The recognition of objects and faces

John Greenwood
Department of Experimental Psychology

NEUR3001

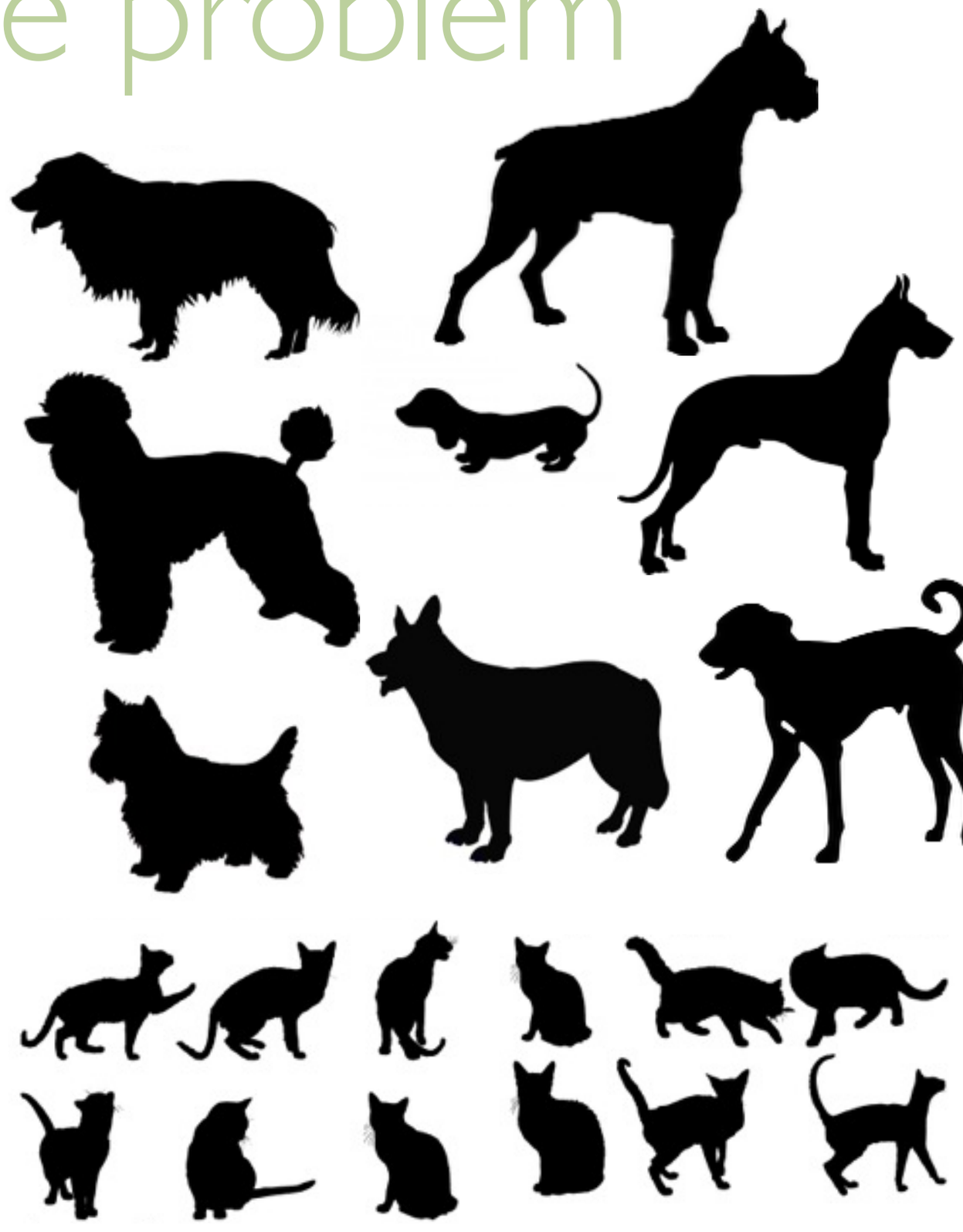
Contact: john.greenwood@ucl.ac.uk

Today

- The problem of object recognition: many-to-one mapping
- Available machinery/physiology
  - Objects and faces in inferotemporal cortex
- Focus on face recognition:
  - Are faces 'special'? Domain specificity vs. expertise
    - Development
    - Prosopagnosia
    - Configural processing (inversion effects, part-whole effect, composite and Thatcher illusions, and the other-race effect)

Objects: the problem

- Human object recognition is highly sophisticated and computationally difficult
- 'Many-to-one mapping'
- Need to disregard great variance to get to the 'essence' or 'category' of an object
- This is true not only for structural differences, but also differences in distance, pose, position, lighting, viewpoint, etc.



Faces

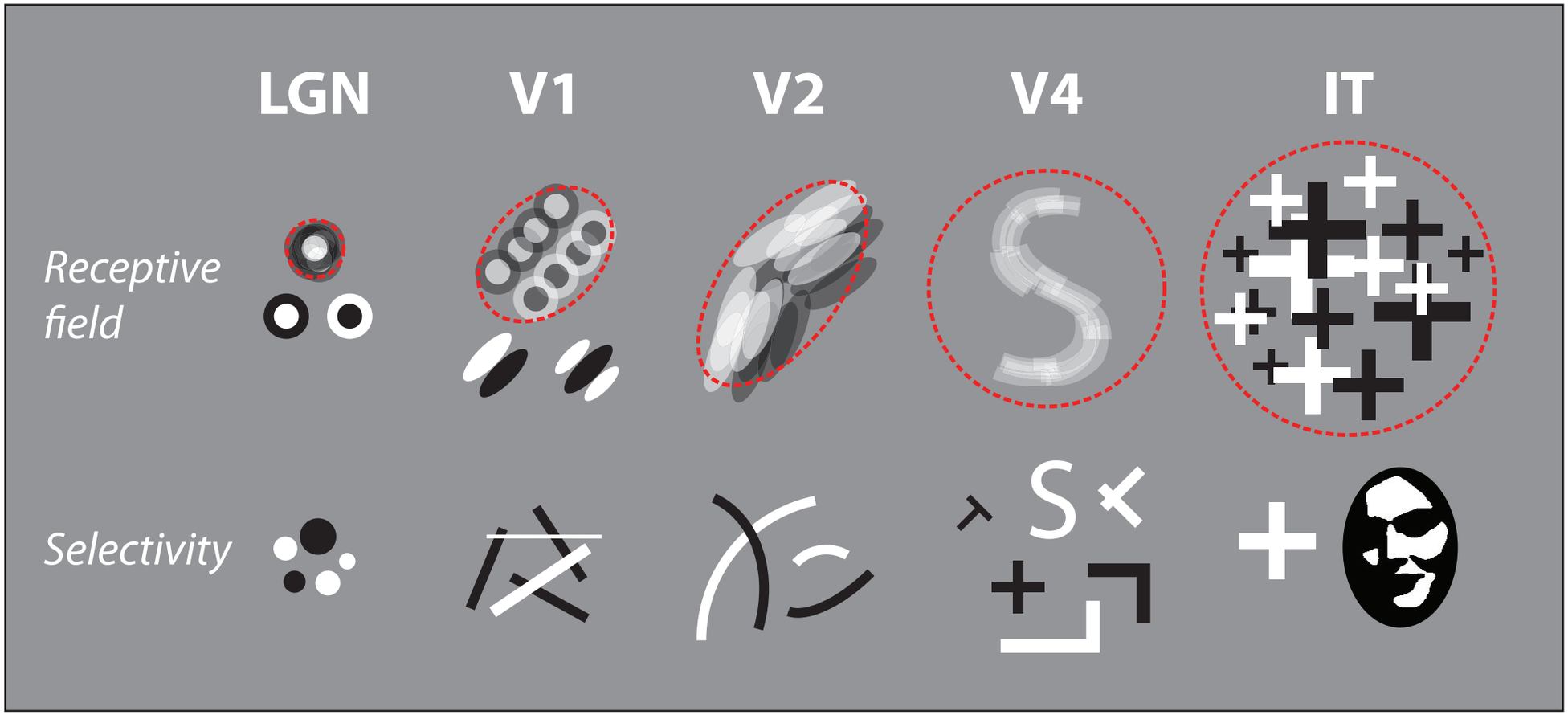
- Faces are a rich source of critical information about identity, age, gender, mood, ethnicity, attractiveness, gaze direction, etc.
- Humans are sensitive to common ("face-ness") and unique (identity) qualities of faces

We are face 'experts'

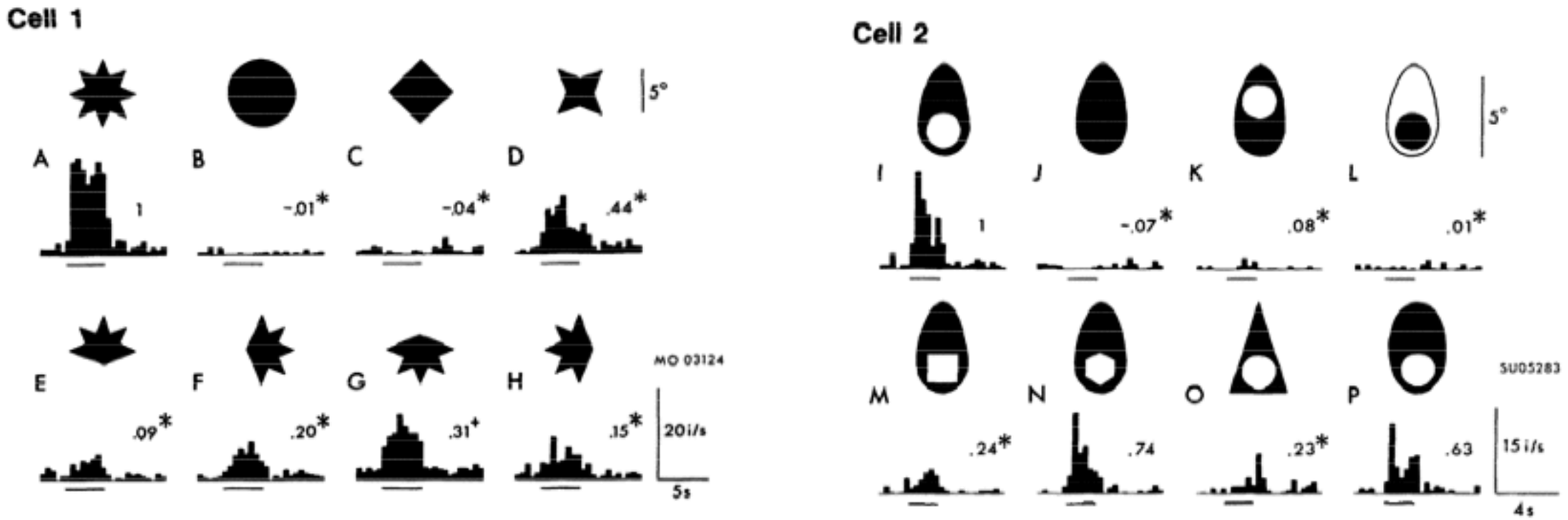
- Compared to other visually homogeneous categories, humans process faces at (sub)-individual level with high efficiency
- But is this ability related to object expertise, or is it subserved by special mechanisms?

The ventral stream

- Selectivity of cells to stimulus properties grows increasingly complex as we move along the ventral stream



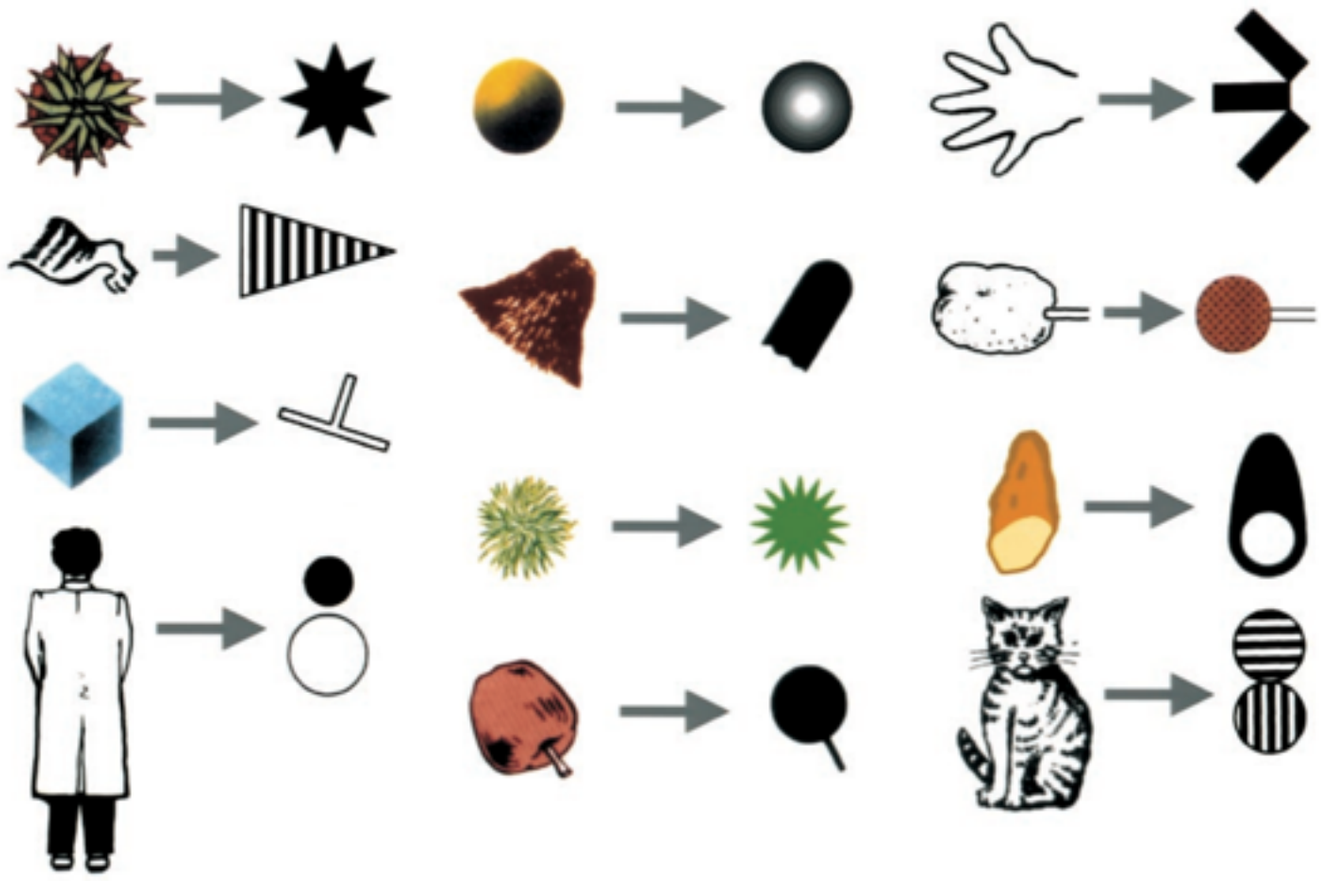
Inferotemporal cortex



- Cells in inferotemporal cortex show complex preferences for particular objects (Tanaka et al., 1991)
  - e.g. preferences for a star shape or a circle within an ellipse
  - Complex forms and conjunctions of elements

The selectivity of IT cells

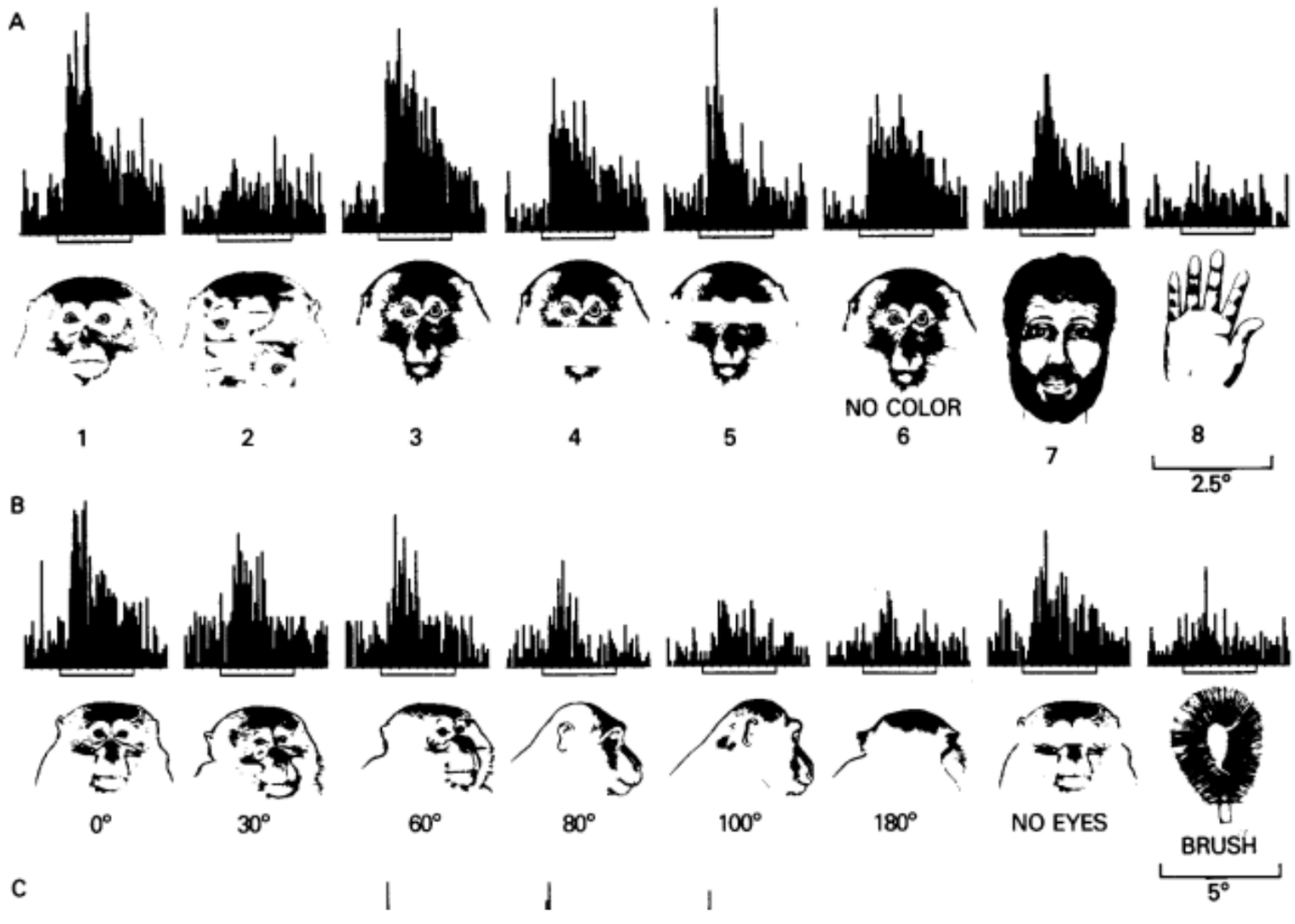
- How can we determine the complex selectivity of these cells?
- The 'reductive determination of optimal features' method
  - Display a range of complex objects and find one that the IT neuron responds to
  - Then subtract features one-by-one until the cell stops responding



Tanaka (2003)

Faces in IT

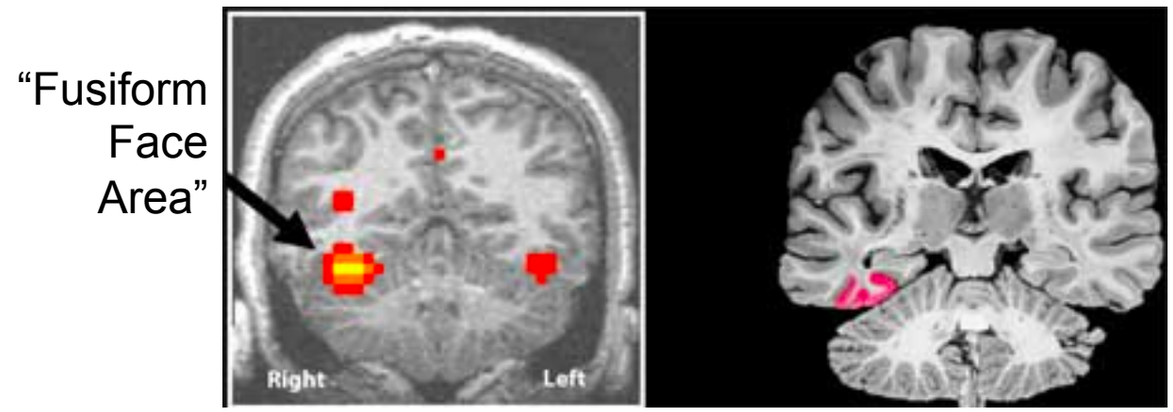
- Also cells in macaque IT that respond to faces
- Attenuated response with jumbled features, occlusion or changes in viewpoint

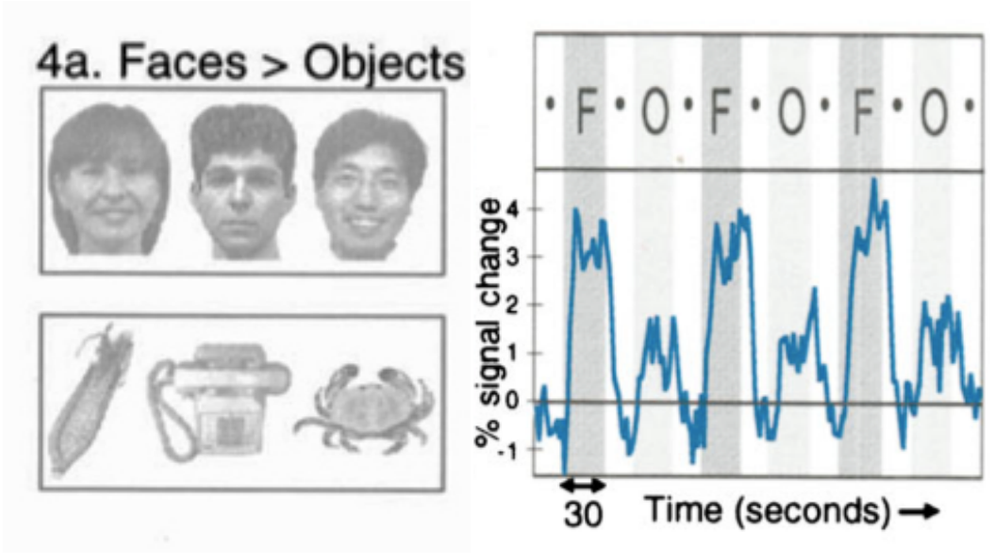


Desimone *et al.* (1984)

The Fusiform Face Area

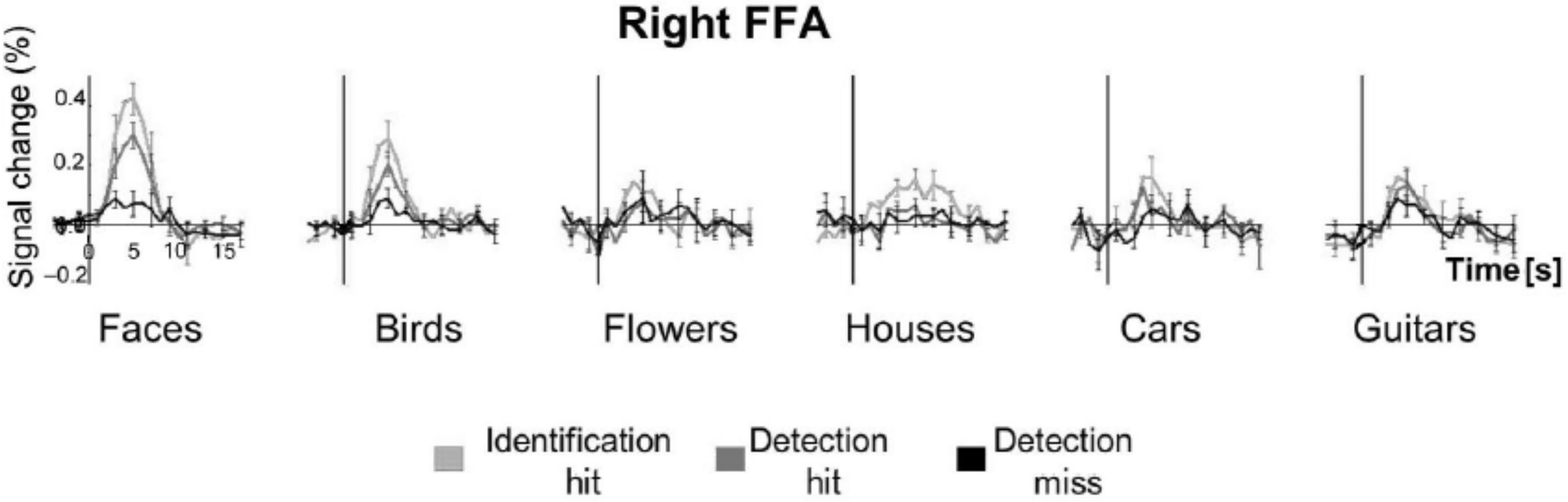
- Humans too have a specialised brain region for faces found in the fusiform gyrus
- fMRI reveals greater BOLD response in the FFA following the presentation of faces vs. other objects





Kanwisher *et al.* (1997)

The FFA and recognition

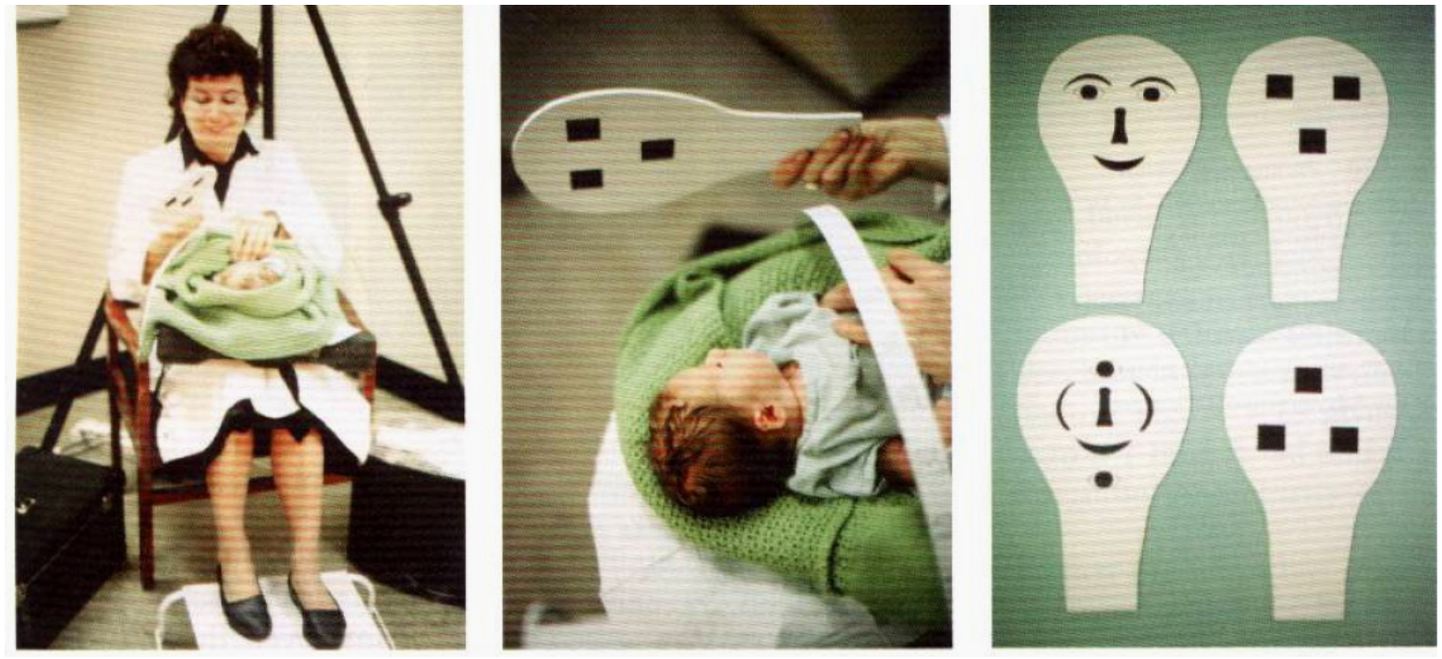


- FFA activity modulated by some objects other than faces but strongest for faces (Grill-Spector, Knouf & Kanwisher, 2004)
- Signal also correlates strongly with performance in face detection & identification tasks, not for other object categories

Faces vs. other objects

- But are these brain regions specialised face detectors or simply modified object areas?
- Two main accounts:
  - Domain specificity hypothesis:
    Face recognition operates independently from general object recognition, with abilities present from birth
  - Expertise hypothesis:
    Face recognition derives from general object recognition mechanisms but becomes finely tuned through extensive practice
- Let's consider the evidence:
  - Development, disorders, configural processing

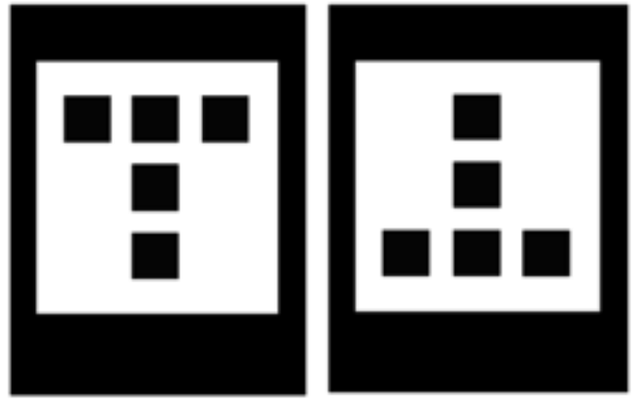
Innate face processing

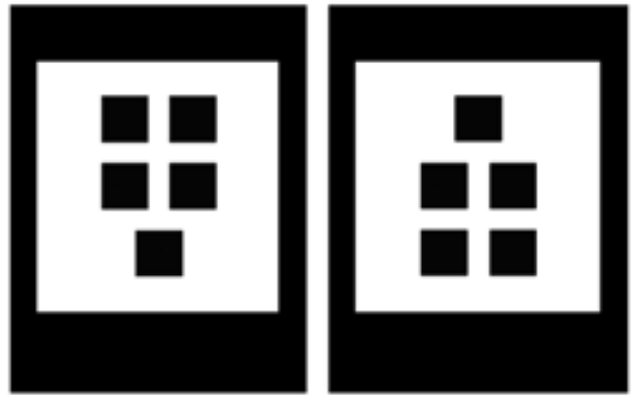


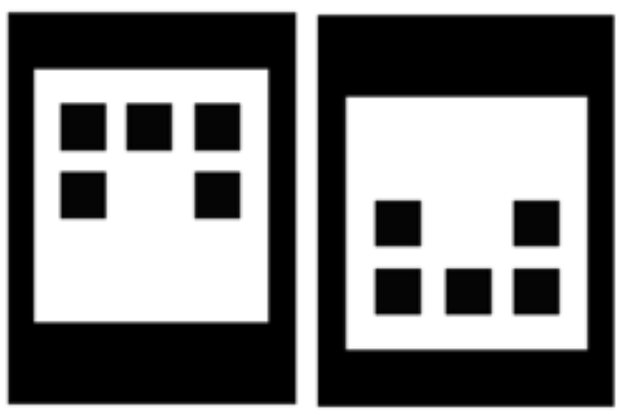
- Newborns (<1 day) will turn further to look at face-like patterns than scrambled versions of the same images (Goren, Sarty & Wu, 1975)
- Suggests a very early separation of face recognition abilities from general object recognition

Faces or patterns?

- But is it a bias for faces or a more general bias for certain patterns?
- Simion et al. (2002) found that infants preferred to look at objects with more features in the upper half than the lower half - a top-heavy bias
- May reflect a general preference for elements in the upper visual field, which may then be co-opted for face recognition: fits with the expertise hypothesis

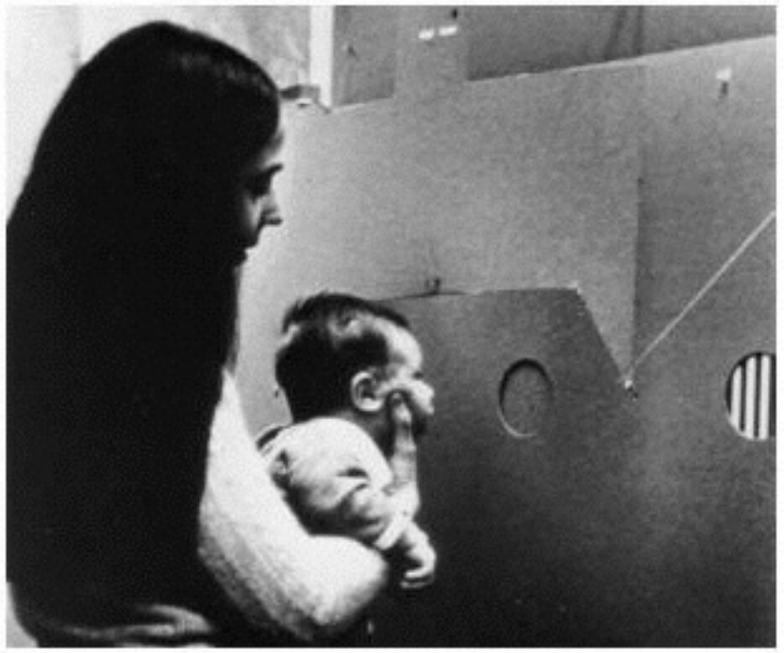






Innate mother detection

- Babies aged 1-4 days presented with their mother's face and that of a stranger (Field et al., 1984)
  - Infants initially looked longer at the mother's face than the stranger
  - Then tested habituation:
    - Presented the mother's face repeatedly until the baby got bored and stopped looking, then showed a stranger's face
    - Babies looked for longer at the stranger (*novelty effect*), suggesting they could tell it was a different face



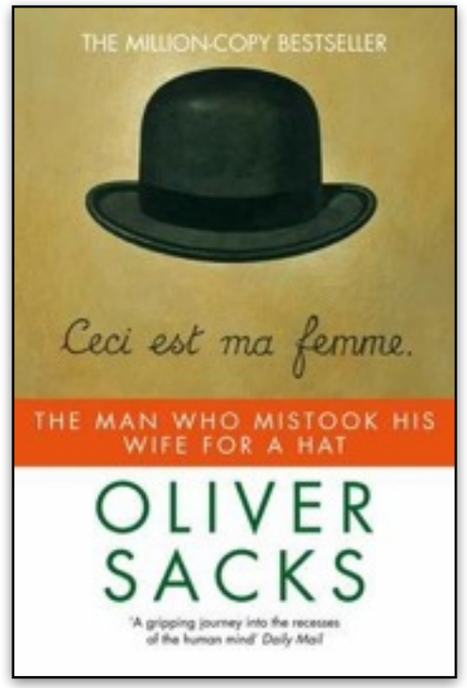
- Suggestive of some specialised face recognition at birth

Prosopagnosia

- Failure to identify or distinguish between faces, despite normal visual acuity and cognitive ability
  - *Prosopon* = 'face'
  - *Agnosia* = 'without knowledge'
- Vision is otherwise intact, i.e. they can 'see' faces but not individuate them and rely instead on distinctive features and non-facial information such as hair, gait, clothing, and voice

Prosopagnosia cases

- Oliver Sacks, "The Man Who Mistook His Wife For A Hat" (p12):
  - *"By and large, he recognised nobody: neither his family, nor his colleagues, nor his pupils, nor himself. He recognised a portrait of Einstein, because he picked up the characteristic hair and moustache; and the same thing happened with one or two other people. 'Ach, Paul!' he said, when shown a portrait of his brother. 'That square jaw, those big teeth, I would know Paul anywhere!' But was it Paul he recognised, or one or two of his features, on the basis of which he could make a reasonable guess as to the subject's identity? In the absence of obvious 'markers', he was utterly lost."*

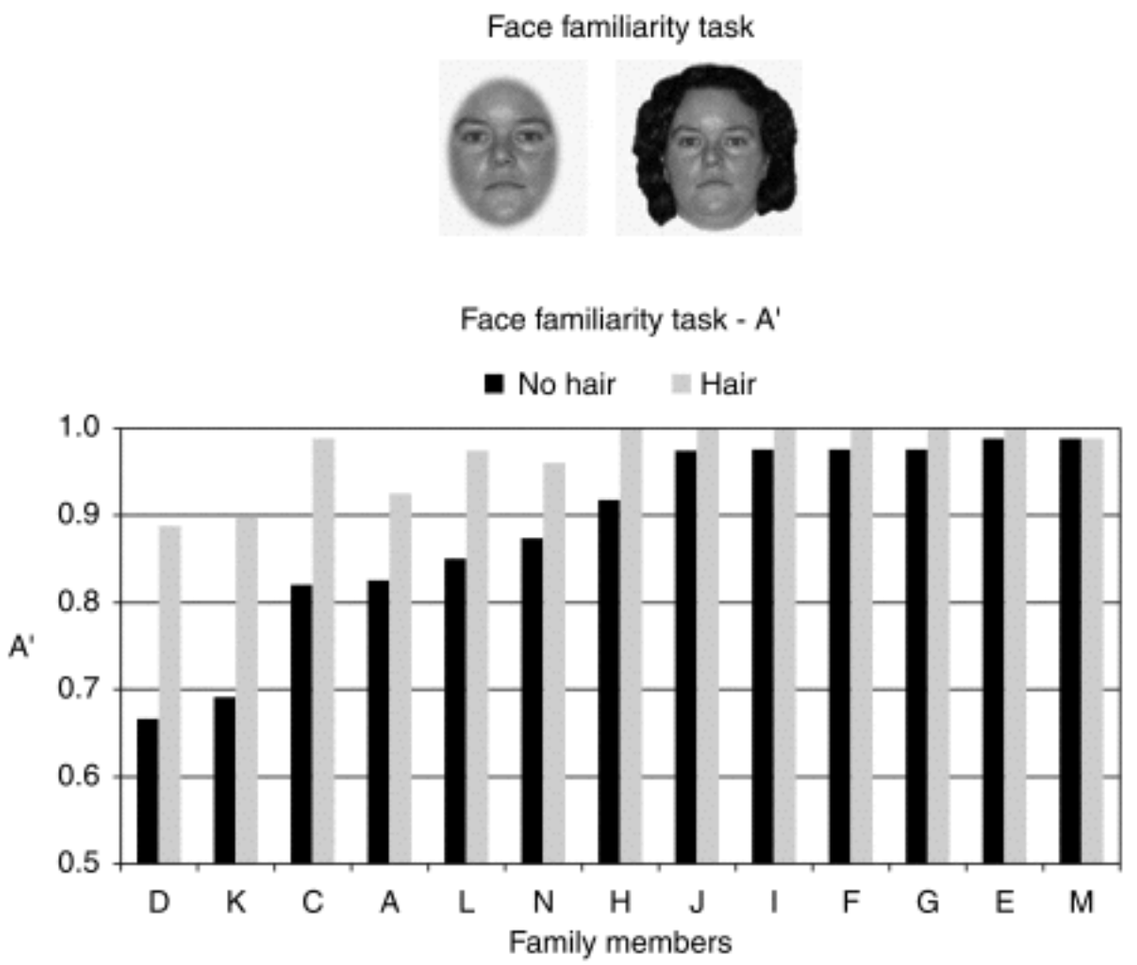


Causes of prosopagnosia I

- Acquired:
  - Can occur after damage to inferior occipital regions and the fusiform gyrus (e.g. by stroke or trauma)
  - Rarely an isolated deficit: often coincides with general object agnosia, as in e.g. "The Man Who Mistook His Wife For A Hat"
    - Dr. P's description of a rose (p12):
      "*A convoluted red form with a linear green attachment…It lacks the simple symmetry of the Platonic solids, although it may have a higher symmetry of its own…I think this could be an inflorescence or flower*"
- Fits with the expertise hypothesis

Causes of prosopagnosia II

- Developmental:
  - Can occur after prenatal damage, but there is also an hereditary form
  - Can be extremely isolated, affecting face processing alone
  - e.g. Schmalzl et al. (2008): 7 individuals in 4 generations of one family scored below 60% correct for familiar face recognition without external hair cues despite otherwise normal visual recognition abilities
  - More consistent with domain specificity than expertise



Schmalzl et al. (2008)

Inversion effects

- Behavioural testing also reveals a range of face-specific effects suggestive of domain specificity
- Yin (1969): It is more difficult to recognise and remember faces when they are upside-down vs. upright

Inversion effects II

- Features of inverted faces are still visible, but it's substantially more difficult to *individuate* the faces
- This deficit is disproportionate for faces: objects like houses and airplanes much less affected

What inversion disrupts

- Feature changes (e.g. eyes, lips) are easy to detect, even with inversion

Upright *feature* changes: 80% correct

Inverted *feature* changes: 81% correct

Le Grand et al. (2001)

What inversion disrupts II

- Feature changes (e.g. eyes, lips) are easy to detect, even with inversion
- Configural changes (e.g. eye spacing) strongly impaired by inversion
- Inversion disrupts configural processing of faces

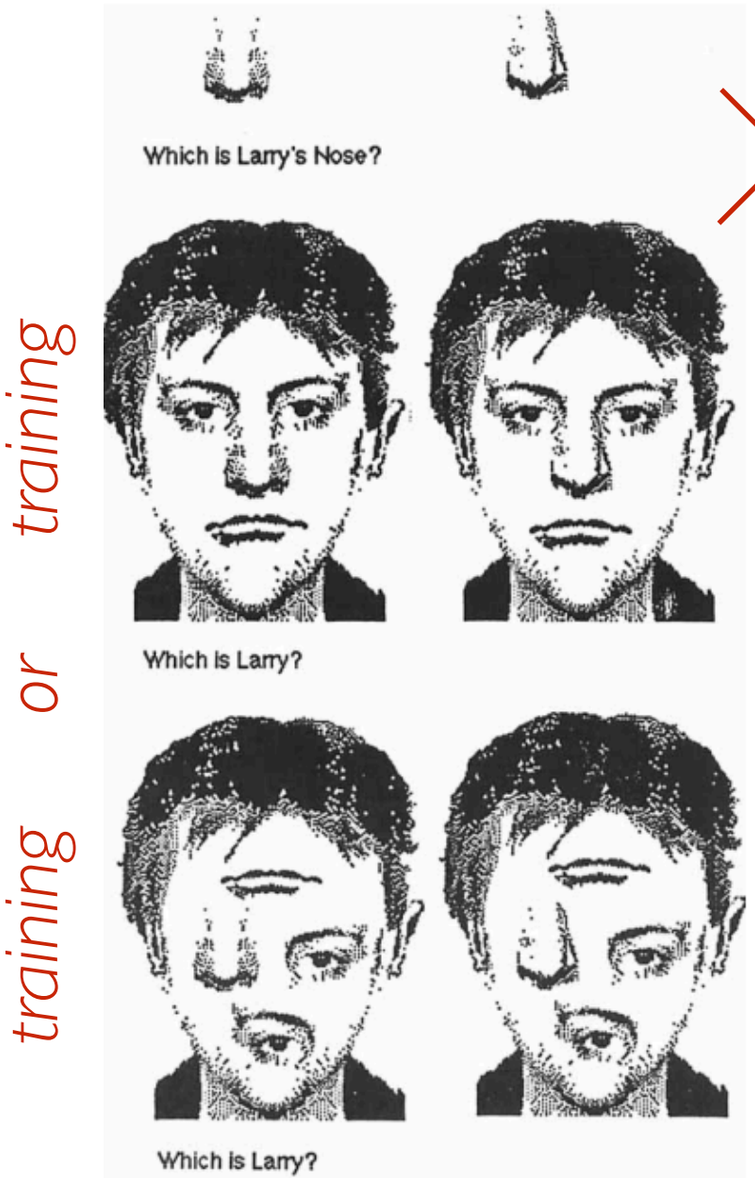
Upright *configural* changes: 80% correct

Inverted *configural* changes: 63% correct

Le Grand et al. (2001)

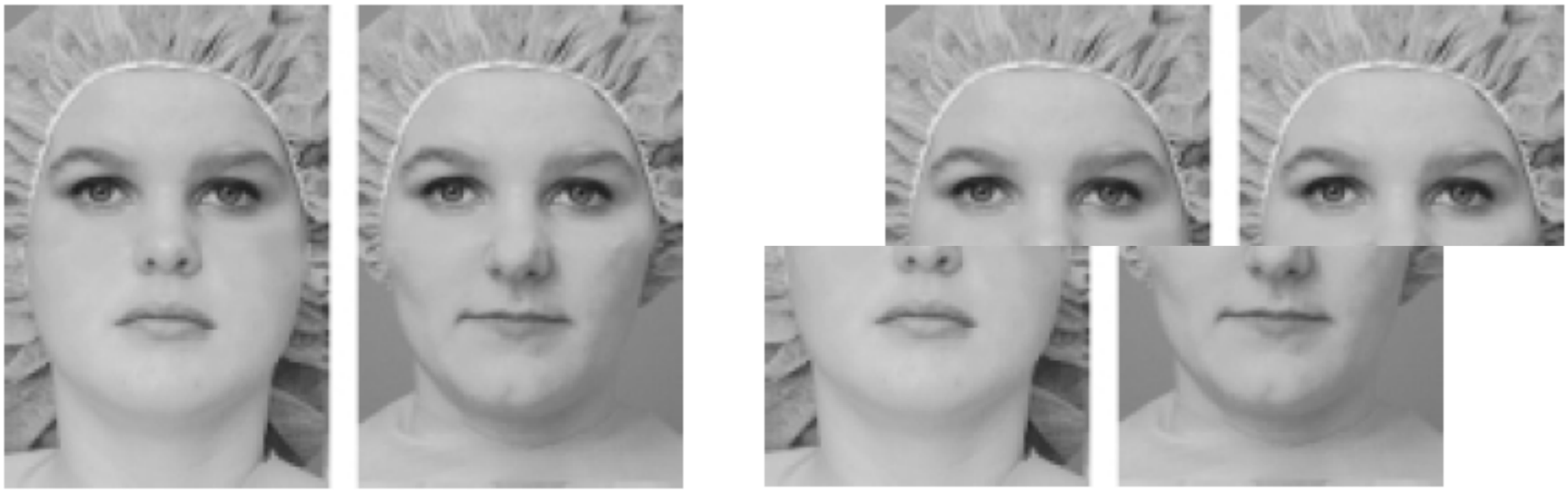
Part-whole effect

- Configural processing can also alter our identification of facial features
  - Subjects learn faces, either intact or scrambled
  - Then tested with either isolated features or normal faces
  - If trained on intact faces, recognition better for the whole face than the isolated feature
  - If trained on scrambled faces, better on isolated features than the intact face
- Learning the face boosts recognition via configural processes, whereas scrambled faces are identified in piecemeal fashion



Tanaka & Farah (1993)

The composite illusion



- Configural processing is difficult to avoid: the composite illusion (Young *et al.*, 1987)
  - Here the top half of each face is identical but the identity changes dramatically when the lower half is switched
  - Subjects far worse at judging whether the eyes are same or different in context vs. with the top & bottom halves misaligned

Inverted composites

- Changes are once more easier to detect when the face is inverted, due to the disruption to configural processing (Young *et al.*, 1987)

The Thatcher Illusion

- Rotation of image features is hard to see in inverted faces
- With upright faces, the rotations disrupt our 'holistic' processes and thus appear grotesque

(Thompson, 1980)

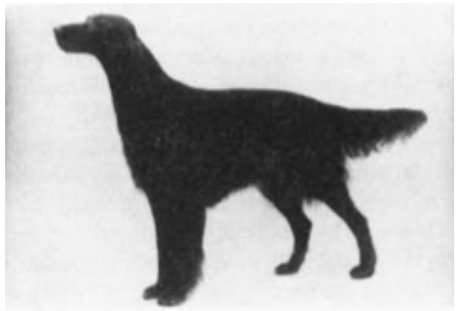
Does inversion affect only faces?

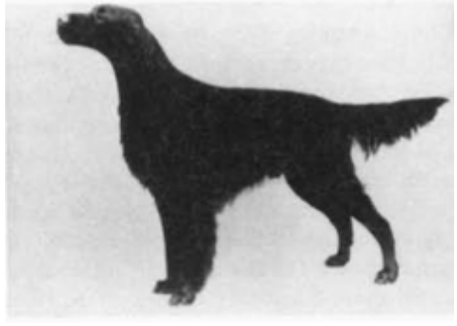
- Yin (1969) found no inversion effect for recognition of pictures of houses or airplanes
- But the expertise hypothesis says:
  - Perhaps we have inversion effects with faces simply because our experience with these stimuli is so disproportionate to that with other objects
  - With extensive practice making subtle intra-category object discriminations for other object types, perhaps orientation will become more critical

An inversion effect for experts

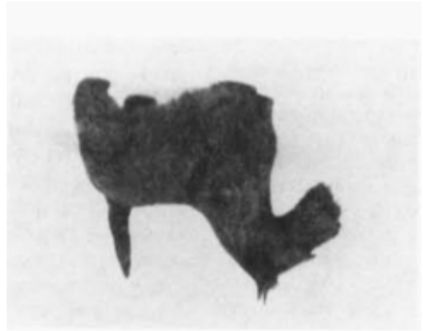
study

test

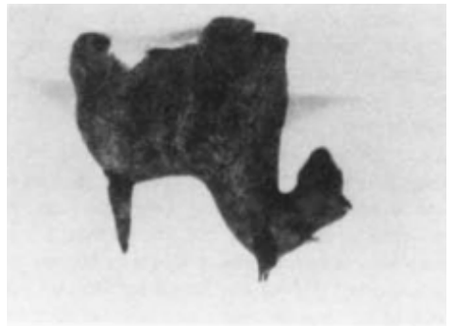




study

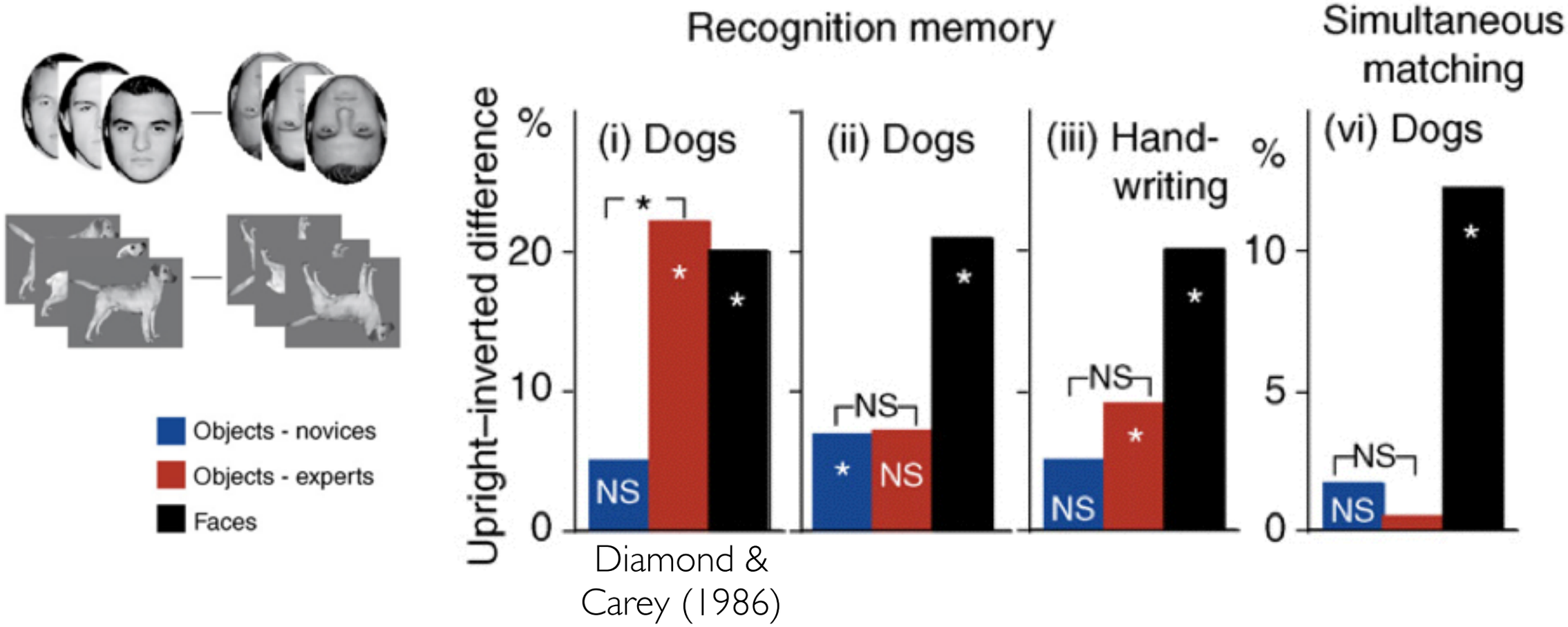


test



- Diamond & Carey (1986) tested dog breeders/judges on their recognition and found inversion effects
- Experts showed a strong inversion effect; novice subjects (university students) showed no difference

Expertise re-examined



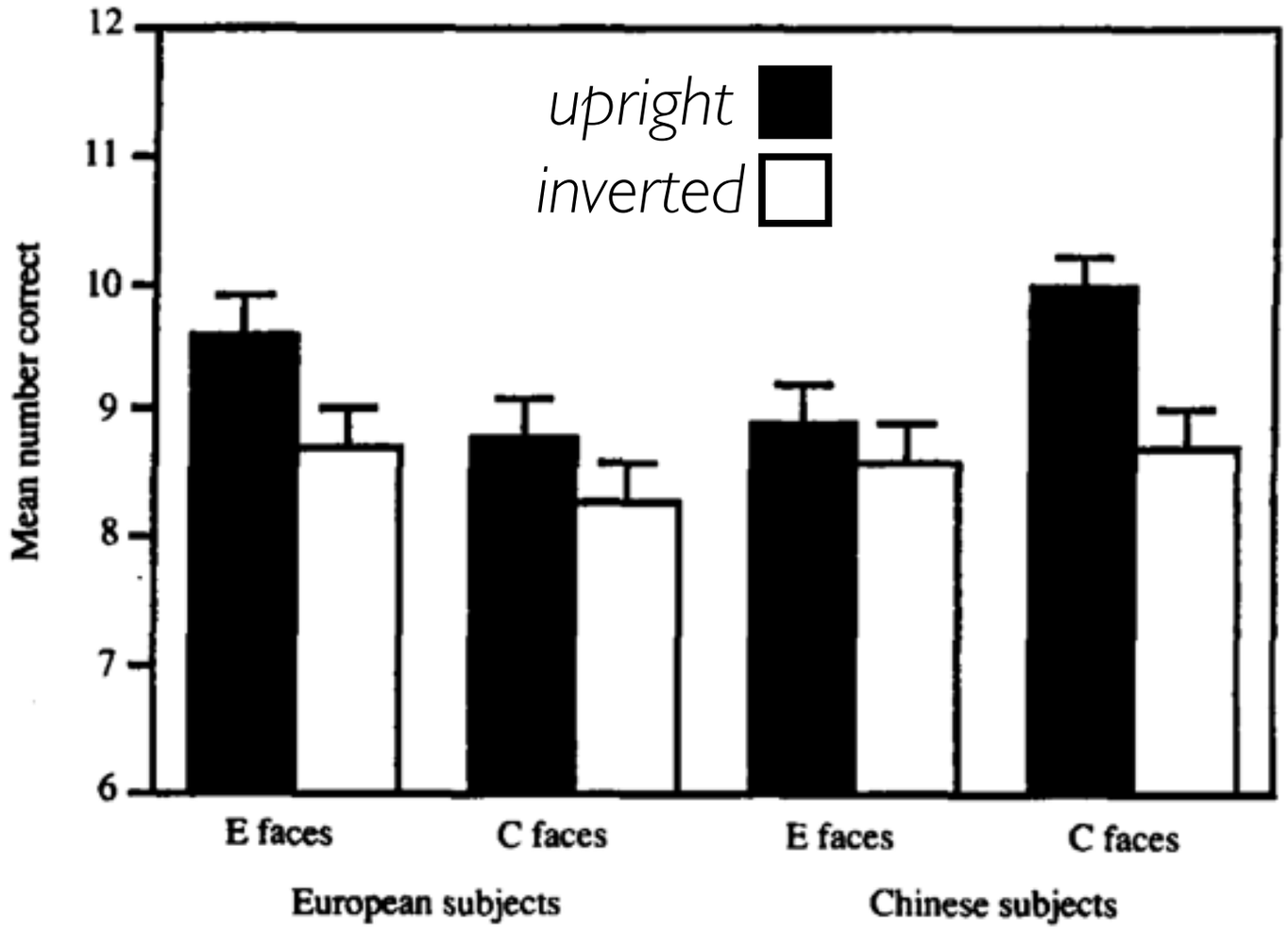
Diamond & Carey (1986)

from McKone, Kanwisher & Duchaine (2007)

- Many subsequent studies have failed to replicate this
- Diamond & Carey subjects familiar with pictured dogs which might have artificially boosted memory for upright images

Expertise: the other-race effect

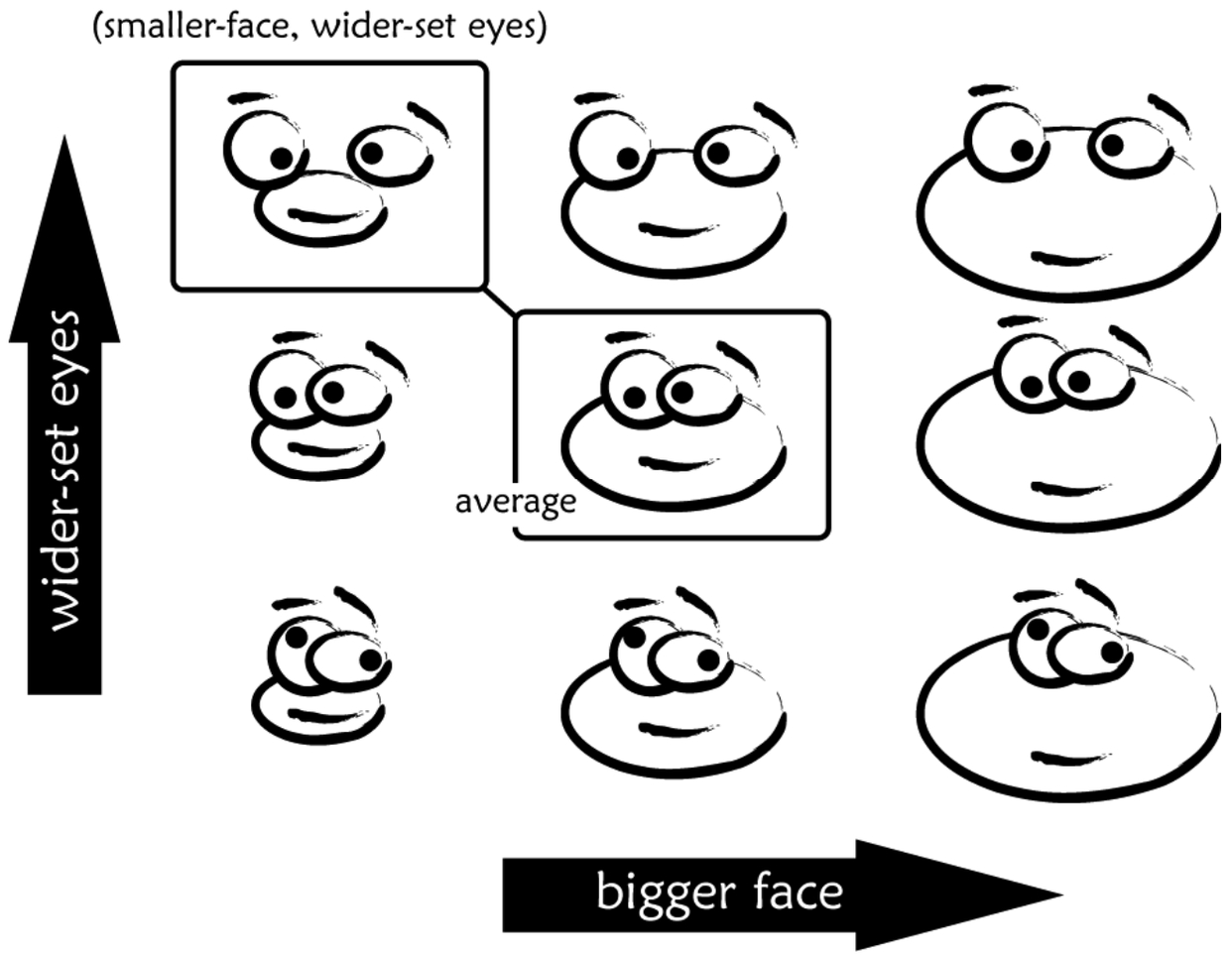
- But in other instances expertise in faces does become important
  - European subjects far worse at recognising Chinese faces, with little-to-no inversion effect; and vice versa for Chinese subjects
- We are experts at our own race: does this fit?
  - Let's consider face coding



Rhodes et al. (1989)

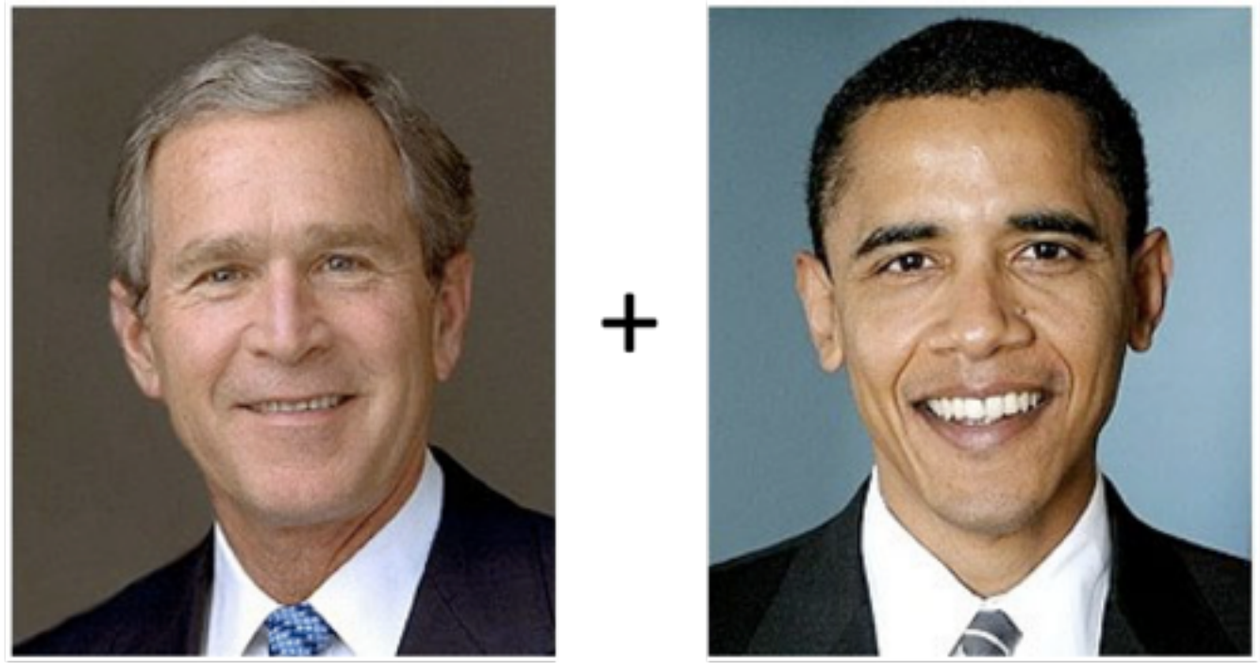
How is identity encoded?

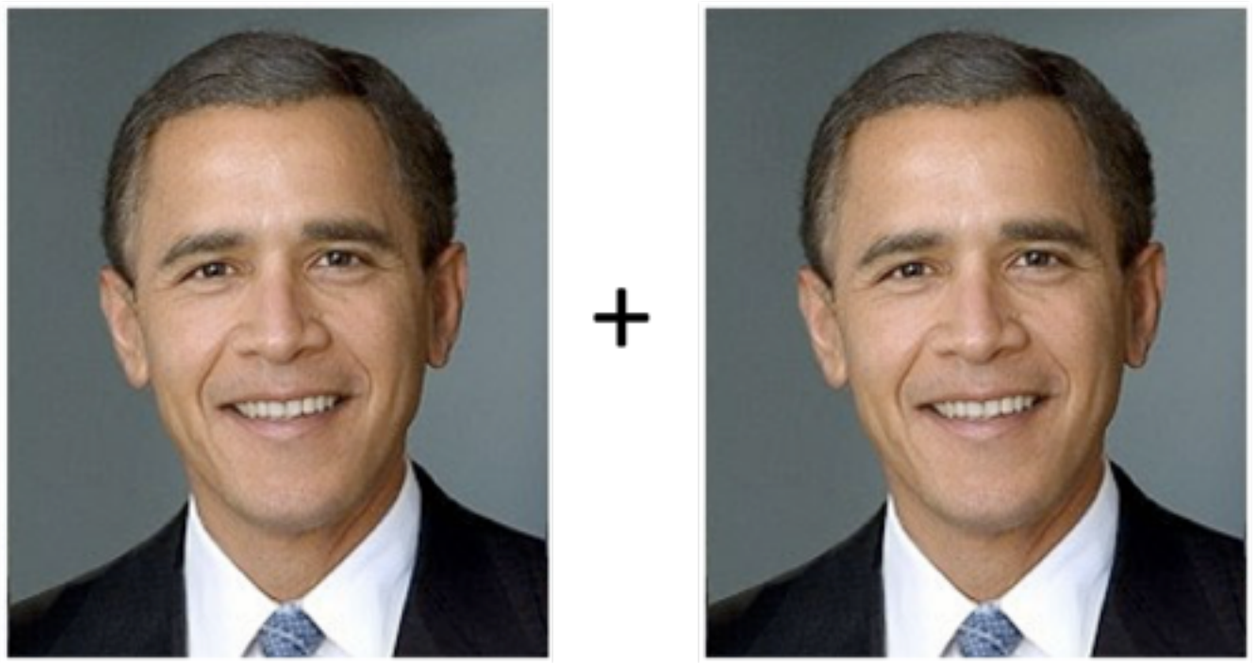
- If face recognition is a configural process, how does the brain encode these dimensions?
- Useful heuristic: face space (Valentine et al., 1991)
  - Faces are coded along a set of dimensions that seek to reduce information and use population coding



Adaptation to faces

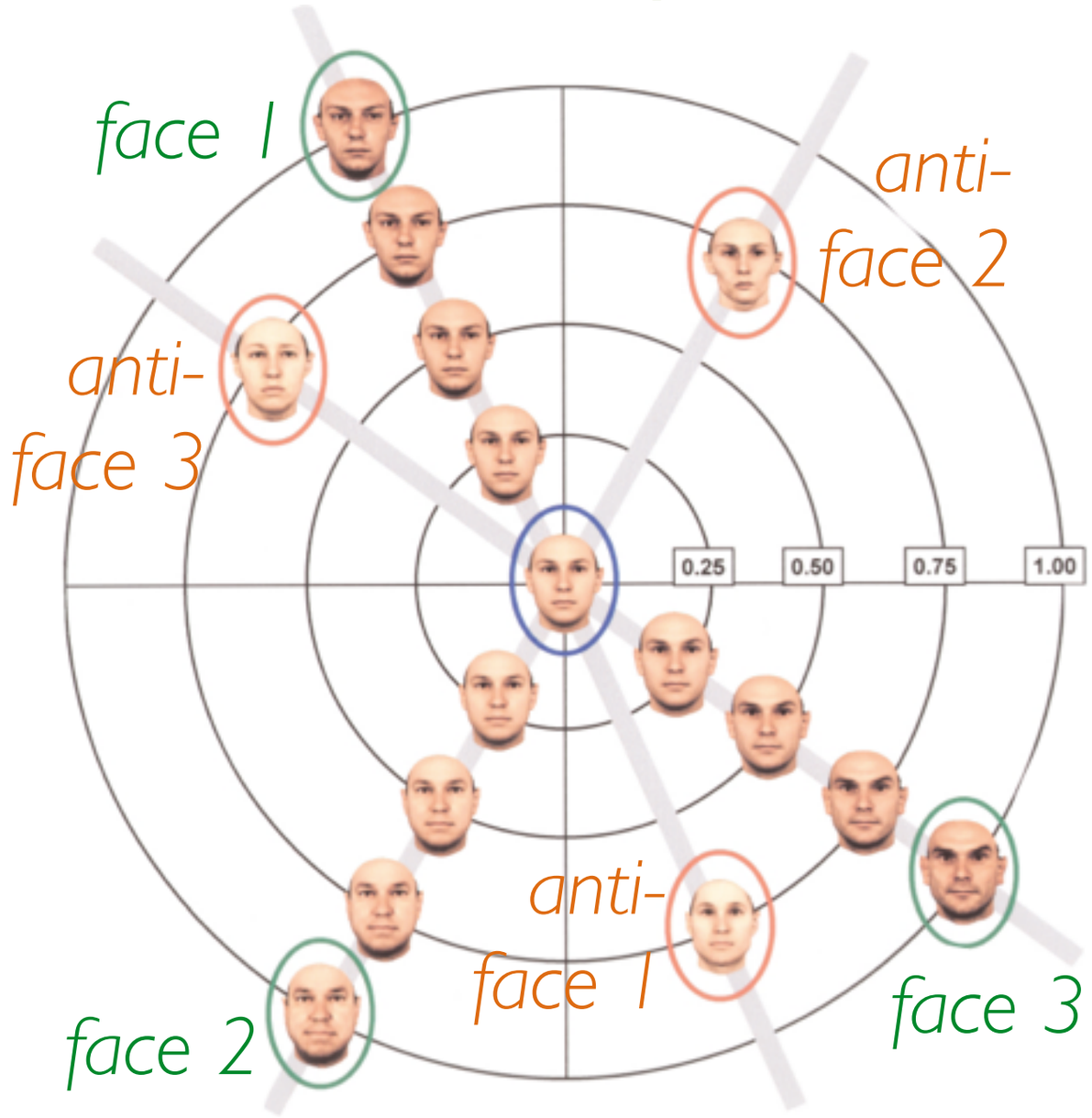
- A particular instance where face space is particularly useful is in understanding face adaptation
- Face morphs: combine key points from different face images
- Adaptation shifts the identity in the opposite direction (Leopold *et al.*, 2001)





Moving around in face space

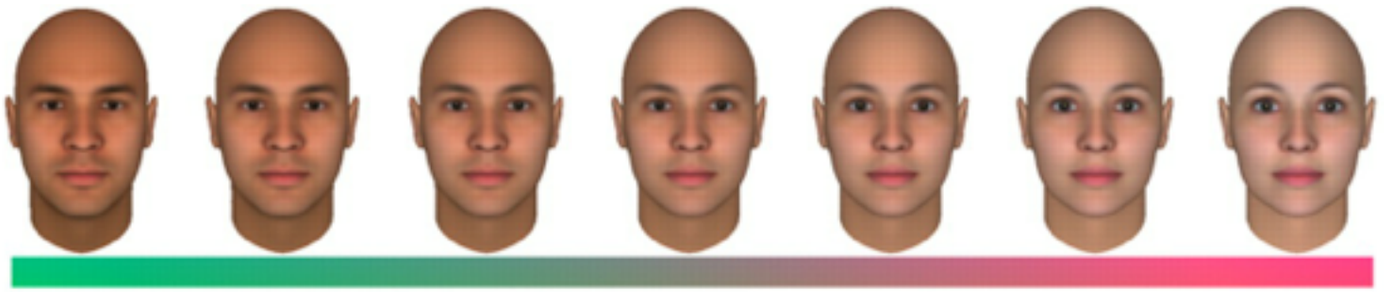
- Faces can be arranged in a space, with the 'average face' at the centre
- The differences that characterise a face from the average can be reversed to create an 'anti-face'
- Images can be morphed continuously between these extremes, passing through the average face

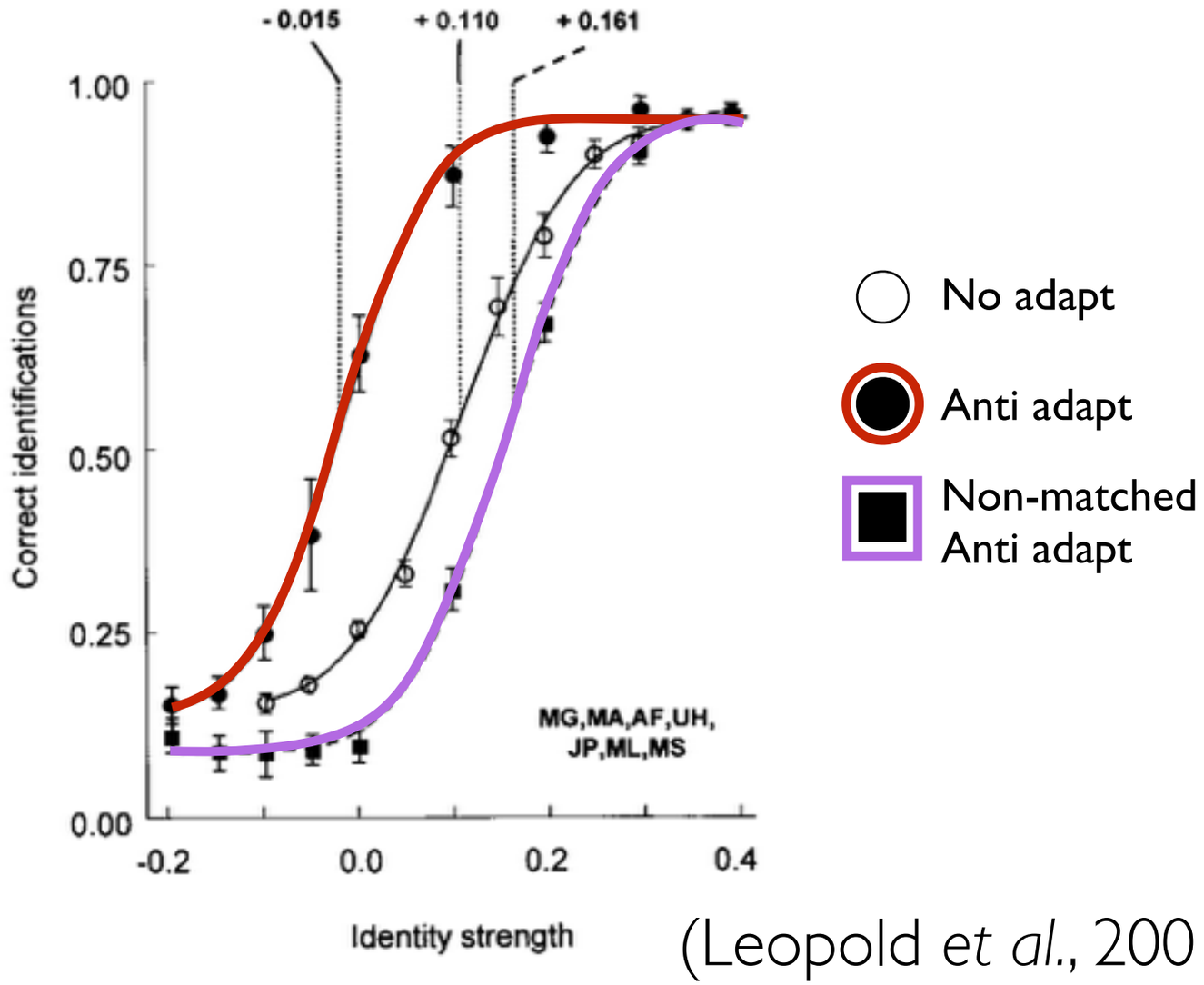


Leopold *et al.* (2001)

Adaptation in face space

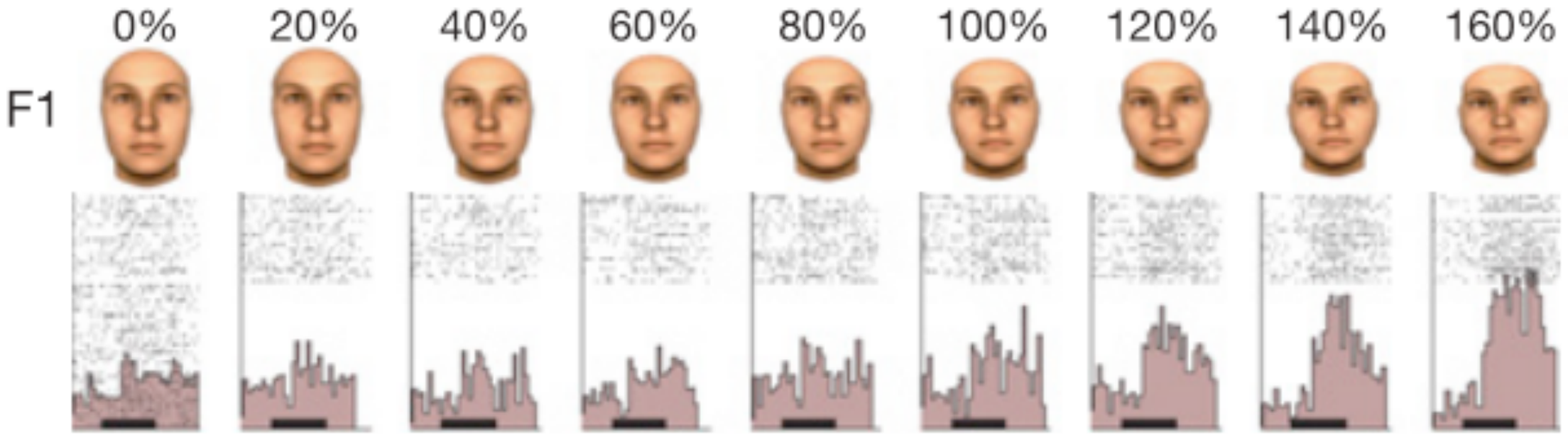
- Adaptation shifts identity around in this space much in the same way as we saw for orientation and spatial frequency
- Suggests some kind of dimensionality to configural processing





(Leopold *et al.*, 2001)

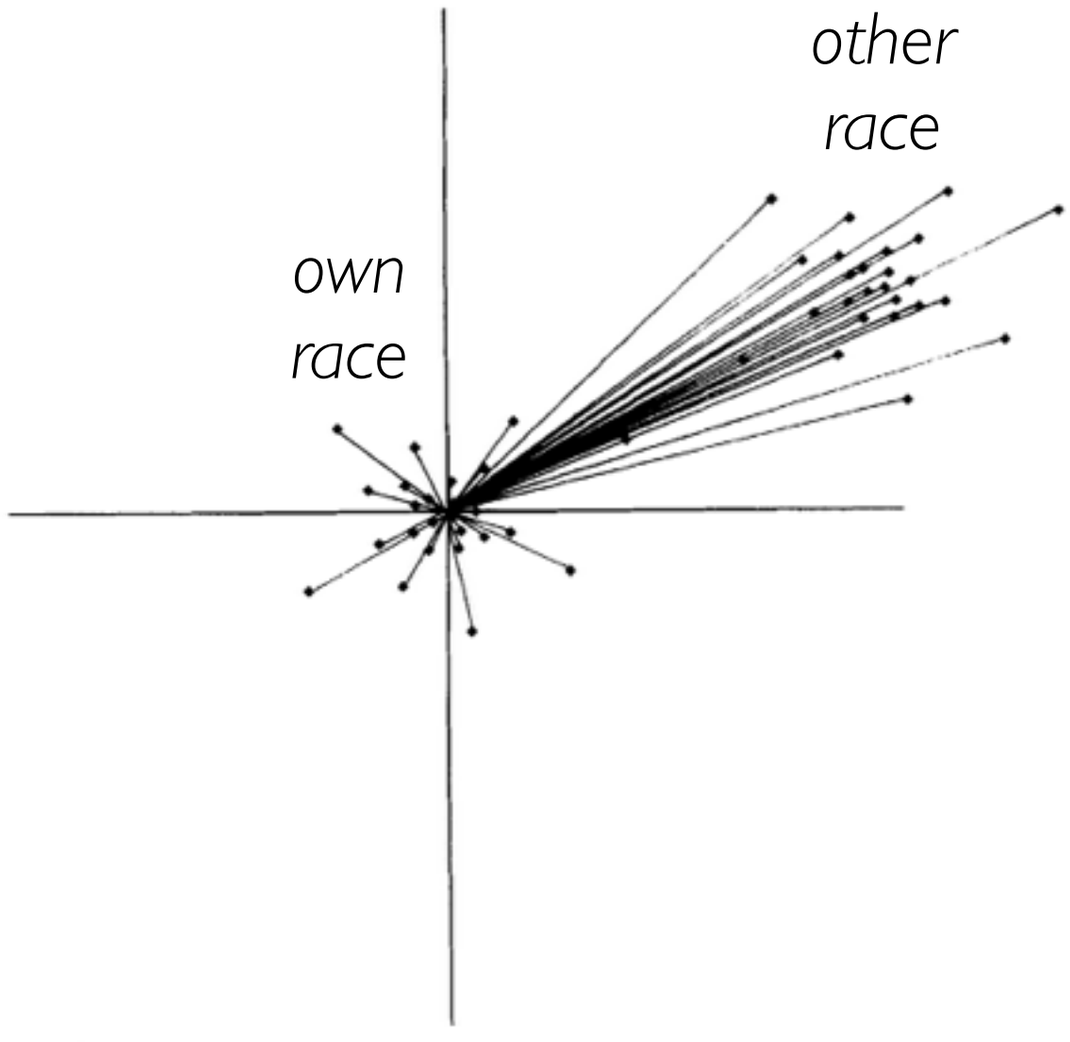
Face space and IT



- Firing rate of neurons in IT can also be predicted using face space (Leopold, Bondar & Giese, 2006)
  - When identity is morphed continuously from the average (0%) through to a preferred face (100%) and further to a caricature (160%), firing increases in a monotonic fashion

Face space and race

- Consider the 'other race effect' in this context
  - If faces are coded relative to a norm (the 'average face') then each face has a vector distance from the centre
  - Other-race faces may be encoded using inappropriate features (i.e. along the wrong dimensions) and so the vector distance would be greater and thus outside the range where your greatest sensitivity lies



Valentine (1991)

Summary

- The recognition of objects and faces is a complex process
- A variety of evidence suggests that face processing is 'special'
  - Relies on specialised neurons in inferotemporal cortex
  - Newborns have a predisposition to facial arrangements (refined in time?)
  - Prosopagnosia disrupts face recognition selectively and may be hereditary
  - Face recognition relies heavily on configural information
    - Faces are disproportionately impaired by inversion, better in context, and subject to illusions derived from configural processing
  - Expertise certainly hones these abilities (e.g. the other-race effect) but this can still be fit within the idea of a dedicated face-recognition system

Reading

- Chapter 4 of Wolfe et al., *Sensation & Perception* gives a brief overview of these ideas
- A more dedicated overview of the debate surrounding domain specificity vs. expertise can be found in: McKone, Kanwisher, & Duchaine (2007). "Can generic expertise explain special processing for faces?" *Trends in Cognitive Sciences* 11: 8-15.