Impaired face discrimination in acquired prosopagnosia is associated with abnormal response to individual faces in the right middle fusiform gyrus

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See also: Rossion et al.in *Brain*. 2003, 126:2381-2395.

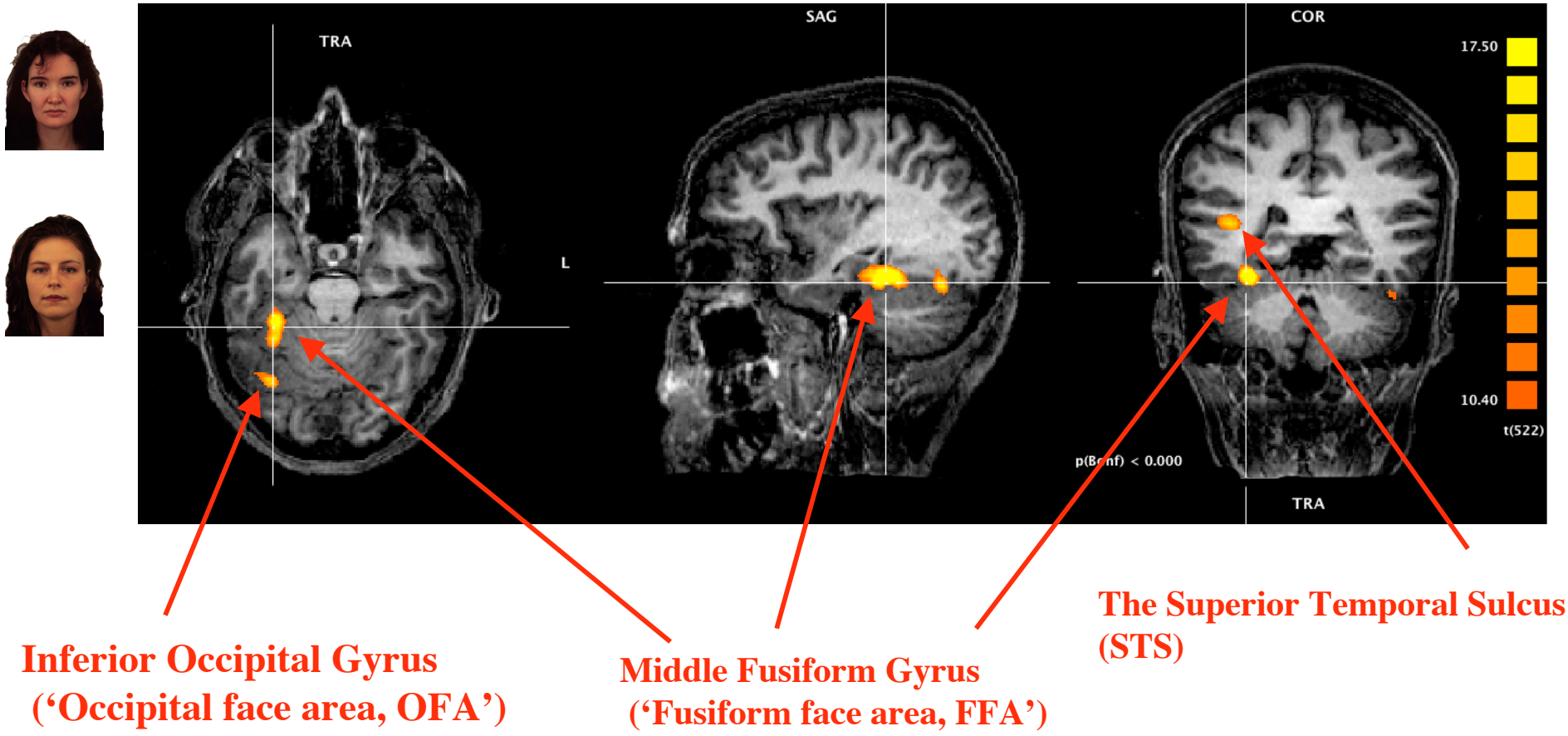
Main findings and conclusions

- Contrary to normal controls, the fMRI signal in the right 'FFA' of a patient with selective prosopagnosia (PS, Rossion et al., 2003) does **not differ** between conditions presenting identical and distinct faces in blocks or in pairs (event-related).

  That is, the fMRI signal in this area *adapts* (decreases) when *different* facial identities are presented, as if the area was processing these faces as identical. This observation is in line with behavioural observations on the patient that she can still categorize a face as a face (vs. another object category) while being impaired at discriminating individual faces.

- **In normals, individual discrimination** of faces critically depends on the integrity of both:
  - the 'FFA' (Fusiform Face Area), structurally intact for PS, but functionally depressed when it comes to individual face discrimination
  - the 'OFA' (Occipital Face Area), lesioned in PS.

Neuroimaging studies have disclosed three visual areas where a larger response to faces than other object categories is consistently observed in single subjects, with a *right hemispheric dominance*:



Inferior Occipital Gyrus ('Occipital face area, OFA')

Middle Fusiform Gyrus ('Fusiform face area, FFA')

The Superior Temporal Sulcus (STS)

Note on terminology:

FFA	=	MFG	(middle fusiform gyrus)
OFA	=	IOG	(inferior occipital gyrus)

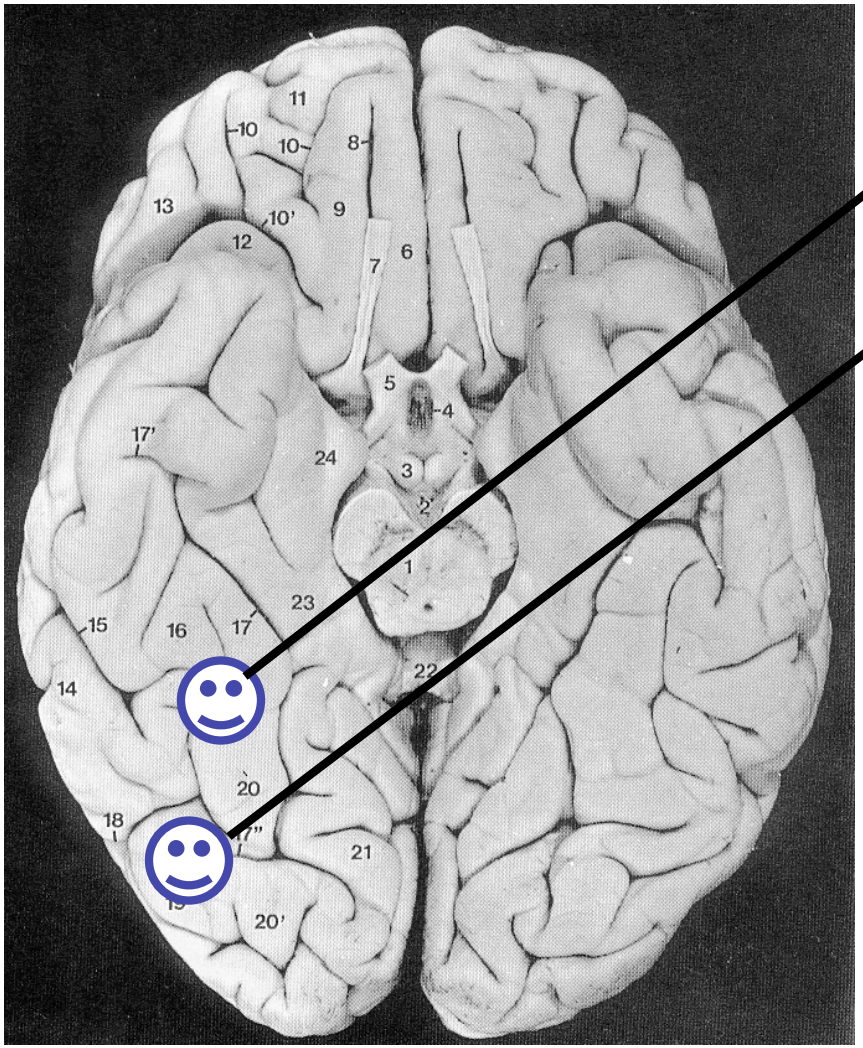
- The two functional regions are defined by a comparison of faces and nonface stimuli

- Either MFG/IOG terminology is used here, or the terms ‘FFA’ (Kanwisher et al., 1997) and ‘OFA’ (e.g. Gauthier et al., 2000) are used with quotes , since there are somewhat misleading.

- <u>Indeed</u>
  These regions do respond:
  - to other stimuli than faces
  - to a different level to distinct objects

  (e.g. Ishai et al., 2000; Grill-Spector et al., 2004)

Two of the areas responding preferentially to faces are located in the ventral visual stream

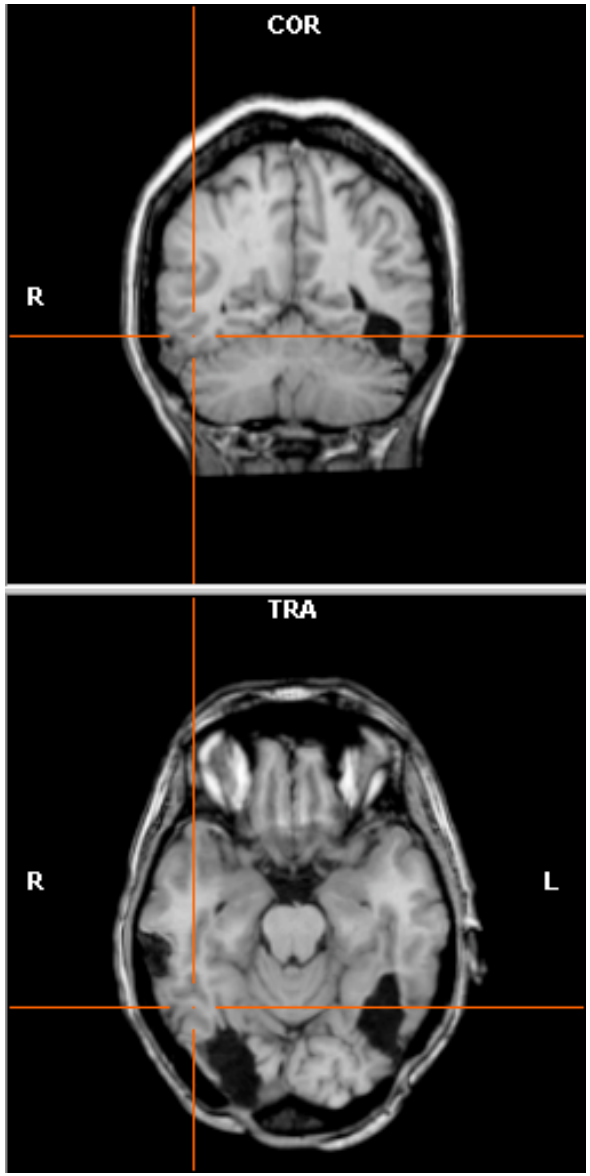


‘Fusiform face area’ (MFG)

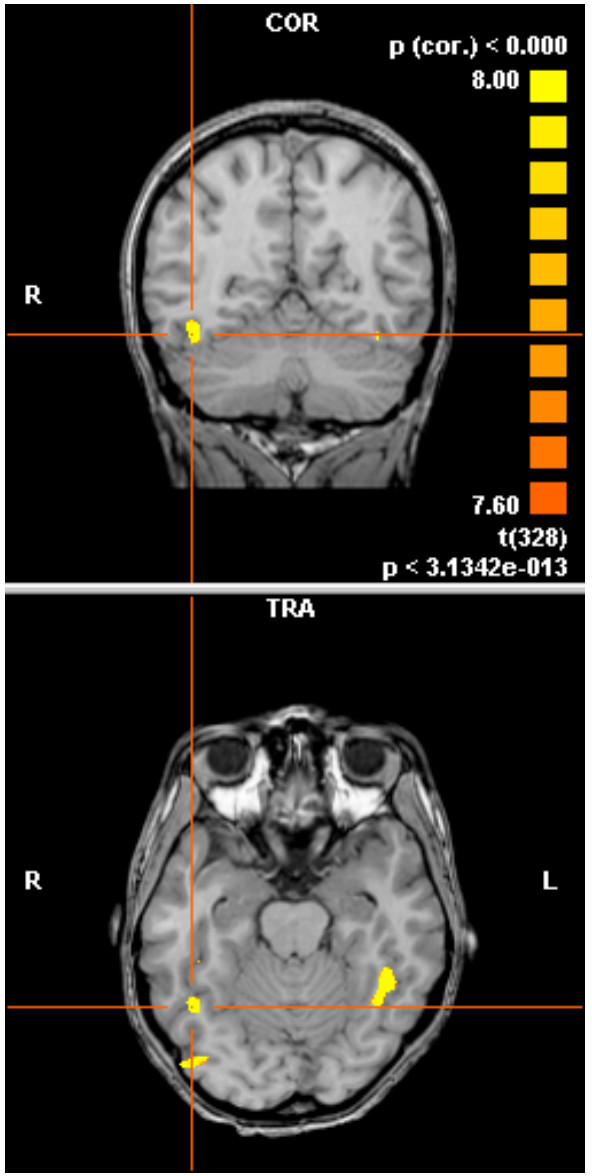
‘Occipital face area’ (IOG)

Anatomical scan: PS's lesions spare the right 'FFA'

PS



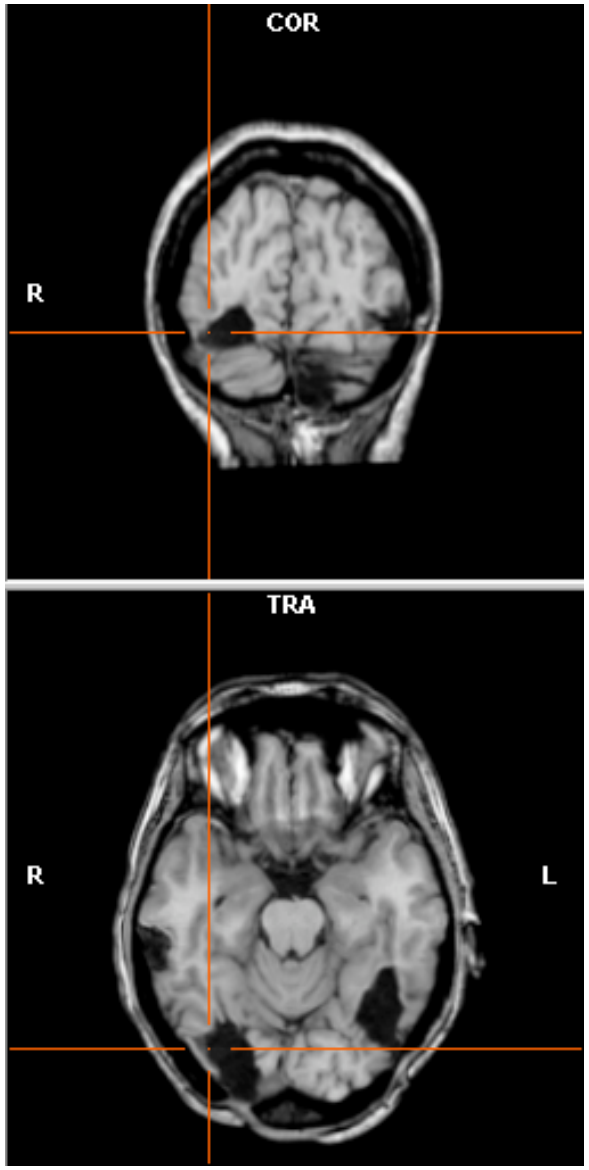
Control



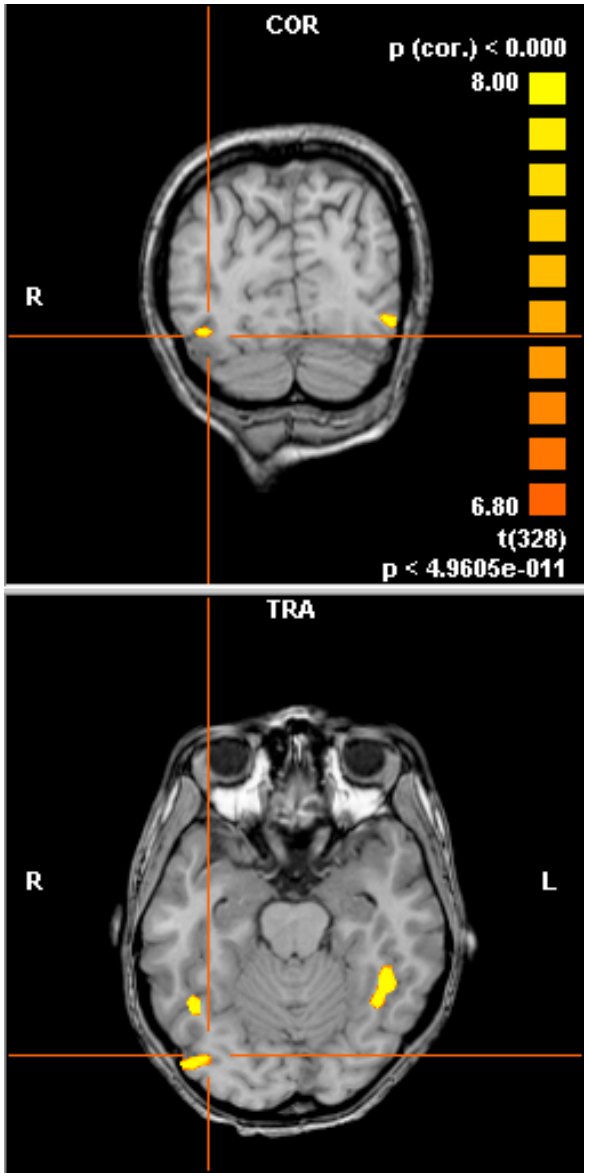
Results

PS's lesions concern the right 'OFA'

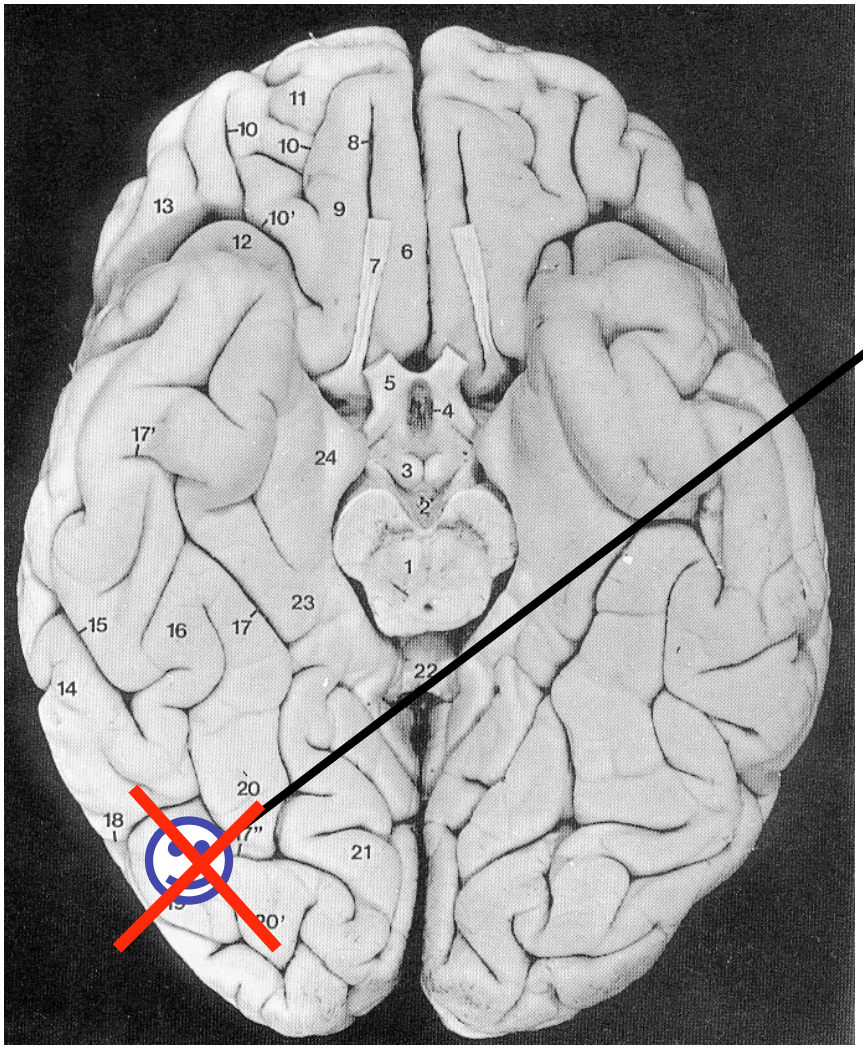
PS



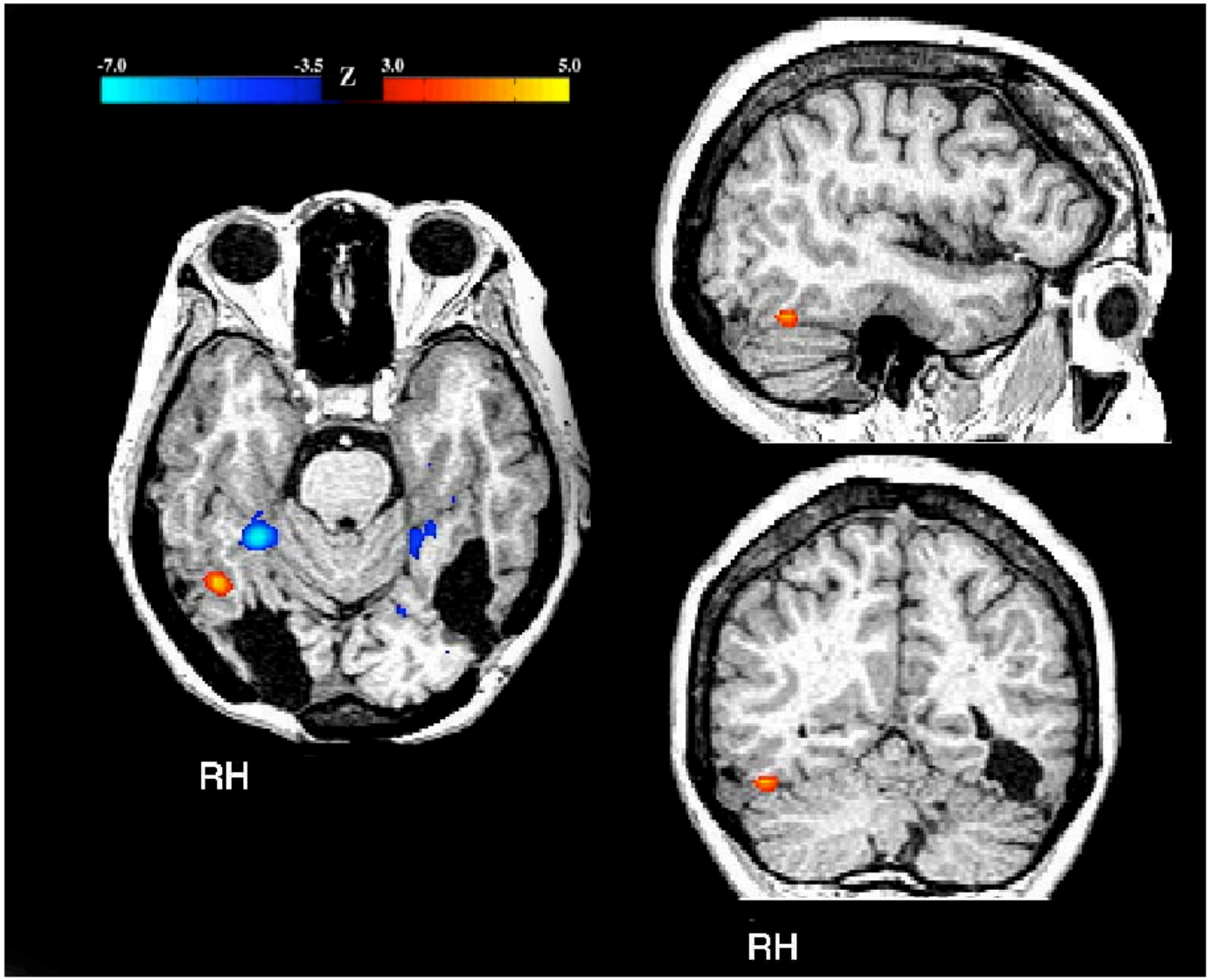
Control



Results



right ‘OFA’/IOG



Previous study: Right ‘FFA’ activation in patient PS despite ‘OFA’ damage (Rossion et al., 2003, Brain)

PS has normal visual functions and object recognition

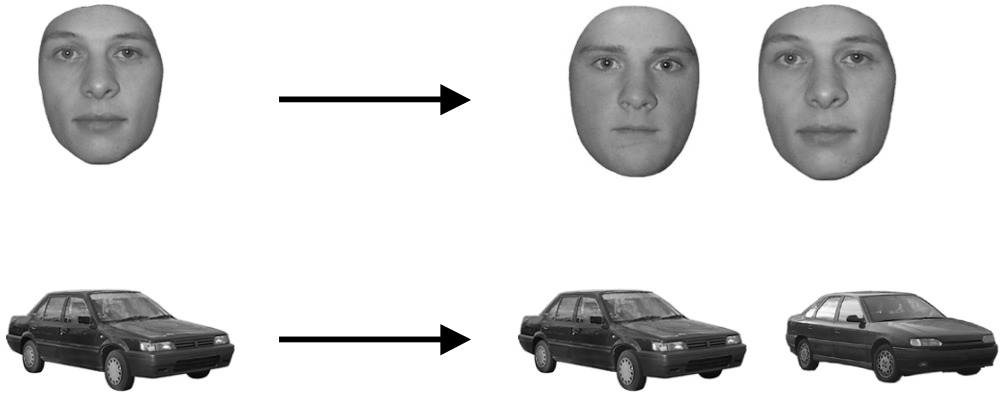
- Low-level: small left paracentral scotoma, acuity: 8/10 both eyes

- Reading OK

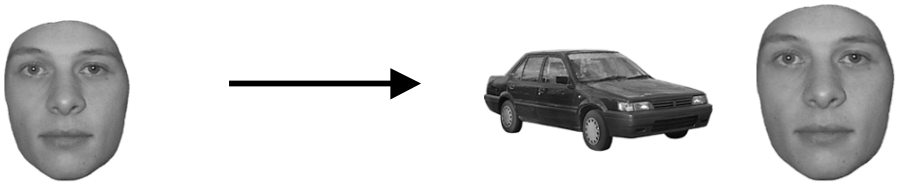
- 100% object recognition (Colorized Snodgrass and Vanderwart set by Rossion & Pourtois, 2004)

- No deficit at subordinate object recognition, even when RTs are considered

2AFC: Matching at basic and individual level



Individual

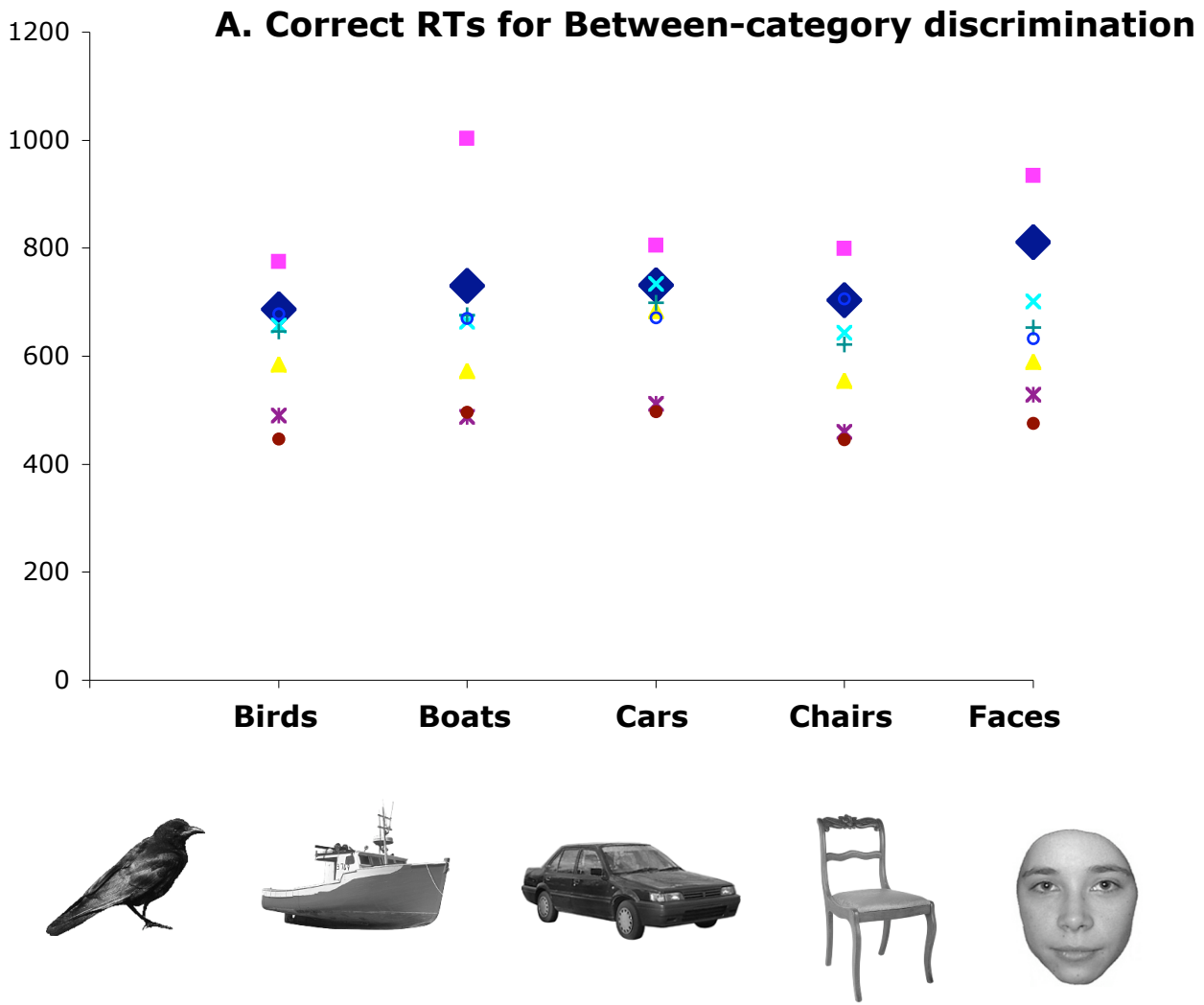


Basic

First stimulus 2000 ms; pair until response

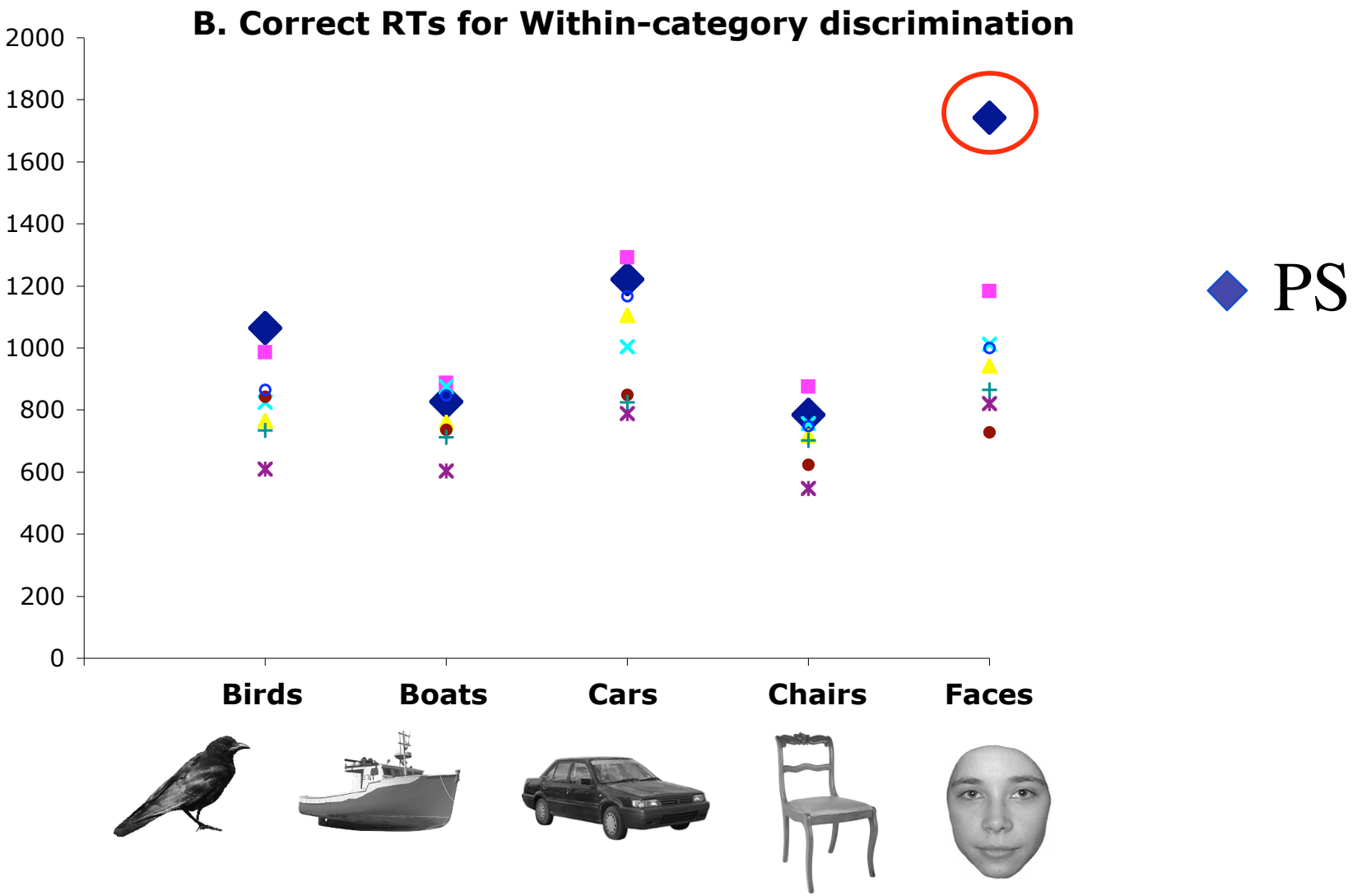
Case description

2AFC: Matching at basic level



Case description

2AFC: Matching at individual level



Case description

PS = exceptionally pure case of prosopagnosia

- Prosopagnosic patients generally present associated deficits in object recognition

The question:

Given that PS is strongly impaired and slowed down at individual face discrimination and recognition (see also Rossion et al., 2003; Caldara et al., 2005) how does her structurally intact 'FFA' deal with individual face discrimination?

→ fMR-adaptation paradigm to identity

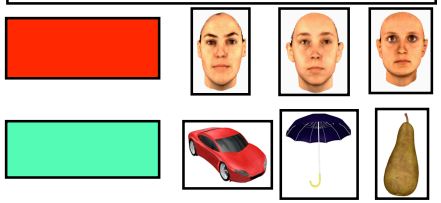
fMRI methods

1.5 T scanner (Philips)
EPI sequence
TR: 100 ms - TE: 40ms - flip: 80°
30 contiguous, near-axial slices (5 mm, 128 x 128)

(1) Classical localizer design

→ Where are the individual 'FFA's located?

(Faces - Objects)



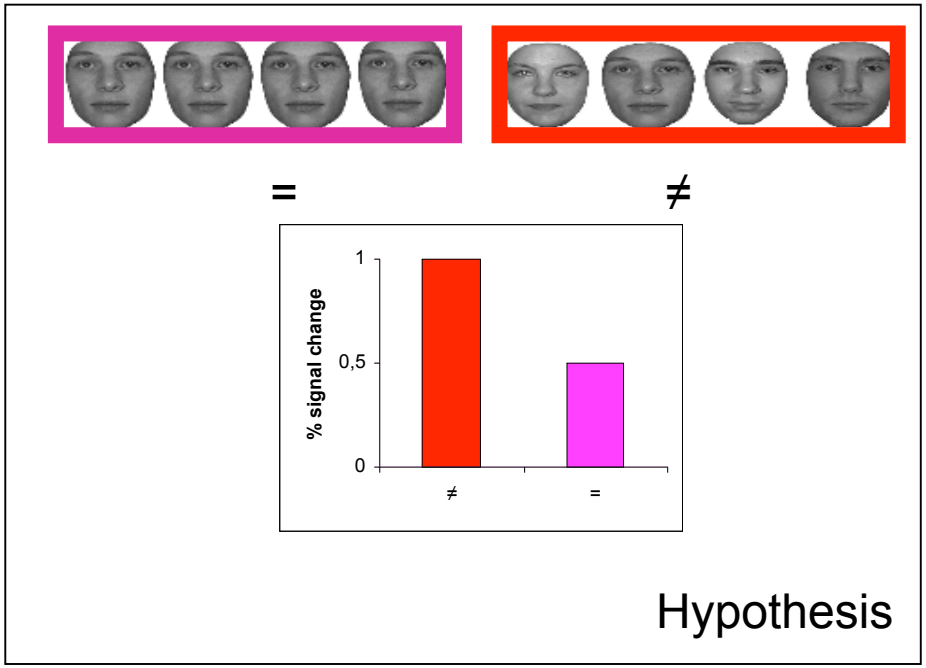
(2) FMR- adaptation design

→ Are neurons in the 'FFA' coding facial identity?

Methods

fMR-adaptation

- See
  - Grill-Spector *et al.*, 1999
  - Grill-Spector & Malach, 2001
  - Henson, 2003
  - Gauthier et al., 2000



Rationale of the adaptation paradigm:

Specifically the **regions coding facial identity**:

→ yield a **larger** blood oxygenation level-dependent (**BOLD**) signal in response to:

blocks or pairs of trials displaying **different** individual faces as compared >
to blocks or pairs of trials with **identical** faces

In a cortical area responding preferentially to faces:

Recovery from fMR-adaptation to facial identity

is taken as evidence that:

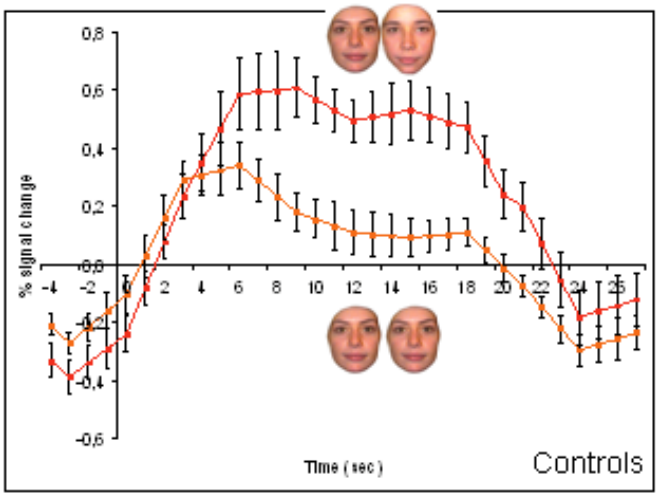
→ different facial identities are represented by distinct neuronal response patterns

Methods

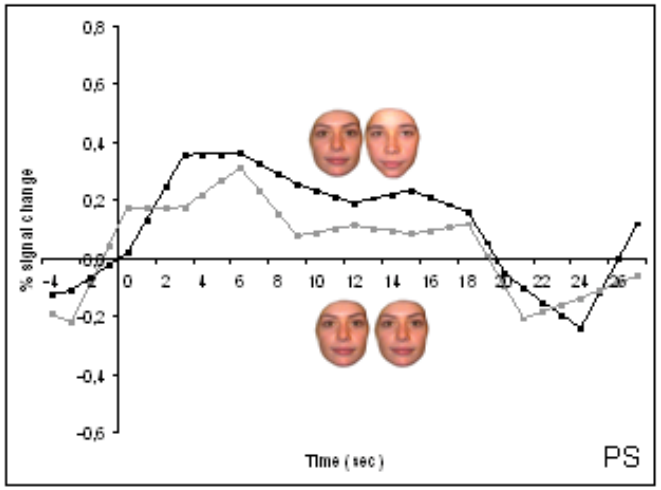
Role of the rMFG in face discrimination

Block design
Experiment 1

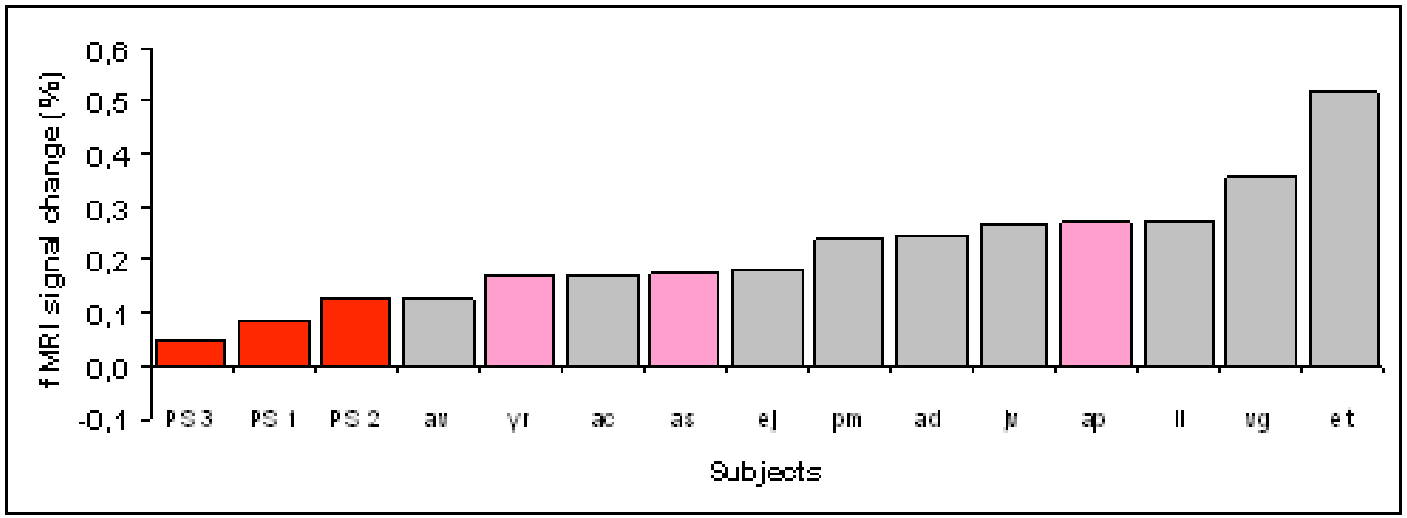
A. BOLD response to faces in the rMFG of controls



B. BOLD response to faces in the rMFG of PS



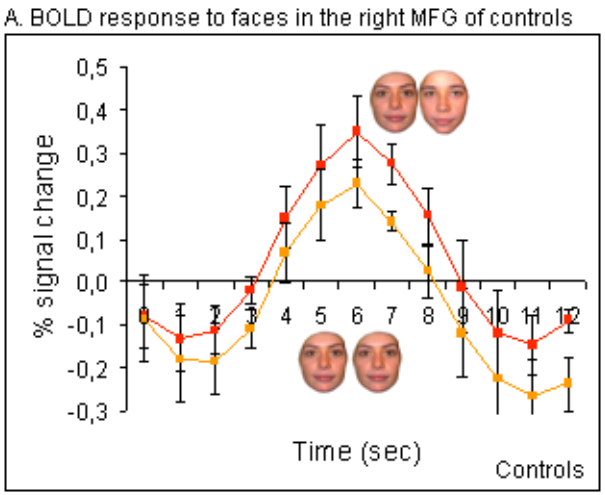
A. Recovery from fMR-adaptation to faces (rMFG)

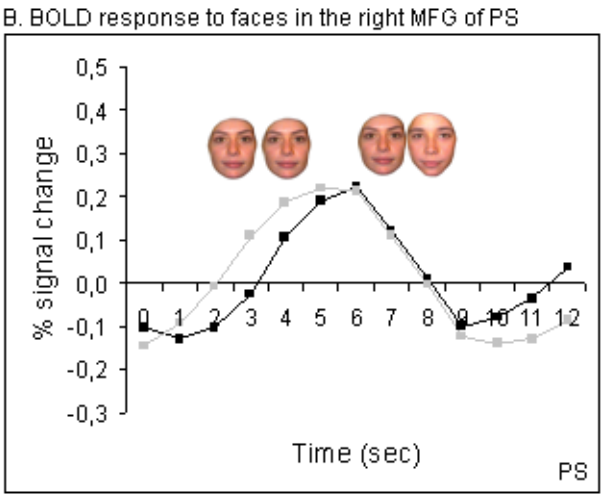


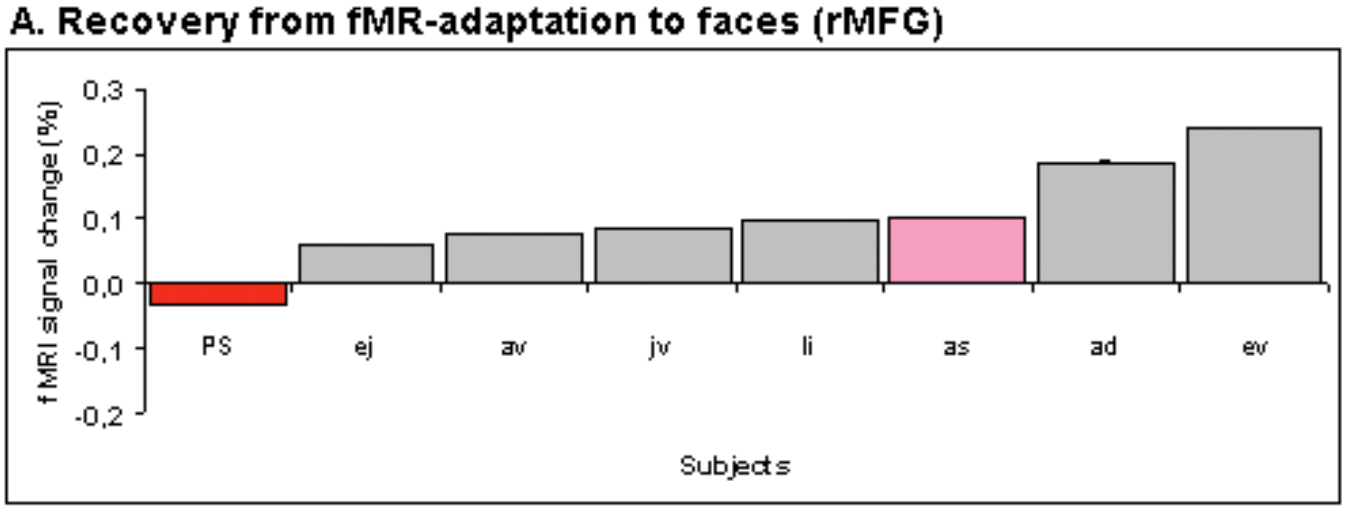
Results

Role of the rMFG in face discrimination

Event-related design
Experiment 2







Results

Role of the rMFG in face discrimination

- Face-preferring neurons in the rMFG of PS:

  present an anomalous response pattern with respect to individual face discrimination

  Despite:

  – being structurally intact

  – responding as well as in normal subjects to faces at the basic category level

Role of the right MFG in face discrimination

In the patient PS the BOLD response to both identical and distinct faces is at the level of the response to identical faces in normal control subjects

→ The abnormal signal in PS's rMFG most likely reflects a failure of recovery to adaptation to different facial identities (or an adaptation to different facial identities)

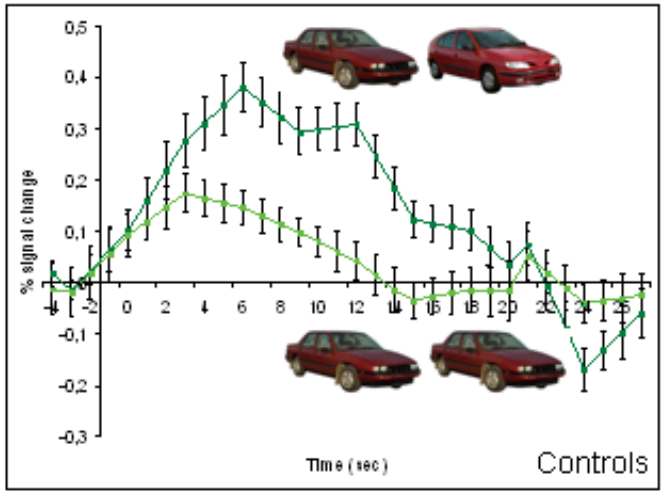
Selective deficit for face discrimination in the rMFG

The lack of recovery from adaptation is not unspecific

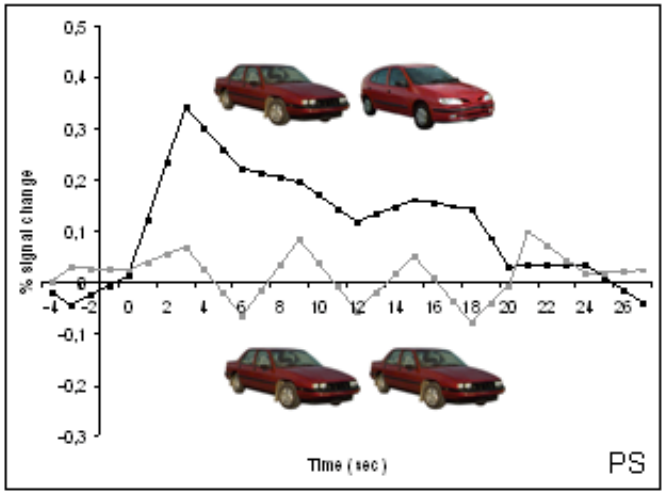
→ PS has normal recovery from fMR-adaptation to objects (i.e. cars and chairs) in the object-sensitive region in the right parahippocampal gyrus (rPHG)

Block design
Experiment 1

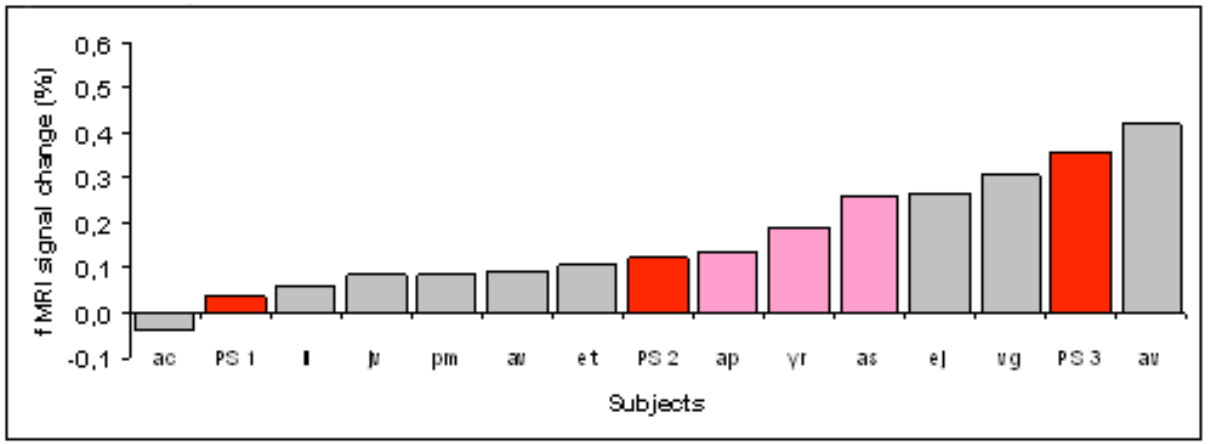
C. BOLD response to cars in the rPHG of controls



D. BOLD response to cars in the rPHG of PS



B. Recovery from fMR-adaptation to cars (rPHG)

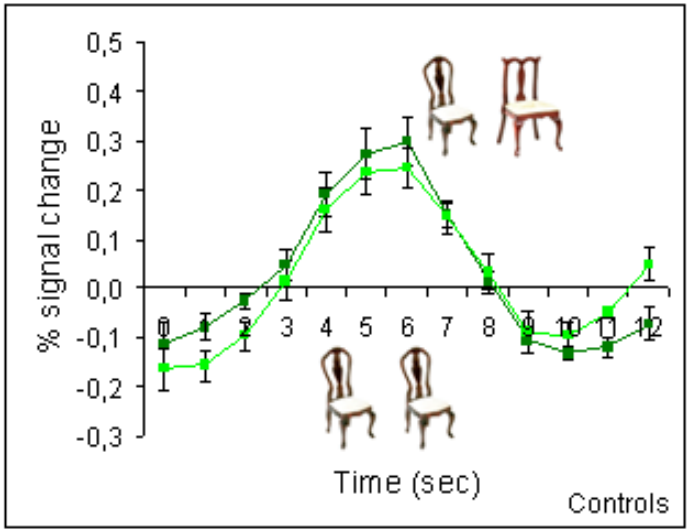


Results

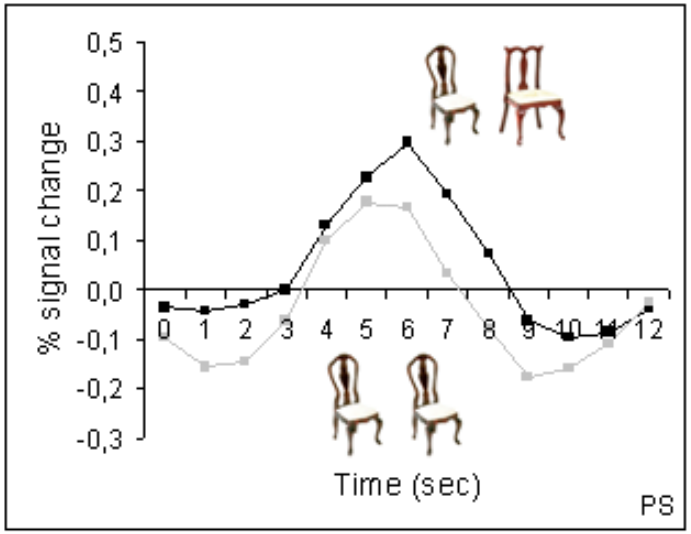
Selective deficit for face discrimination in the rMFG

Event-related design
Experiment 2

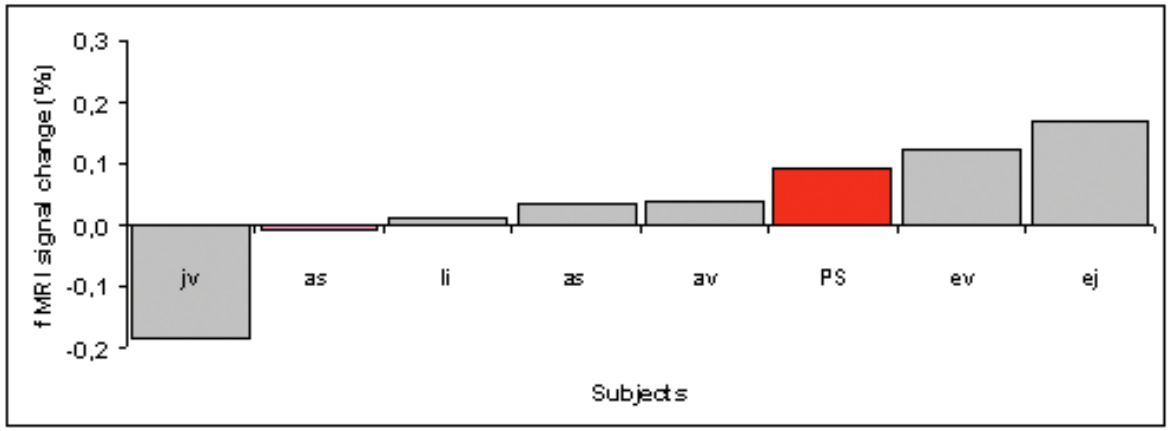
C. BOLD response to chairs in the right PHG of controls



D. BOLD response to chairs in the right PHG of PS



B. Recovery from fMR-adaptation to chairs (rPHG)



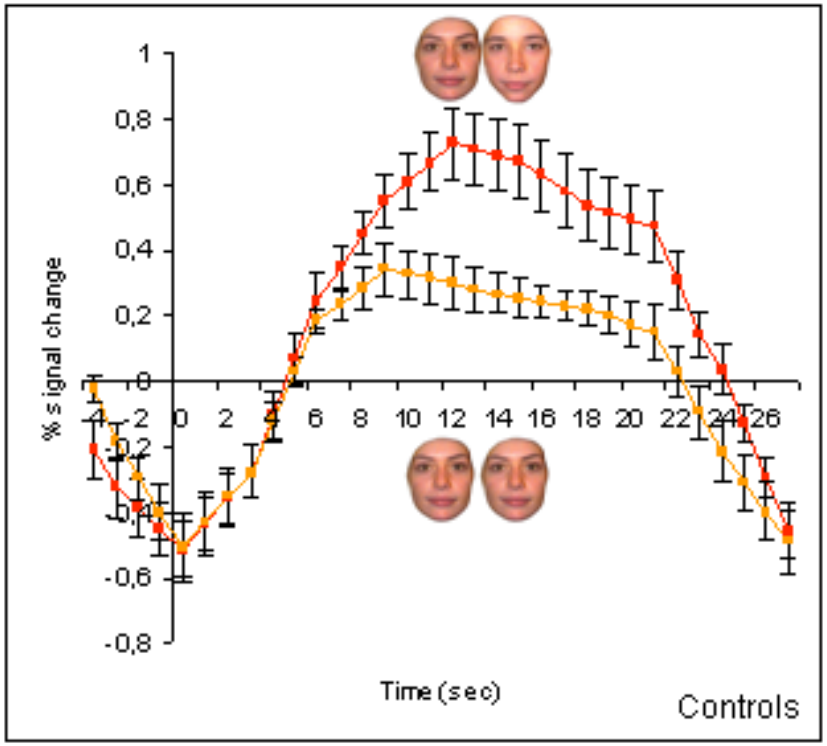
Results

Role of the rIOG in face discrimination

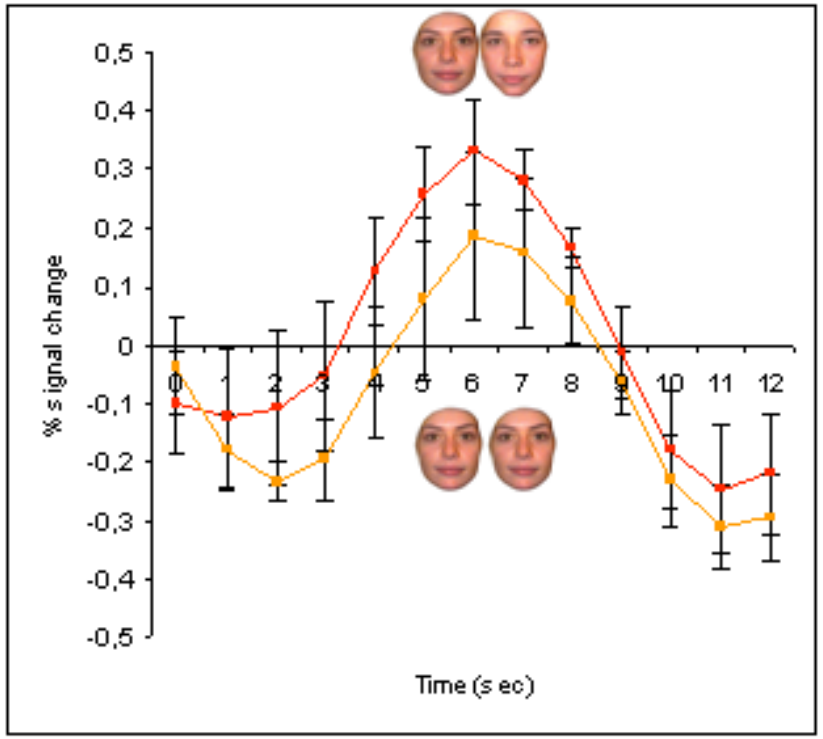
Significant recovery from fMR-adaptation to facial identity in the right IOG of control subjects

region that is structurally damaged in PS

BOLD response to faces in the rIOG of controls



BOLD response to faces in the rIOG of controls



Block design

Event-related design

Results

Role of the rIOG in face discrimination

In prosopagnosia:

- rIOG: region with largest overlap of lesions causing prosopagnosia
  → see Bouvier and Engel, 2005

- The damage to the rIOG underlies PS' prosopagnosic deficit, both:
  - directly
    → through a damage to the representations and processes taking place normally in this area
  - indirectly
    → this region cannot provide normal inputs to other areas, such as the rMFG

In normal face processing:

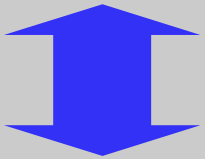
- To differentiate faces:
  both the rMFG and the rIOG are critical

- The rMFG appears to be dependent on normal sustained inputs from the rIOG

SUMMARY

In **normal** control subject:

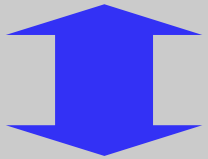
'recovery from adaptation'
to facial identity in the fusiform gyrus



behavioral abilities
in face individual discrimination

In brain-damaged **prosopagnosic** patient PS:

diminished 'recovery from adaptation'
to facial identity in the fusiform gyrus



behavioral impairment
in individual face discrimination

These results suggest that:

→ neurons in the right 'MFG' play a critical role
in identifying faces at the individual level

Complementary analysis in the face-localizer experiment

Paradox: how can the fMRI signal be of normal amplitude in PS's FFA when contrasting different faces and different objects while it should adapt to face identity?

Face-localizer: response to faces vs. objects in the rMFG

- The differential BOLD response to faces vs. objects in the rMFG is:

  PS:

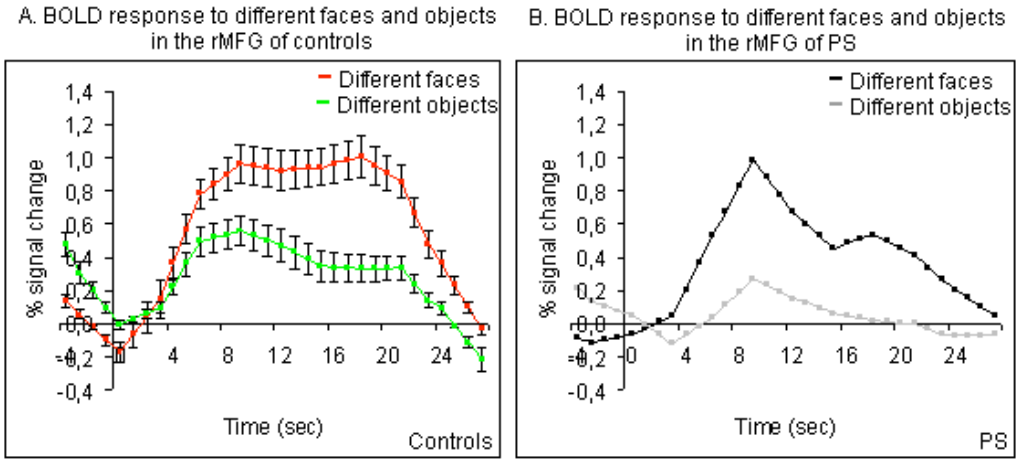
  not sustained throughout the second half of the stimulus presentation block

  Normal controls:

  sustained signal throughout the second half of the stimulus presentation block

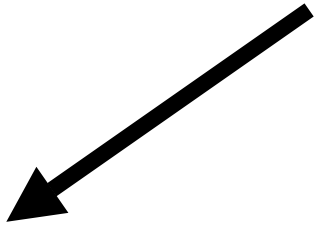
- When the block is divided into two parts:
  - (1-9 sec) differential response PS > controls
  - (10-18 sec) differential response PS < controls

Response to faces vs. objects in the rMFG



To be tested in the future

- Recovery from adaptation to nonface objects in the lateral occipital complex (LOC) in PS



defined as a region that responds more to objects than scrambled images of objects (Malach et al., 1995)

- LOC:
  - does not present a larger response to face than nonface object categories
  - shows adaptation to shape repetition
  - See Kourtzi & Kanwisher; Grill-Spector et al., 1999; Grill-Spector & Malach, 2001