Top-Down Facilitation of Visual Recognition

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Paper Info

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- **Title:** Top-down facilitation of visual recognition
- **Journal:** Proceedings of the National Academy of Sciences
- **Year:** 2006

PNAS
Proceedings of the National Academy of Sciences of the United States of America

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Outline

- Introduction
- Methods and Results
- Discussion
- References

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Introduction

What is the main idea?

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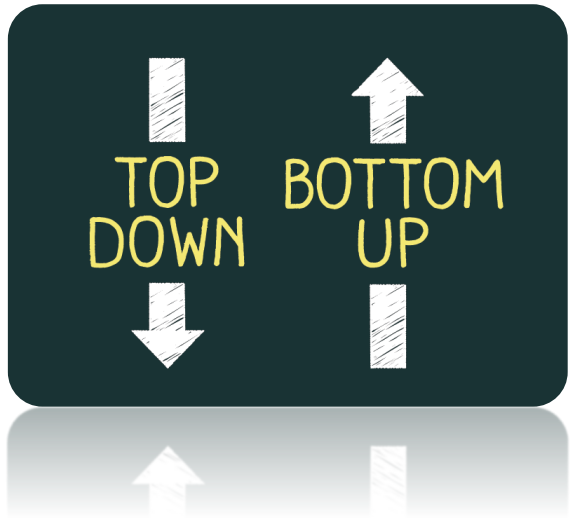
Top-Down and Bottom-Up Processing

Bottom-Up Processing:

- Initiated by external stimuli impacting the sensory receptors
- Relies purely on the details of the sensory input, without prior knowledge
- Important for processing novel or unexpected stimuli

Example: Recognizing the sound of a new musical instrument in a song



Top-Down Processing:

- Initiated by cognitive factors (e.g., knowledge, expectations, context)
- Influences perception by what we expect to see, not just what we observe
- Often used in complex environments where sensory data is uncertain or ambiguous

Example: Understanding difficult handwriting or Seeing a vague image as a face

Visual Object Recognition

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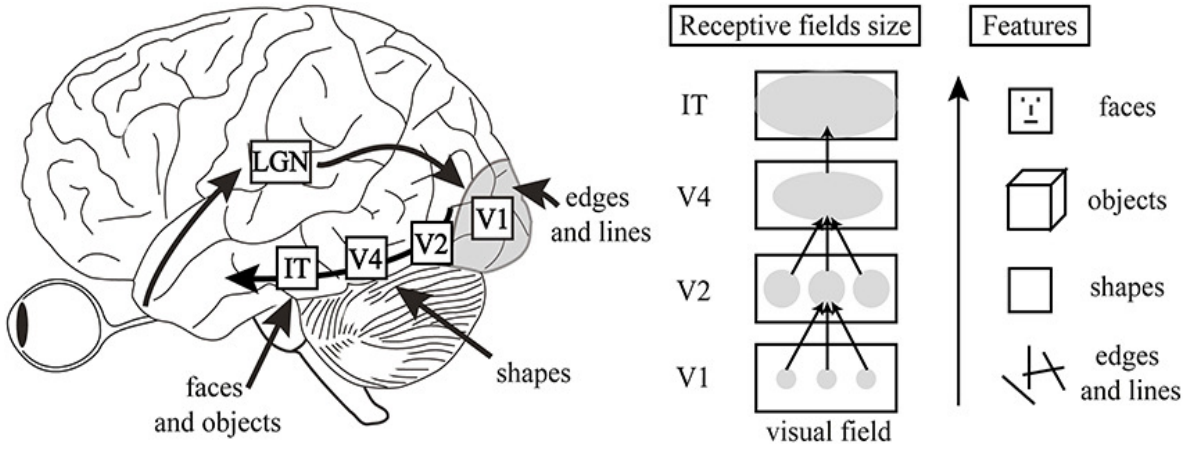
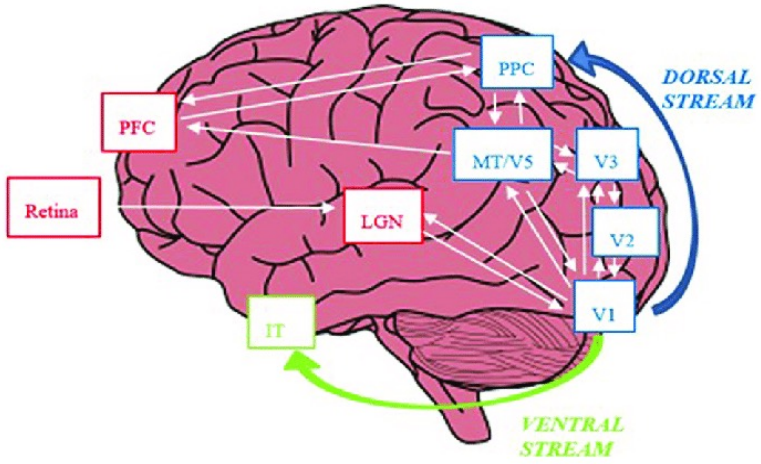
Traditional view of visual recognition:

- Bottom-Up processing



Recent view of visual recognition:

- Top-Down integration
- How it starts?



Brain Regions in Visual Object Recognition

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Key Regions:

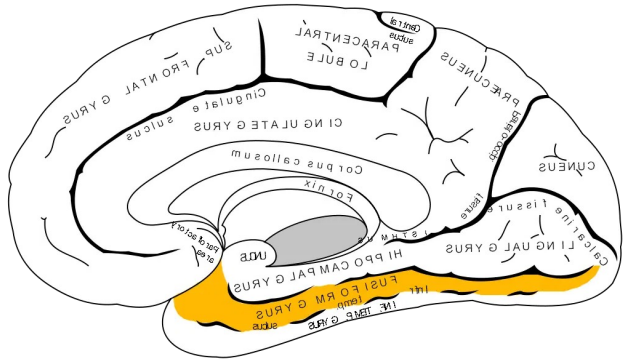
- Fusiform gyrus in temporal lobe and lateral occipital cortex.

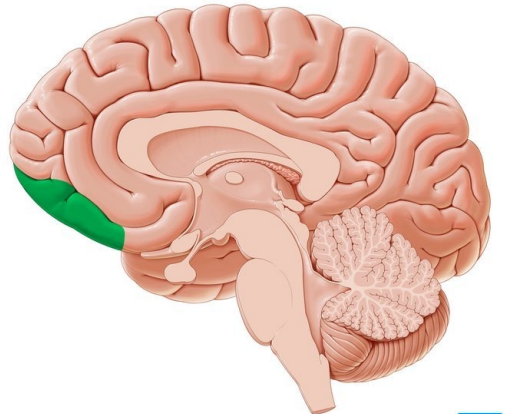
Prefrontal Cortex Role

- Involvement of the prefrontal cortex, particularly the orbitofrontal cortex (OFC), in visual recognition.
- OFC activity differed when objects were recognized versus when they were not, under identical viewing conditions.

Interpretation of OFC Activity

- **Semantic Processing Theory**: Suggests OFC activity may be linked to semantic analysis occurring after objects are recognized.
- **Alternative Perspective**: Proposes that OFC activation represents a source of top-down facilitation in the object recognition network.





From Blurred Images to Clear Recognition

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Mechanism of Top-Down Facilitation

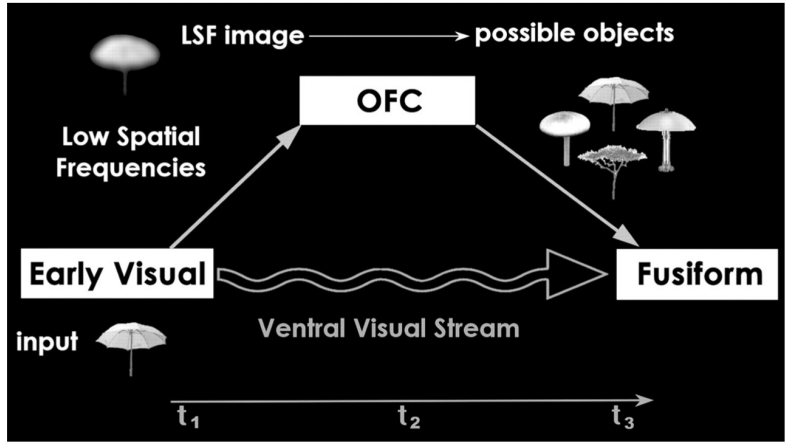
- **Initial Trigger**: LSF images rapidly projected from early visual areas to prefrontal cortex, possibly via the dorsal magnocellular pathway
- **Role**: Aiding recognition by narrowing down potential interpretations.

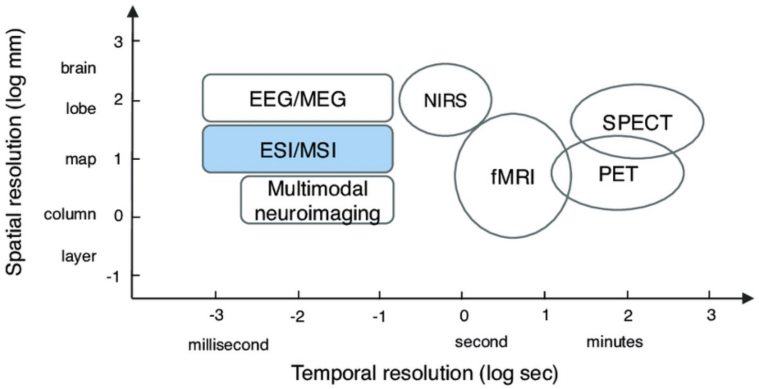
Early Activation and Recognition

- **Timing of Activation**: Top-down processing starts before full recognition, with critical early activity in the orbitofrontal cortex (OFC).
- **Neuroimaging Evidence**: Milliseconds-resolution MEG used to track timing.

Experimentation and Findings

- **Phase-Synchrony Analysis**: Explores interactions between visual and OFC regions.
- **Differential Processing of Spatial Frequencies**: Compares effects of LSF versus HSF on OFC activation.





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Methods and Results

What we observed?

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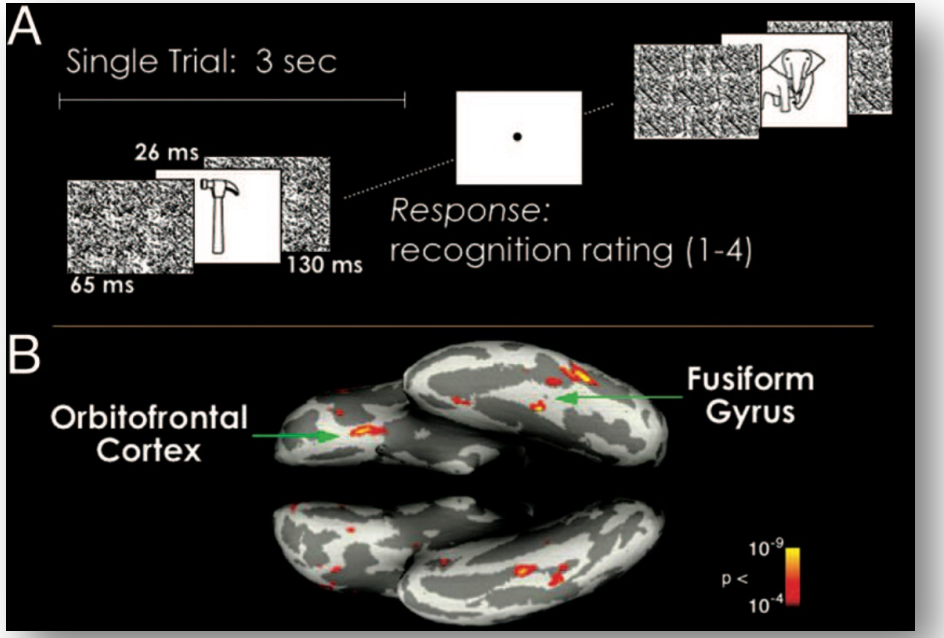
Experiment 1

Goal: Find that recognition-related activity in the OFC precedes the corresponding activity in the temporal cortex

Subjects: Nine healthy volunteers

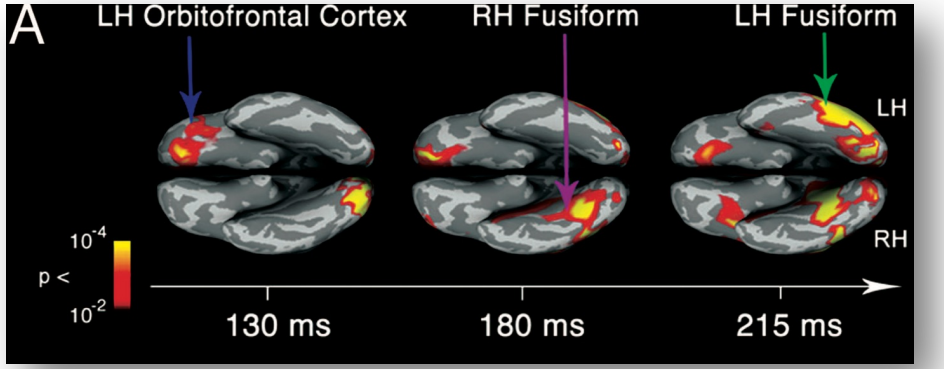
Experimental Design:

- 420 masked presentations of 154 different objects, and 84 nonmasked presentations of 84 of these objects.
- **Duration of Presentation:**
  - Each stimulus: 63 ms
  - The first mask: 27 ms
  - The second mask: 108 ms
  - Pictures were presented repeatedly up to five times in random order, intermixed with the presentations of other objects.
  - To find easy object recognition, some of the stimuli appeared for the sixth time, nonmasked for 198ms.



Findings

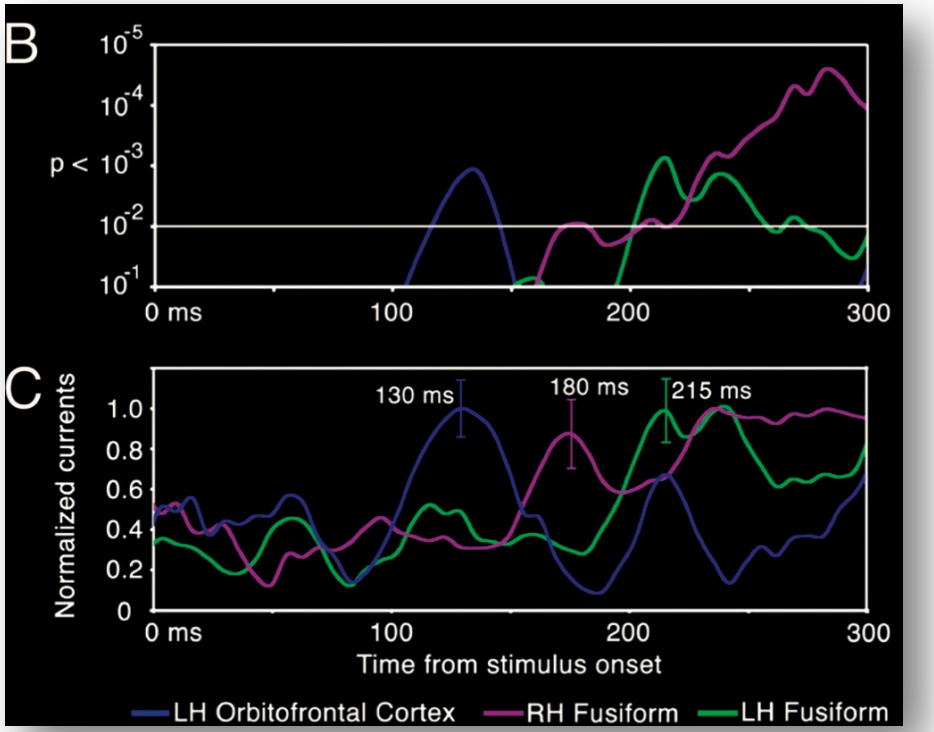
- Represents the contrast between trials in which the masked objects were recognized successfully and trials in which the same masked objects could not be recognized.
- Differential activation (recognized vs. not recognized) peaked in the left OFC 130 ms from stimulus onset, 50 ms before it peaked in recognition-related regions in the temporal cortex.



Anatomically (MRI) constrained statistical parametric maps calculated from MEG averaged across all nine subjects.

Findings

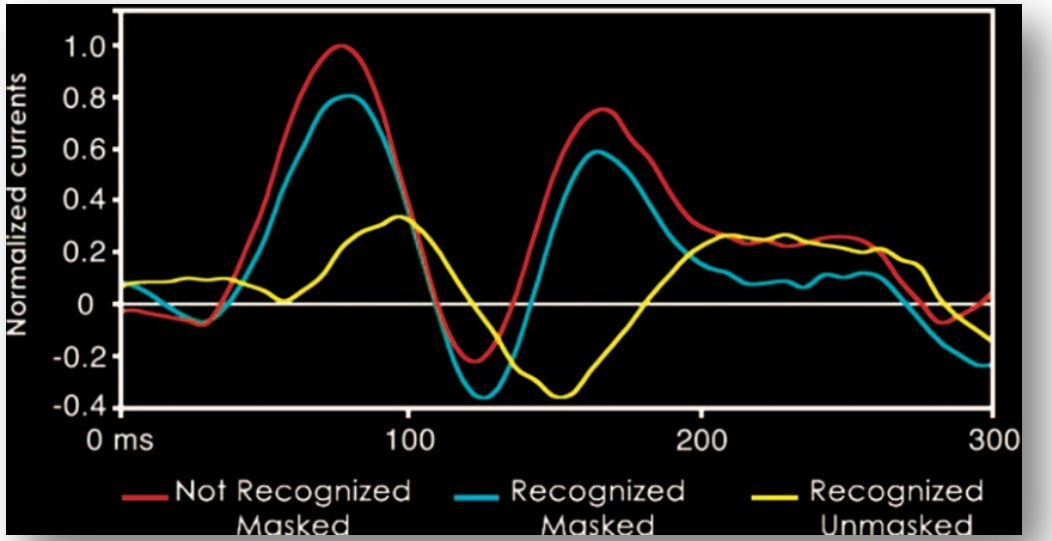
- The early activity peaked in the left posterior orbital gyrus at 130 ms from stimulus onset and remained statistically significant for about 40 ms.
- **Sequence of recognition-related differential activity:**
  - Left OFC (130 ms)
  - Right fusiform gyrus (180 ms)
  - Left fusiform gyrus (215 ms)



B) *p* values of the difference between recognized and not-recognized trials as a function of time from stimulus onset. C) Corresponding time courses for normalized current values. Current and statistical values are presented in absolute, unsigned units.

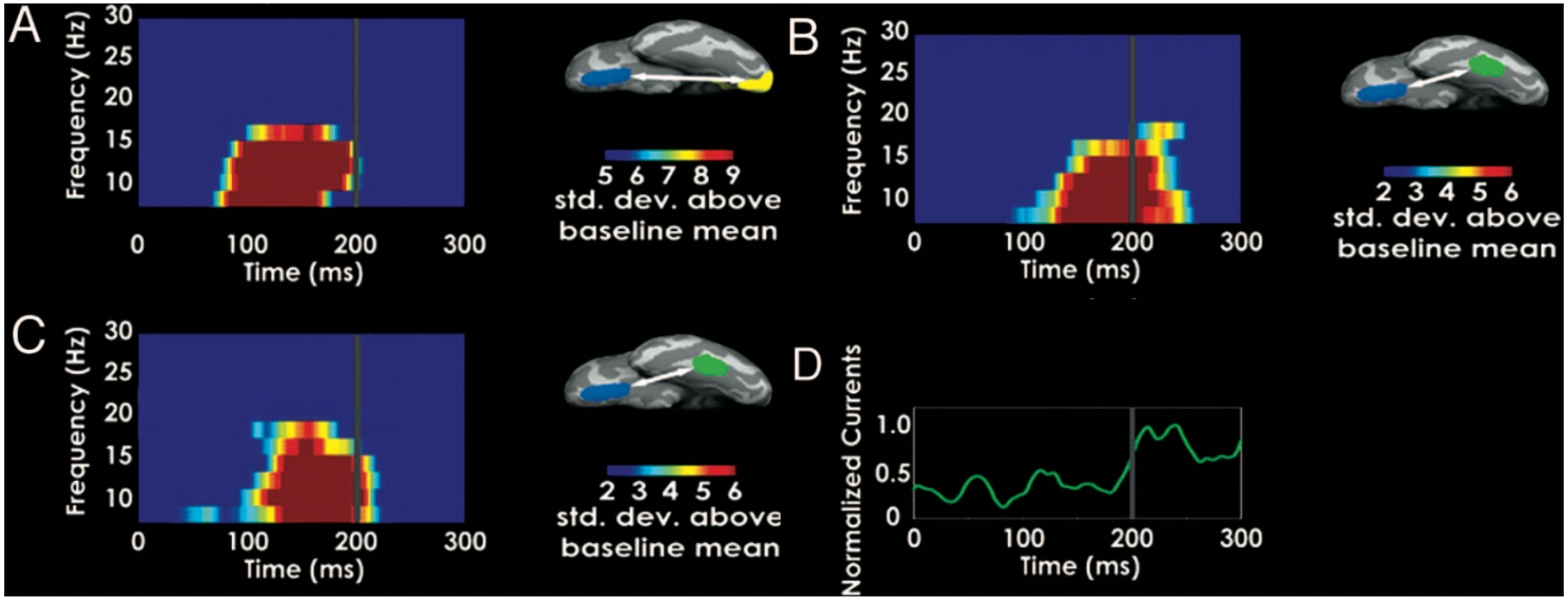
Occipital early activities

- Stronger activation for not-recognized trials compared with recognized trials. ⟶ **Maybe that's why they are not recognized.**
- Only in masked trials, two peaks, separated by 90 ms, perfectly aligned with the temporal onset of the forward and backward masks.
- This early occipital activity reflects response to the masks.



Normalized time courses for the occipital cortex.

Phase-locking Analysis



(A) Standard deviations above baseline of the phase-locking between the occipital visual areas and the OFC. (B) OFC–fusiform phase-locking statistics of masked recognized trials. (C) OFC–fusiform phase-locking statistics of masked not recognized trials. (D) Recognized vs. not-recognized activity in the fusiform

- Early occipital–OFC feed-forward (80 ms after stimulus onset)
- Later OFC–fusiform feedback projection (130 ms after stimulus onset)
- OFC–fusiform synchrony lasted 40 ms longer for recognized trials compared with not-recognized trials.

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Finally, can these data inform us about a specific “aha”moment of recognition?

Experiment 2 (A & B)

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Goal: Find that the early recognition-related activity in the OFC depends on spatial frequencies in the image

Experiment 2-A (MEG):

- **Subjects:** Nine subjects participated in the experiment.
- **Stimuli:** The images were grayscale photographs of common, everyday objects without background.
- Each subject saw each object only once, in one of its three possible conditions (i.e., LSF, HSF, or intact), and the sequence of presentation was pseudorandomized across subjects. All images were presented for 750 ms.

Experiment 2-B (fMRI):

- **Subjects:** Twelve subjects participated in the experiment. Four of which were excluded.
- **Stimuli and experimental design:** Same as 2-A.

Experiment 2

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- **What is Initial Guess?**
- **Previous findings:**
  - Physiological: the magnocellular pathway conveys LSF information early and rapidly.
  - Anatomical: direct connections between temporal cortex and prefrontal cortex only in monkeys not in humans.
  - LSFs are processed first and fast
- **Prediction:**
  - LSF and HSF filtered images would have different effects on activity in the specific OFC site.
- **Methods:**
  - MEG & fMRI

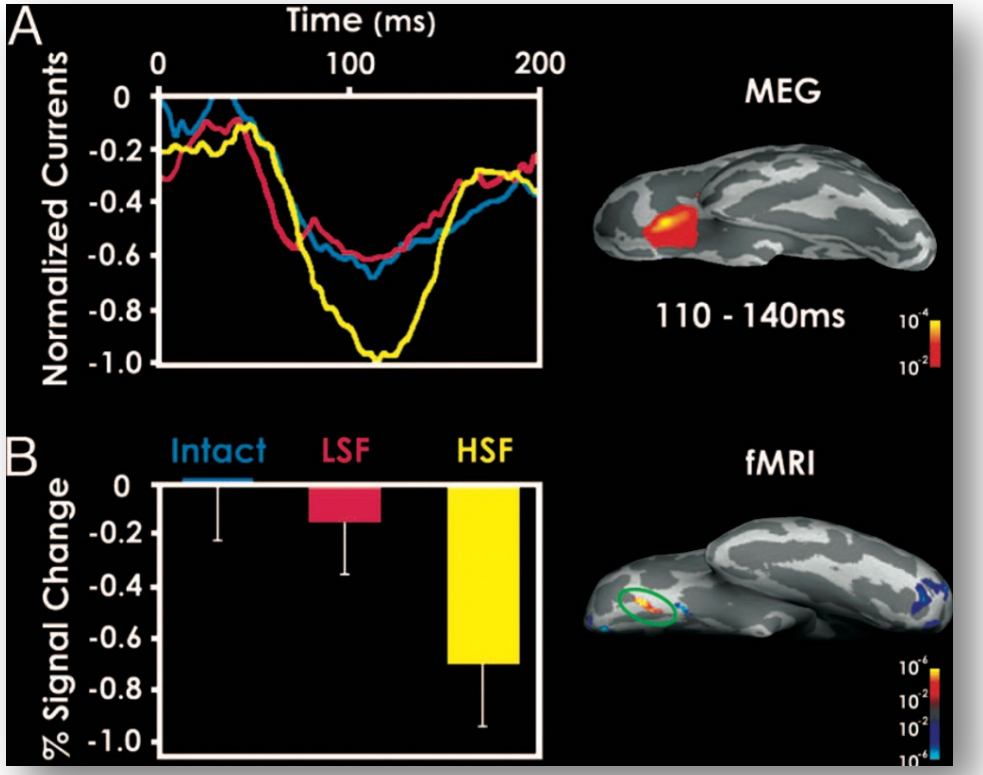
Experiment 2

- To ensure that there was no significant RT difference → selected a subset of trials with the same mean reaction time.
- Recognition of intact images are faster → Optimal recognition relies on both types of information.

	ACC (%)	Correct Mean RT (ms)	Selected Mean RT (ms)
HSF	90	668 ± 50	700 (78% trials)
LSF	71	723 ± 88	700 (90% trials)
Intact	-	607 ± 52	-

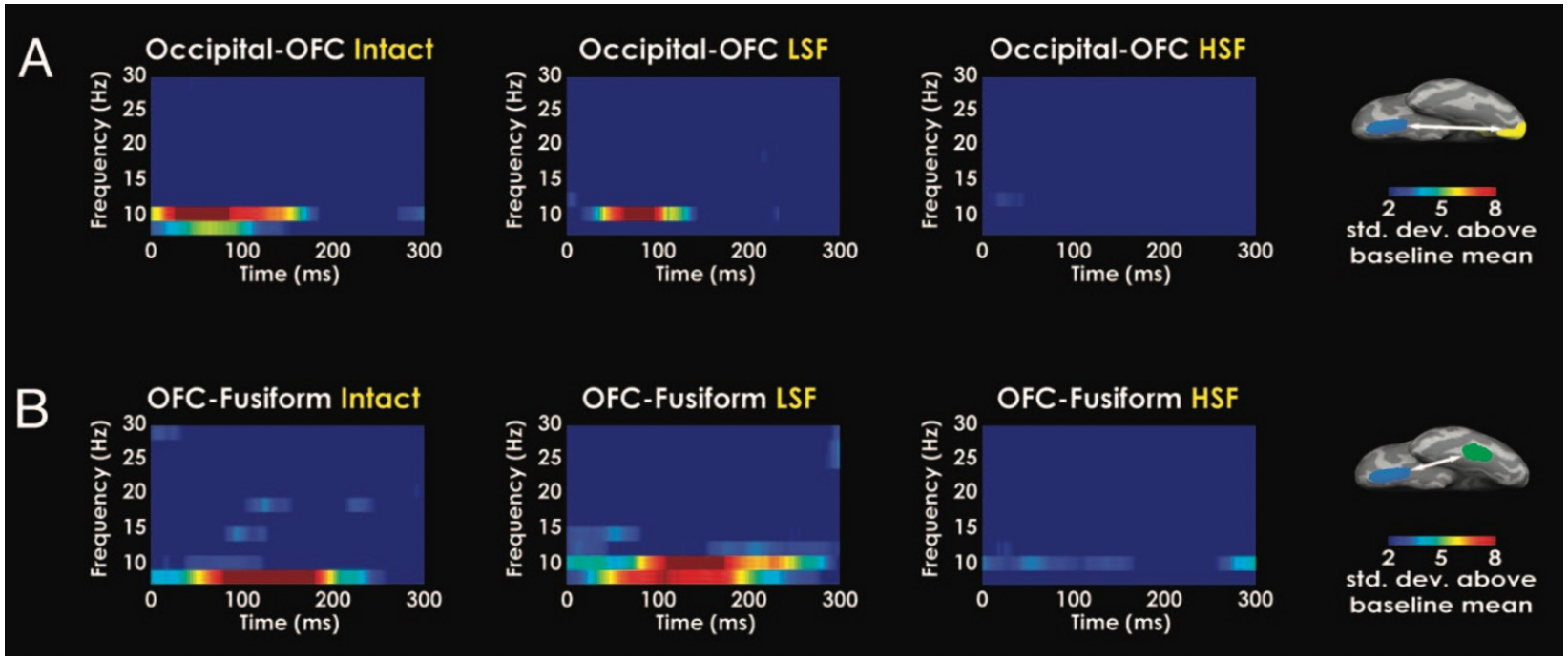
Findings

- Higher fMRI signal in LSF object images than the HSF images in the OFC.
- Significant difference between the MEG current amplitudes estimated from the LSF and HSF conditions within the same OFC region.
- LSF–HSF differential activity peaked 115 ms from stimulus onset in MEG → Arrival of information to the OFC.
- The OFC activity was highly similar for the LSF and intact conditions and significantly different from that elicited by the HSF images
- Lack of LSF information will diminish the contribution of top-down processes and will therefore result in relatively slower recognition performance.



Comparison of the cortical signal elicited by LSF and HSF during recognition.

Phase-locking Analysis



Phase-locking analysis, implying that cortical interactions between the occipital visual areas and the OFC and, relatively later, between the OFC and the fusiform gyrus require LSF.

- No significant occipital–OFC and OFC–fusiform phase-locking for HSF images.
- OFC–fusiform phase-locking peaked from 80 to 190 ms from stimulus onset for intact and LSF images, 50 ms later than occipital–OFC phase-locking.

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Discussion

What do these results mean?

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Top-Down Facilitation in Mechanism

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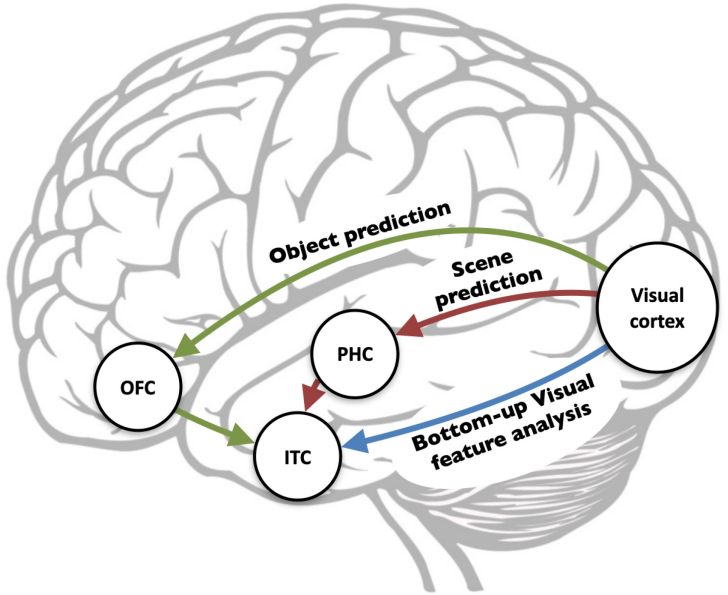
- Earlier activity in OFC region compared with fusiform region
- Sensitivity to LSF in images
- Phase synchronization between OFC, fusiform and early visual regions
- Stronger functional connectivity for LSF images

Notice : OFC is not a region that is traditionally considered a visual area!

How about the dynamics

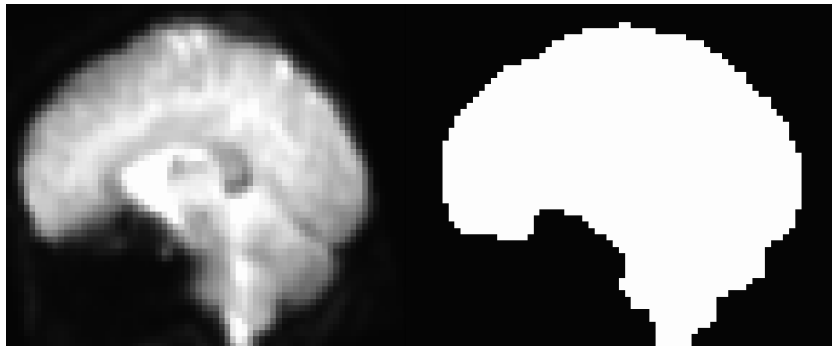
- Ok then could we consider the top-down facilitation as the dynamic of recognition of objects?
- OFC associates with guessing and hypothesis-testing.
- Proposed model : this stream propagates from the OFC, 130 ms before stimulus onset



- An interesting experiment for longer durations and not masked images.

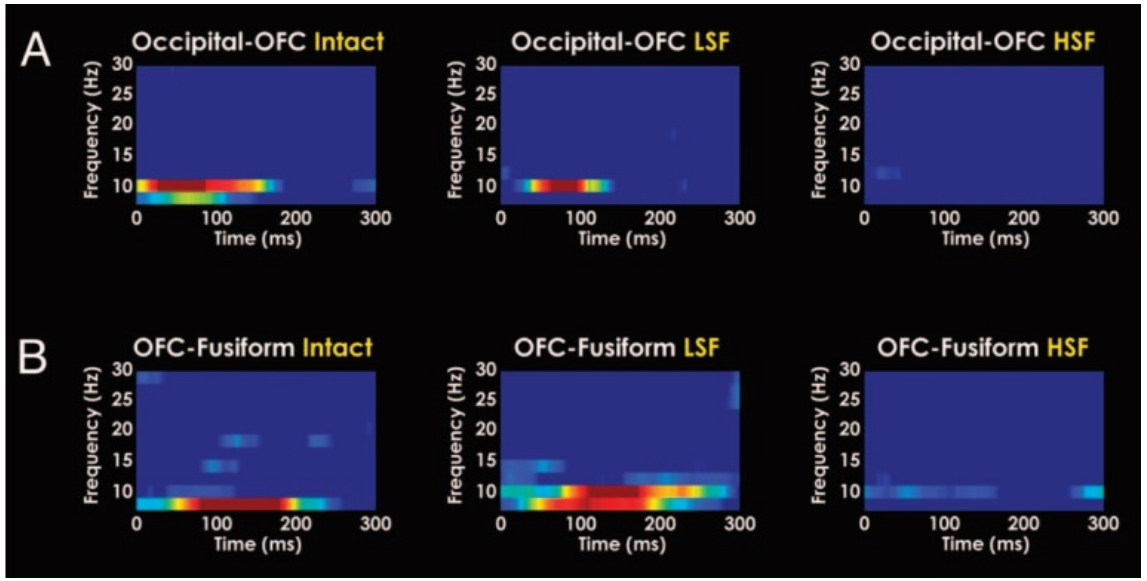
- **Prefrontal patients :**
  - No problem in final recognitions of images

- **Role of OFC in context :**
  - emotional processing
  - reward system
  - decision-making
  - analysis of visual information and in visual memory



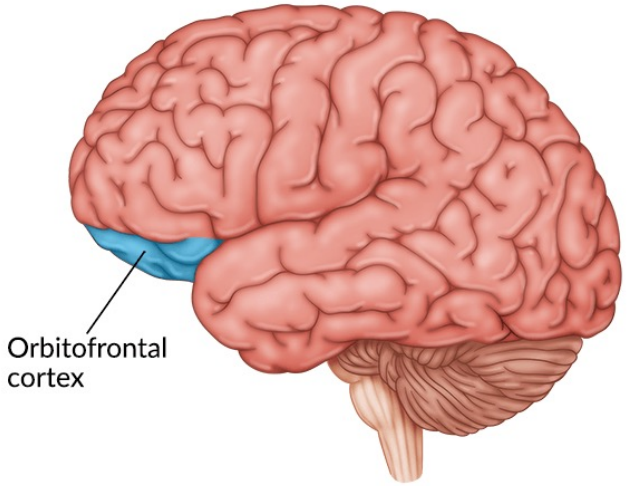
Phase-locking analysis

- The strength and delay of this phase-locking varied as a function of recognition success.
- Top-down attention signals enhance perceptual processing in the sensory cortex
- The top-down signal depends on the particular physical properties
- The feedback signal sensitizes only the representation of the most likely interpretations of the input.



Conclusion

- These results provide critical support for the proposed model and demonstrate that the prefrontal cortex plays a more active role in object recognition than previously considered.



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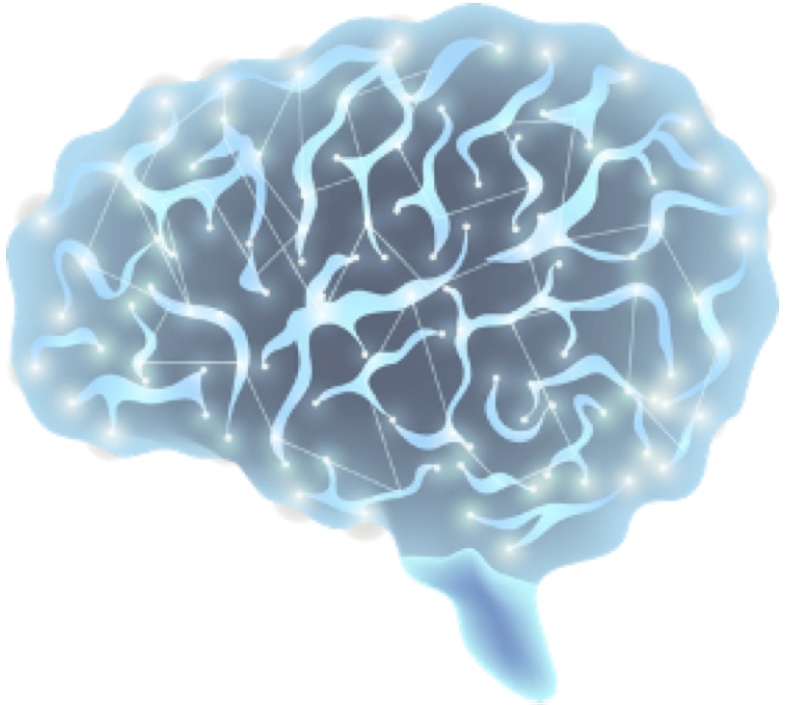
THANKS!

Any questions?



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