Face perception

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Principles of Cognition (MSc. CoDeS)
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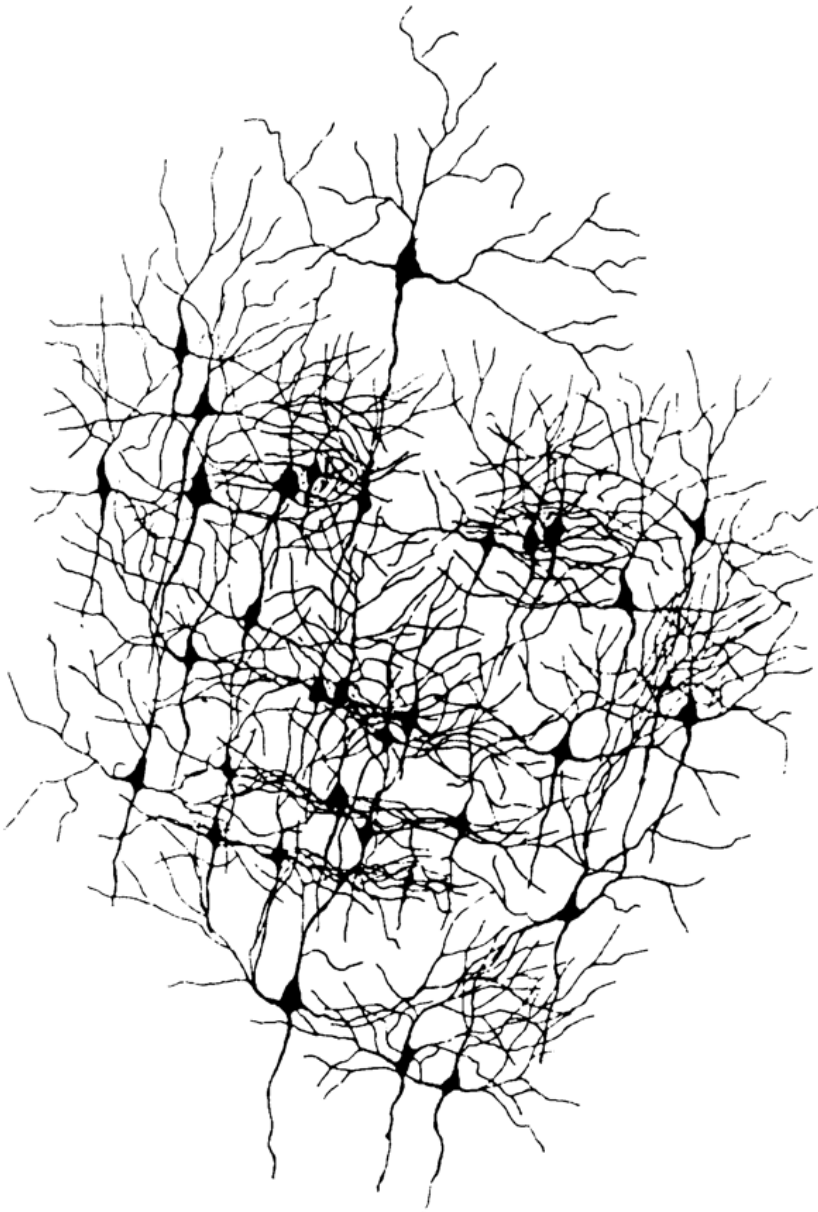
Plan

1. Are faces special?
2. Holistic processing
3. Two models of face perception
4. Face space
5. Development

1. Are faces special?



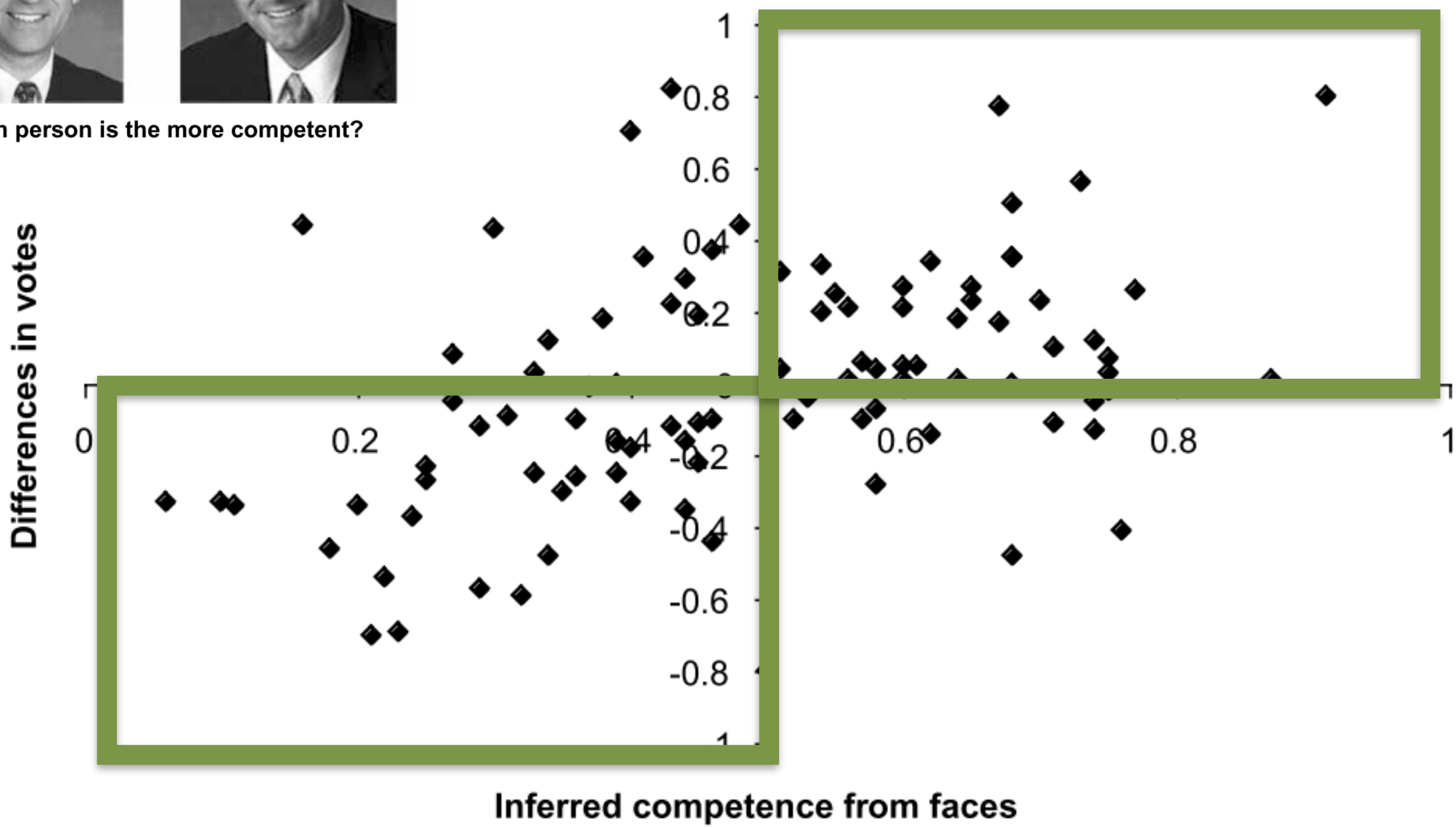
 

Which person is the more competent?

Todorov et al, 2005, Science

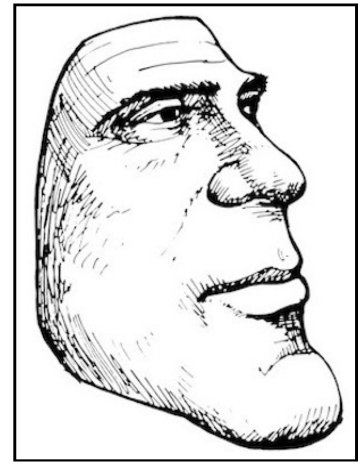
Which person is the more competent?

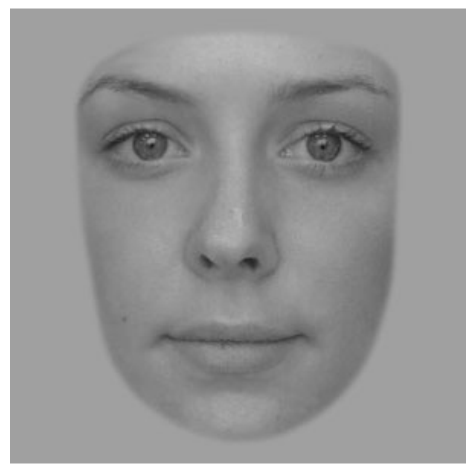
72%



Todorov et al, 2005, Science




Prosopagnosia (face-blindness)

Brad Pitt Says He Can't Remember Faces, Thinks He Suffers From Prosopagnosia

CELEBRITY NEWS MAY 22, 2013 AT 7:15PM BY ALLISON TAKEDA

Like 878 Tweet 74 62 +1 9 Pin it 1

"So many people hate me because they think I'm disrespecting them…"

"… I piss…people off. You get this thing, like, 'You're being egotistical. You're being conceited.' But it's a mystery to me, man. I can't grasp a face…"

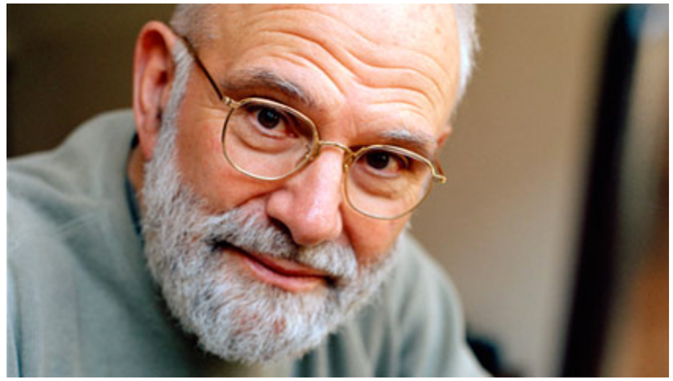
Esquire Magazine (2013)

Jane Goodall

I used to think it was due to some mental laziness, and I tried desperately to memorise the faces of people. Sometimes I knew that people were upset that I did not immediately recognise them – certainly I was. And because I was embarrassed, I kept it to myself.

– *Reason for Hope*, 1999

Oliver Sacks



THE NEW YORKER

NEWS CULTURE BOOKS & FICTION SCIENCE & TECH BUSINESS HUMOR CARTOONS MAGAZINE

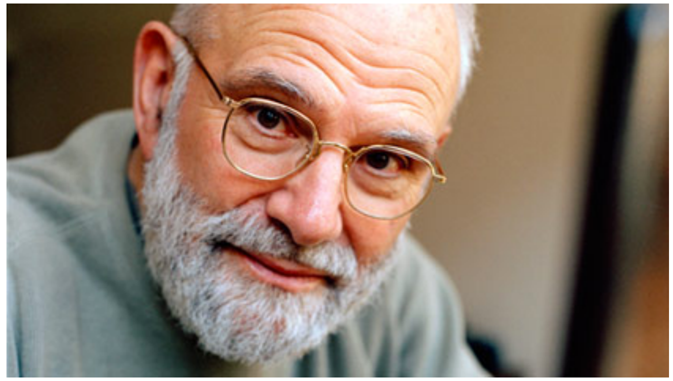
A NEUROLOGIST'S NOTEBOOK | AUGUST 30, 2010 ISSUE

FACE-BLIND

Why are some of us terrible at recognizing faces?

BY OLIVER SACKS

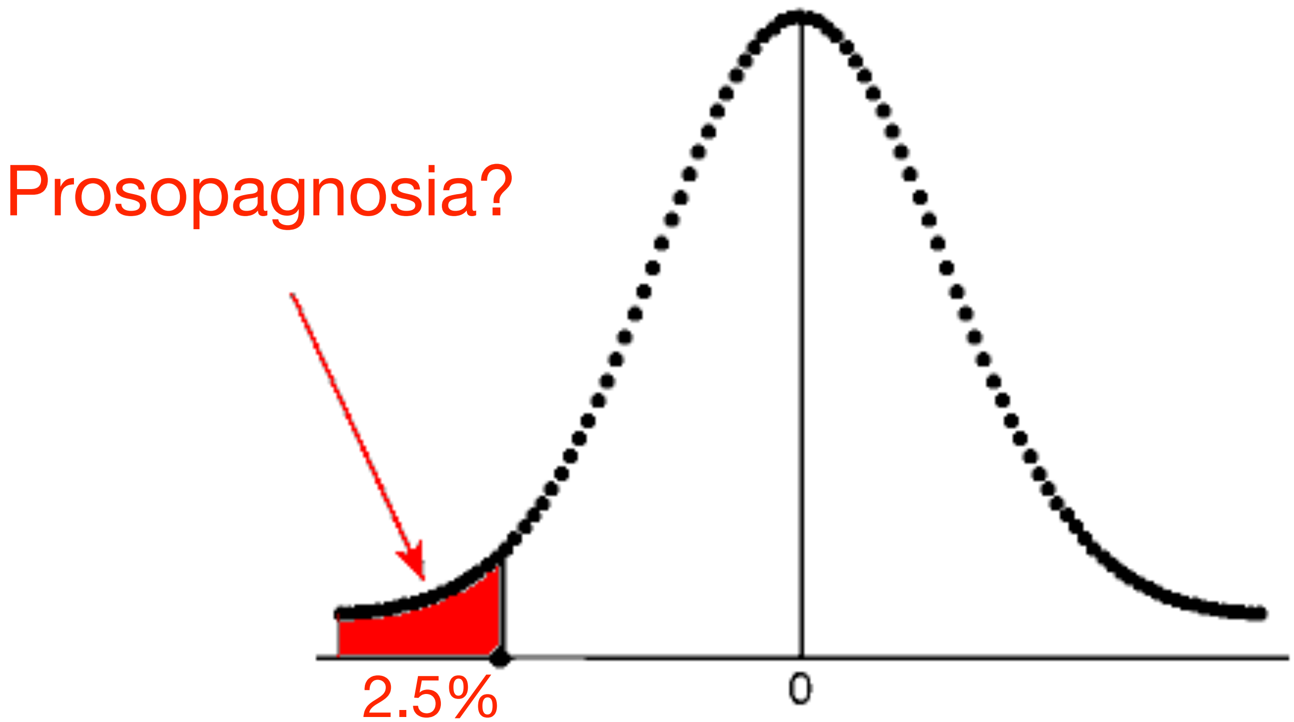
Oliver Sacks



On several occasions I have apologized for almost bumping into a large bearded man, only to realize that the large bearded man was myself in a mirror. The opposite situation once occurred at a restaurant. Sitting at a sidewalk table, I turned toward the restaurant window and began grooming my beard, as I often do. I then realized that what I had taken to be my reflection was not grooming himself but looking at me oddly.

– *New Yorker*, 2010

Special stimuli ->
specific brain mechanisms ?


Prosopagnosia?
2.5%
0

Face processing debate

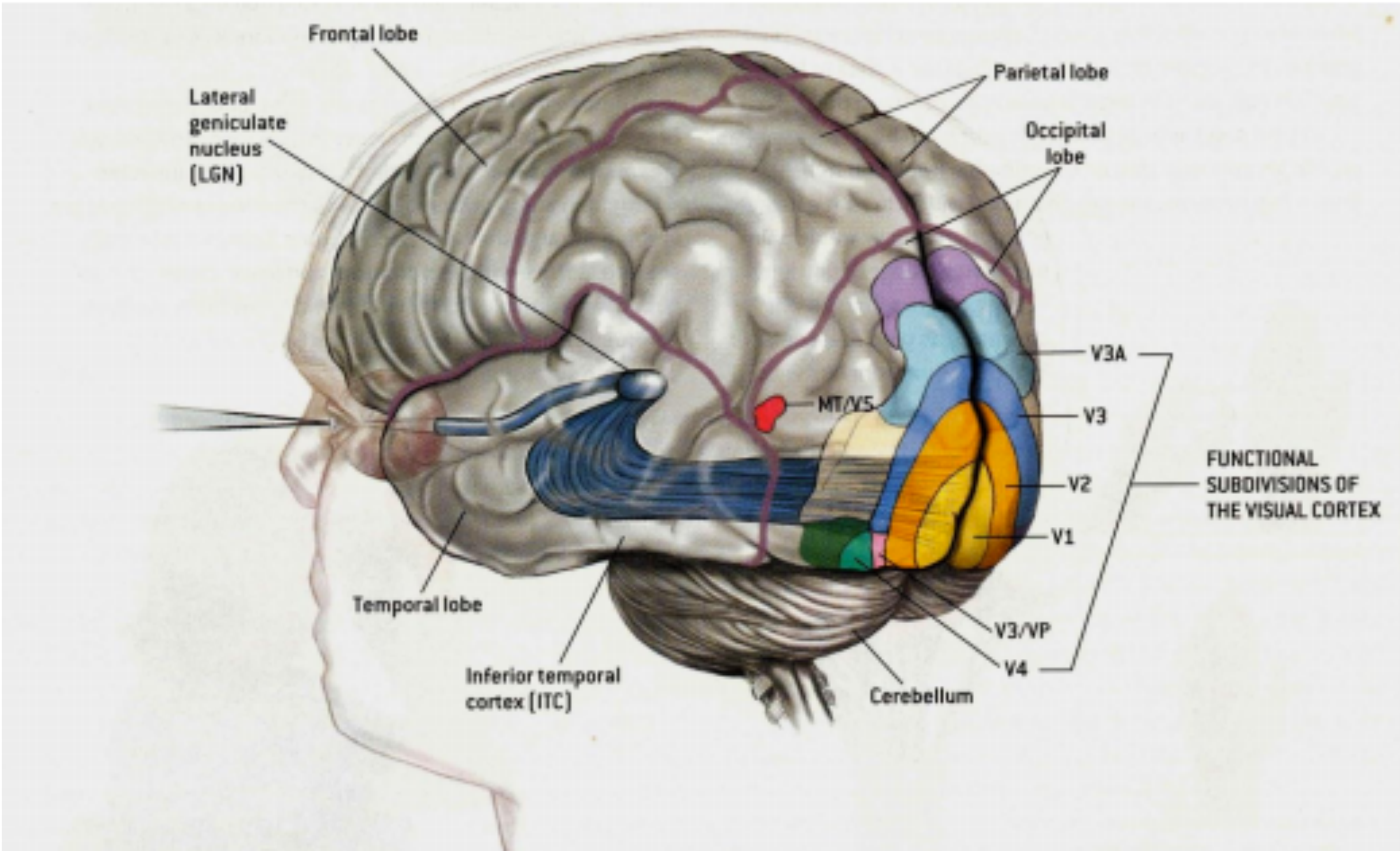
For almost 50 years, researchers debated the specificity and nature of mechanisms of face recognition - excellent example of scientific process in psychology.

- Evidence from many sources.
- Debate has focused primarily on the question – **“Are faces special?”**
- In other words, do faces receive **processing that differs** from the processing applied to other objects and does this processing have a **distinct neural substrate**?

Face-specificity hypothesis

FUNCTIONAL
Face processing relies on specialised mechanisms that play little to no role in processing of non-face objects

NEURAL
These specialised mechanisms are implemented in "face-selective areas" and "face-selective neurons/cells"



Key idea in studies of secondary/higher-order visual areas: specific areas carry out specific functions (motion processing in MT, colour processing in V4, object processing in IT, etc.)

How is face recognition performed?

A number of possibilities:

- Domain-general object recognition procedures that operate on **all objects - ITEM-LEVEL HYPOTHESIS**
- Object recognition procedures that operate on **particular objects**, including faces
    - e.g. objects of expertise - **EXPERTISE HYPOTHESIS**
- A face-specific procedure or procedures that operate solely on **faces - FACE-SPECIFICITY HYPOTHESIS**
    - specialized either phylogenetically or ontogenetically
- A **mixture** of domain-general & face-specific procedures.

Sources of evidence in debate

- Behavioural experiments/psychophysics
- Single-cell studies and neuroimaging
- Studies of neuropsychological cases

Behavioural experiments

- Are faces processed differently than other object classes?
- If there are different procedures, this is powerful evidence.
- However, stimulus characteristics could activate

special procedures, so one must choose stimuli carefully.

- Inverted faces provide an ideal test case.

Importance of orientation

Importance of orientation

Alternative hypotheses

- Within-class object recognition

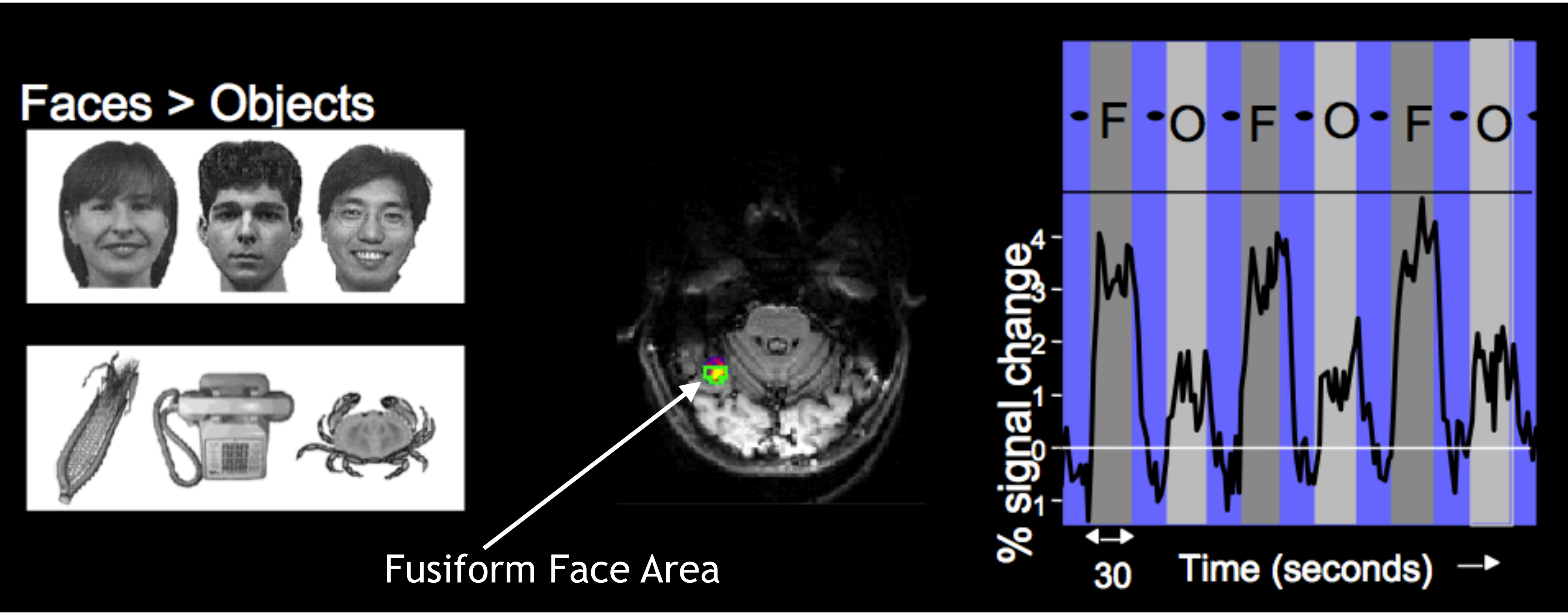
- Within-class recognition of objects of expertise

	Expert type	Task	Faces	Objects novices	Objects experts
Dogs (Robbins and McKone, 2007, Experiment 3)	Real world	Simultaneous matching	11%*	1%^{ns}	2%^{ns}
Dogs (Robbins and McKone, 2007, Experiment 1)	Real world	Long-term memory	23%*	3%^{ns}	7%^{ns}
Fingerprints (Busey and Vanderkolk 2005)	Real world	Face/print classification	16%*	6%^{ns}	8%^{ns}
Houses [a b] (Husk et al., 2007)	Lab trained	Sequential matching	35%*	1%$^{-}$	4%*
Cars (Xu et al., 2005)	Real world	Sequential matching	—	8%$^{-}$	8%$^{-}$
Handwriting (Bruyer and Crispeels, 1992)	Real world	Long-term memory	20%*	5%^{ns}	9%*
Greebles [a] (Rossion et al., 2002)	Lab trained	Sequential matching	75ms^{-}	25 ms^{-}	46 ms^{-}
Dogs (Diamond and Carey, 1986 - Experiment 3)	Real world	Long-term memory	20%*	5%^{ns}	22%*

<u>Face inversion effect</u>

Face recognition is dramatically impaired, *much more* than object recognition, when stimuli are shown upside-down

Neuroimaging evidence

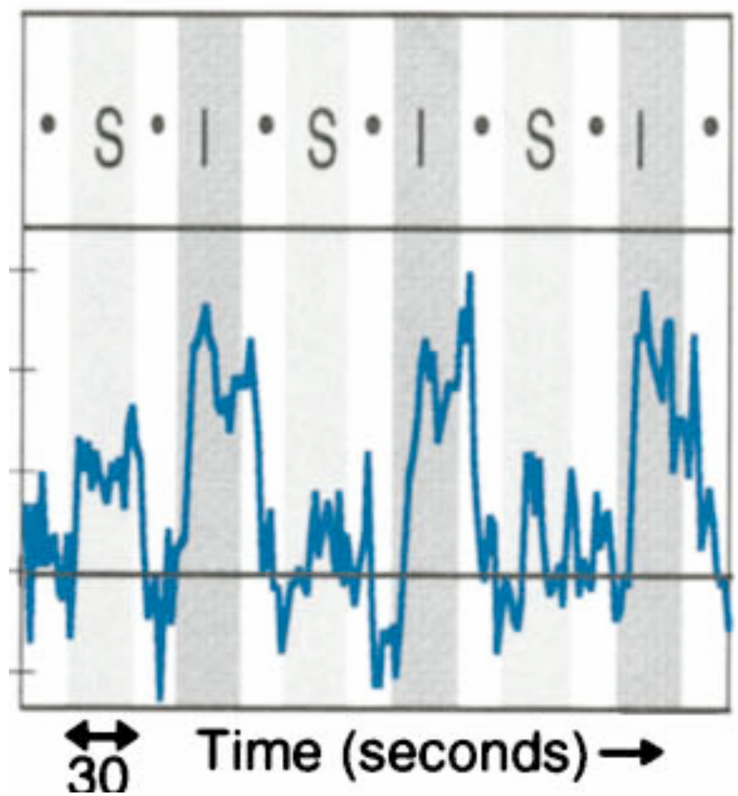


Kanwisher et al., 1997, JoN

Alternate account	Control stimuli
Low-level features	Scrambled faces
Item-level recognition	
Animate objects	

Intact

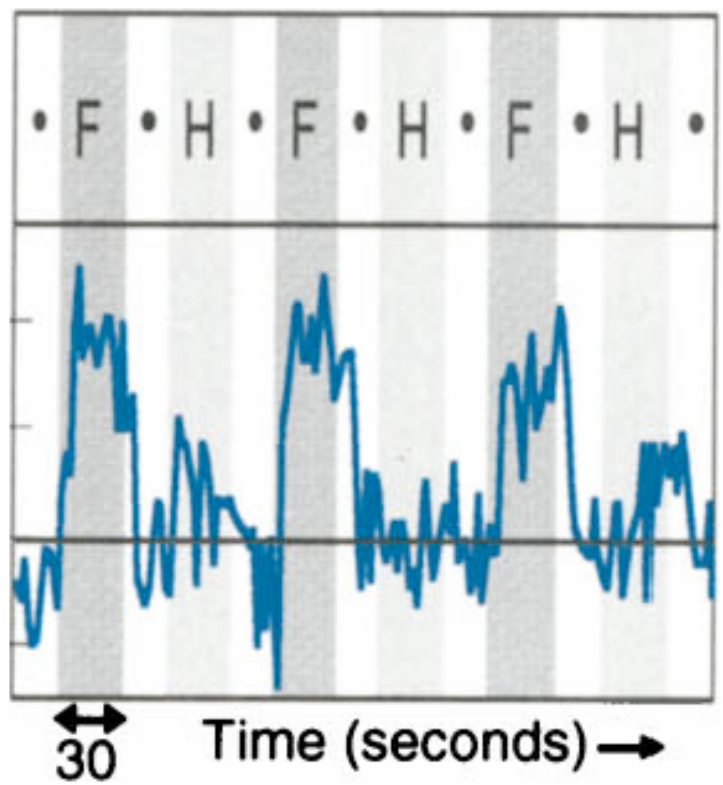
Scrambled



Alternate account	**Control stimuli**
~~Low-level features~~	~~Scrambled faces~~
Item-level recognition	Houses
Animate objects	

Faces

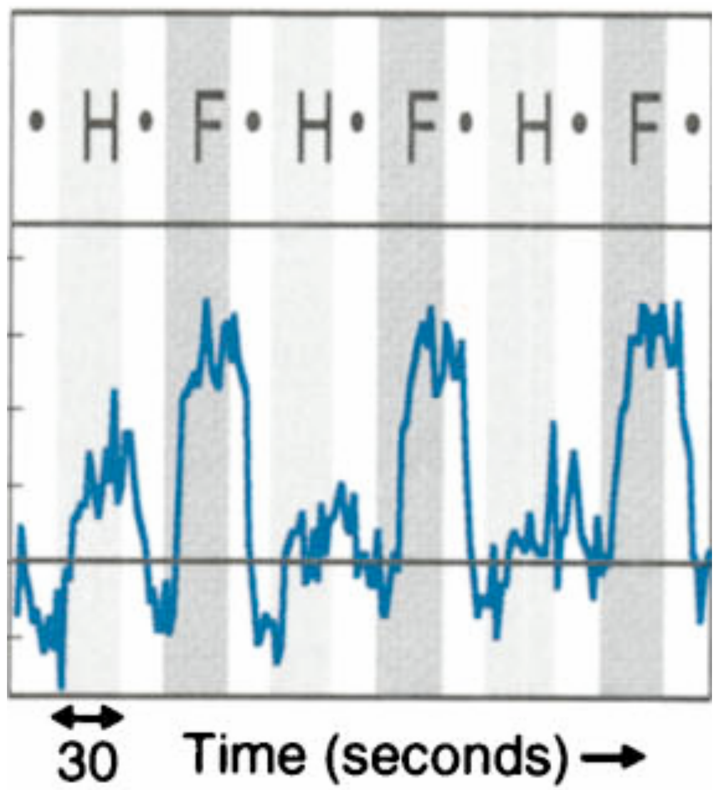
Houses



Alternate account	**Control stimuli**
~~Low-level features~~	~~Scrambled faces~~
~~Item-level recognition~~	~~Houses~~
Animate objects	Hands

Faces

Hands



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~~Low-level features~~	~~Scrambled faces~~
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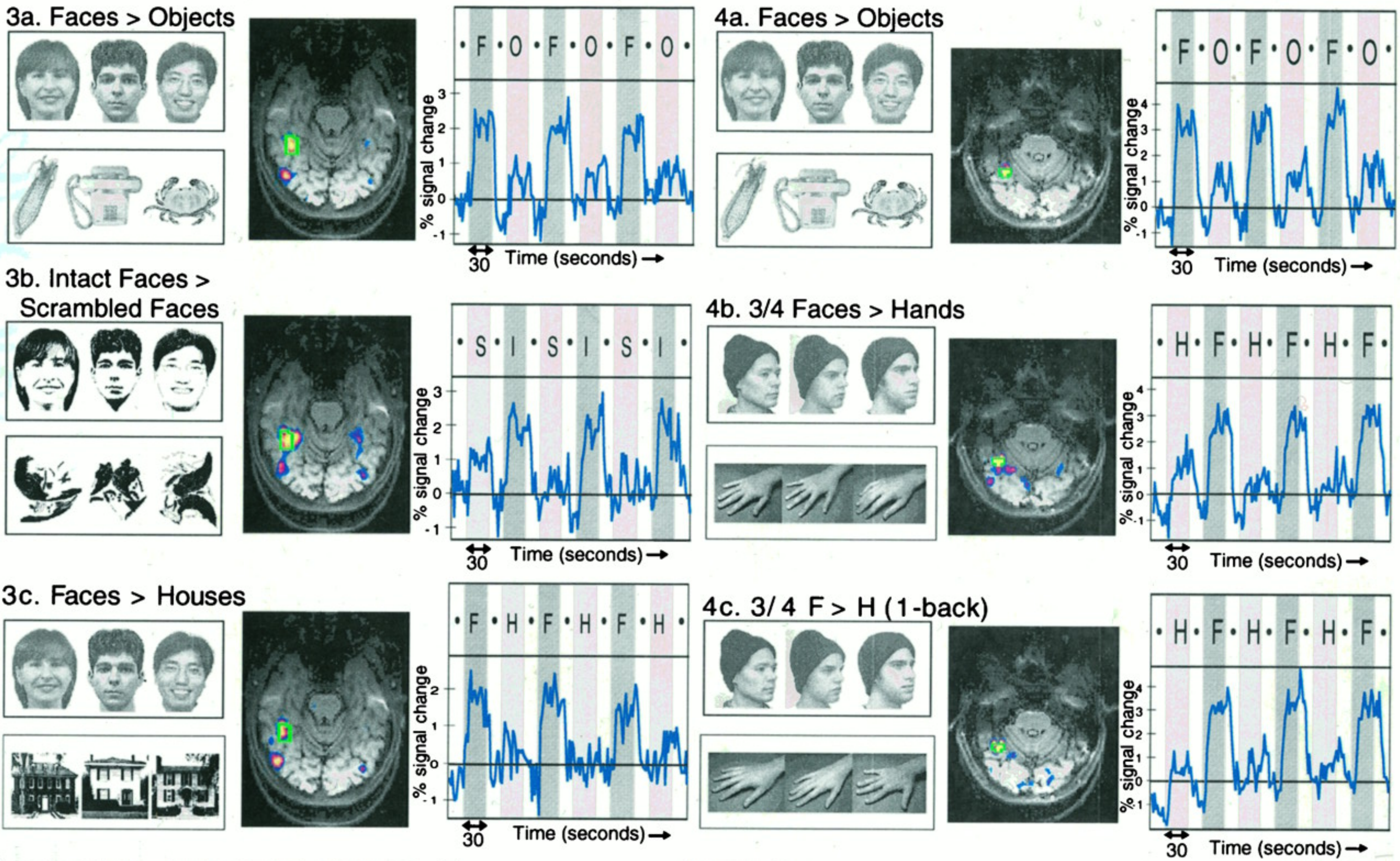
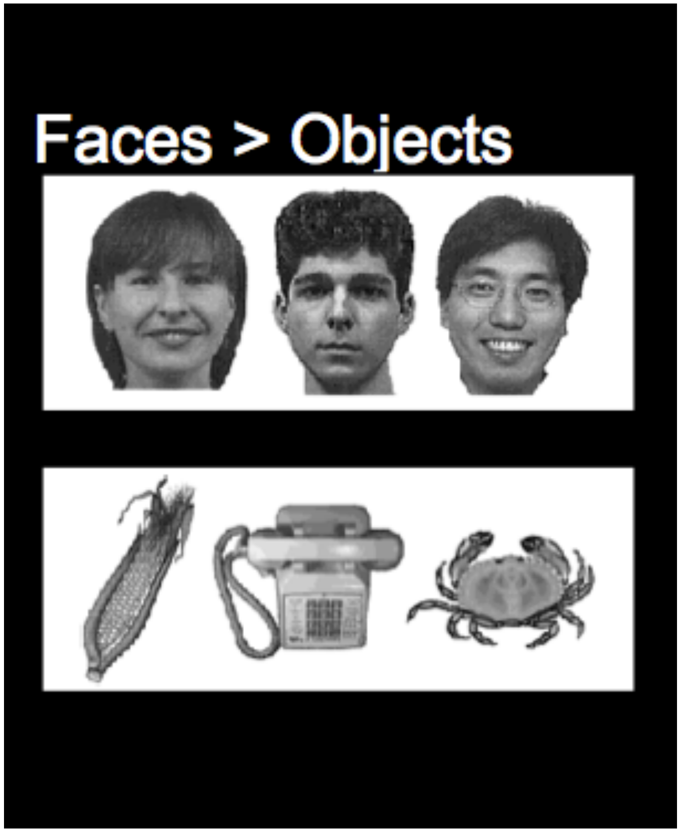
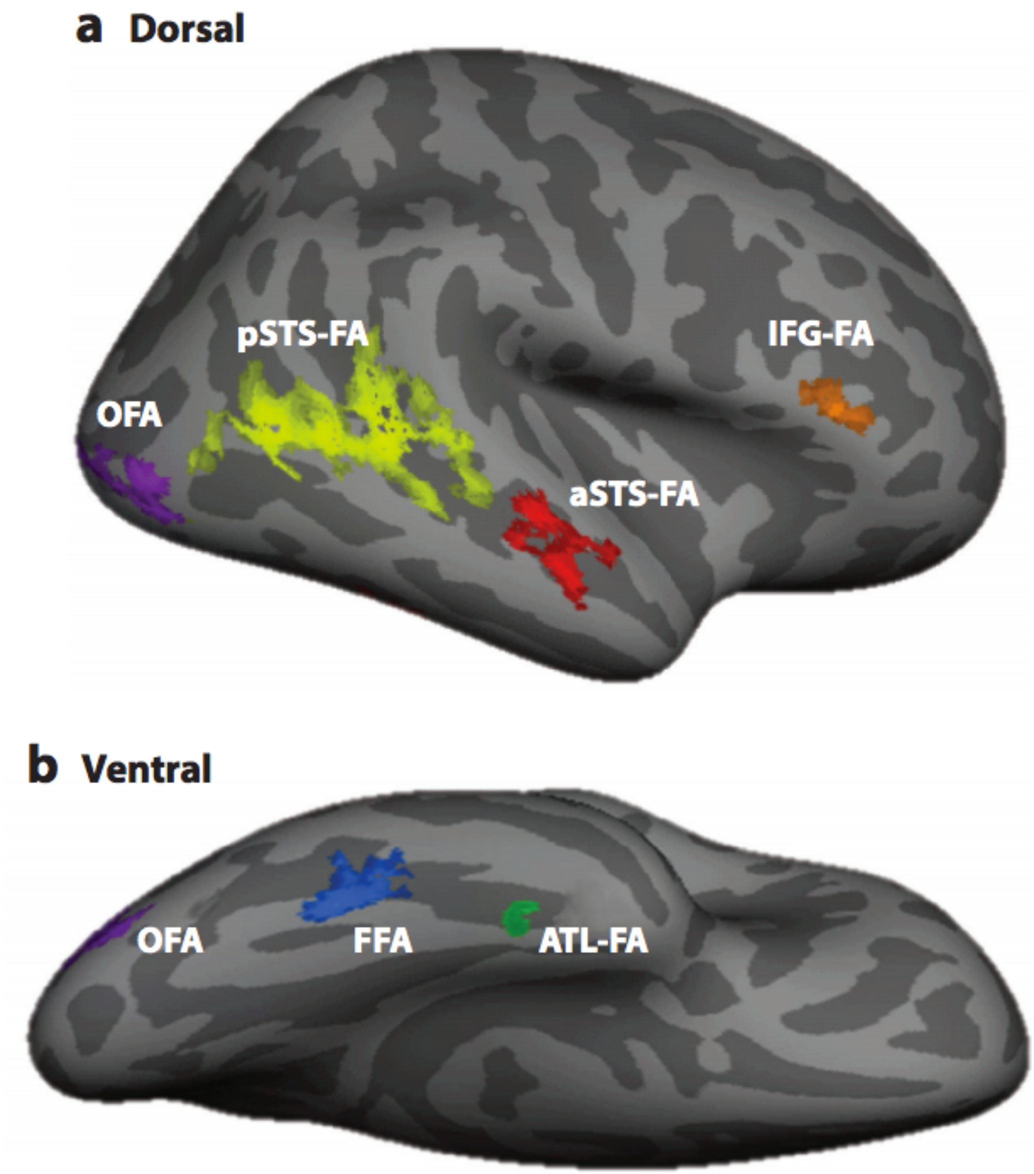
~~Animate objects~~	~~Hands~~



Kanwisher et al., 1997, JoN



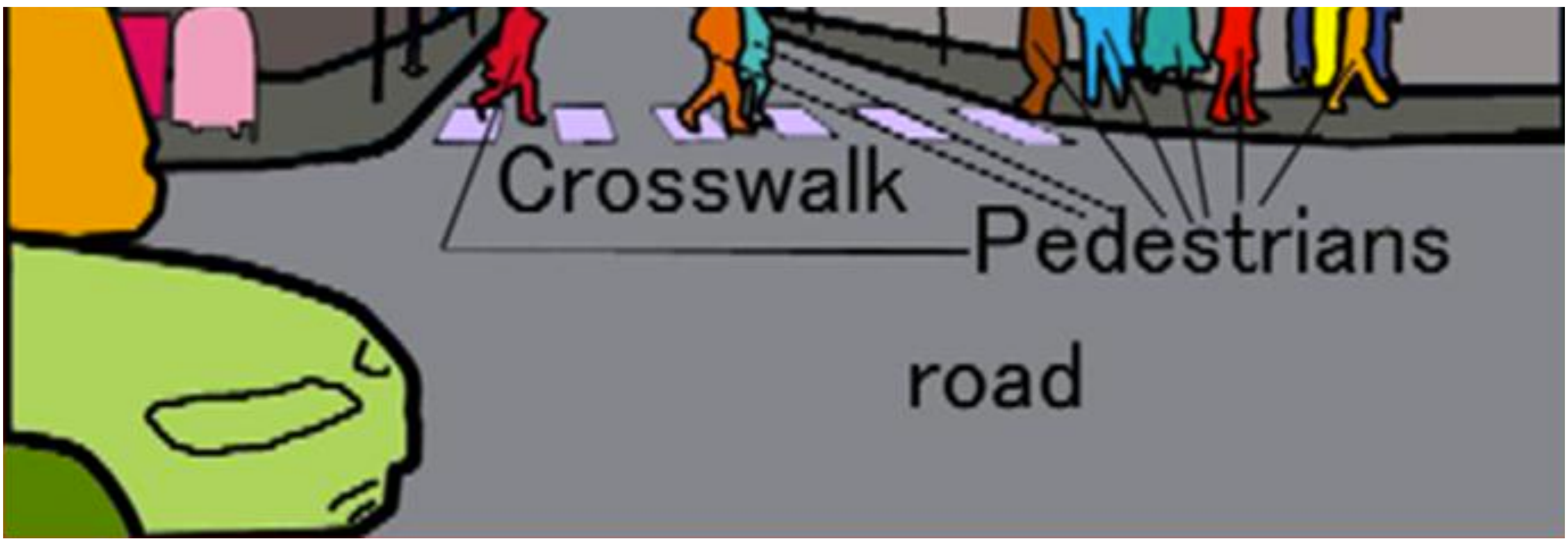


<u>Face-selective areas</u>

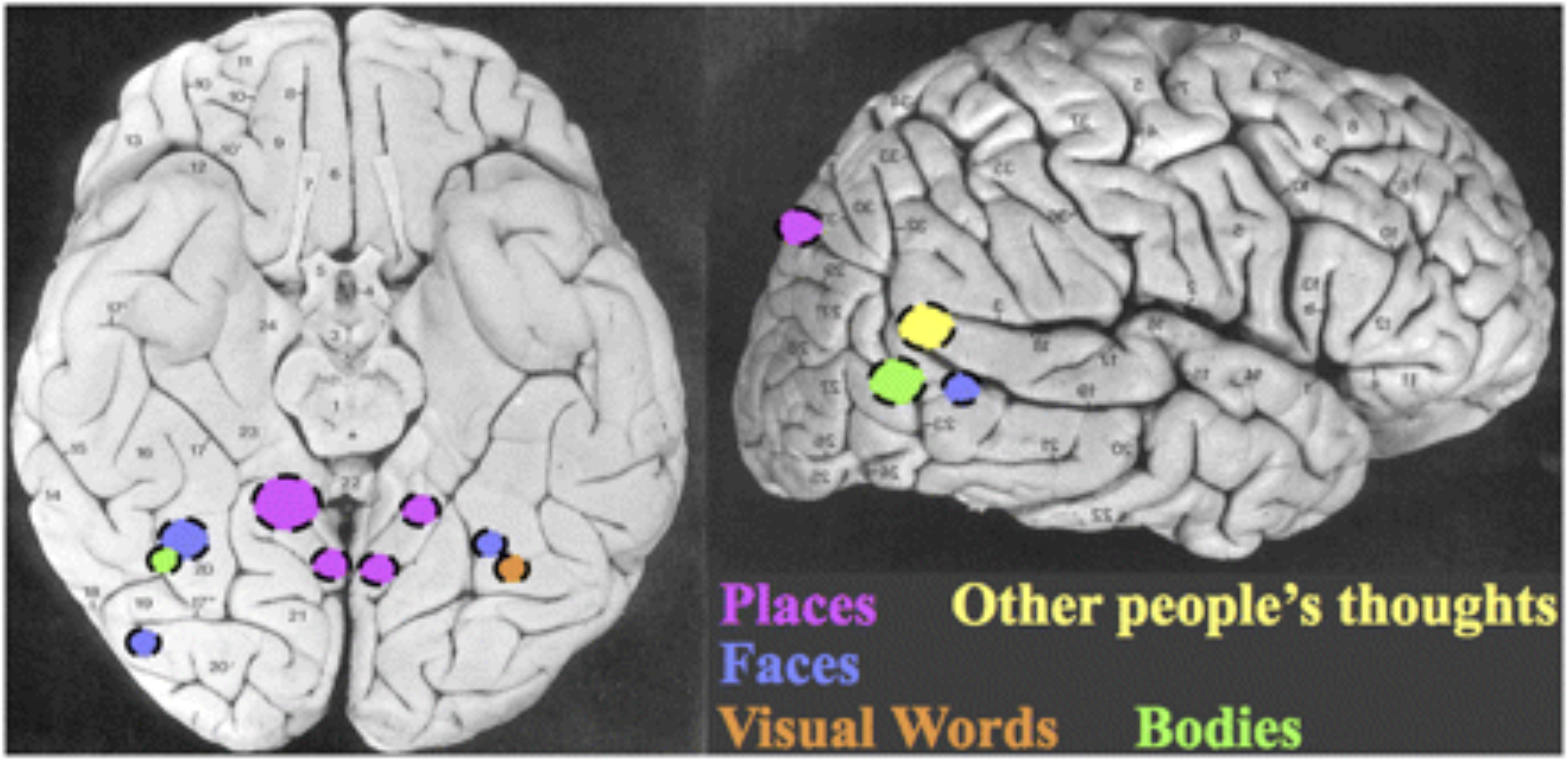
fMRI-defined regions that respond more strongly to faces than to various control stimuli


Putnam

Many objects, many recognition systems?



Category-selective areas/regions

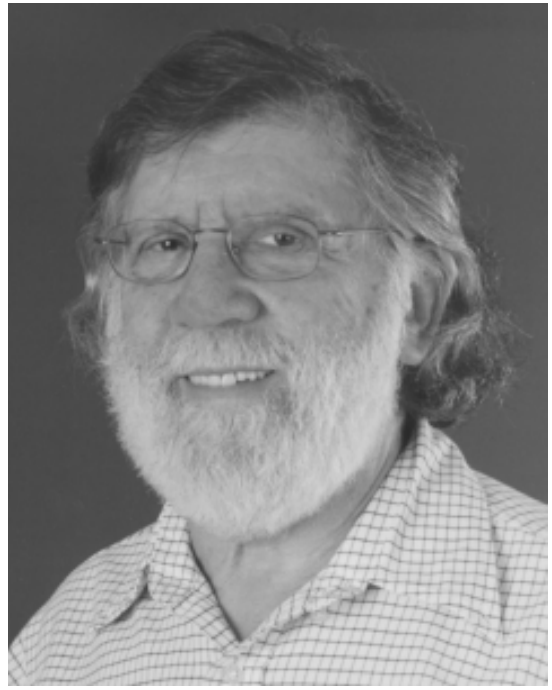


Kanwisher, 2010, PNAS

fMRI-defined regions that respond more strongly to particular stimulus classes than various control stimuli

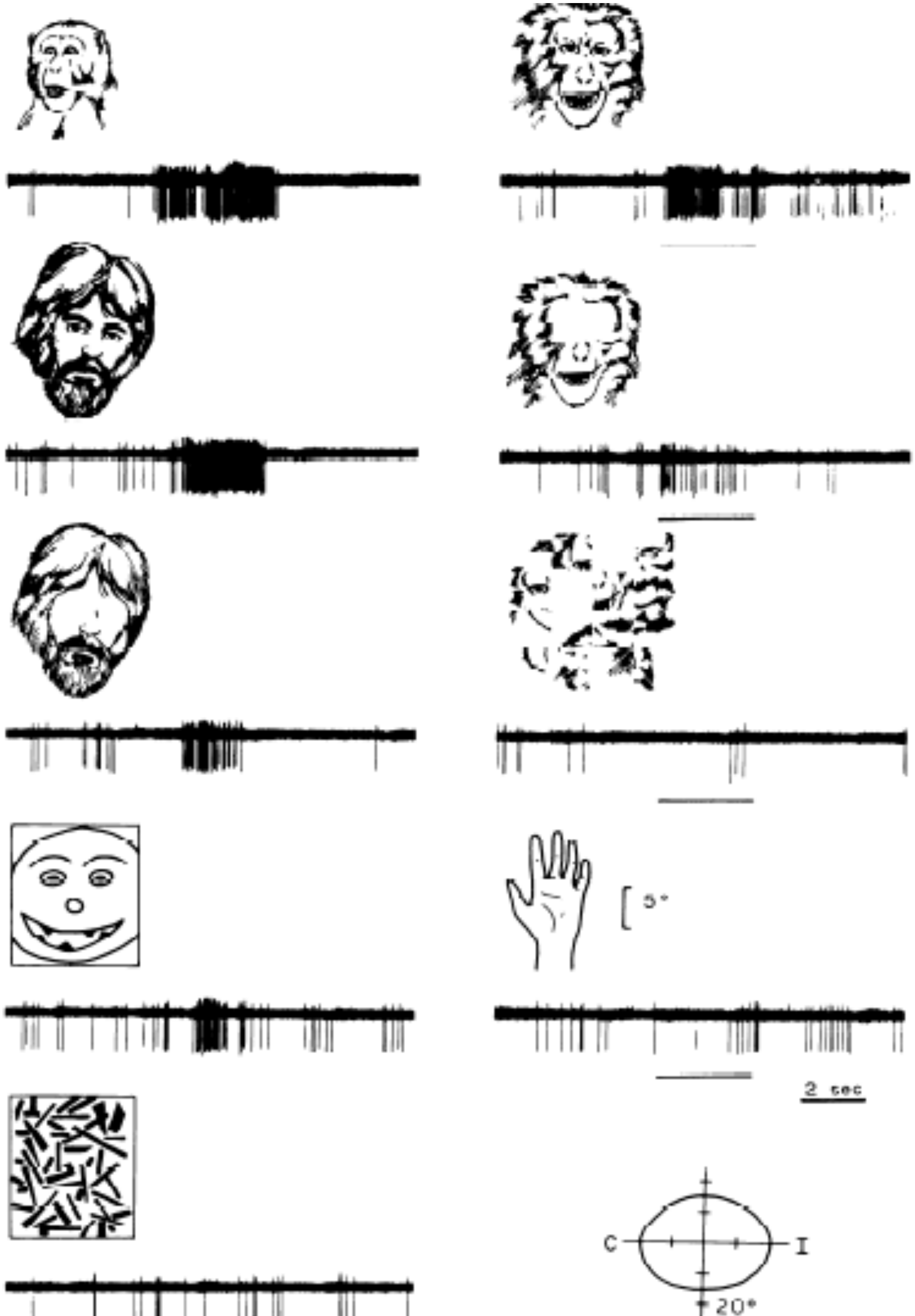
Evidence from single-cell recordings

- Evidence from single-cell recording was critical to understand organization of lower-level visual areas.
- Researchers have been exploring higher visual areas for the last 30 years in search of the neurons involved with object recognition.



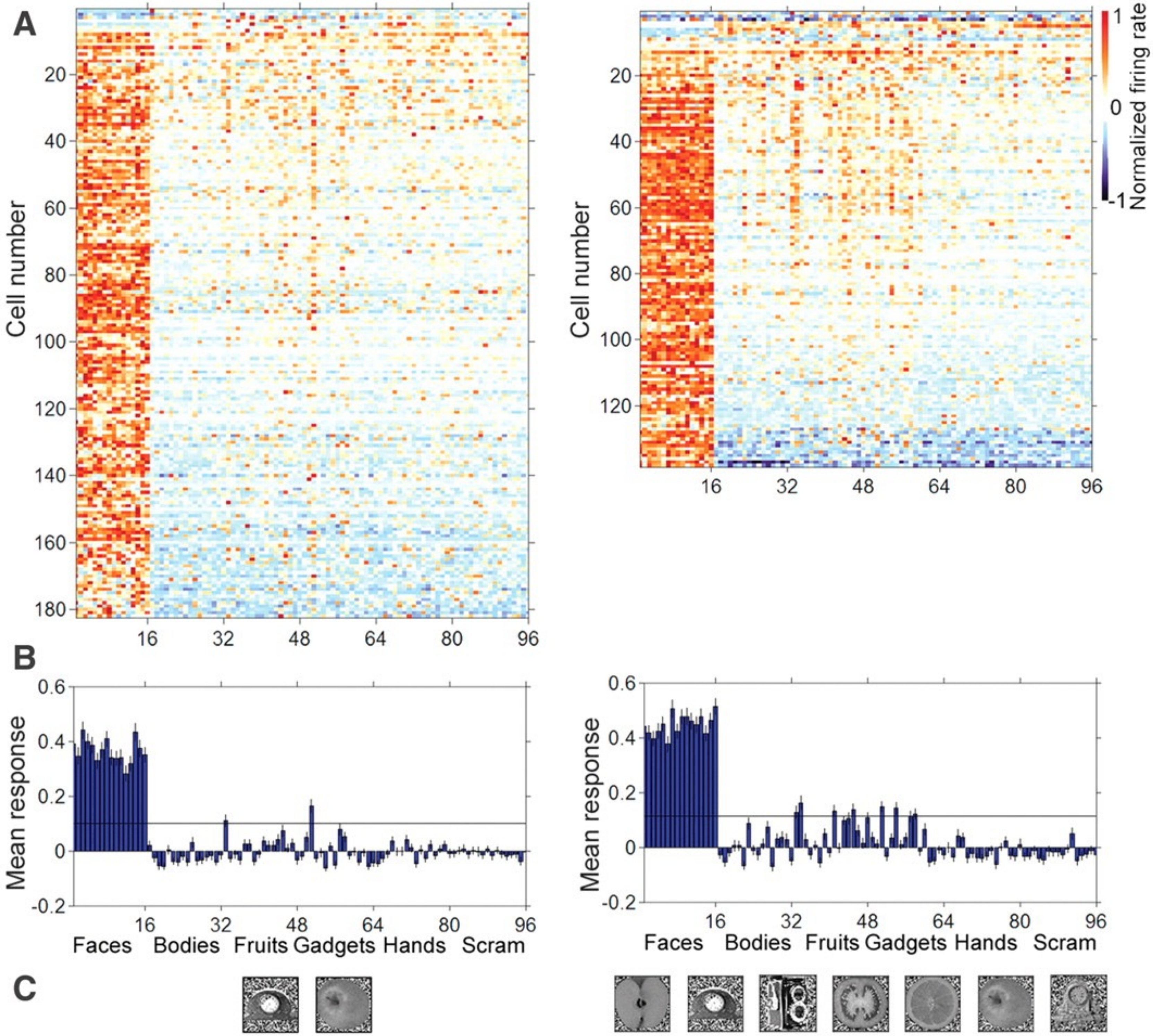
One day…having failed to drive a unit with any light stimulus, we waved a hand at the stimulus screen and elicited a very vigorous response from the previously unresponsive neuron. We then spent the next 12 hr testing various paper cutouts in an attempt to find the trigger feature for this unit. When the entire set of stimuli used were ranked according to the strength of the response that they produced, we could not find a simple physical dimension that correlated with this rank order. However, the rank order did correlate with similarity (for us) to the shadow of a monkey hand.

– Gross et al (1972)

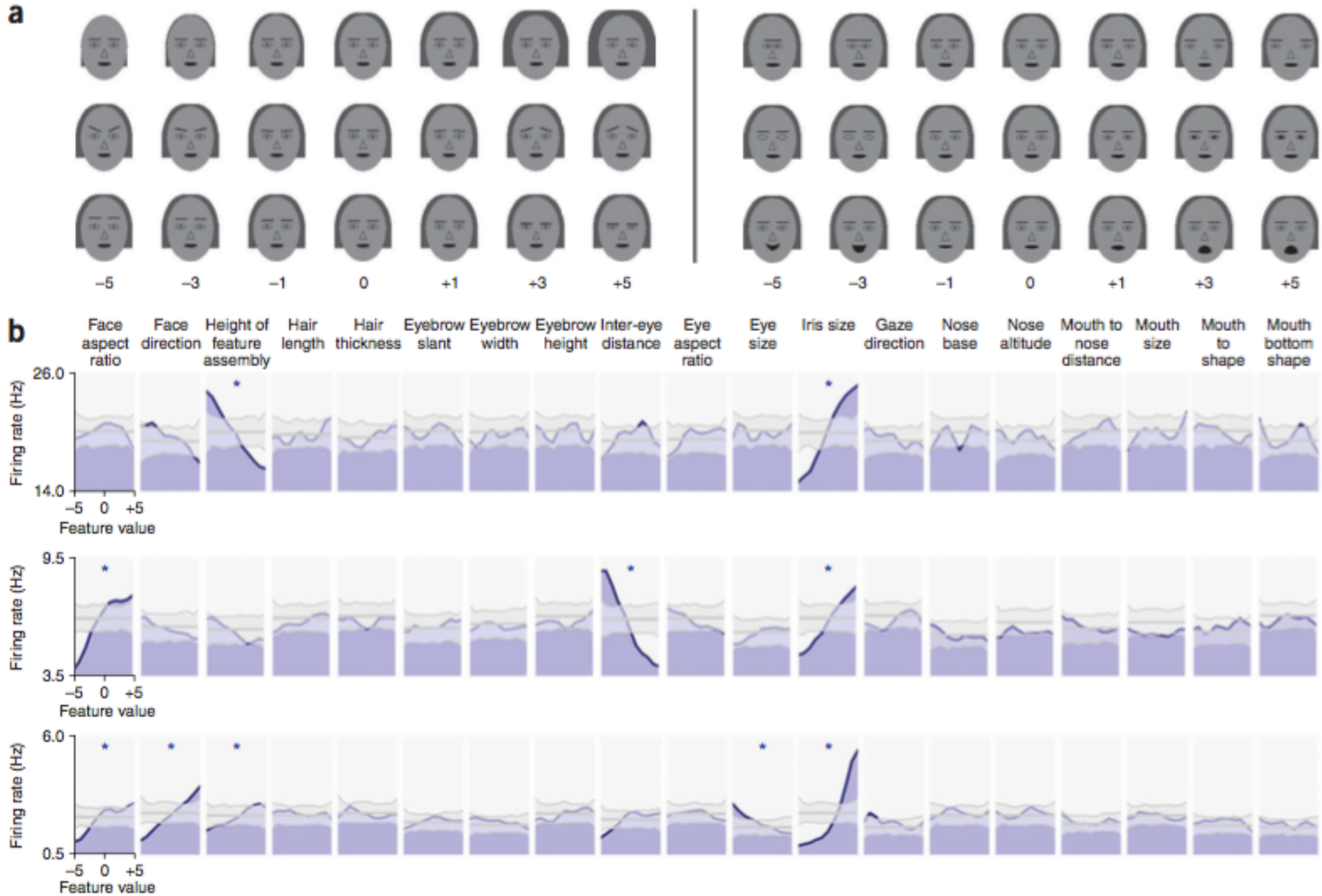


Gross et al (1972)

Monkey
Human
A
M1
1 cm
MF
PL
ML
AF
AL
AM
STS-FA
OFA
FFA



A
B
C
Cell number
Normalized firing rate
1
0
-1
Mean response
Faces
Bodies
Fruits
Gadgets
Hands
Scram



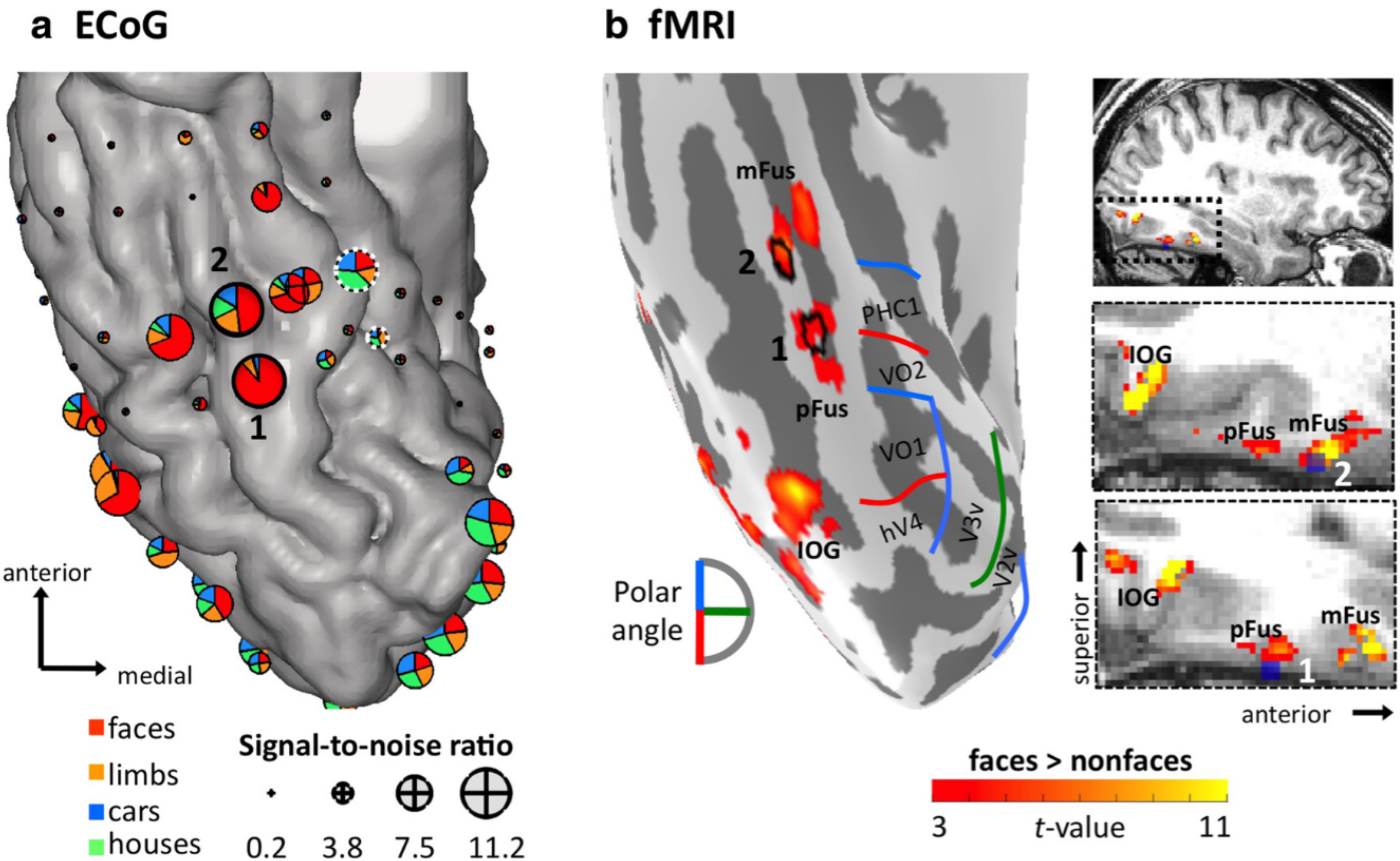
<u>Face space in middle face patch</u>

Most neurons code between 3-4 face features and they respond monotonically as feature values get larger/smaller

Deep brain stimulation

SHICEP

Stanford Human Intracranial
Cognitive Electrophysiology
Program



Parvizi et al, 2012, JoN

Neuropsychological evidence

Face-blindness

Developmental prosopagnosia

- Lifelong face-blindness without brain injury or disease
- Affects up to 1 in 50 people!
- Autism: between 0.5-1%; Dyslexia: between 5-10%

Acquired prosopagnosia

- Face recognition problems following brain damage (resection, accident, stroke, disease)

Face-specificity of prosopagnosia

Is prosopagnosia an impairment of perceptual mechanisms that are specialised for face processing?

Alternative hypotheses

Object agnosia hypothesis: Prosopagnosia is the most visible symptom of visual object agnosia

Item level hypothesis: Prosopagnosia impairs recognition of any objects at item level

Visual similarity hypothesis: Prosopagnosia impairs recognition of visually similar forms

Expertise hypothesis: Prosopagnosia impairs recognition of *objects-of-expertise*

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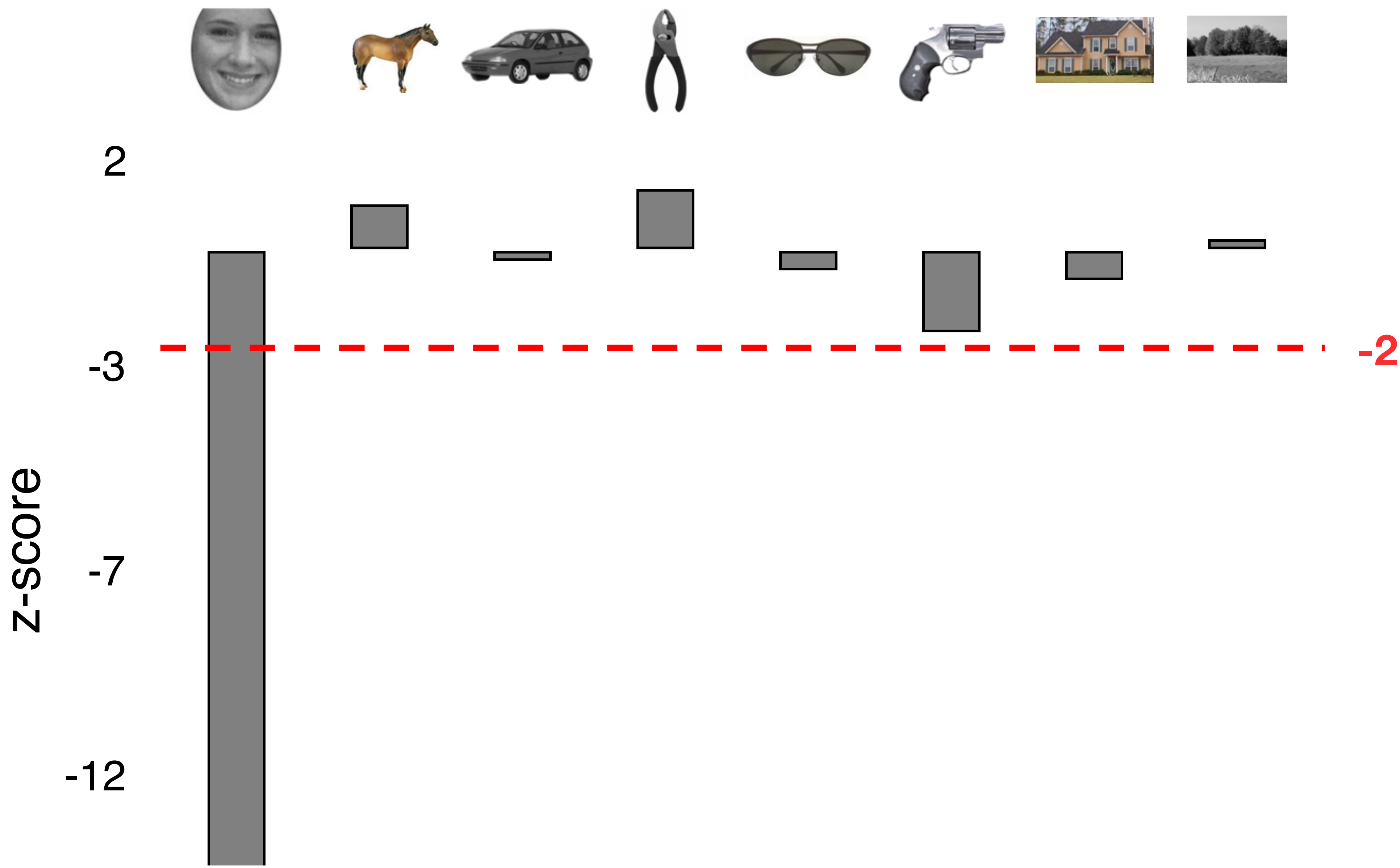
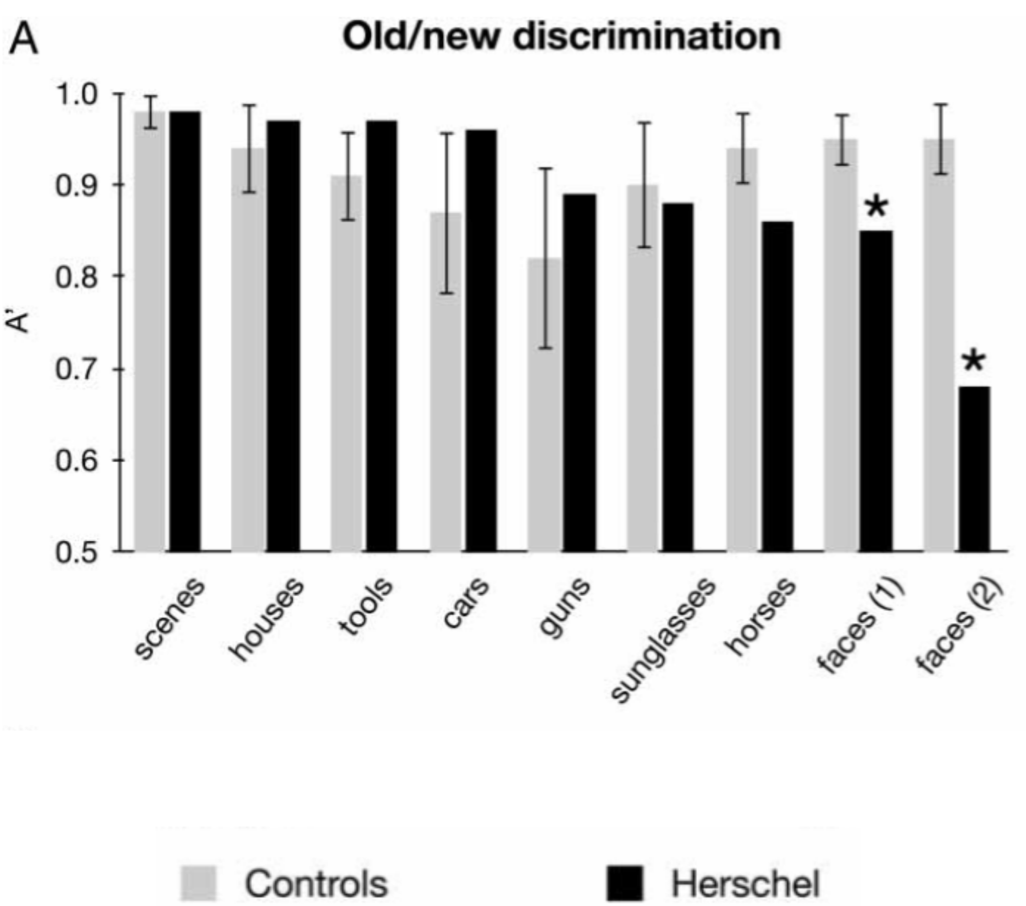
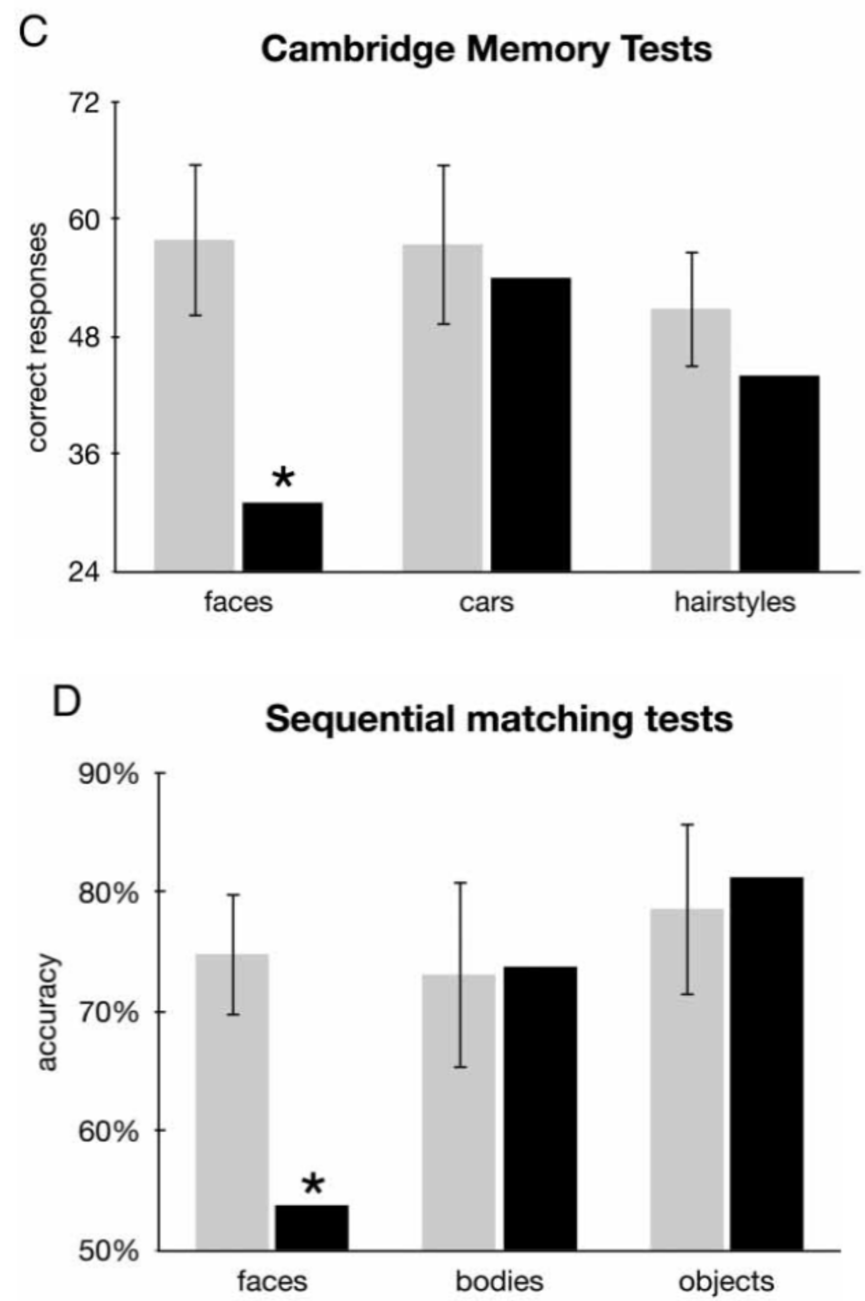


Prosopagnosia without item-level deficits

Some prosopagnosics can recognise many objects at the item level





Herschel

(Rezlescu et al, 2012)

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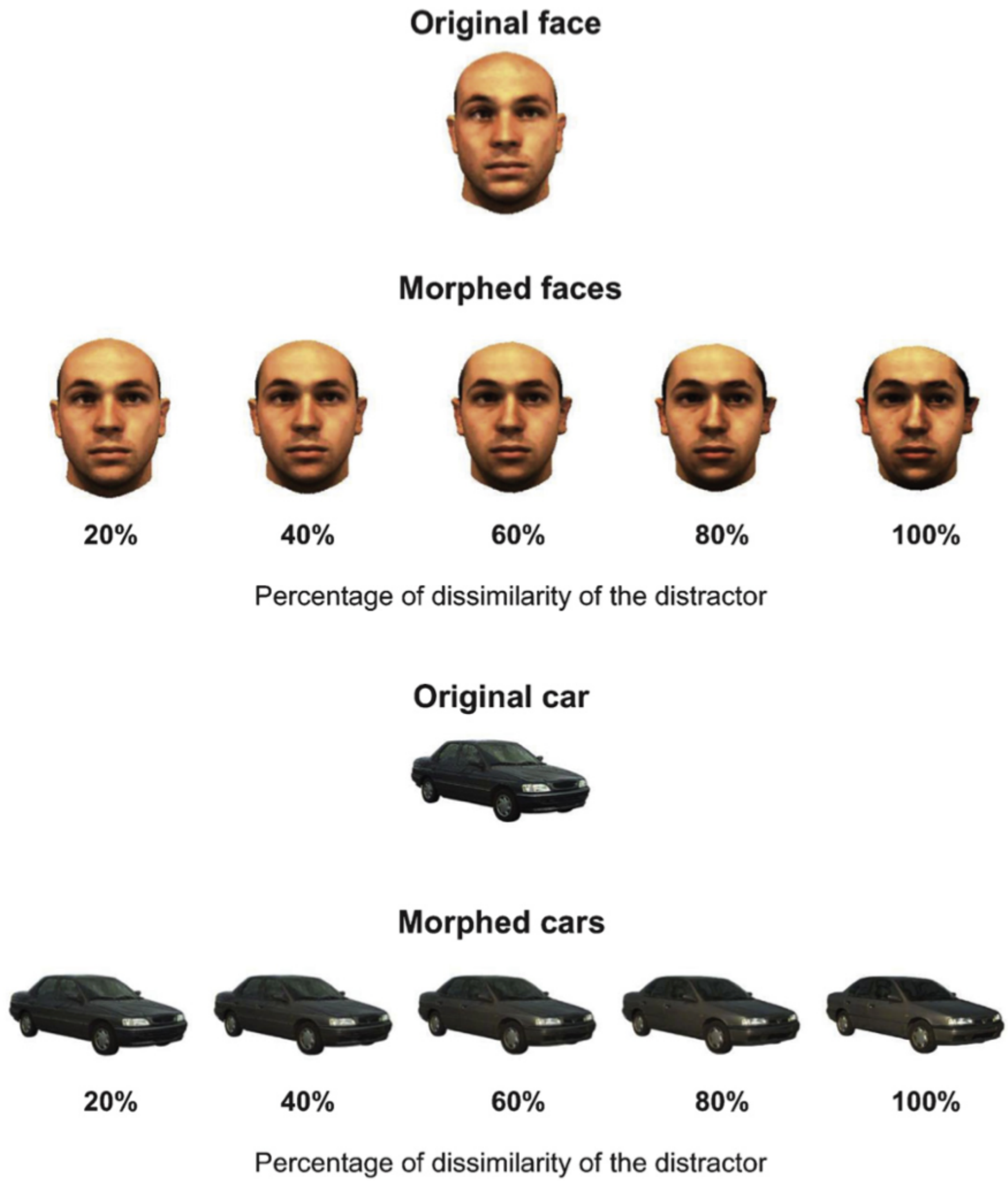
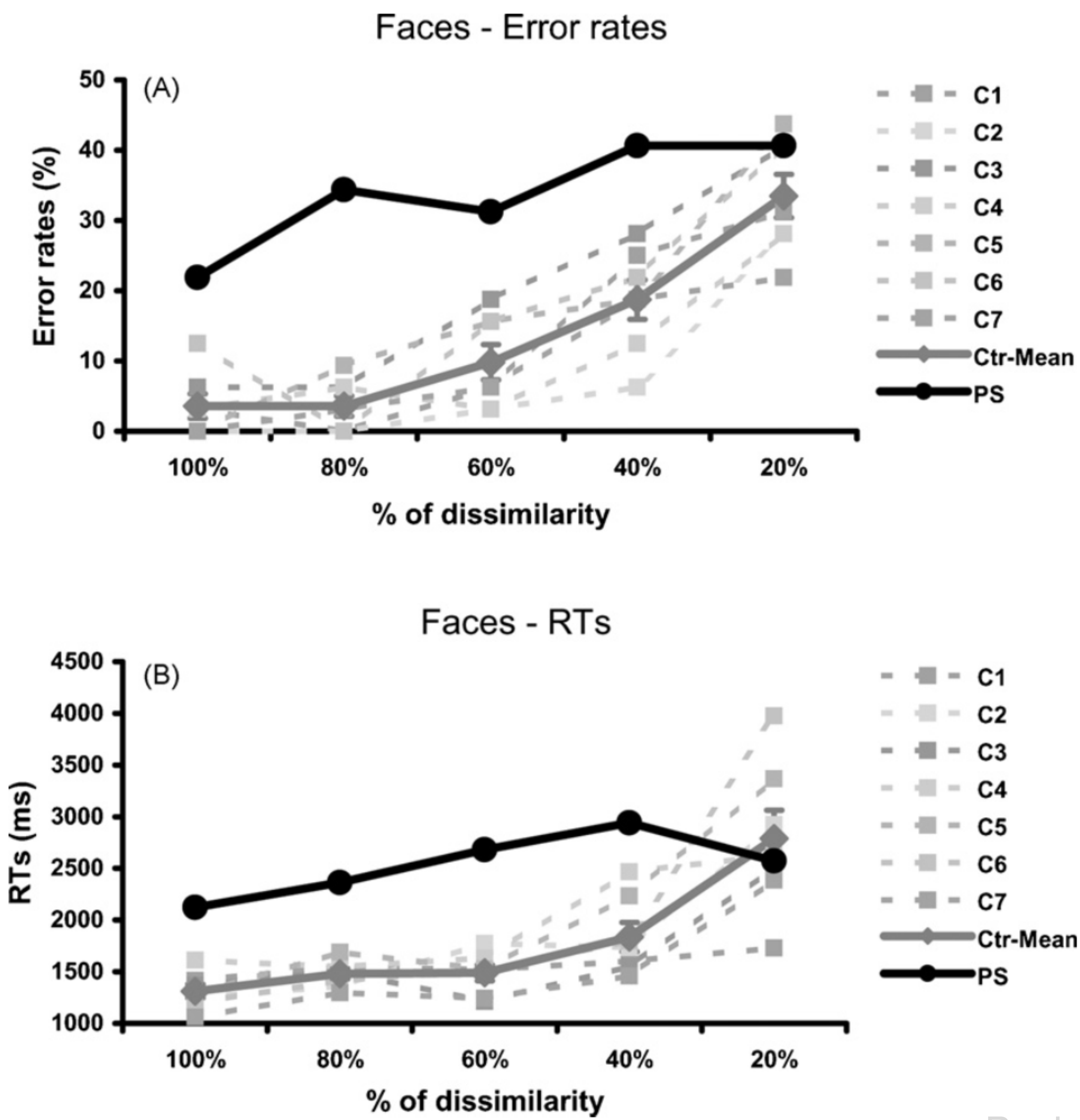
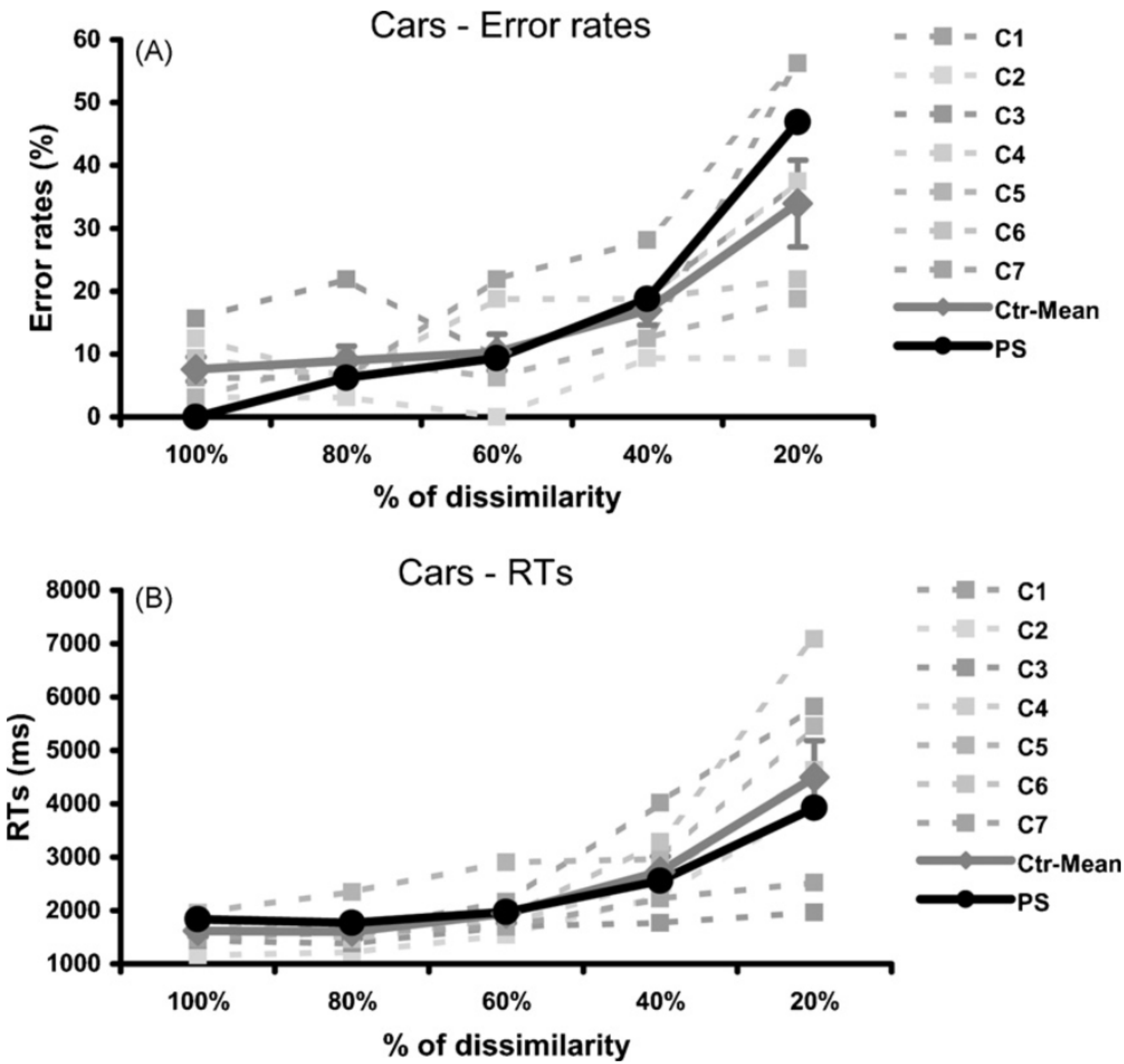


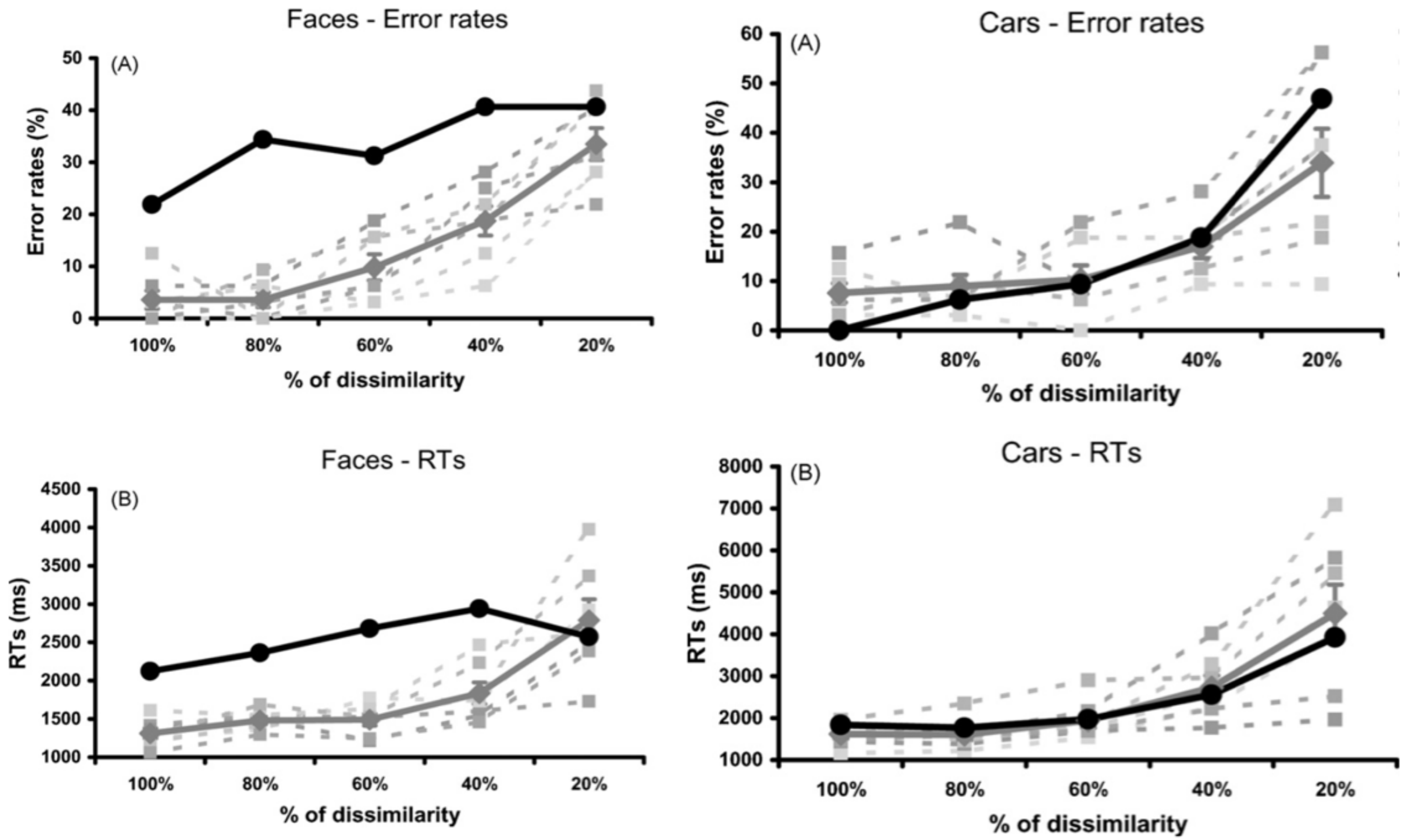
Busigny et al (2010)



Busigny et al (2010)



Busigny et al (2010)



<u>Prosopagnosia without visual similarity deficits</u>

Some prosopagnosics can recognise non-face objects that are just as similar to each other as faces are

Alternative hypotheses

Object agnosia hypothesis: Prosopagnosia is the most visible symptom of visual object agnosia

Item level hypothesis: Prosopagnosia impairs recognition of any objects at item level

Visual similarity hypothesis: Prosopagnosia impairs recognition of visually similar forms

Expertise hypothesis: Prosopagnosia impairs recognition of *objects-of-expertise*

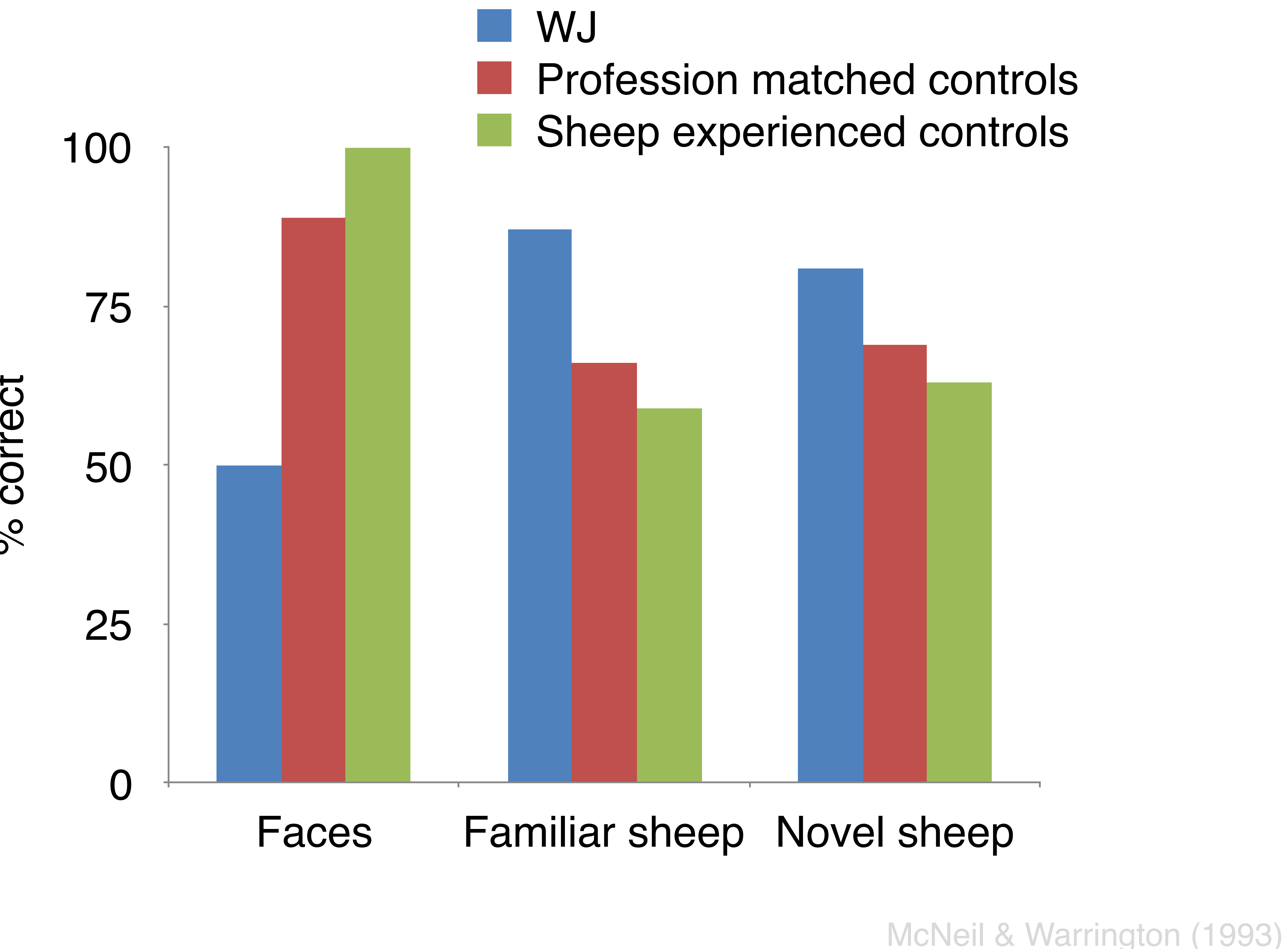






Real-world expertise:

McNeil & Warrington (1993)


WJ
Profession matched controls
Sheep experienced controls
100
75
50
25
0
% correct
Faces
Familiar sheep
Novel sheep
McNeil & Warrington (1993)

Alternative hypotheses

Object agnosia hypothesis: Prosopagnosia is the most visible symptom of visual object agnosia

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Face-specificity implies that face processing is separate from object processing, but do they rely on *independent* systems?

Can face processing be normal when object processing is impaired? (i.e. *is there a double dissociation between face and object processing*?)

What Is Special about Face Recognition? Nineteen Experiments on a Person with Visual Object Agnosia and Dyslexia but Normal Face Recognition

Morris Moscovitch and Gordon Winocur
Rotman Research Institute

Marlene Behrmann
Carnegie Mellon University

Abstract

■ In order to study face recognition in relative isolation from visual processes that may also contribute to object recognition and reading, we investigated CK, a man with normal face recognition but with object agnosia and dyslexia caused by a closed-head injury. We administered recognition tests of upright faces, of family resemblance, of age-transformed faces, of caricatures, of cartoons, of inverted faces, and of face features, of disguised faces, of perceptually degraded faces, of fractured faces, of faces parts, and of faces whose parts were made of objects. We compared CK's performance with that of at least 12 control participants. We found that CK performed as well as controls as long as the face was upright and retained the configurational integrity among the internal facial features, the eyes, nose, and mouth. This held regardless of whether the face was disguised or degraded and whether the face was represented as a photo, a caricature, a cartoon, or a face composed of objects. In the last case, CK perceived the face but, unlike controls, was rarely aware that it was composed of objects. When the face, or just the internal features, were inverted or when the configurational gestalt was broken by fracturing the face or misaligning the top and bottom halves, CK's performance suffered far more than that of controls. We conclude that face recognition normally depends on two systems: (1) a holistic, face-specific system that is dependent on orientation-specific coding of second-order relational features (internal), which is intact in CK and (2) a part-based object-recognition system, which is damaged in CK and which contributes to face recognition when the face stimulus does not satisfy the domain-specific conditions needed to activate the face system. ■

Moscovitch et al (1997)

2. Holistic processing

Holistic/configural processing

Faces are special: faces are processed in a *qualitatively* different manner and/or by *specific cognitive and neural mechanisms* than upside-down faces or other objects.

Many have speculated that this special cognitive process is holistic and/or configural.

Holistic

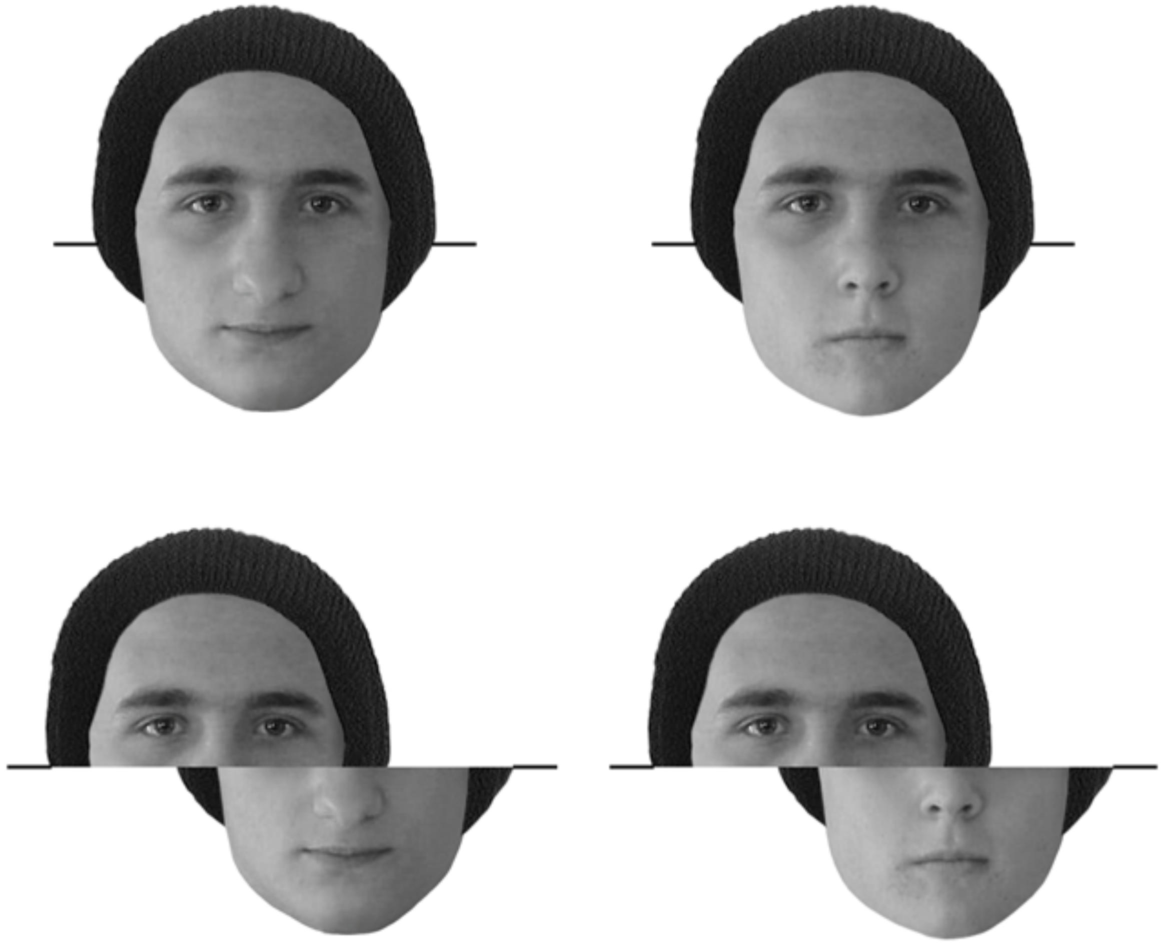
- integration of information from the whole face; faces are represented as one unit in which face parts are processed interactively rather than independently

Configural

- representation and recognition of the spatial configuration of the parts of the face.

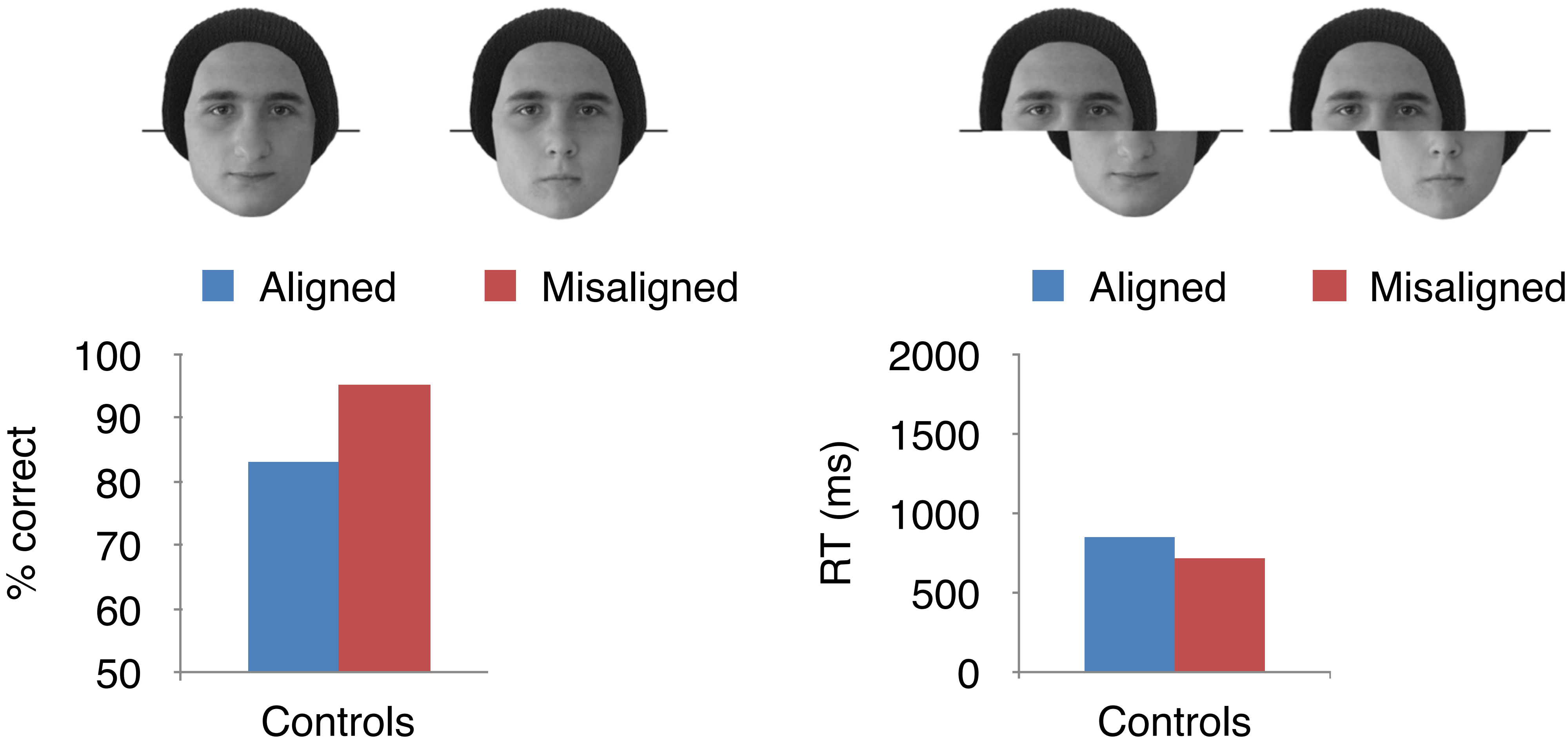
Can holistic face processing be quantified?

Face composite effect



Easier to discriminate top-halves when misaligned with bottom-halves; shows that face-halves are integrated

Face composite effect

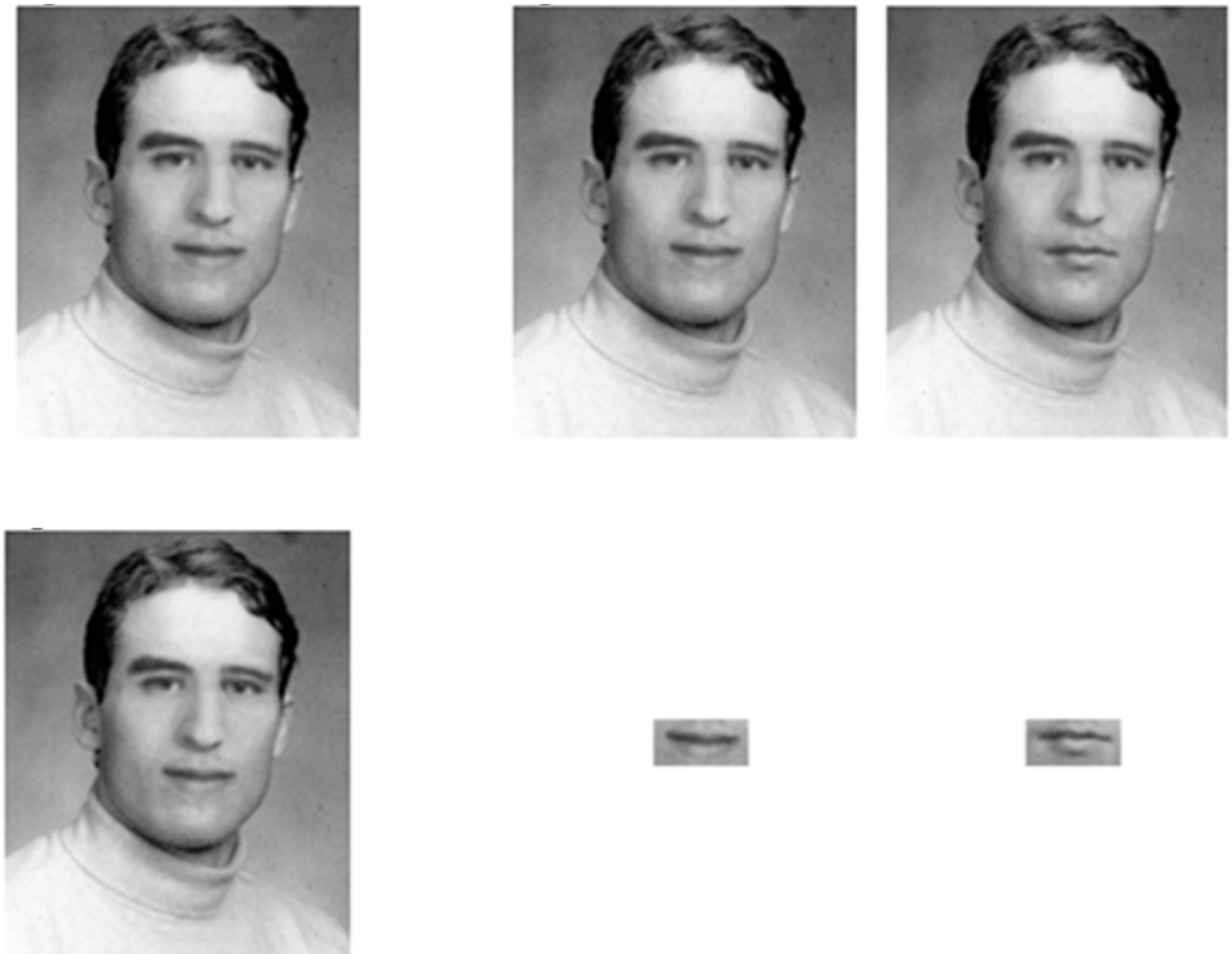


Easier to discriminate top-halves when misaligned with bottom-halves; shows that face-halves are integrated

Specificity of the composite effect

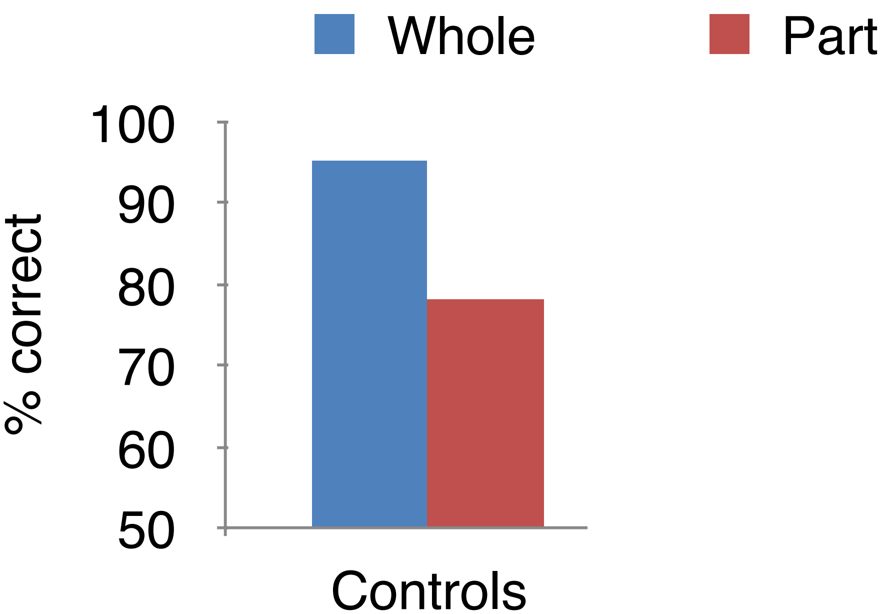
	Task	Faces	Inverted faces	Objects (novices)	Objects (experts)	sig of expertise increase
No objects (Young et al., 1987)	Speeded naming	212 ms*	9 ms[ns]	—	—	—
No objects (McKone, 2008)	Speeded naming	74 ms*	14 ms[ns]	—	—	—
No objects (Robbins and McKone, 2003)	Naming twins	8.8%*	–1.2%[ns]	—	—	—
Cars (Macchi Cassia et al., 2009)	Sequential matching	58 ms	—	0 ms	—	—
Greebles, same-family halves (Gauthier et al., 1998)	Speeded naming	—	—	—	115 ms[ns] 0%	— —
Greebles, different-family halves (Gauthier et al., 1998)	Speeded naming	—	—	—	–37 ms[reverse] –3%[reverse]	— —
Greebles, same-family halves (Gauthier and Tarr, 2002)	Speeded naming	—	—	–42 ms[–]	12 ms[–]	– [a]
Dogs (Robbins and McKone, 2007)	Simultaneous matching	6.1% *	–3.5%[ns]	–0.8%[ns] 0.8%[ns b]	0.7%[ns]	ns Reverse

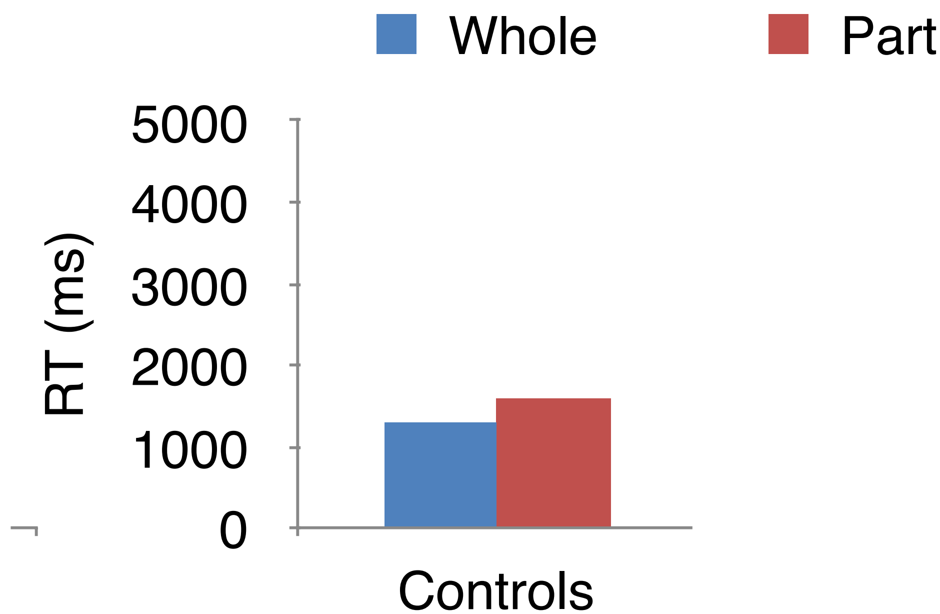
Part-whole effect



Easier to discriminate face features (e.g. eyes) in context of a whole face; shows that faces are not decomposed into parts

Part-whole effect



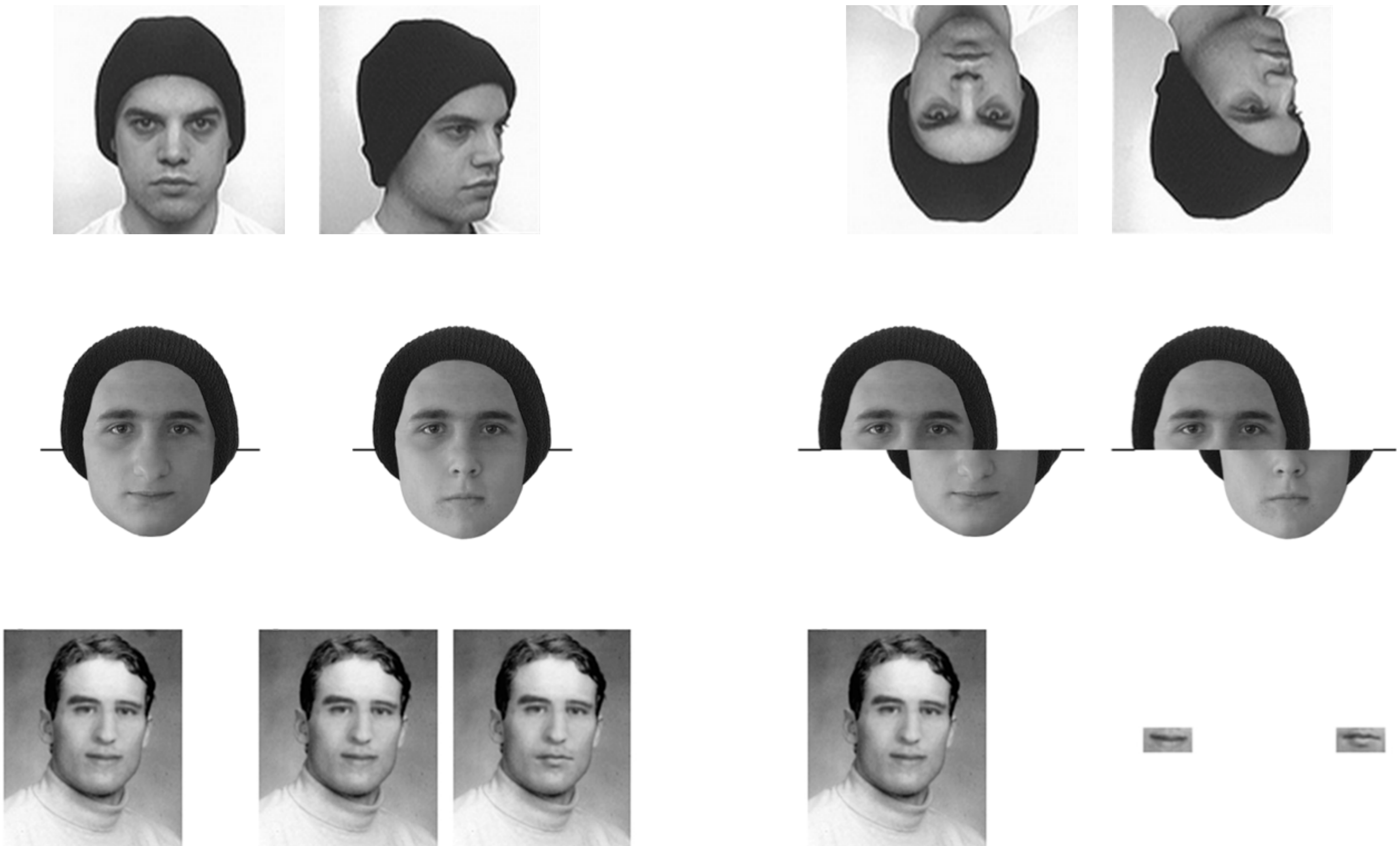


Easier to discriminate face features (e.g. eyes) in context of a whole face; shows that faces are not decomposed into parts

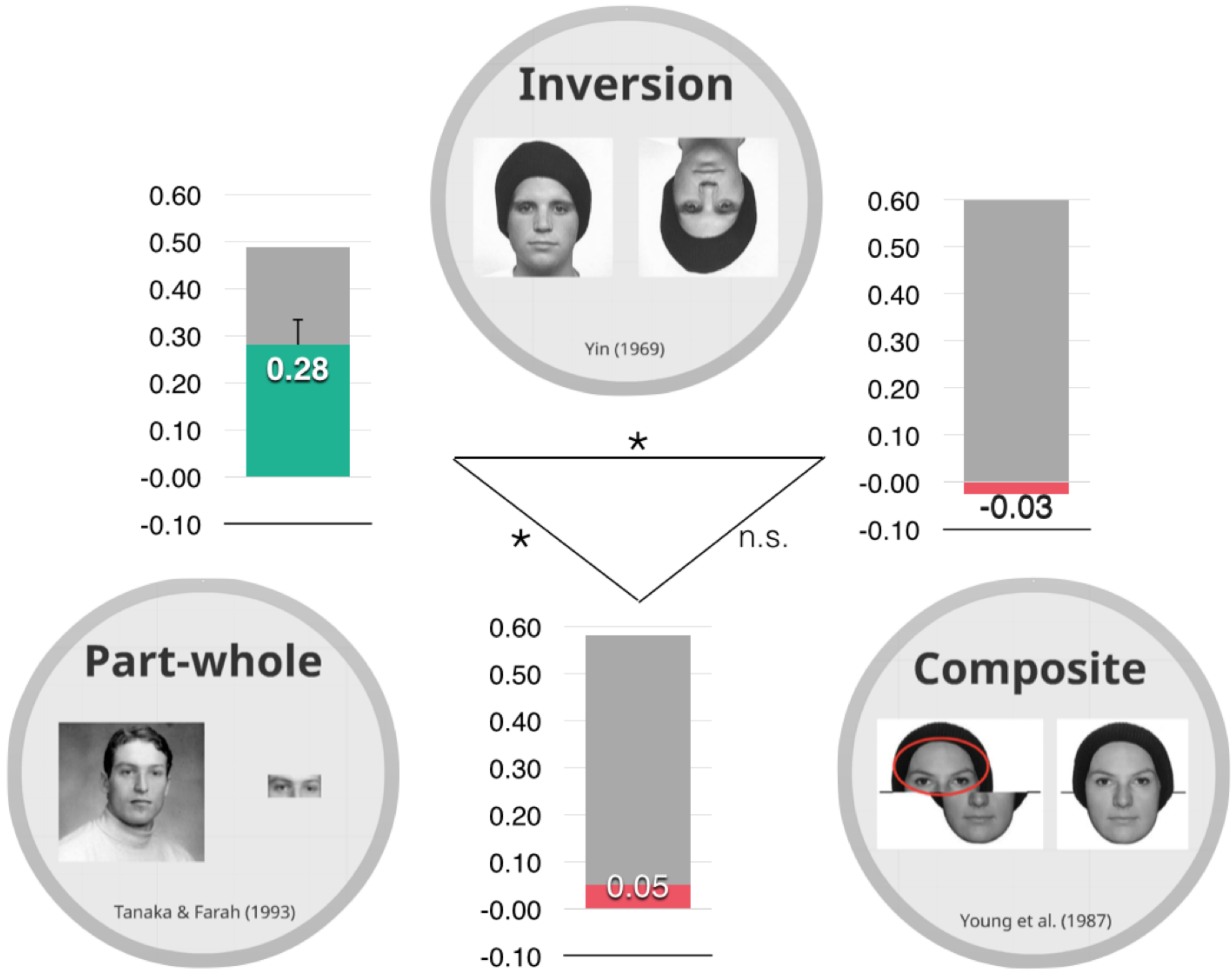
Specificity of the part-whole effect

	Faces	Inverted faces	Objects (novices)	Objects (experts)	sig of expertise increase
No objects (Pellicano et al., 2006)	13%*	−2%^{ns}	—	—	—
Houses (Tanaka and Farah, 1993)	11%*	−1%^{ns}	−2%^{ns}	—	—
Houses (Tanaka and Sengco, 1997)	15%*	0%^{ns}	1%^{ns}	—	—
Chairs (Davidoff and Donnelly, 1990)	11%*	—	4%^{ns}	—	—
Dog faces (Tanaka et al., 1996)	20%*	—	2%^{ns}	8%^{ns}	ns
Cars (Tanaka et al., 1996)	18%*	—	8%$^{-}$	6%$^{-}$	Reverse
Biological cells (Tanaka et al., 1996)	26%*	—	16%*	10%*	Reverse
Greebles (Gauthier and Tarr, 1997)	—	—	5%^{ns}	11%*	ns
Greebles (Gauthier et al., 1998)	—	—	7%$^{-}$	0%$^{-}$	Reverse
Greebles (Gauthier and Tarr, 2002)	—	—	d' = 0.75^{-}	d' = 0 .68^{-}	Reverse

Measures of holistic processing



Correlations between holistic measures



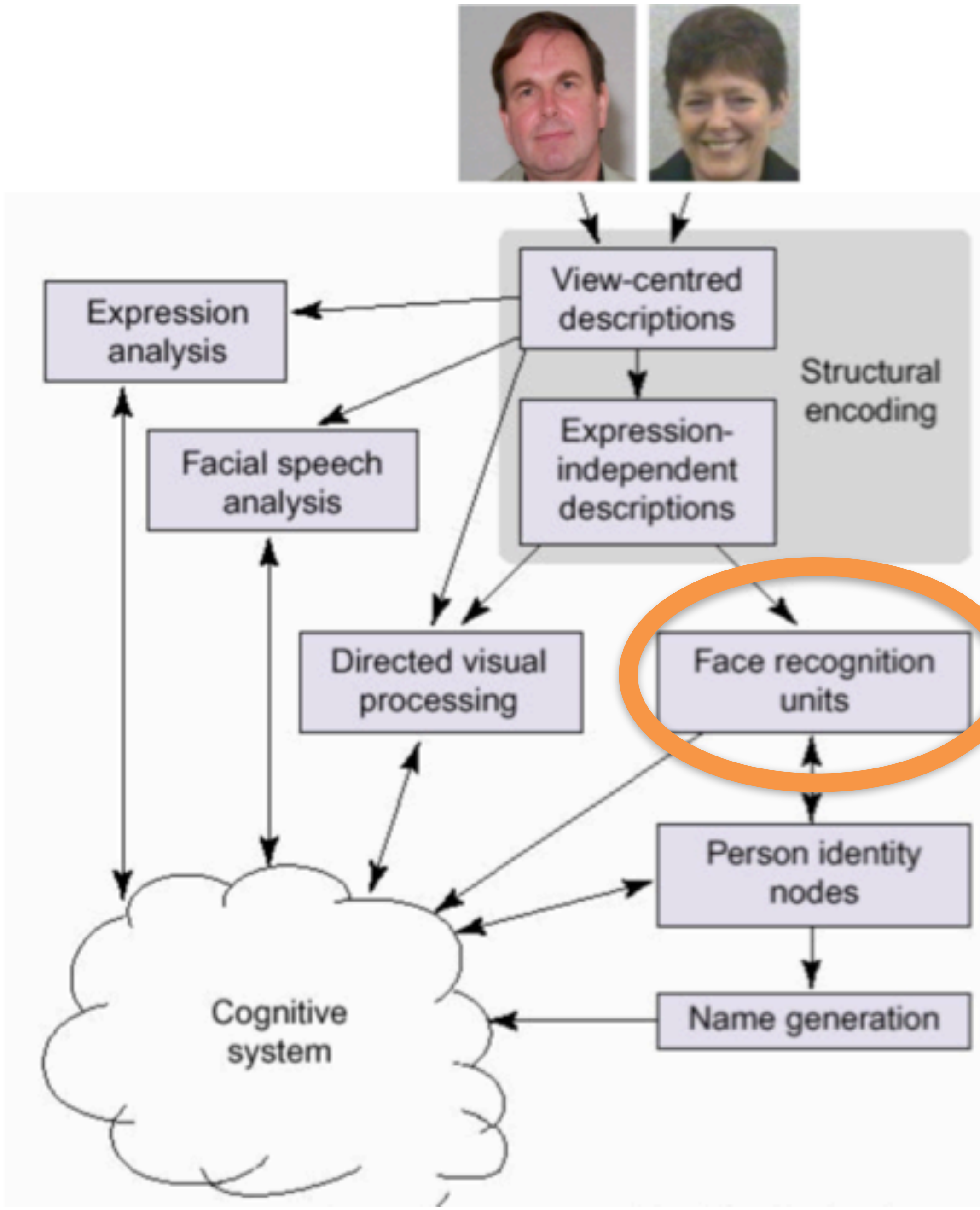
Rezlescu et al, 2016

Can holistic measures predict face recognition abilities?

Rezlescu et al, 2016

3. Models of face perception

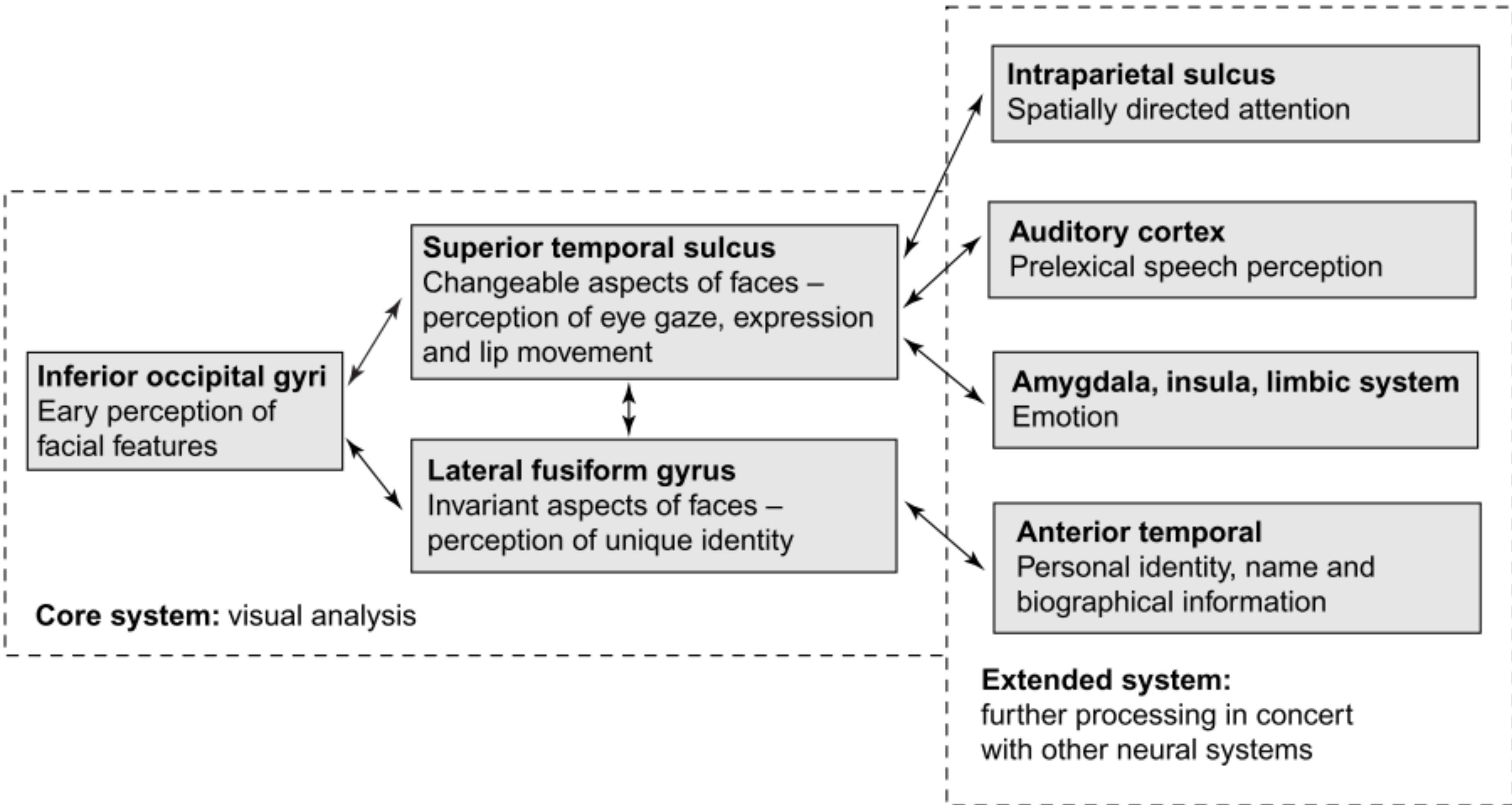
Functional model



stores structural codes describing known faces

Bruce & Young, 1986

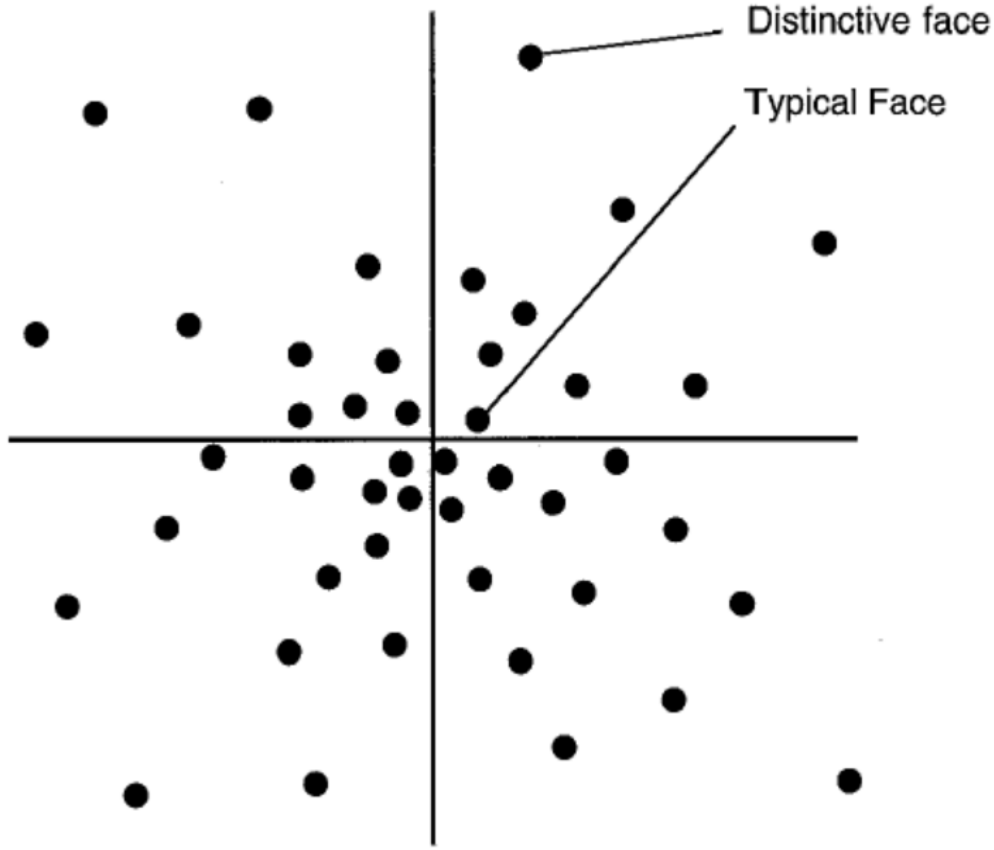
Neural model of face processing



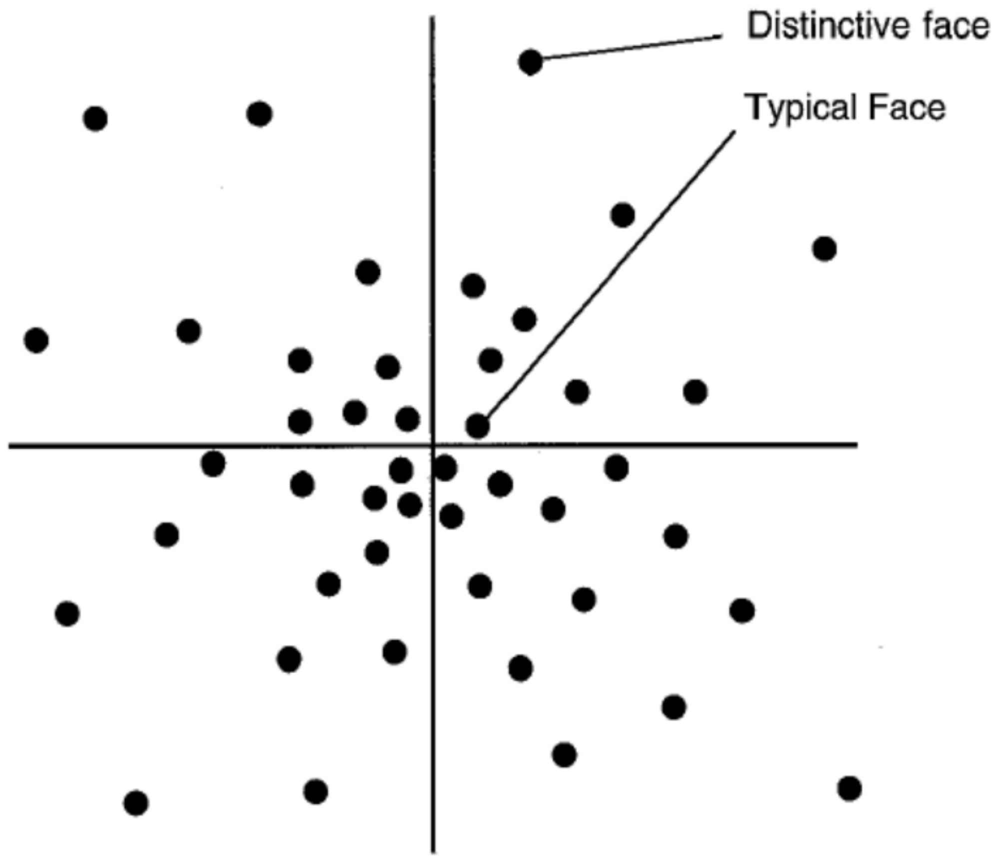
Haxby et al., 2000, TiCS

4. Face space

Face space

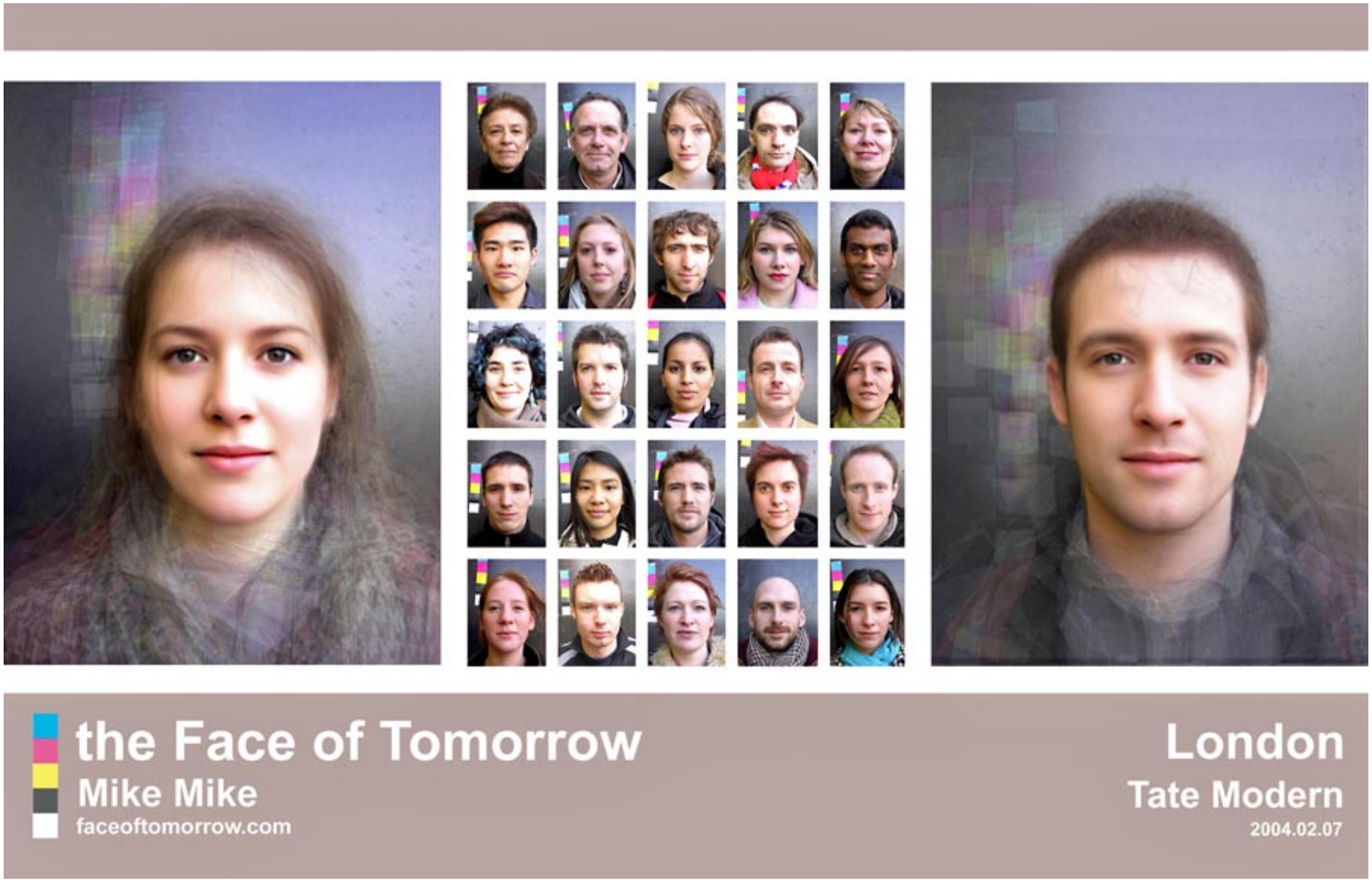


A multidimensional perceptual space in which the dimensions are features we use to discriminate faces (eye height, nose size, etc.); individual faces are mapped according to their values on the dimensions



Norm or prototype face

A face that sits at the center of face space because it has the average value on all dimensions. Norm face doesn’t exist in real world so it’s a statistical average of all faces one has ever seen.



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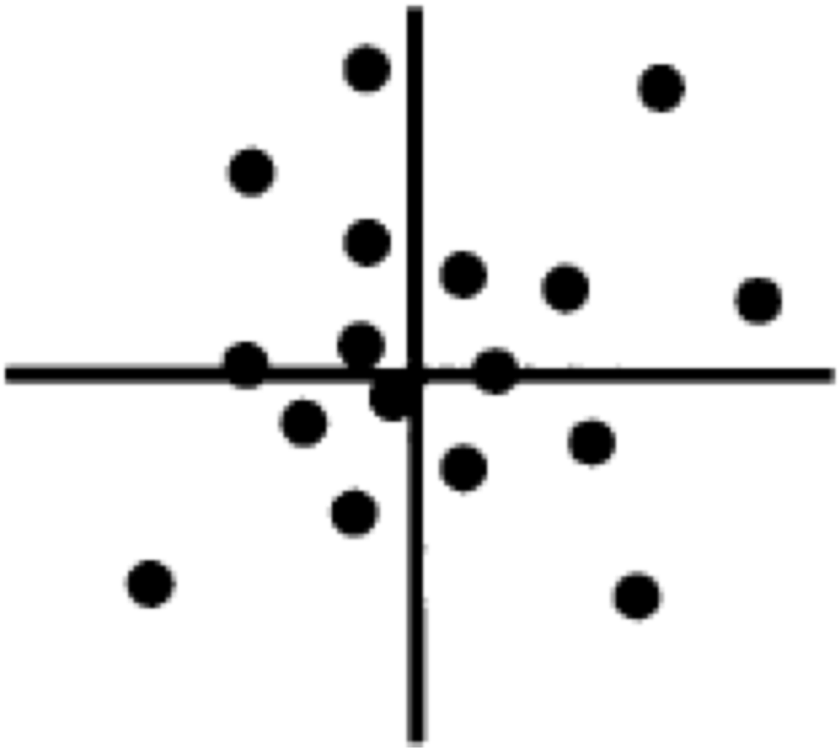
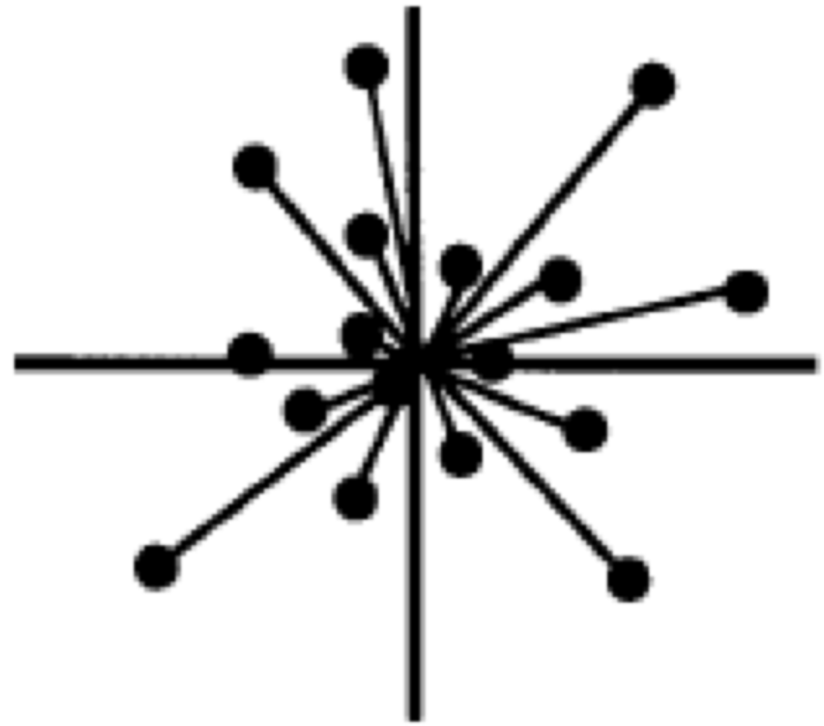




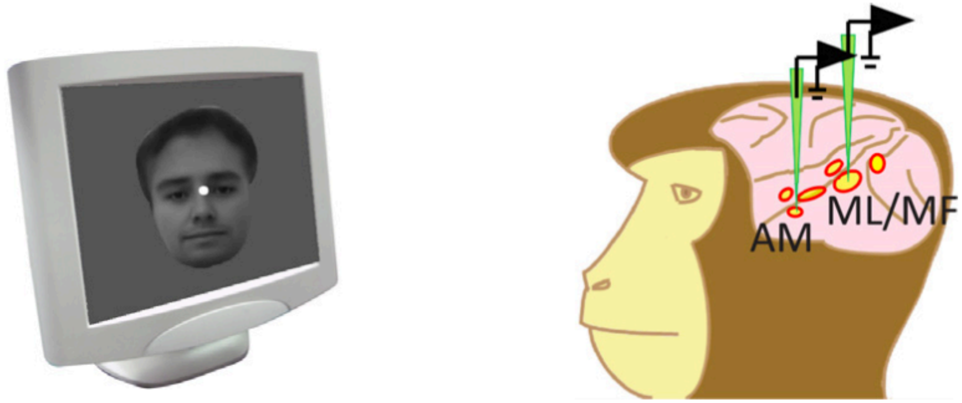
<u>Exemplar-based vs norm-based coding</u>

In *exemplar-based coding* faces are mapped solely by their coordinates in face space; in *norm-based coding* faces are mapped relative to the “norm face” – each individual face has a trajectory arising from the centre of face space

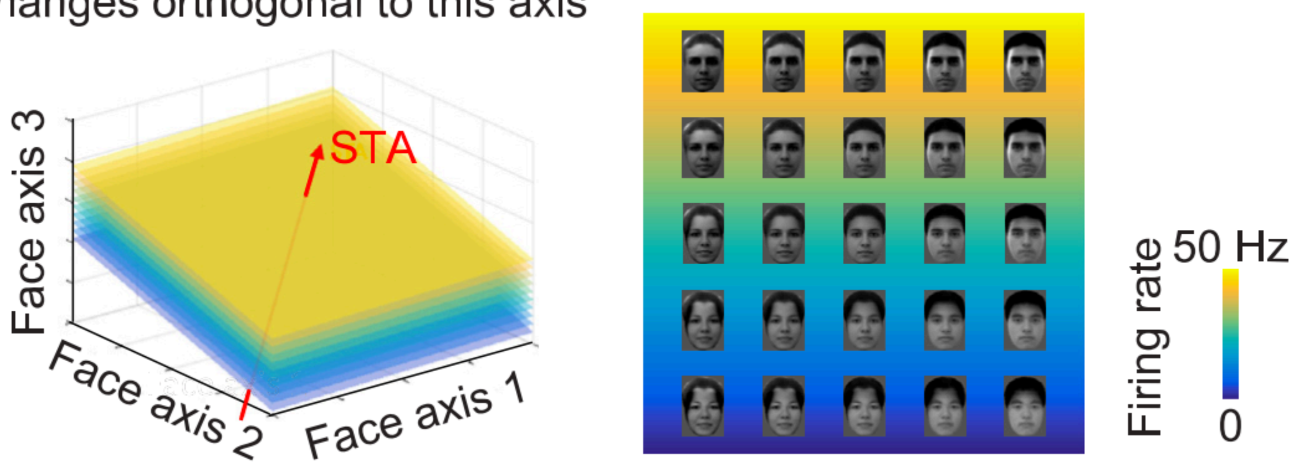
The Code for Facial Identity in the Primate Brain

(Chang & Tsao, 2017)

1. We recorded responses to parameterized faces from macaque face patches



2. We found that single cells are tuned to single face axes, and are blind to changes orthogonal to this axis



Facial images can be linearly reconstructed using responses of ~200 face cells

5. Development

Innate mechanisms: orienting

- Innate mechanisms cause preferential orienting to faces
- Newborns have a preference to look at face-like patterns over non-face-like patterns

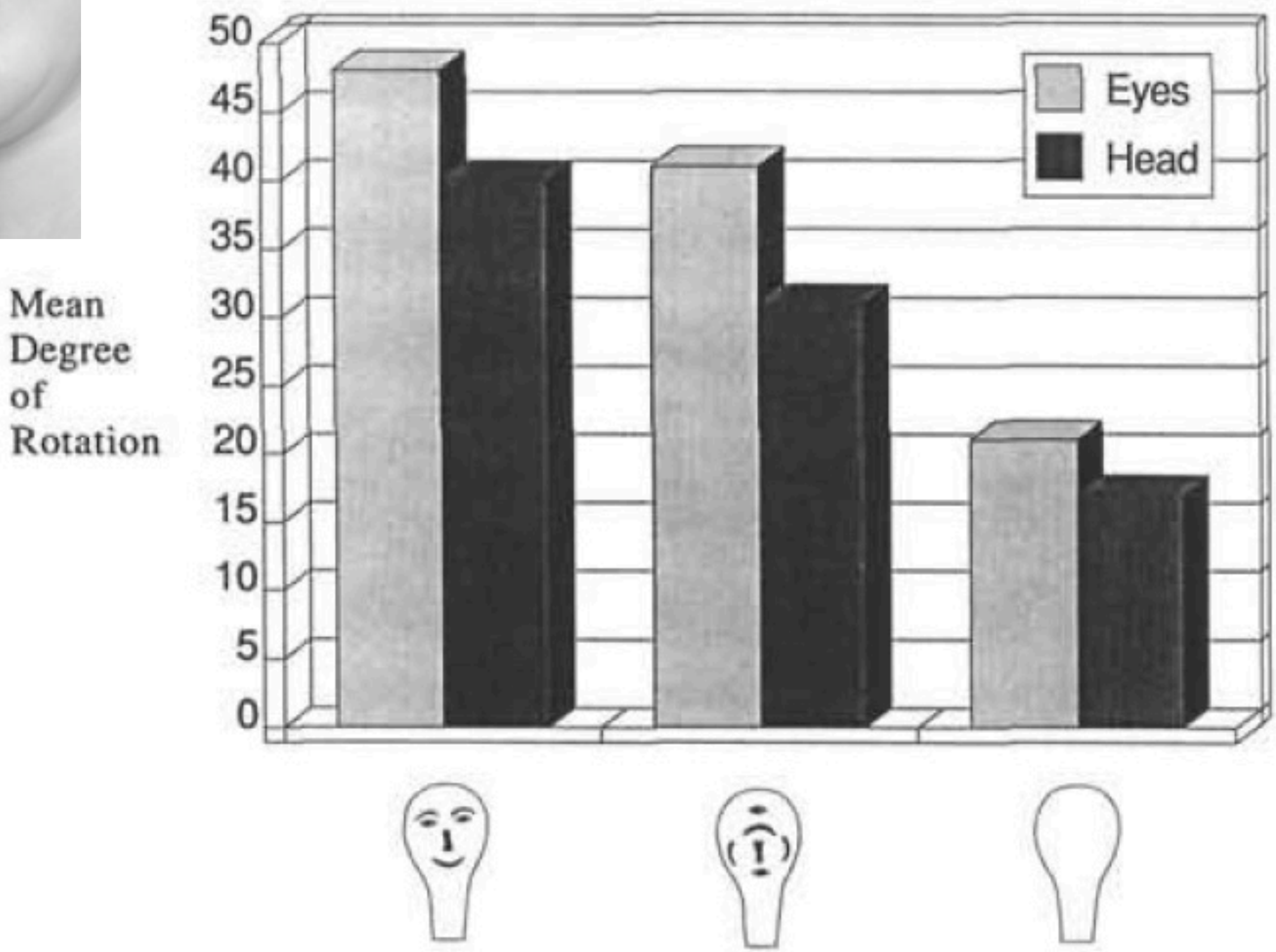
- They orient both head and eyes towards faces to a greater degree than to non-face stimuli of equal complexity (Johnson & Morton, 1991)
- Once oriented, they fixate faces longer than non-face stimuli

Innate mechanisms: orienting

The arrangement of experimenter, baby, stimulus, protractor and camera (drawing by Mani).

(Johnson & Morton, 1991)

Innate mechanisms: orienting



(Johnson & Morton, 1991)

Development: Nature vs. experience