials
3. Only conscious processing shows **reentry** (Edelman), **loops** (Lamme), or **top-down amplification** (Roelfsema, Dehaene).
 → Not present in this experiment: absence of late generalization of early decoders that would be specific to conscious trials.
4. **Conscious maintenance**, reduced on non-conscious trials
 → Better fit, but fails to account for the “thick diagonal” in the data.
 Conscious and non-conscious processing involve **dynamic processes**.
5. **Dynamic processing wave with deeper processing** on conscious trials.
 → Better fit, but still rejected because temporal generalization is narrower for early processes (50 ms) than for late ones (315 ms), and narrower on non-conscious trials (288 ms) than on conscious trials (447 ms).
6. Dynamic processing wave, with **longer duration** on conscious trials
 → Not quite right, because it predicts an asymmetry in generalization which is not observed in the data
7. The best model is a hybrid one
 - **A dynamic wave of sequential processing stages**
 - Transient initially activity, and **late metastable** processing stages
 - **Increasing amplitude** of those late stages with subjective visibility



Access to consciousness reflects a divergent dynamic trajectory

Comparison with the observed data



Conclusion :

- The hypothesis of an **all-or-none separation** between conscious and non-conscious trials is true only in first approximation.
- A non-conscious stimulus may traverse virtually all of the same processing steps as a conscious one, but with smaller amplitude and shorter duration.

Ignition = Fast divergence of two dynamic trajectories

- The best model is a hybrid one
 - **A dynamic wave of sequential processing stages**
 - Transient initially activity, and **late metastable** processing stages
 - **Increasing amplitude** of those late stages with subjective visibility

Conscious and non-conscious processing : divergent dynamic trajectories

Salti, M., Harel, A., & Marti, S. (2018). Conscious Perception: Time for an Update? *Journal of Cognitive Neuroscience*, 31(1), 1–7.

https://doi.org/10.1162/jocn_a_01343

Baria, A. T., Maniscalco, B., & He, B. J. (2017). Initial-state-dependent, robust, transient neural dynamics encode conscious visual perception. *PLoS Computational Biology*, 13(11), e1005806.

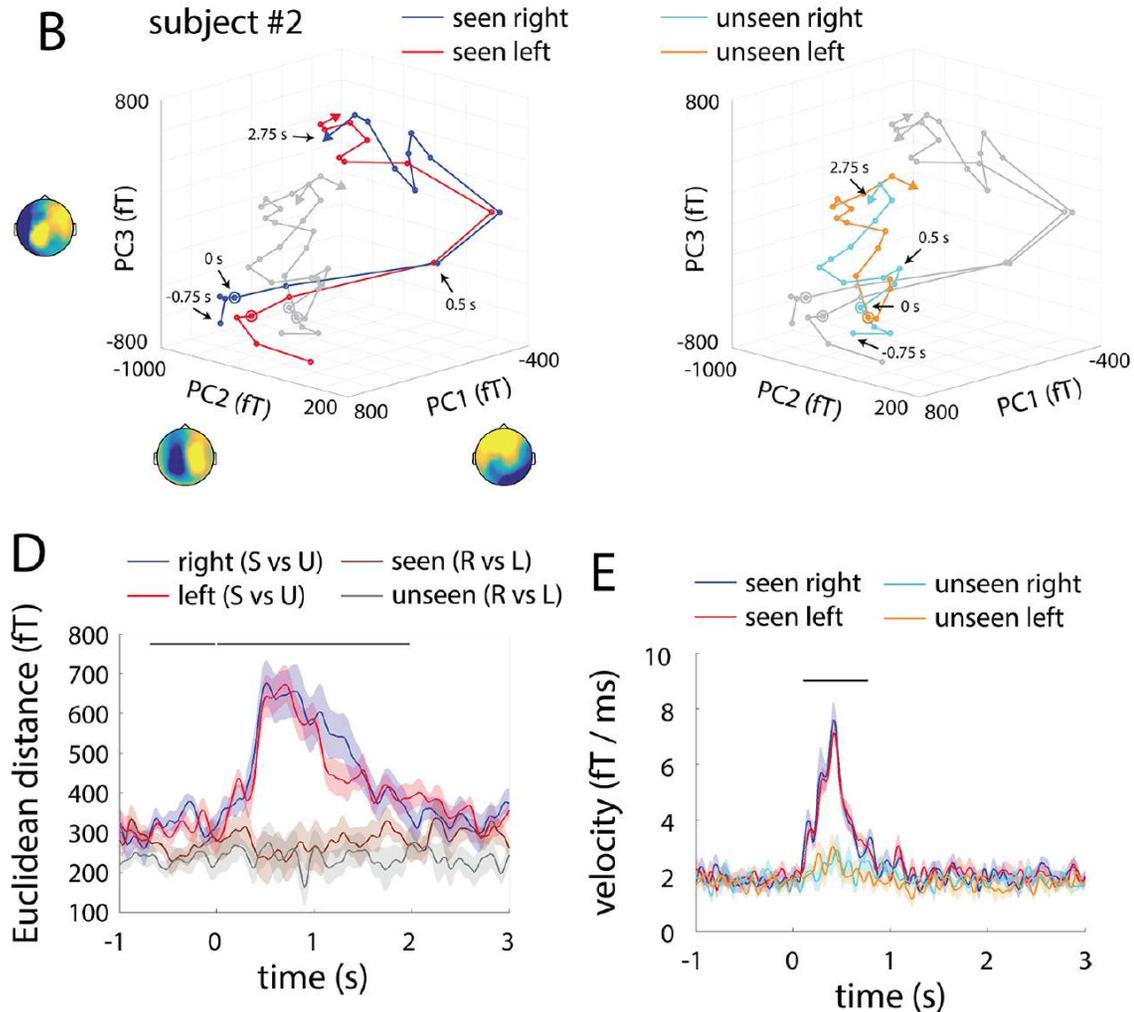
<https://doi.org/10.1371/journal.pcbi.1005806>

In MEG, seen and unseen trials follow well separated trajectories that diverge sharply after 300 ms.

Euclidean distance changes suddenly around 200-300 ms.

There is a peak in the “velocity” of evoked fields (speed of activation changes)

→ All of these are markers of a non-linear bifurcation or phase transition = the predicted **ignition**.

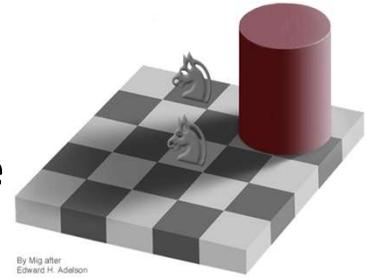




Jean-Rémi King
+ Gabriela Meade

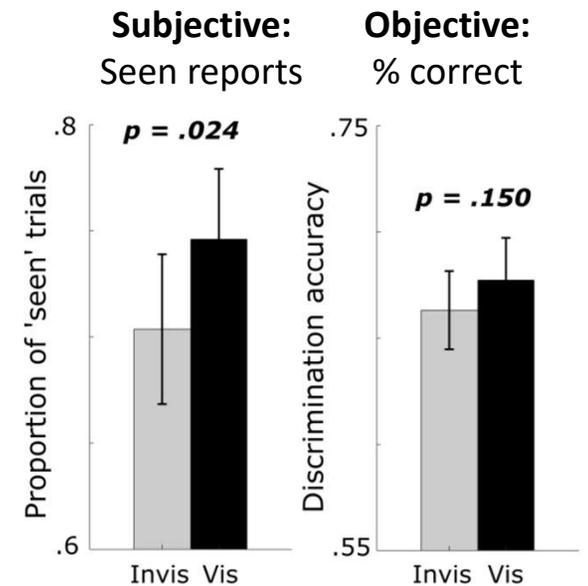
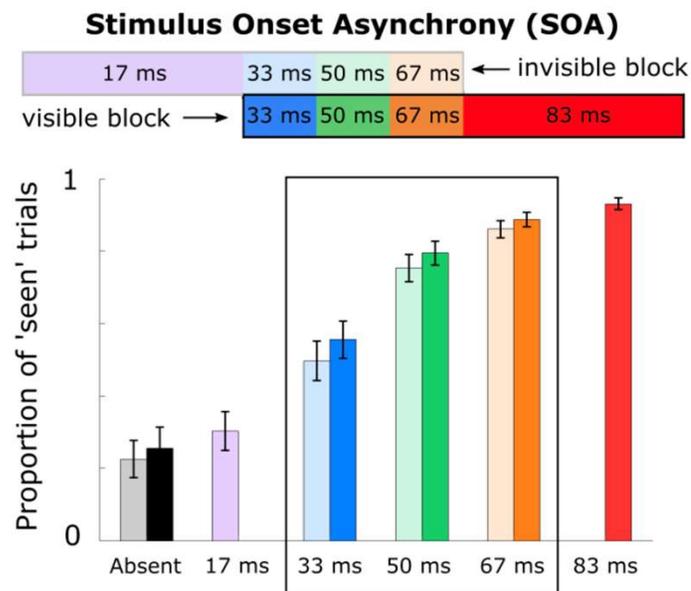
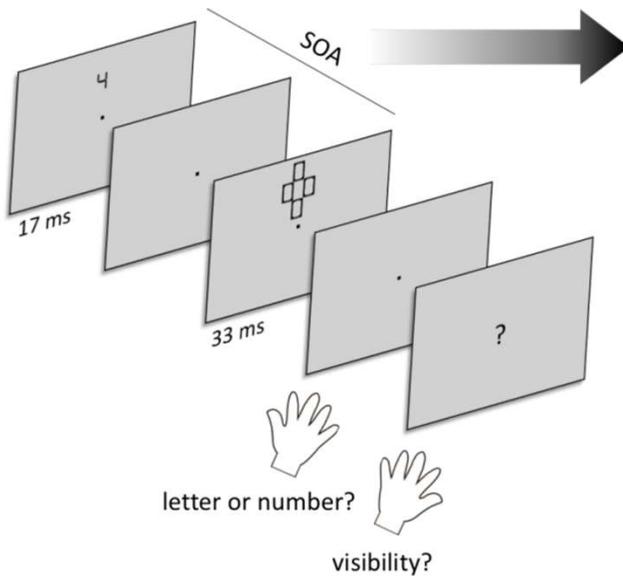
What might be the **function** of those successive stages? A simple hypothesis: subjective report reflects the **posterior**, on perceptual decision, following a long nonconscious inference

King, J.-R., & Dehaene, S. (2014). A model of subjective report and objective discrimination as categorical decisions in a vast representational space. *Phil Transact Royal Soc London. Series B*, 369(1641)

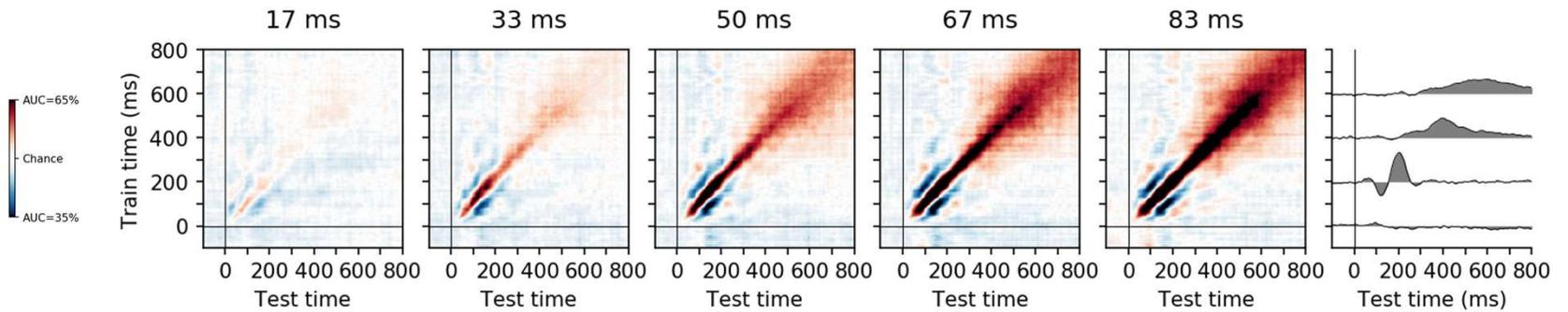


“What we call a ‘subjective’ report may simply be the brain’s best attempt at solving a difficult perceptual decision problem with myriads of potential classes, each with different costs and prior probabilities that depend on the subject’s prior experience.”

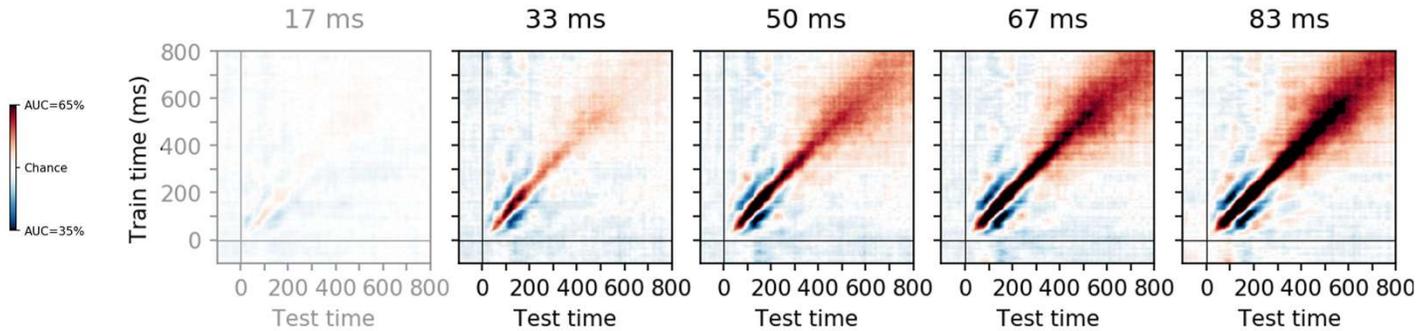
To better dissociate the **evidence** from the **posterior**, Jean-Rémi and Gabriela also manipulated the **prior**: Masking paradigm with a majority of either “visible” trials or “invisible” trials.



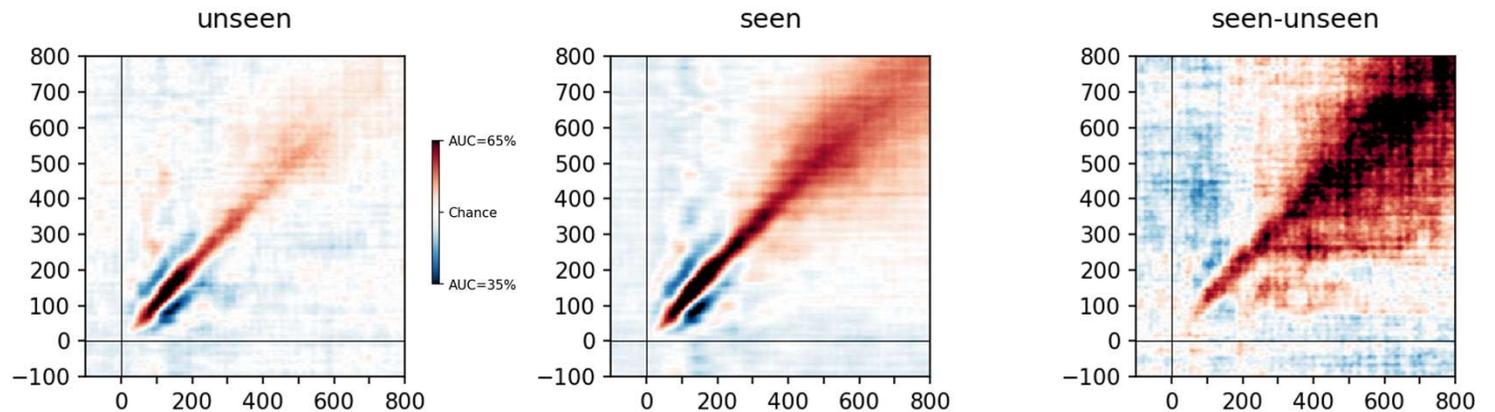
Decoding **target-present** versus **target-absent** at each objective duration



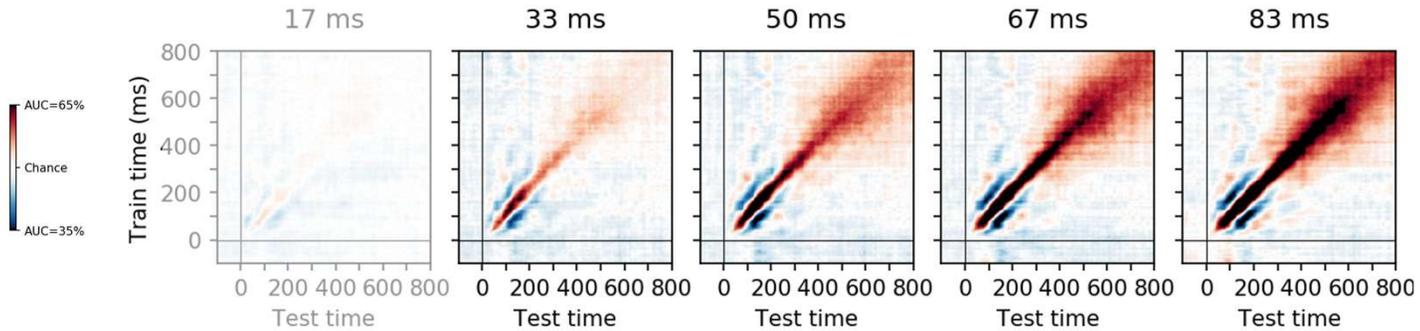
Decoding **target-present** versus **target-absent** at each objective duration



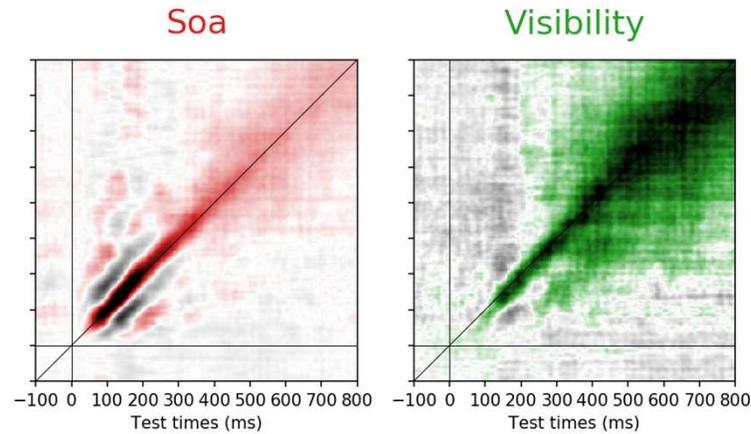
Separating the **objective evidence** (SOA) and the **subjective report** (unseen/seen):



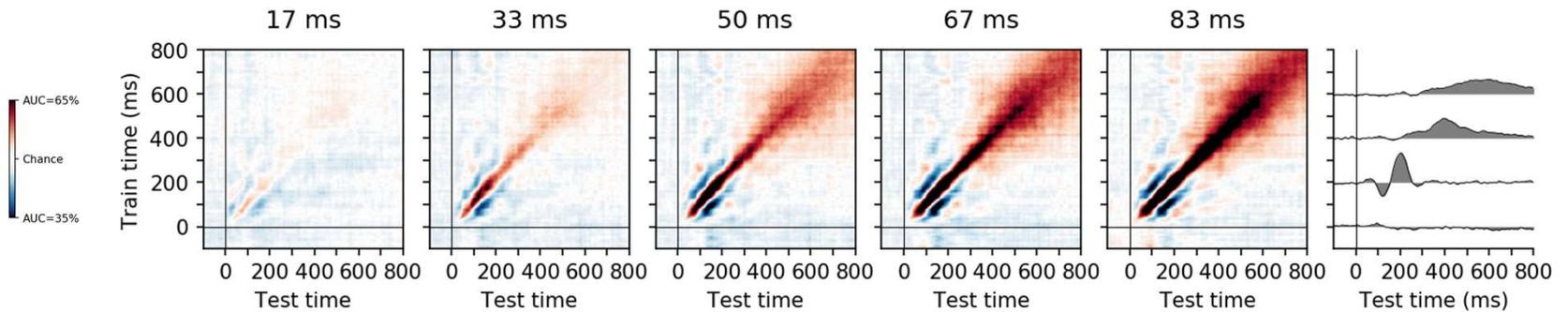
Decoding **target-present** versus **target-absent** at each objective duration



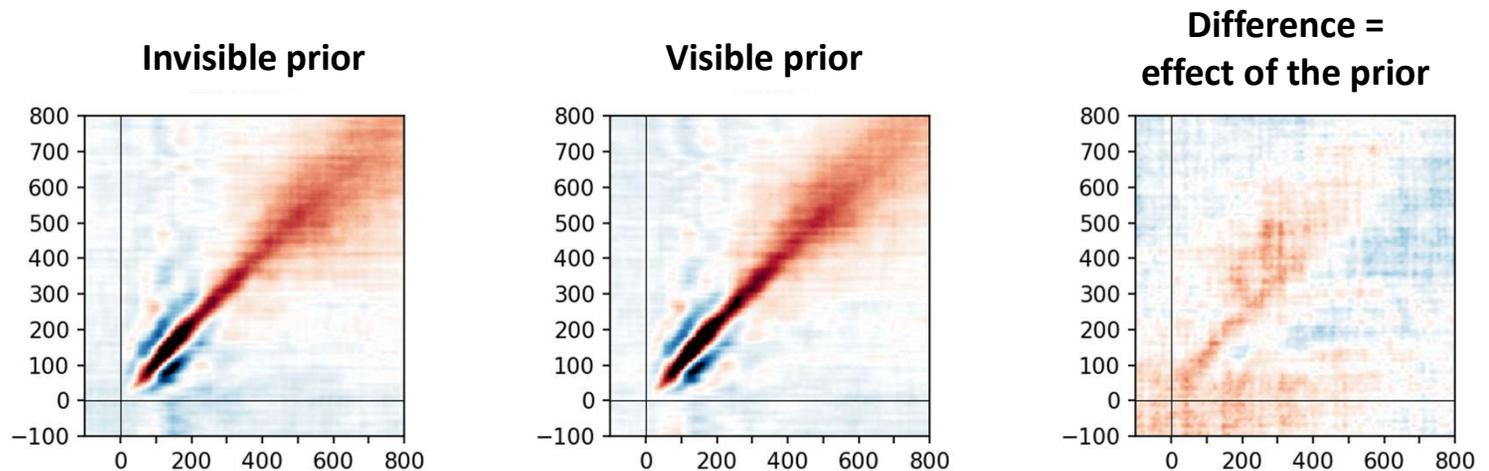
Separating the **objective evidence** (SOA) and the **subjective report** (unseen/seen):



Decoding **target-present** versus **target-absent** at each objective duration



... and now also separating the **prior** (block type with a majority of invisible or visible trials)

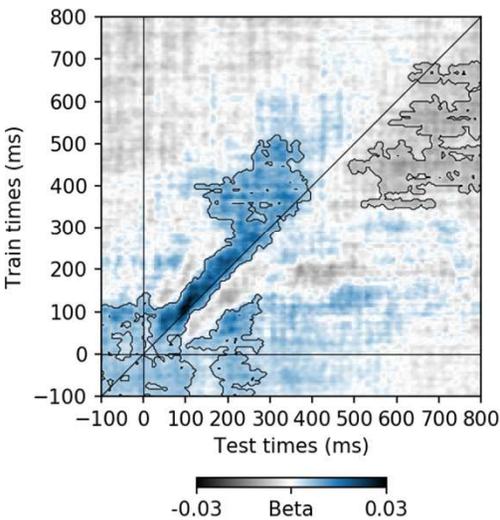


Putting it all together:
Sequential influences of prior, evidence, and posterior
at each of several processing stages

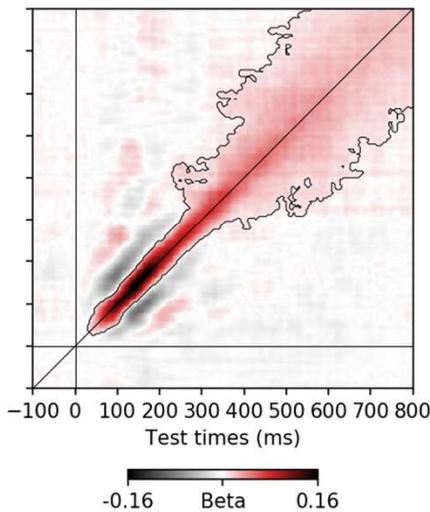
with the last, sustained stage being entirely dominated by **subjective visibility**

Conscious ignition may reflect the final all-or-none conclusion of a Bayesian inference process

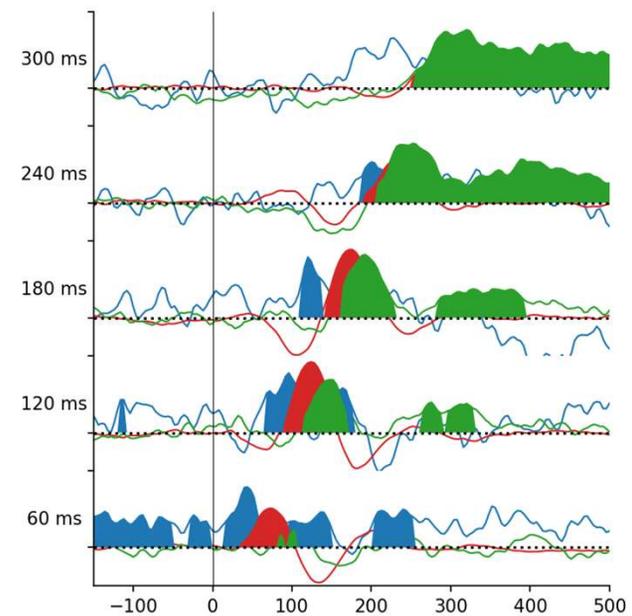
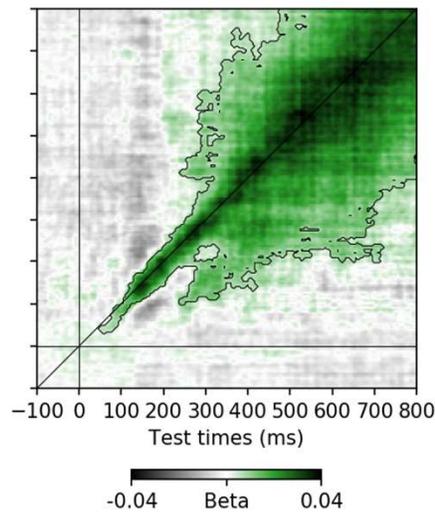
Prior
Block



Evidence
Soa



Posterior
Visibility



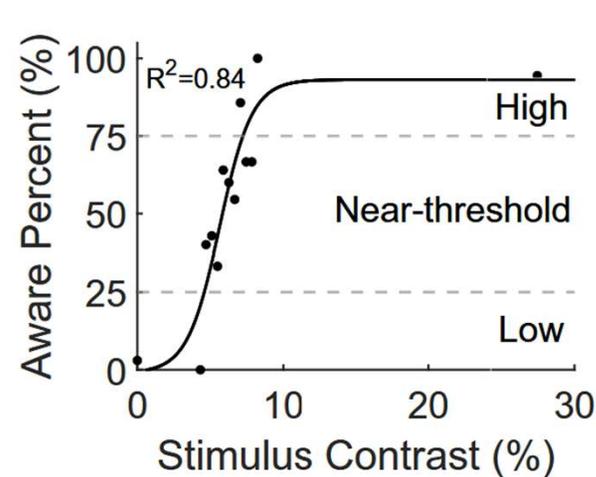
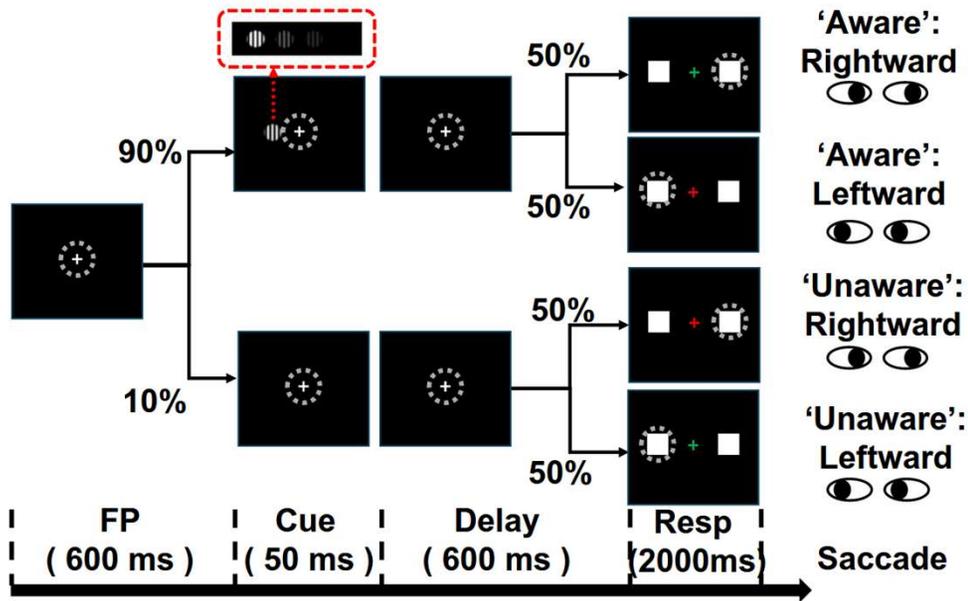
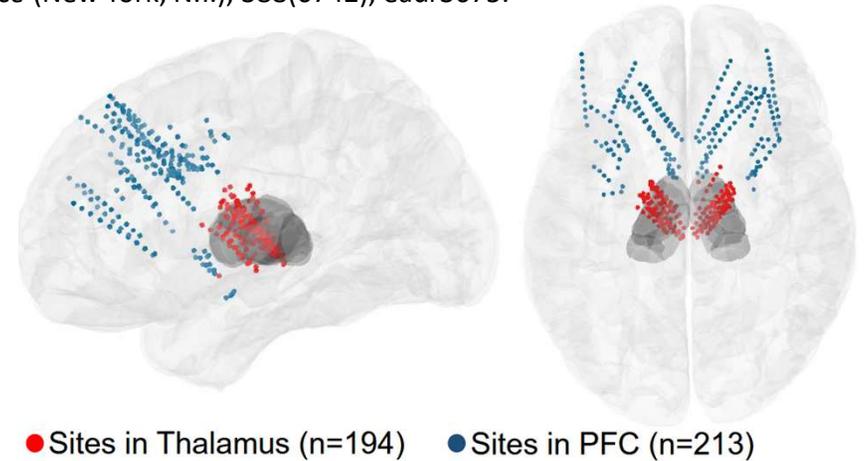
Ignition as a thalamo-cortical state

Fang, Z., Dang, Y., Ping, A., Wang, C., Zhao, Q., Zhao, H., Li, X., & Zhang, M. (2025). Human high-order thalamic nuclei gate conscious perception through the thalamofrontal loop. *Science* (New York, N.Y.), 388(6742), eadr3675.

Intracranial recordings can provide a more precise localization of the sources of ignition.

The GNW simulations suggest that ignition involves thalamo-cortical circuits.

Here, the authors recorded from many thalamic and prefrontal sites during a paradigm of visual perception at threshold.



Division into four conditions

- high contrast conscious (HC),
- near threshold conscious (NC)
- near threshold unconscious (NU)
- low contrast unconscious (LU)

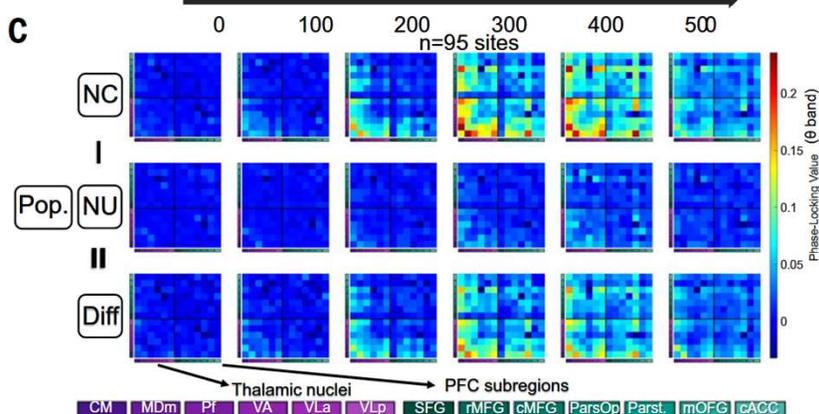
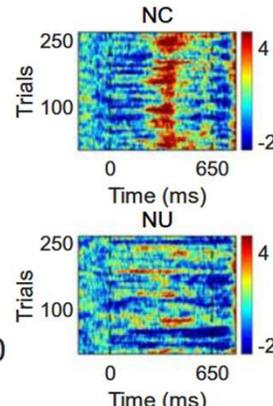
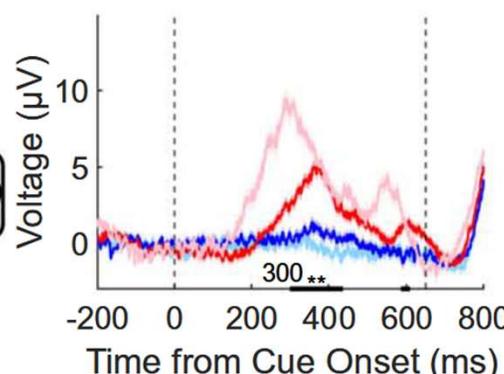
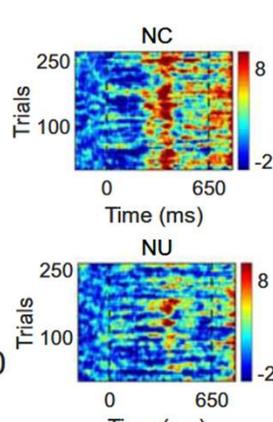
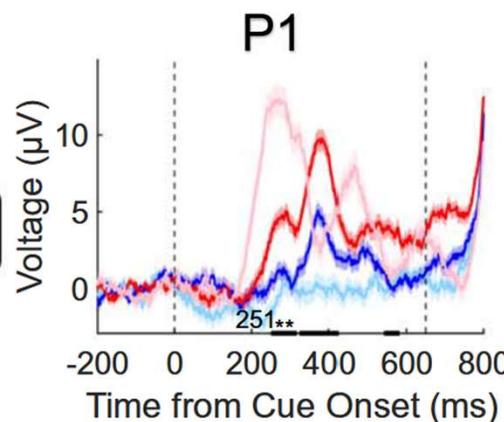
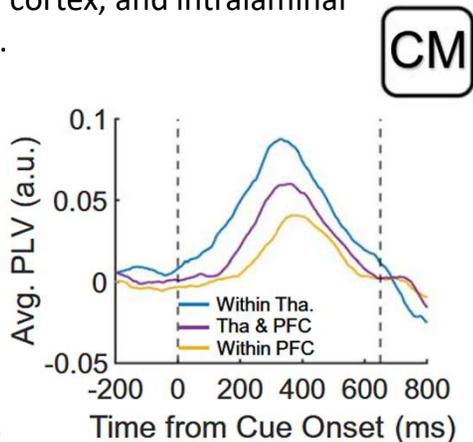
Ignition : A thalamo-cortical state

Fang, Z., Dang, Y., Ping, A., Wang, C., Zhao, Q., Zhao, H., Li, X., & Zhang, M. (2025). Human high-order thalamic nuclei gate conscious perception through the thalamofrontal loop. *Science* (New York, N.Y.), 388(6742), eadr3675.

In all patients, the conscious and nonconscious conditions (even for similar stimuli) diverge suddenly around 200 ms in the central median nucleus (CM) and ventral lateral posterior nucleus (VLp) of the thalamus. This effect is more frequently found in intralaminar and medial nuclei (reminder: dorsomedial nucleus connects to prefrontal cortex, and intralaminar show very broad connectivity with PFC, cingulate, etc.).

Synchronous phase-locking between electrodes appears around 200 ms, much more strongly in the conscious conditions. It starts within the thalamus, then synchronizes with the prefrontal cortex.

- Conscious (high contrast), HC
- Conscious (near-threshold), NC
- Unconscious (near-threshold), NU
- Unconscious (low contrast), LU



Ignition : A thalamo-cortical state

Fang, Z., Dang, Y., Ping, A., Wang, C., Zhao, Q., Zhao, H., Li, X., & Zhang, M. (2025). Human high-order thalamic nuclei gate conscious perception through the thalamofrontal loop. *Science* (New York, N.Y.), 388(6742), eadr3675.

Phase-amplitude coupling also appears as a marker of conscious ignition:

The **phase** of the slow theta-band activity (2-8 Hz) in the thalamus predicts the **amplitude** of fast high-gamma-band activity (60-150 Hz).

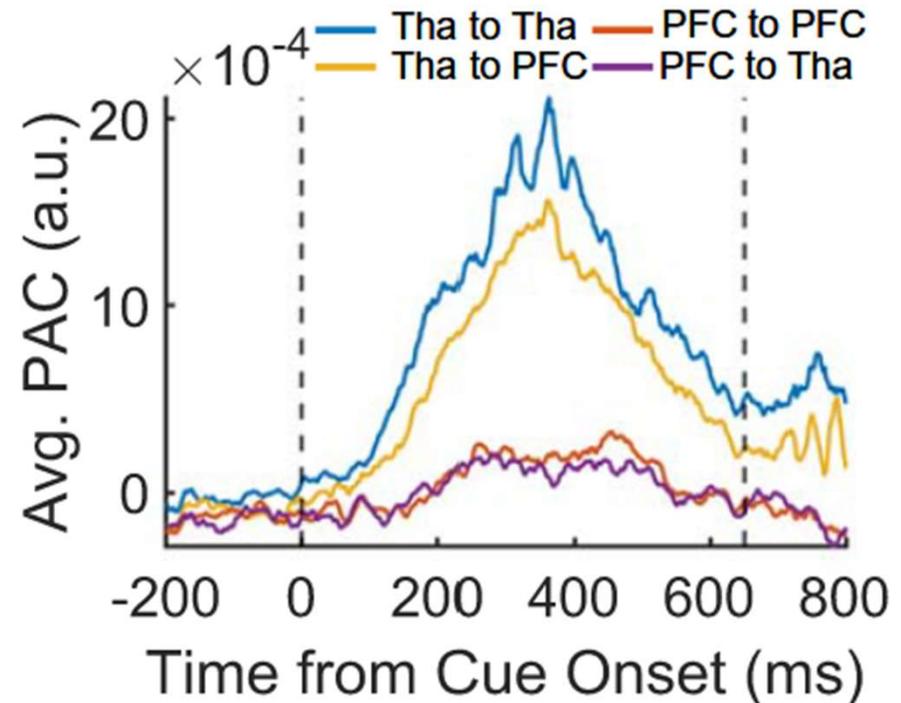
Interpretation :

Thalamic theta may open a “gate”, a time window within which cortical ignition can occur, in prefrontal cortex and other associative areas.

This is consistent with the key role of thalamo-cortical connections in wakefulness and anesthesia

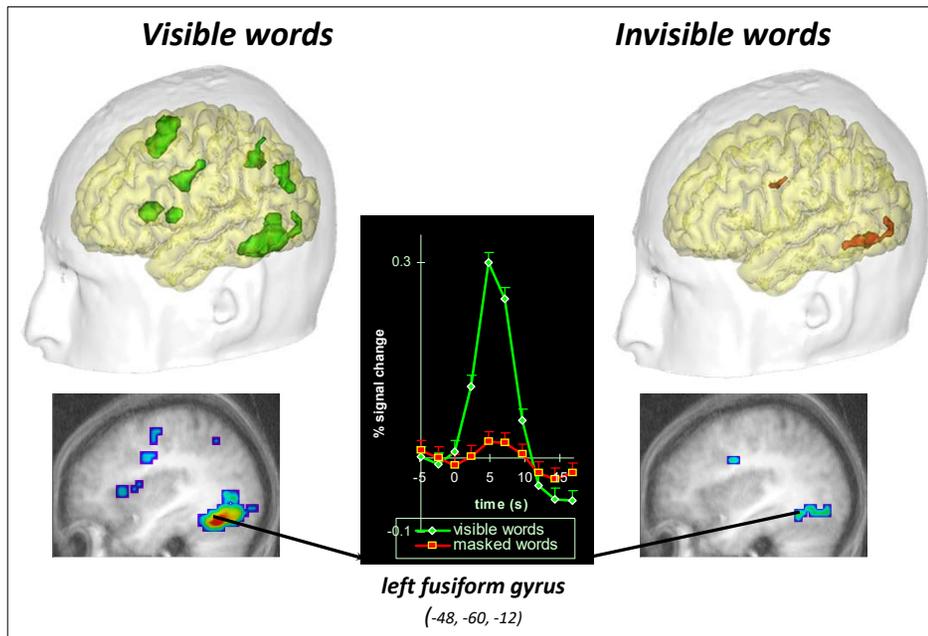
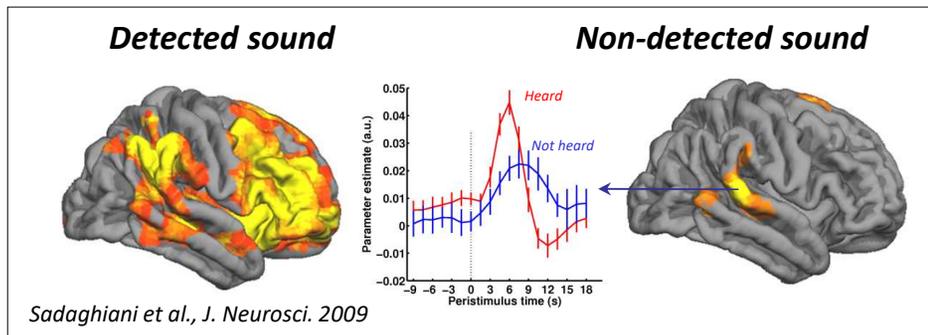
(see Suzuki, M., & Larkum, M. E. (2020). General Anesthesia Decouples Cortical Pyramidal Neurons. *Cell*, 180(4), 666-676.e13.)

Prediction : the cortex should have a decodable representation of the detailed contents of conscious experience.

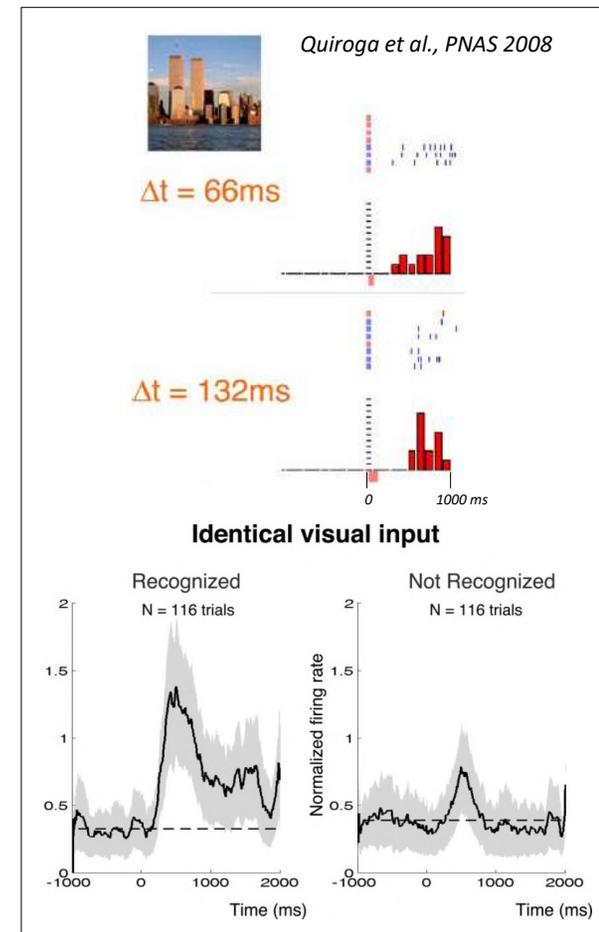


Late global « ignition » as a signature of consciousness

fMRI with threshold or masked stimuli



Single-neuron recordings in humans to masked pictures

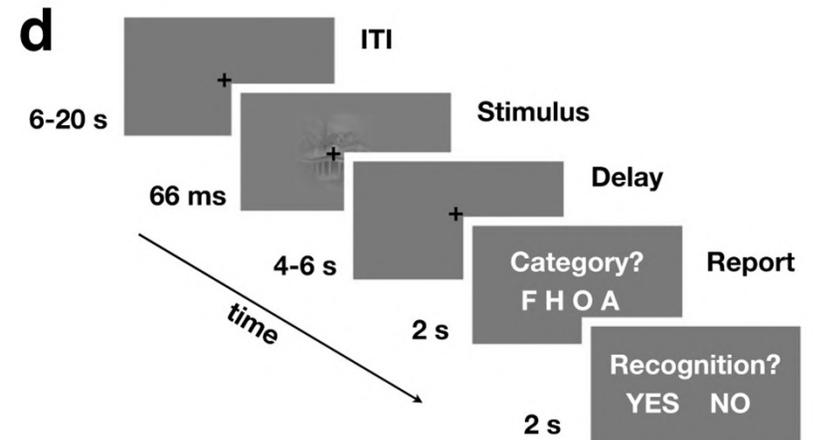
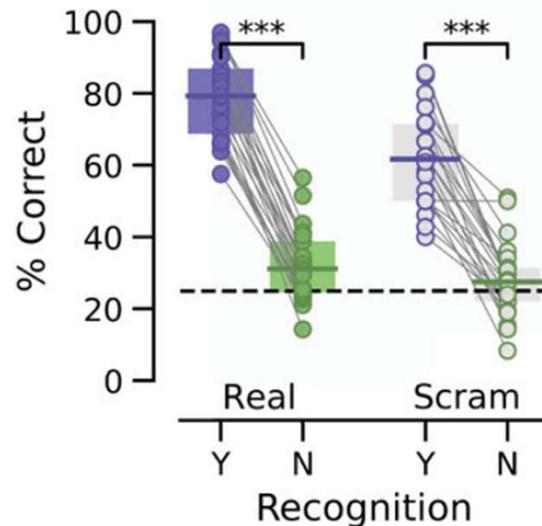


Decoding the **contents** of conscious representations

Levinson, M., Podvalny, E., Baete, S. H., & He, B. J. (2021). Cortical and subcortical signatures of conscious object recognition. *Nature Communications*, 12(1), Article 1. <https://doi.org/10.1038/s41467-021-23266-x>*

Low-contrast images were flashed at the individual participant threshold – every image was titrated to be at 50% recognition. The images belonged to four decodable categories (animals, faces, objects and houses ; also scrambled). Participants were asked to guess the category, and to report whether they consciously recognized the picture or not. The very same picture could sometimes be seen (and categorized correctly most of the time) or unseen (but still categorized above chance level).

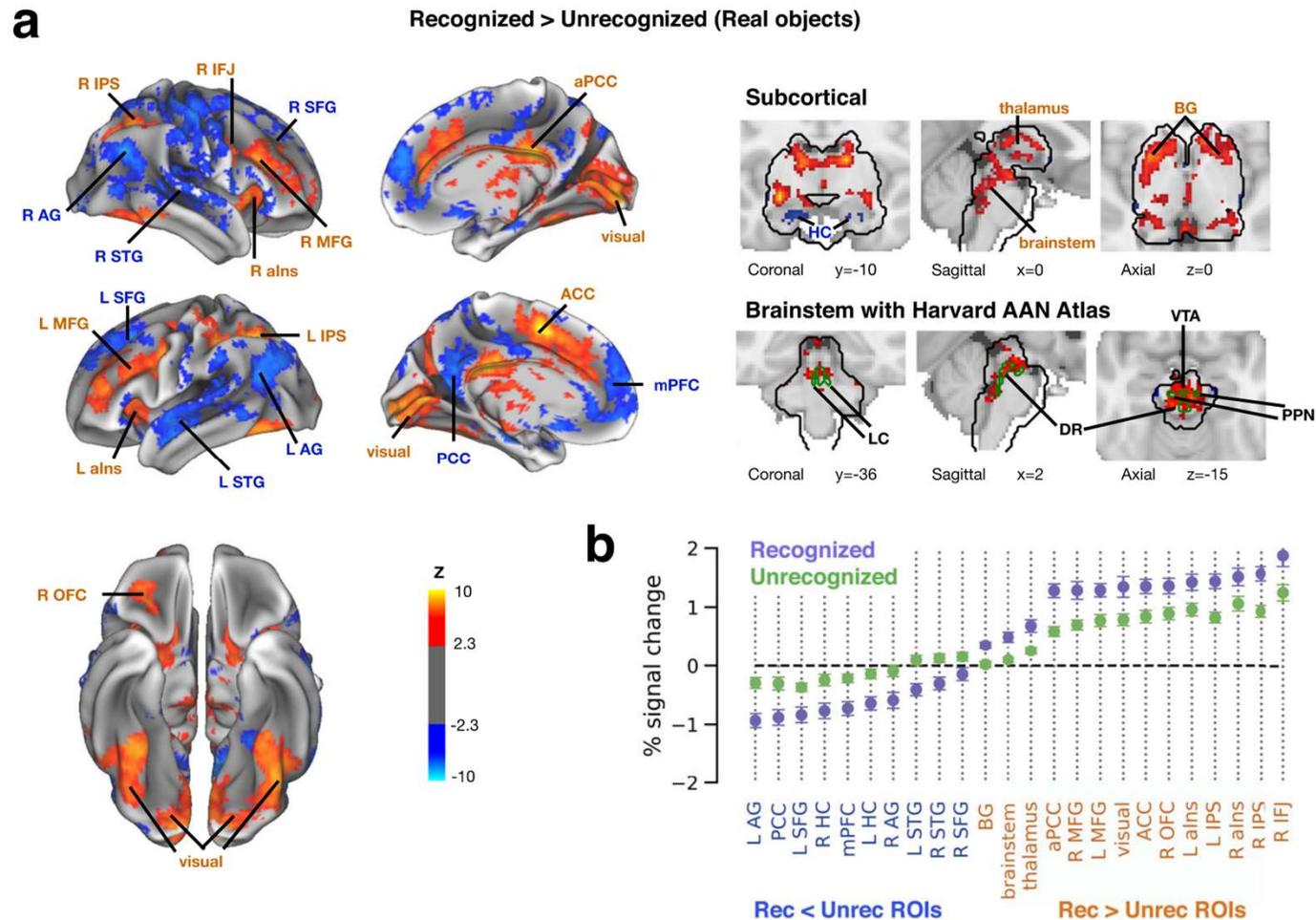
Activation was acquired with a 7 Tesla fMRI scanner (2x2x2 mm resolution)



Decoding the contents of conscious representations

Levinson, M., Podvalny, E., Baete, S. H., & He, B. J. (2021). Cortical and subcortical signatures of conscious object recognition. *Nature Communications*, 12(1), Article 1. <https://doi.org/10.1038/s41467-021-23266-x>*

Recognized images elicit enhanced activation of visual, frontoparietal, and subcortical networks
 There was also a stronger deactivation of the default-mode network (in blue).



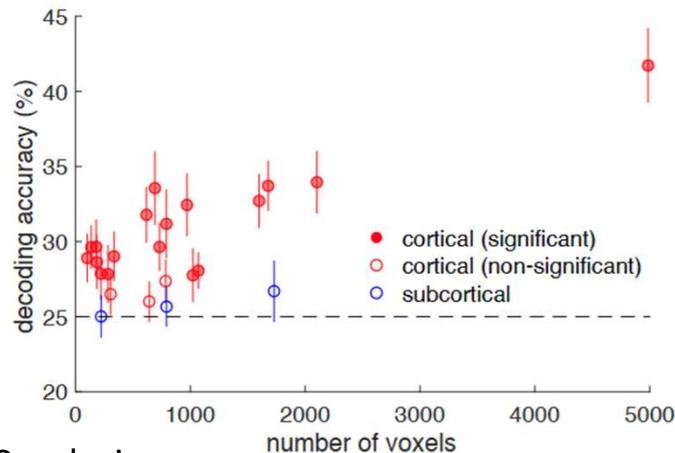
Decoding the contents of conscious representations

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What about decoding ?

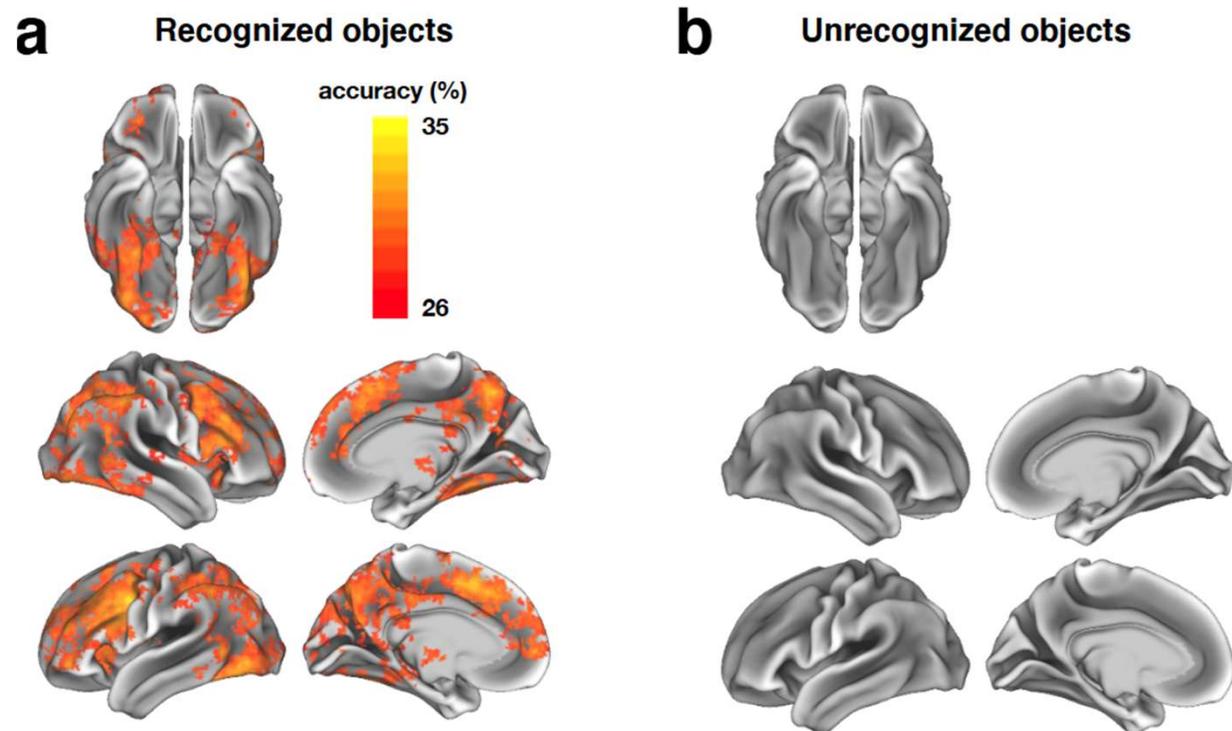
For recognized images, object category information could be decoded from all of the involved **cortical** regions but not from subcortical regions.

And this was not due to the number of voxels:



Conclusions:

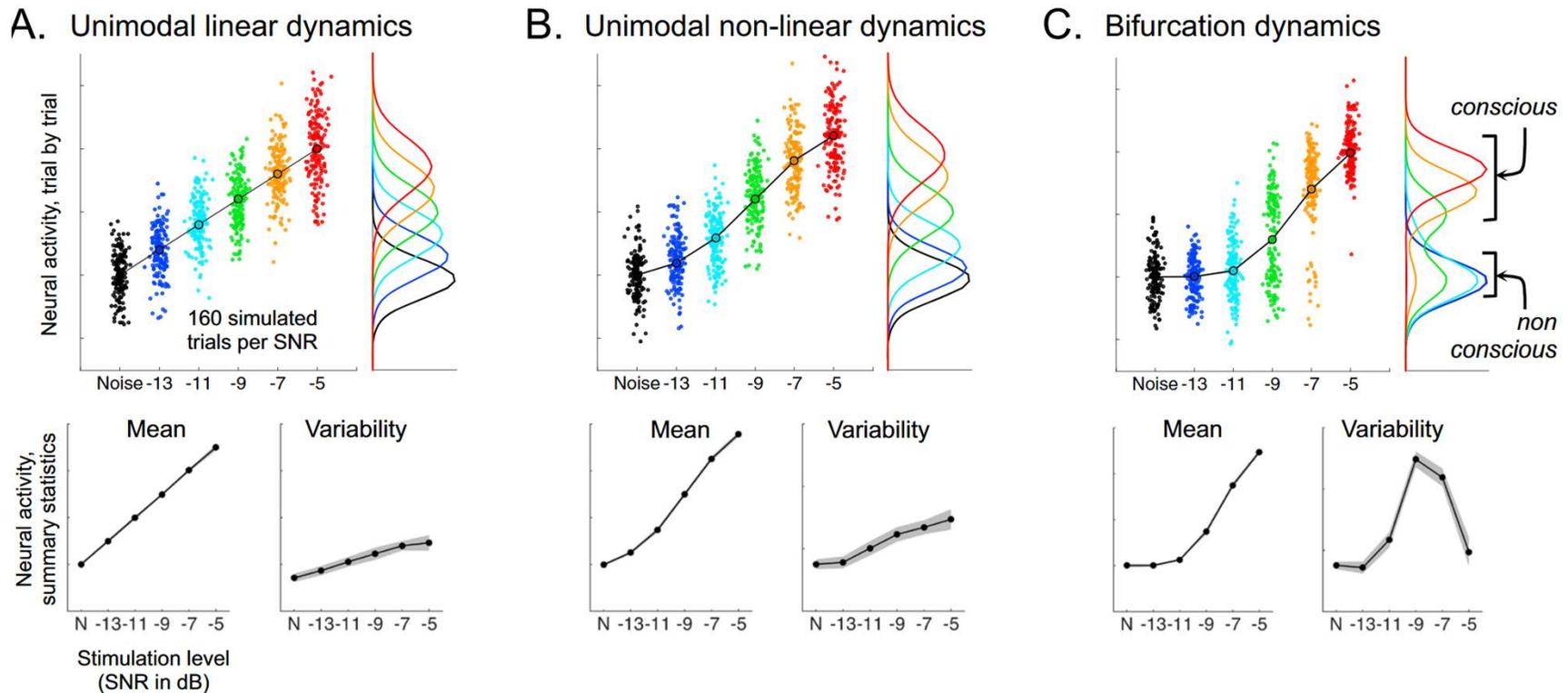
- For the very same visual input, a sudden surge of cortical and subcortical activity only on recognized trials.
 - Cortical regions, but not subcortical regions, hold **content-specific activity** (in both activated and deactivated areas)
- Results compatible with GNW ignition and the concept of **global broadcasting**.



Variability as an additional signature of the bifurcation underlying conscious access

Sergent, C., Corazzol, M., Labouret, G., Stockart, F., Wexler, M., King, J.-R., Meyniel, F., & Pressnitzer, D. (2021). Bifurcation in brain dynamics reveals a signature of conscious processing independent of report. *Nature Communications*, 12(1), Article 1.

A very simple idea: bifurcation dynamics should imply that, near the threshold, some trials are perceived and others are not, thus increasingly the **variability** in behavioral reports, but also in the corresponding brain activity. Important point: mean activity is a poor signature of bifurcation (it could be non-linear but continuous).

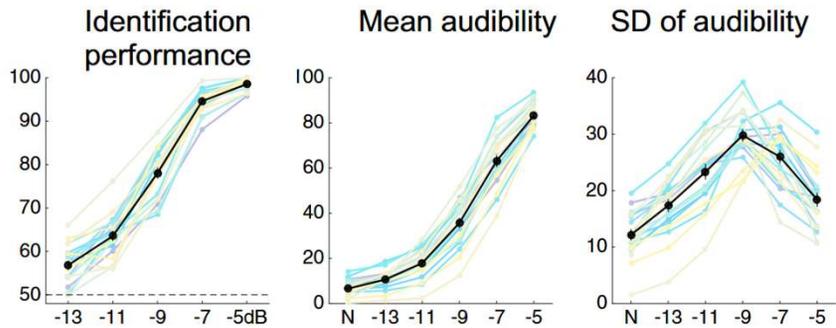


Variability as a signature of the bifurcation underlying conscious access

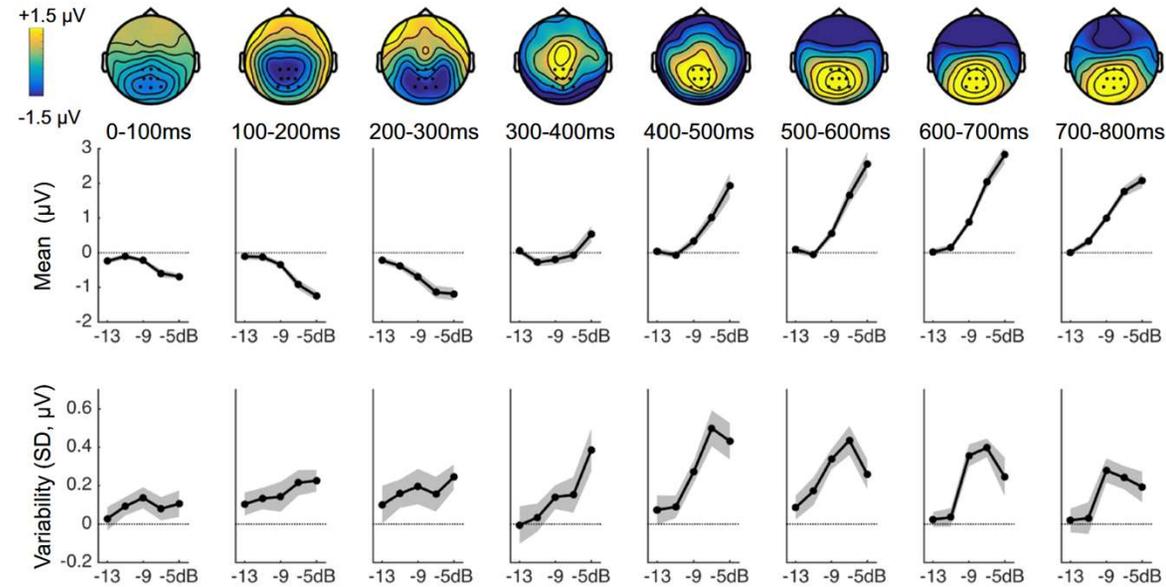
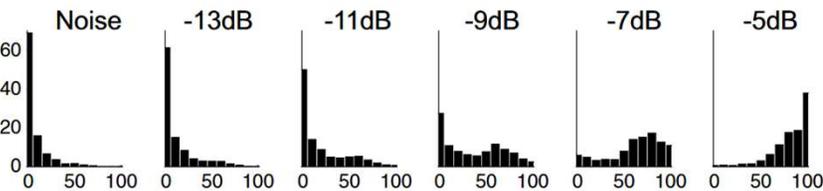
Sergent, C., Corazzol, M., Labouret, G., Stockart, F., Wexler, M., King, J.-R., Meyniel, F., & Pressnitzer, D. (2021). Bifurcation in brain dynamics reveals a signature of conscious processing independent of report. *Nature Communications*, 12(1), Article 1.

Experimental paradigm: listening to a vowel in noise, at different signal-to-noise ratios.

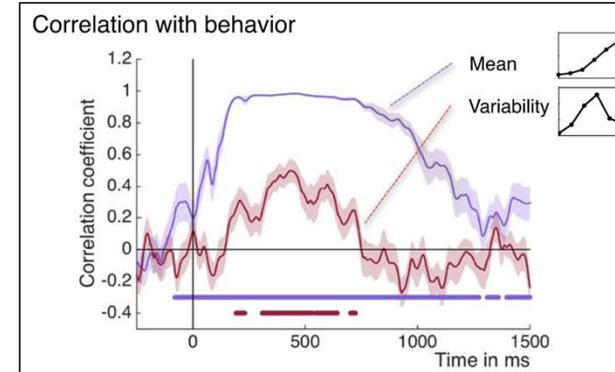
Behavioral results:



Audibility distributions



The shape of the mean ERPs is ambiguous, while the variability profile shows a clear peak around 400 ms.

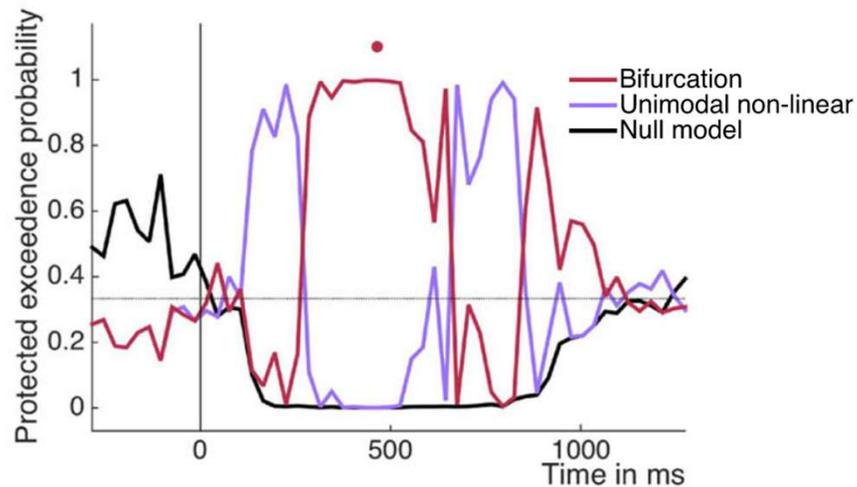


Variability as a signature of the bifurcation underlying conscious access

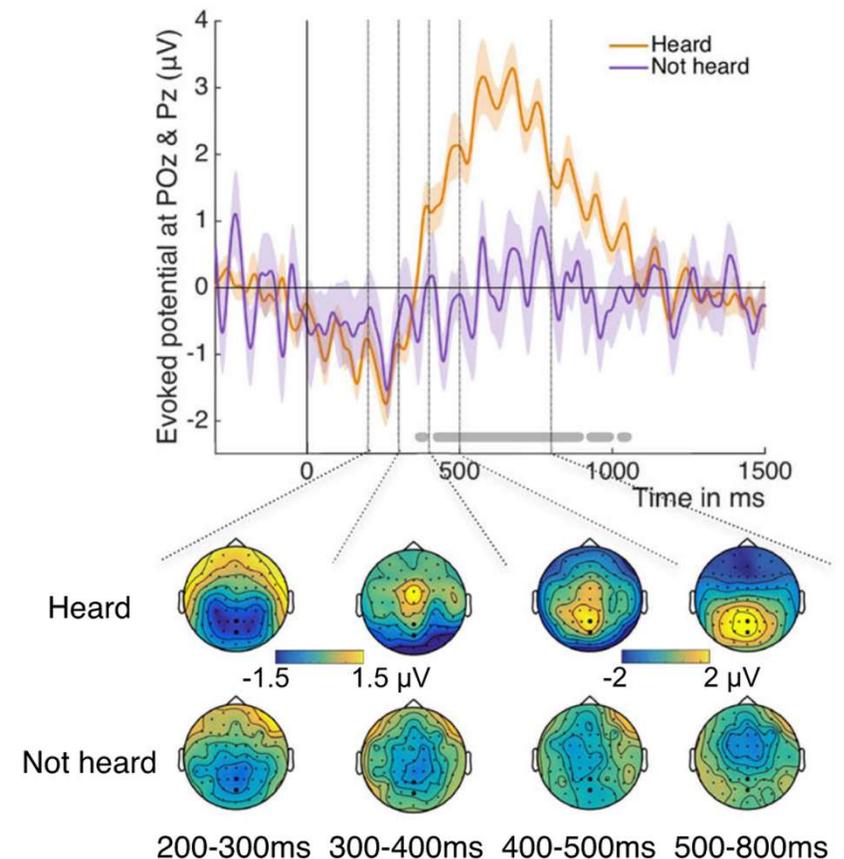
Sergent, C., Corazzol, M., Labouret, G., Stockart, F., Wexler, M., King, J.-R., Meyniel, F., & Pressnitzer, D. (2021). Bifurcation in brain dynamics reveals a signature of conscious processing independent of report. *Nature Communications*, 12(1), Article 1.

Bayesian modeling indicates the superiority of the bifurcation model, starting around 300 ms after stimulus onset :

Model comparison



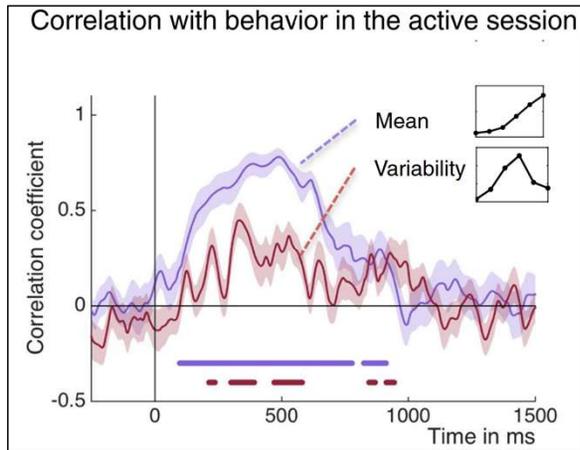
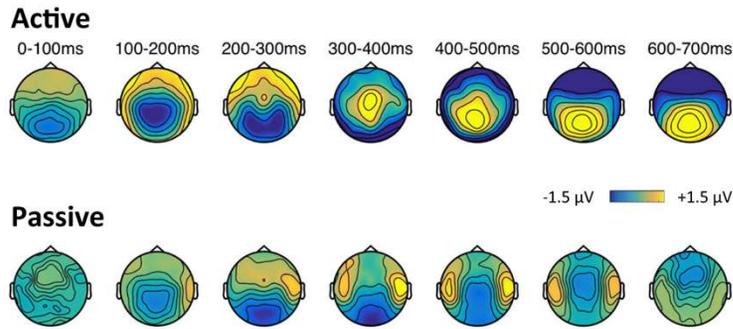
Those conclusions fit with a more classical analysis, based on a comparison of heard versus non-heard trials →
... but with this new signature, there is no need for report !



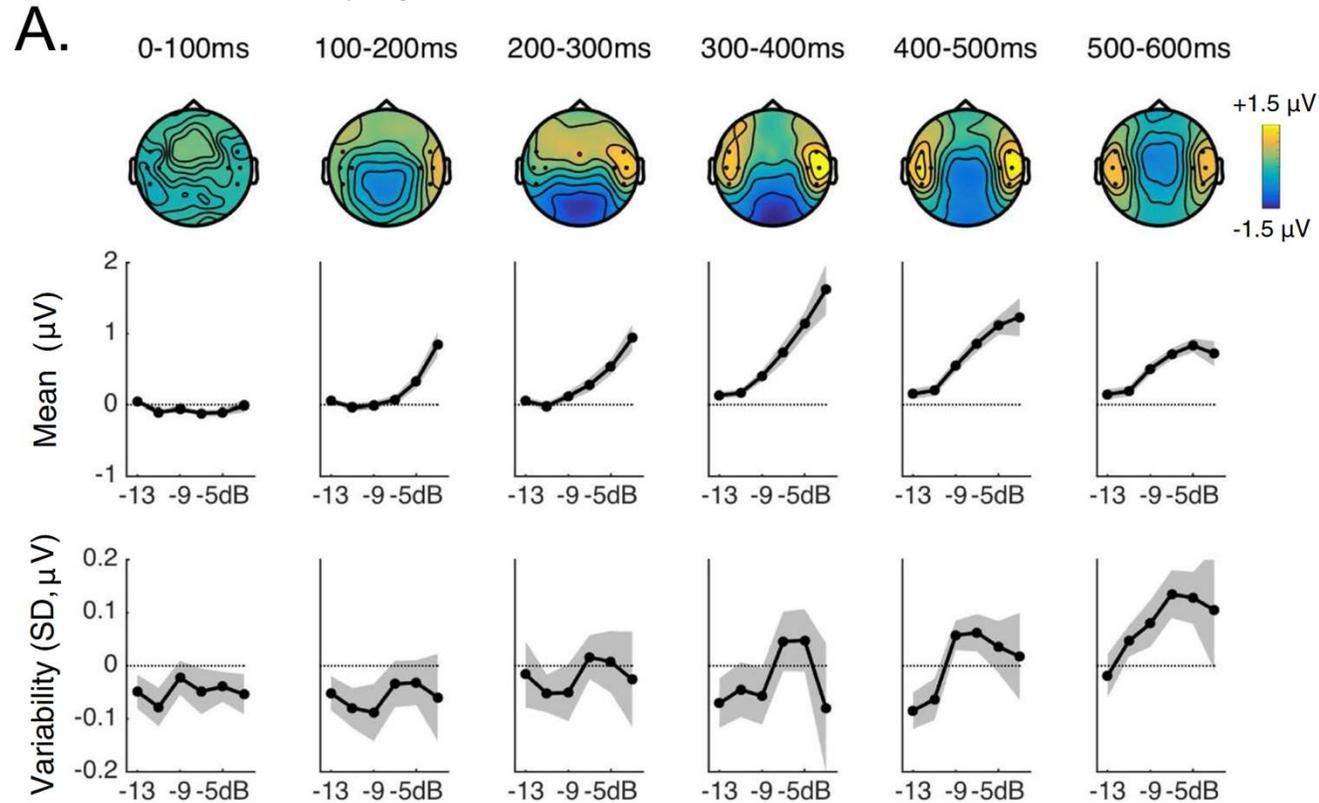
Variability as a signature of the bifurcation underlying conscious access

Sergent, C., Corazzol, M., Labouret, G., Stockart, F., Wexler, M., King, J.-R., Meyniel, F., & Pressnitzer, D. (2021). Bifurcation in brain dynamics reveals a signature of conscious processing independent of report. *Nature Communications*, 12(1), Article 1.

Under **passive instructions**, the shape of late ERPs change dramatically (no P3)



... but the variability signature remains in the same late time window !

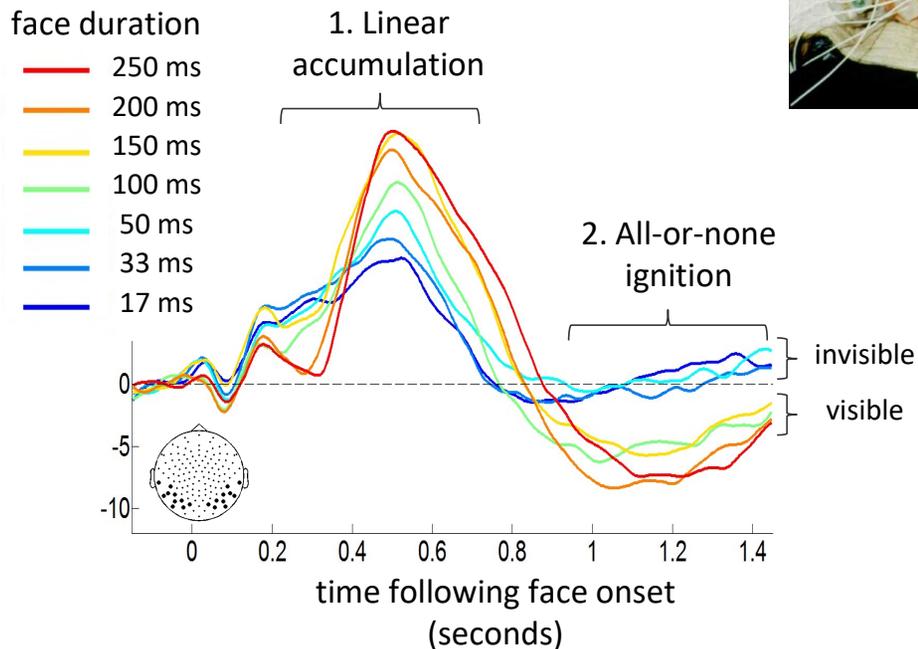
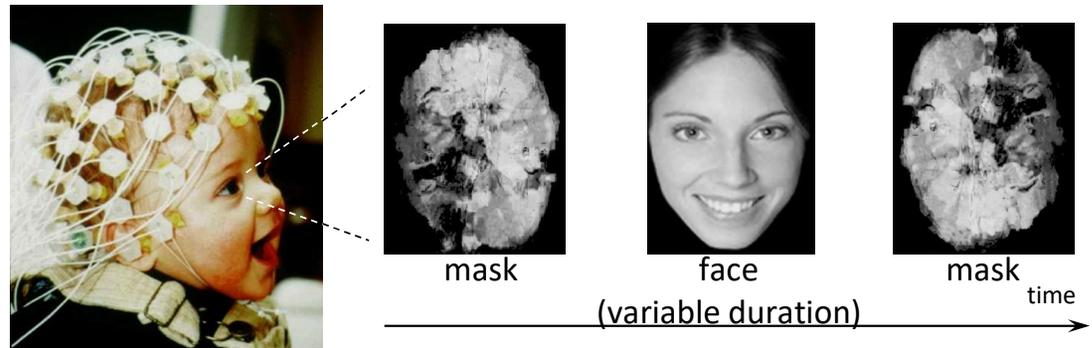


Conclusion: the presence of ignition may thus serve as a signature of consciousness, even in patients or other organisms unable to report verbally.

Linear processing versus conscious ignition in the infant brain

Kouider, S., Stahlhut, C., Gelskov, S. V., Barbosa, L. S., Dutat, M., de Gardelle, V., Christophe, A., Dehaene, S., & Dehaene-Lambertz, G. (2013). A neural marker of perceptual consciousness in infants. *Science*, 340(6130), 376-380. <https://doi.org/10.1126/science.1232509>

A masked face is flashed for a variable duration. Independent behavioral evidence indicates that infants turn to the face only if its duration is 100 ms or more.



Infant ERPs already show two stages:

- linear evidence accumulation
- very late non-linear ignition

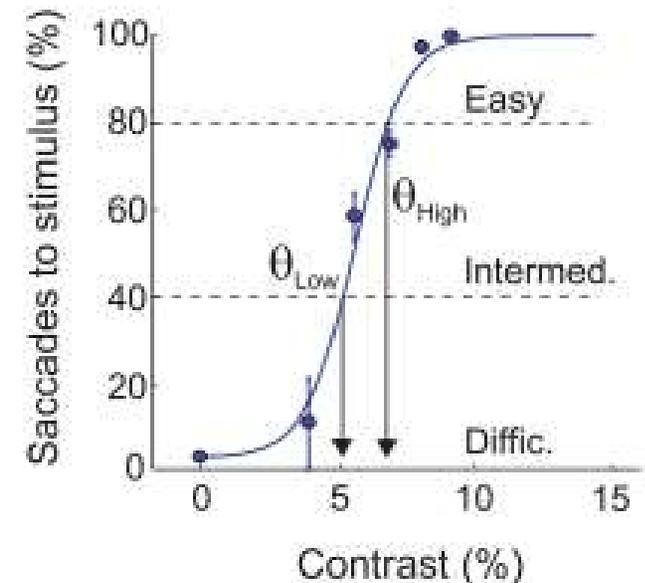
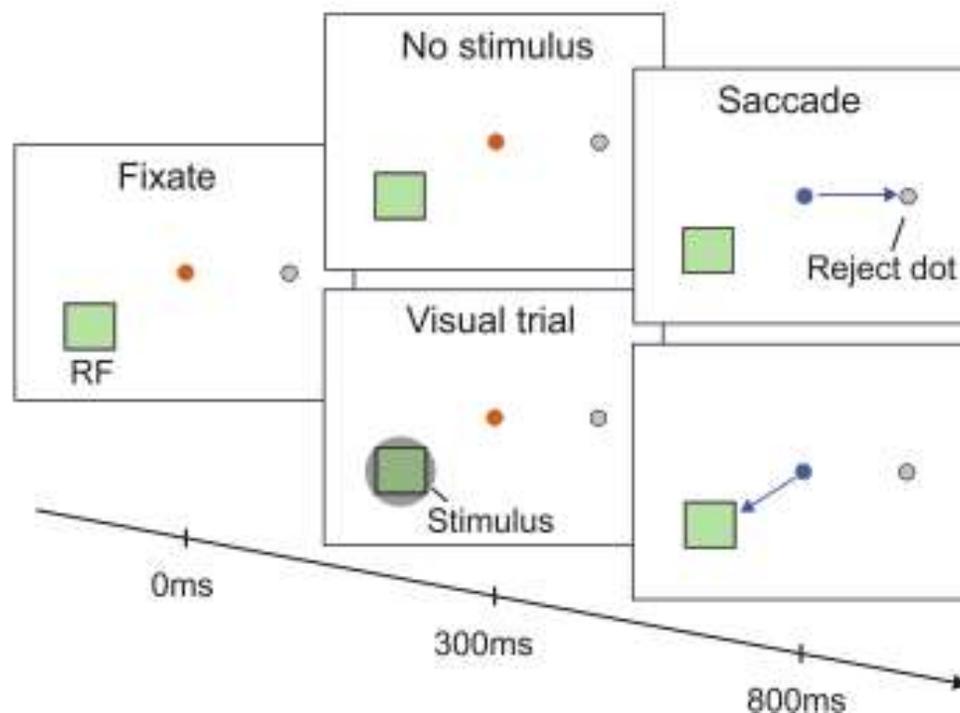
This effect is already present in 5-month-old infants, and other data suggest that late negativities are already present at 2 months.

Conclusion: non-verbal infants already show a signature of conscious perception – but 3 times slower than in adults!

Conscious ignition in monkey prefrontal cortex

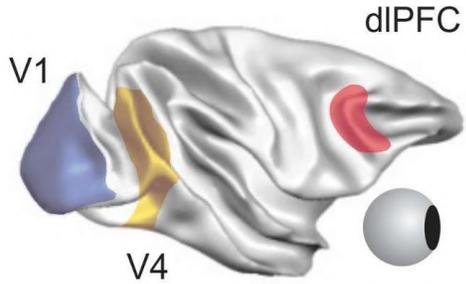
Van Vugt, Dagnino, Vartak, Safaai, Panzeri, Dehaene & Roelfsema, *Science* 2018

- A stimulus is flashed at a variable contrast (difficult to see, intermediate, or easy to see).
- Monkeys report their *subjective* perception by making a saccade towards the stimulus (« seen ») or towards a reject dot (« not seen »).
- Consciousness is characterized by a threshold function, as in humans.



We aimed to answer the following questions:

1. Where in the visual hierarchy do subliminal signals get lost?
2. Which neuronal mechanisms underlie the threshold for reporting a stimulus?
3. What are the sources of fluctuations ("noise") that allow a fixed stimulus to either cross or fail to cross the threshold?



Conscious access : an all-or-none ignition in prefrontal cortex

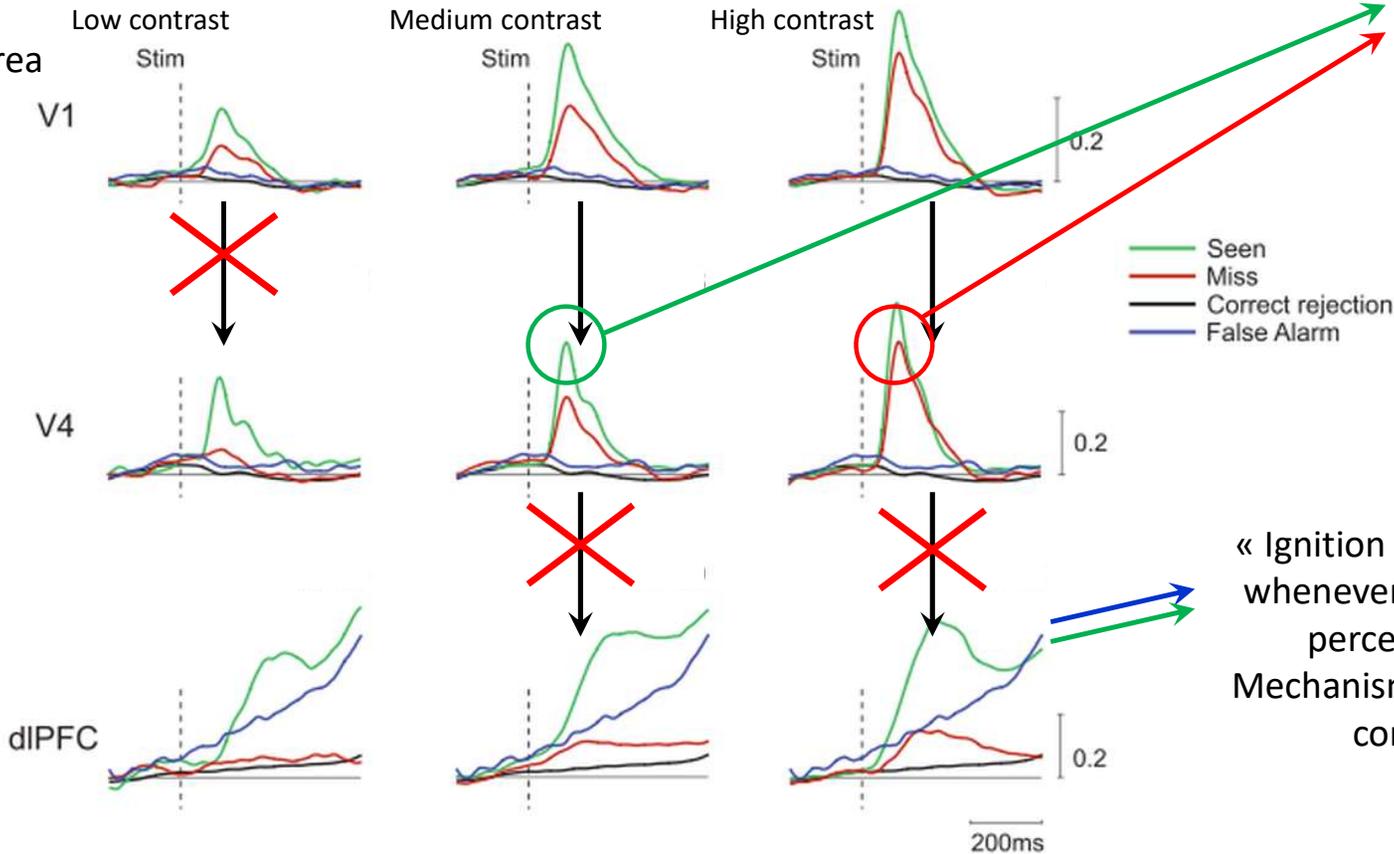
Van Vugt, Dagnino, Vartak, Safaai, Panzeri, Dehaene & Roelfsema, *Science* 2018

Low contrast:
Lack of transmission
from V1 to V4

Intermediate or high contrast:
Lack of transmission from V4 to PFC

Same level of
activation on seen
and missed trials:
V1 or V4 cannot be
the basis of
conscious
reportability

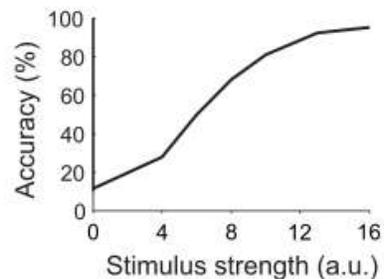
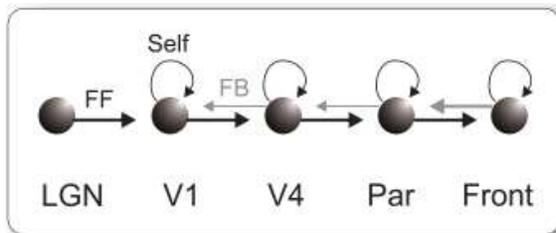
Multiunit
activity in area



« Ignition » of prefrontal cortex
whenever the monkey reports
perceiving a stimulus :
Mechanism of the threshold for
conscious report

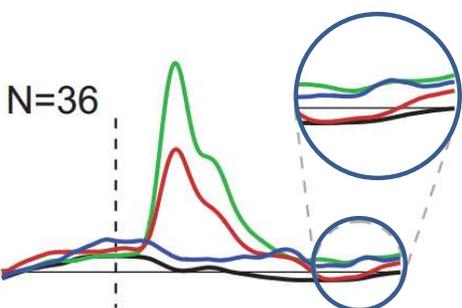
A minimal model of prefrontal ignition during conscious perception

Van Vugt, Dagnino, Vartak, Safaai, Panzeri, Dehaene & Roelfsema, *Science* 2018

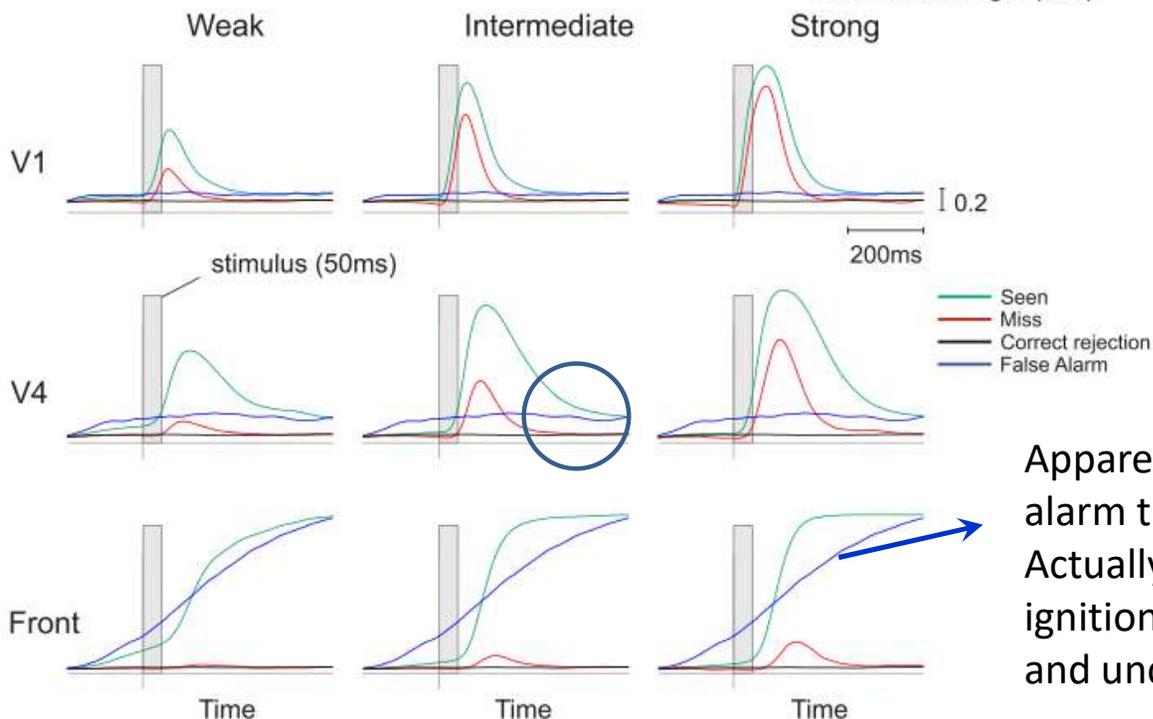


Data from area V4

N=36



Evidence for top-down amplification

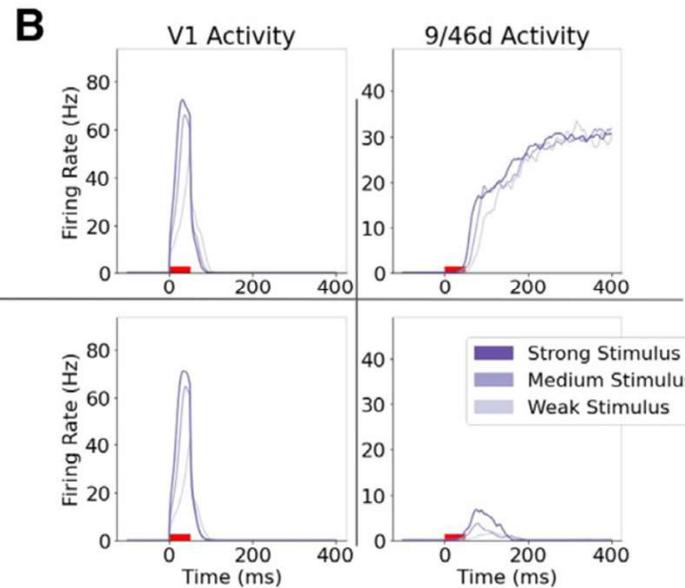
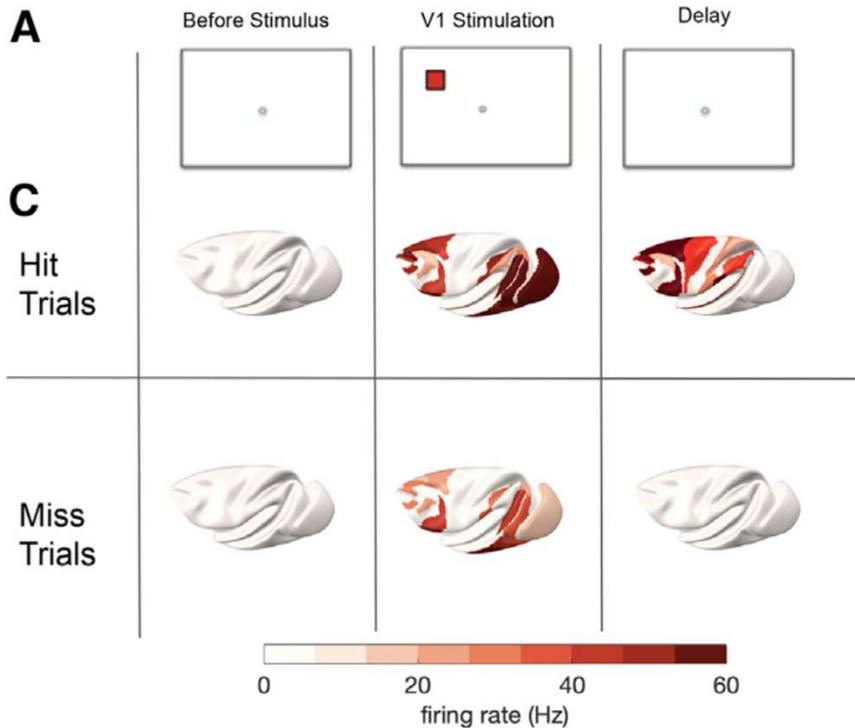
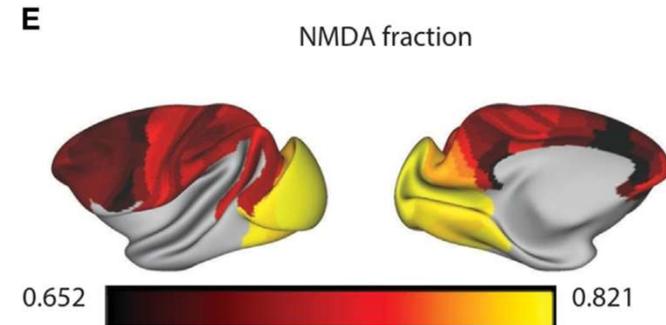


Apparent *ramping* on false alarm trials :
 Actually due to *all-or-none* ignition, but with a variable and uncontrolled onset

A more realistic model of brain-wide ignition and bifurcation in brain activity

Klatzmann, U., Froudist-Walsh, S., Bliss, D. P., Theodoni, P., Mejías, J., Niu, M., Rapan, L., Palomero-Gallagher, N., Sergent, C., Dehaene, S., & Wang, X.-J. (2025). A dynamic bifurcation mechanism explains cortex-wide neural correlates of conscious access. *Cell Reports*, 44(3).

Ulysse Klatzmann, Sean Froudist & Xiao-Jing Wang developed a much more realistic model of ignition, based on actual whole-brain connectivity of the monkey.



This model incorporates several pharmacological details (e.g. AMPA and NMDA receptors) and even made a new, verified prediction concerning the ratio of NMDA to AMPA receptors (higher in sensory regions)

What causes the fluctuations in perception for a fixed stimulus?

Van Vugt, Dagnino, Vartak, Safaai, Panzeri, Dehaene & Roelfsema, *Science* 2018

Pre-stimulus measures of

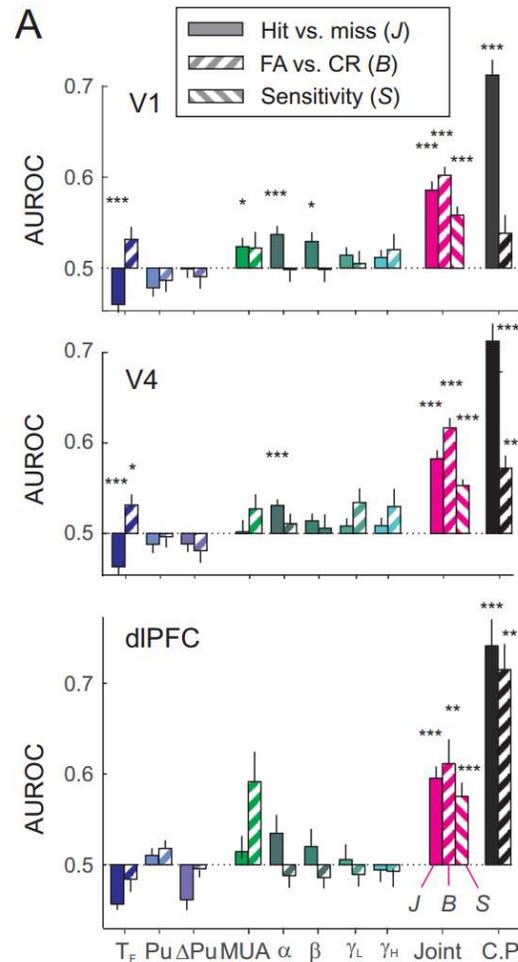
- Motivation (time to initiate a trial)
- Pupil diameter and its derivative
- Firing rate in V1, V4, PFC
- Power in alpha, beta, low-gamma and high-gamma bands

Different combinations of these measures were predictive of:

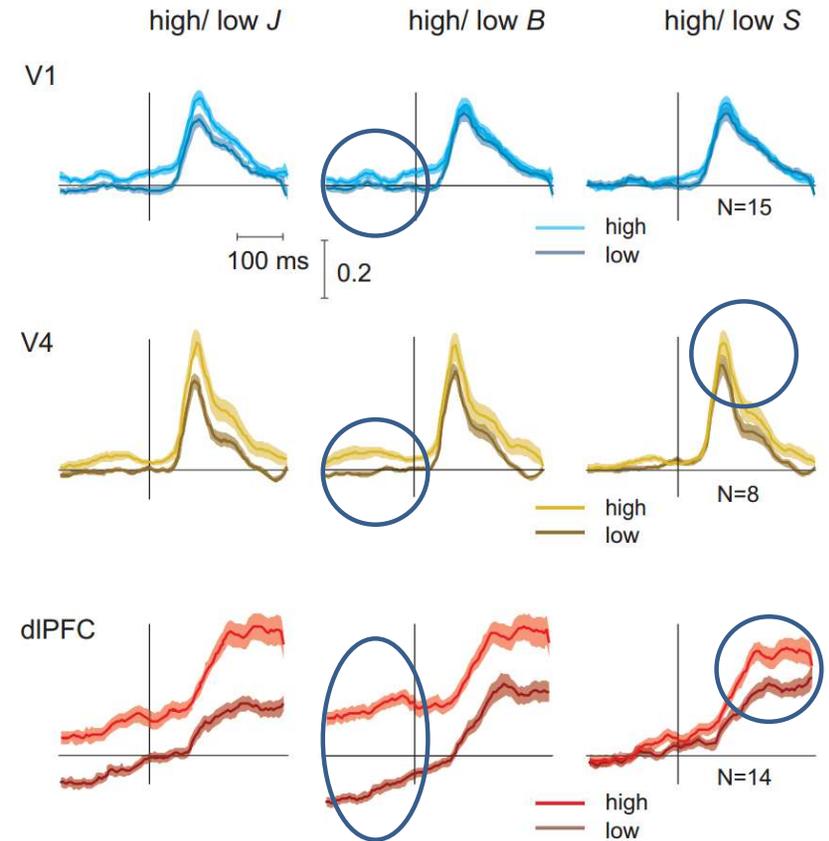
- Hits versus misses (J)
- B = Bias (distinguishes false alarms versus correct rejections)
- S = Sensitivity (distinguishes hits vs misses, but without affecting false alarms)

Bias relates to pre-stimulus firing, bringing neurons closer to the ignition threshold.

Sensitivity relates to a better propagation to V4 and especially to PFC.



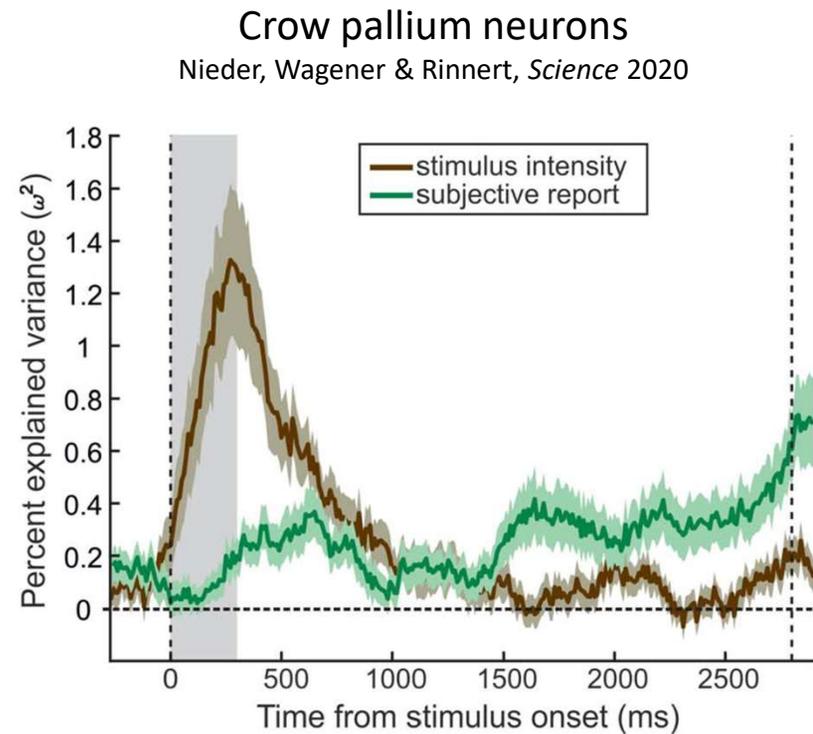
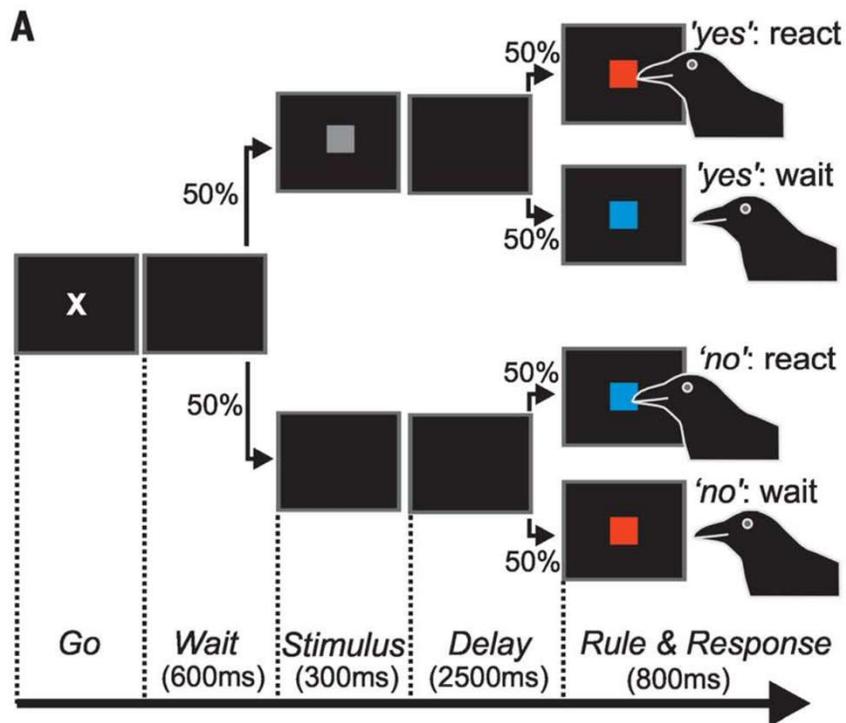
Neuronal activity on stimulus-present trials as a function of J (hit – miss) Bias B Sensitivity S



Ignition in crows

Nieder, A., Wagener, L., & Rinnert, P. (2020). A neural correlate of sensory consciousness in a corvid bird. *Science*, 369(6511), 1626-1629.

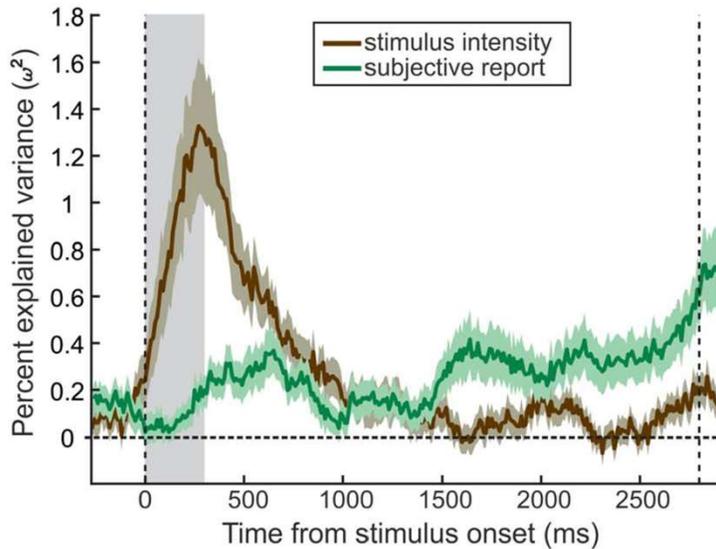
The Van Vugt et al monkey paradigm was then adapted to corvids.



A systematic transition from early objective to late subjective representations

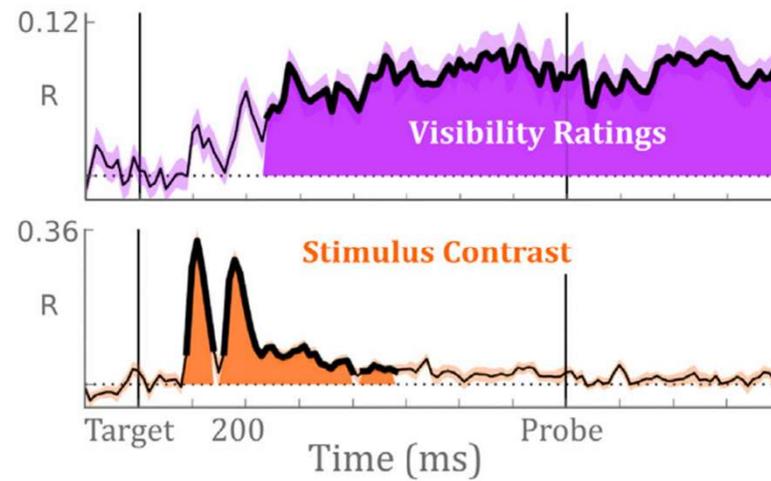
Crow pallium neurons

Nieder, Wagener & Rinnert, *Science* 2020



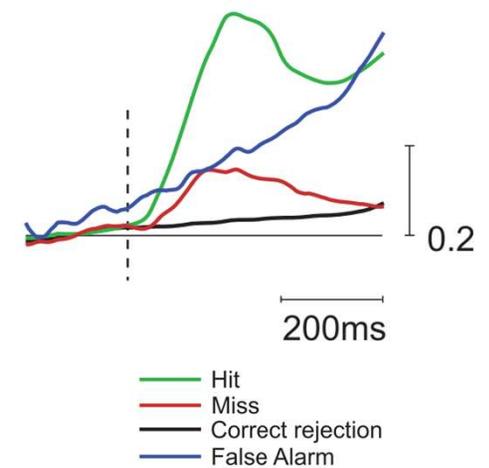
Human MEG

King, Pescetelli & Dehaene, *Neuron* 2016



Monkey prefrontal neurons

Van Vugt, Dagnino, Vartaak, Safaai, Panzeri, Dehaene & Roelfsema, *Science* 2018



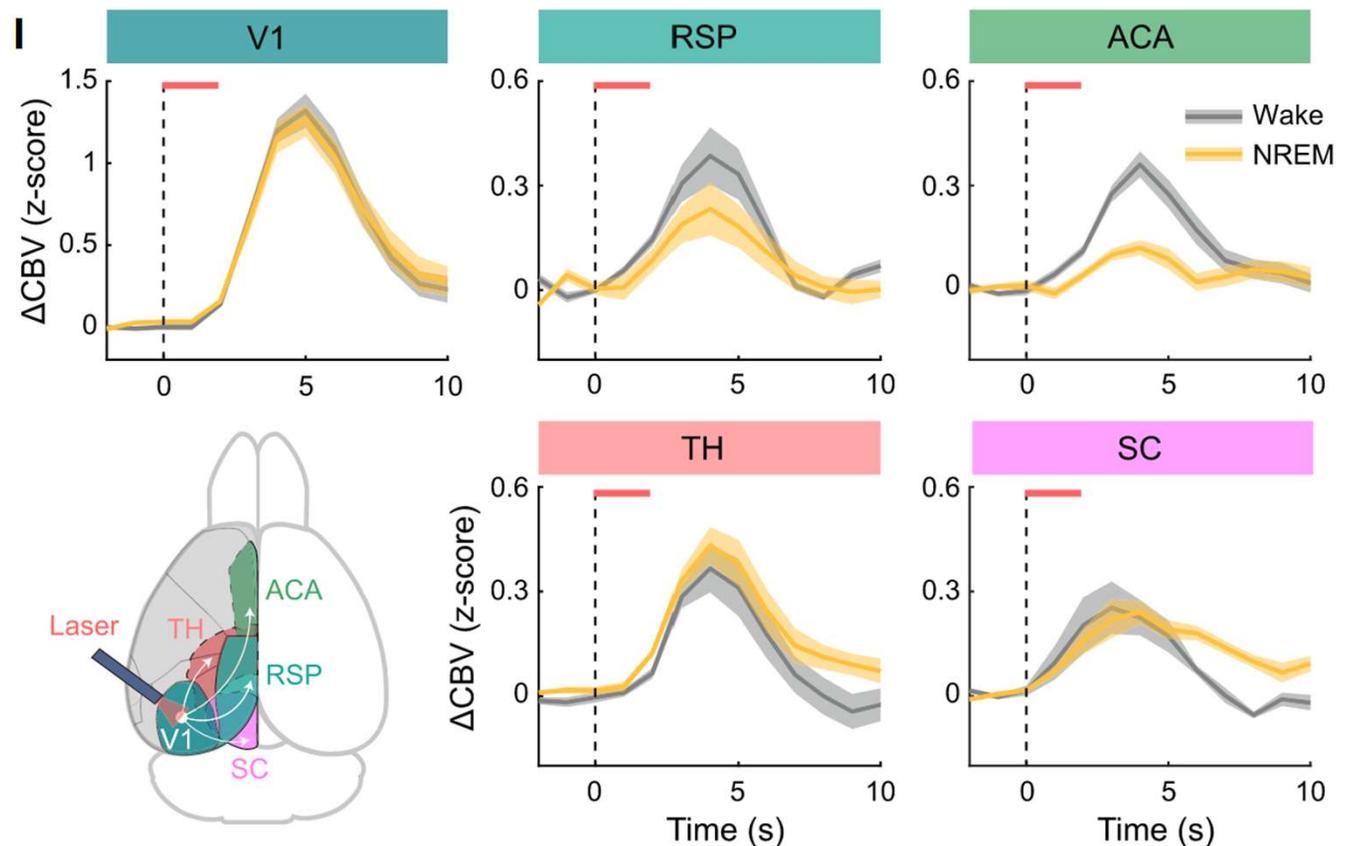
Ignition in mice visualized using brain-wide ultrasound imaging

Li, B., Ma, C., Huang, Y.-A., Ding, X., Silverman, D., Chen, C., Darmohray, D., Lu, L., Liu, S., Montaldo, G., Urban, A., & Dan, Y. (2023). Circuit mechanism for suppression of frontal cortical ignition during NREM sleep. *Cell*, S0092867423012291. <https://doi.org/10.1016/j.cell.2023.11.012>

Stimulus = optogenetic stimulation of V1 neurons.

The propagation of activity is monitored at the whole-brain level using ultrasound, but also calcium imaging.

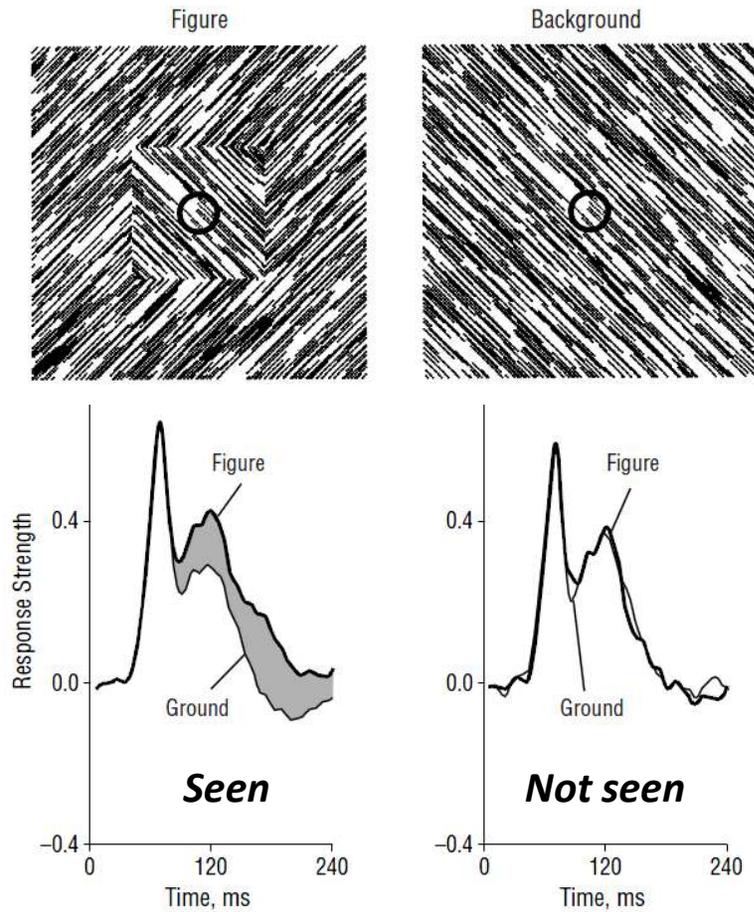
Activity propagates from visual to frontal cortex, but this “ignition” is markedly reduced during NREM sleep, due to strong inhibition of frontal pyramidal neurons



Putative neural mechanisms of top-down ignition

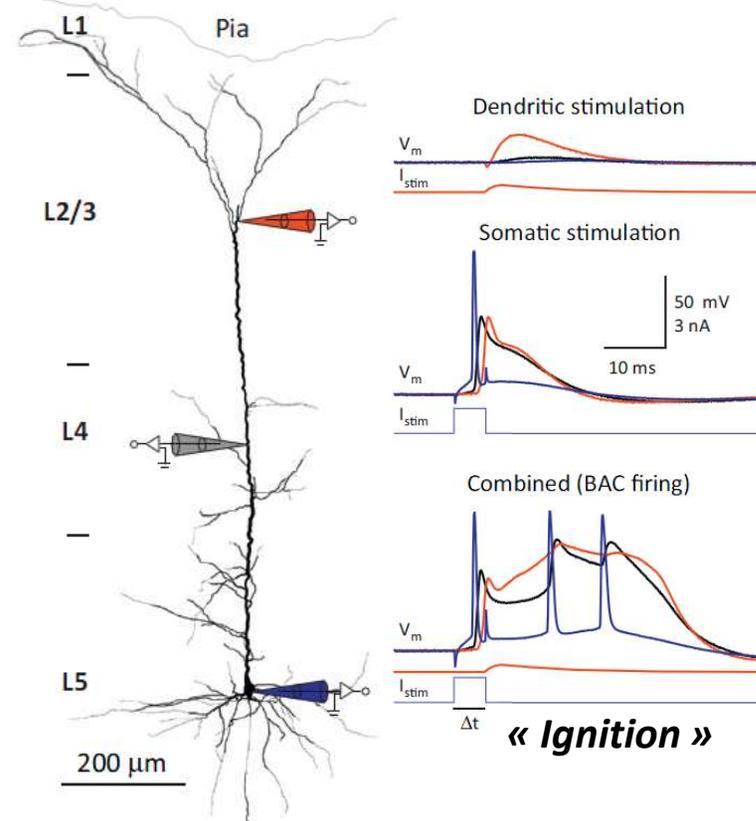
Viktor Lamme, **Pieter Roelfsema**, Matthew Self

Late V1 firing correlates with perception and depends on top-down NMDA-mediated inputs



Matthew Larkum

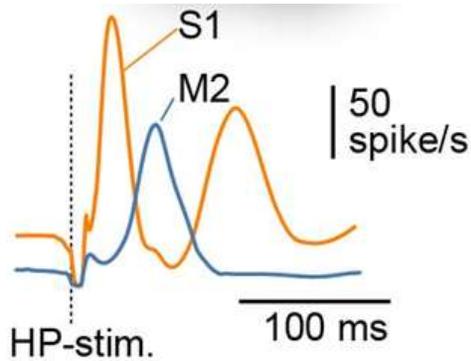
« Backpropagation-activated calcium-spike firing »:
Top-down inputs impinging on apical dendrites of L5 neurons, massively amplify firing.



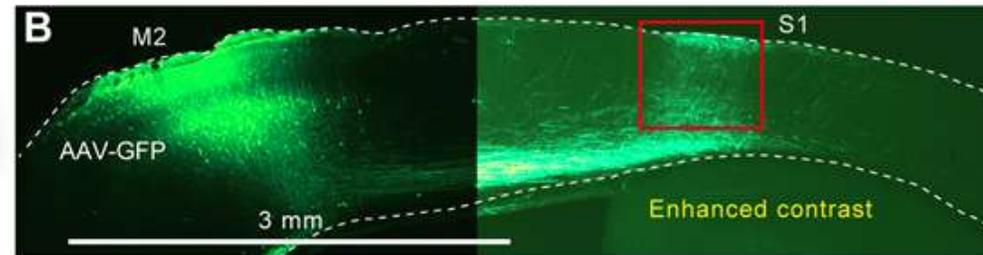
Mobilization : Causal role of long-distance top-down inputs in tactile perception

Manita, S., Suzuki, T., Homma, C., Matsumoto, T., Odagawa, M., Yamada, K., Ota, K., Matsubara, C., Inutsuka, A., Sato, M., Ohkura, M., Yamanaka, A., Yanagawa, Y., Nakai, J., Hayashi, Y., Larkum, M. E., & Murayama, M. (2015). A Top-Down Cortical Circuit for Accurate Sensory Perception. *Neuron*, 86(5), 1304-1316.

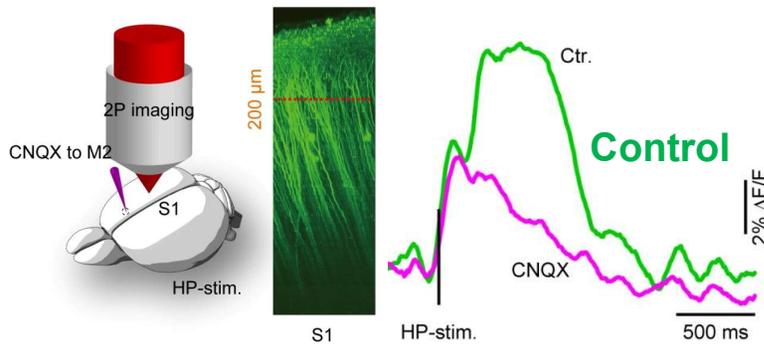
Biphasic response of somatosensory neurons



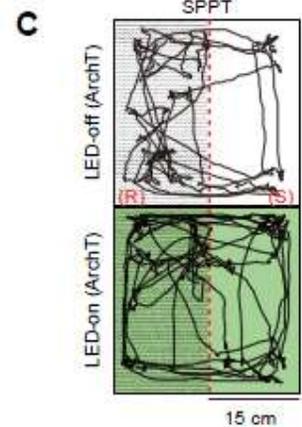
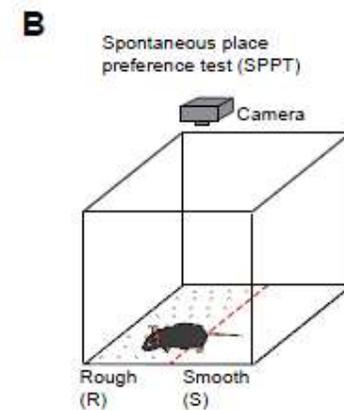
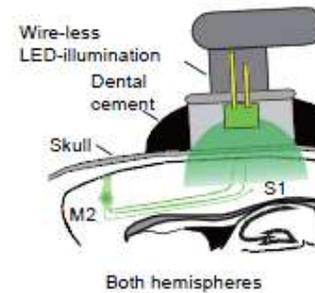
Long-distance top-down projections from M2 to S1

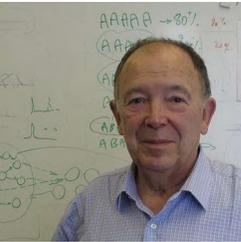


Disruption of M2 activity blocks late large Ca⁺⁺ spikes in the apical dendrites of L5 neurons in area S1...



... and optogenetic disruption of top-down M2 input to S1 interferes with touch perception : the mouse no longer uses touch to guide its behavior !





Jean-Pierre Changeux

Conclusion: the biological reality of conscious ignition

Dehaene & Changeux, PNAS 1998 ; Dehaene & Naccache, Cognition 2001



Lionel Naccache

Crossing the threshold for conscious access corresponds to a **late activation of several high-level regions, including prefrontal cortex**

It may correspond to the Bayesian **posterior** given the incoming data and prior expectations.

The divergence between ignited and non-ignited states is **fast**, like a **phase transition**, though not fully all-or-none (due to the presence of residual non-conscious activity).

It is well captured by a bimodal model (Claire Sergent)

Ignition can serve as a signature of consciousness in the absence of verbalization:

- in babies

- in other animals : monkeys, crows, mice

- thus opening the study of its neuronal mechanisms

Ignition is a **thalamo-cortical state**.

Next week: distilling consciousness, purifying the paradigms even further

