

THE BRAIN, BIOLOGY AND COGNITION

Attending to Stimuli and making sense of objects and faces

1

Marr: Computational Approach

- Four key aspects:
 - Multidisciplinary - Links neurophysiology with psychology and computational AI
 - Based on information processing
 - Describes perception as series of computations on sensory data
 - Suggests high level visual experience is product of computations
- Perception operates at different levels of description:
 - Computational level – function/purpose
 - Algorithmic level- detailed processes
 - Hardware level- what makes up the object (Brain)



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Marr's Stages of visual processing

- Process of perception involves producing series of increasingly detailed representations of environment (layers)
- Four distinct stages:
 - Raw Primal Sketch:
 - Involves extracting info about edges of objects and basic shades of light and dark.

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Marr's
Stages of
visual
processing

2. Complete Primal Sketch

- Grouping** of surfaces and common areas.
 - From **Gestalt** Psychology (1920s)
- Described different ways in which we can group objects (rules in the mind):
 - Proximity
 - Similarity
 - Continuation
 - Closure

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Proximity



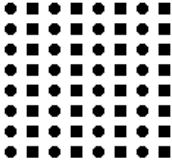
Would you be able to group the above dots?

If so, how?

Things that are close together *seem* part of the same group – but they are just a series of dots.

5

Similarity



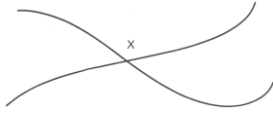
Would you be able to group the above?

If so, how?

Things that are similar *seem* part of the same group.

6

Continuation

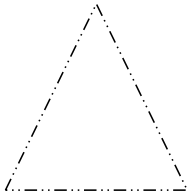


What do you see?

We can see this as two crossing lines, rather than two 'V' shapes.

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Closure



What do you see?

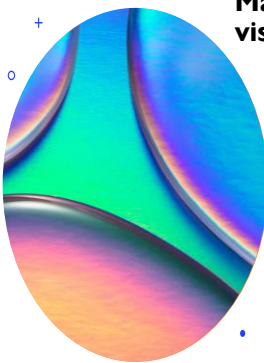
Images *seem* to form closed rather than open patterns.

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Marr's Stages of visual processing

3.2 1/2 D Sketch

- Provides an **estimate of the spatial locations** of objects (or parts) in relation to viewer.
- Binocular disparity:
 - Each eye receives slightly different image of the world
 - Disparity used to compute relative distance
- As well as monocular cues:
 - Texture gradients
 - Occlusion
 - Convergence
 - Relative Size



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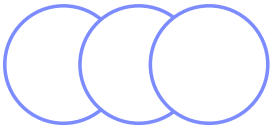
Depth: Textural Gradient



Describe the texture throughout the image above
Surfaces appear to have finer texture as they recede into distance.

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Depth: Occlusion/ superimposition



Are these half moons or circles?
Proximal objects appear to cover over distal objects.

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Depth: Convergence / Perspective

Is the width of the road the same the whole way down?

Parallel lines appear to draw closer together as they go further into the distance.



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Marr's Stages of visual processing

- Final stage of Marr's theory:
- Full 3D description of spatial environment involving identification of volumetric structure of objects and materials in visual scene.



- Allows us to work out 3D environment from non-egocentric point-of-view – a top-down process

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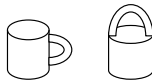
Biederman: Recognition-by-components

Developed and extended Marr's approach.

Assumes objects consist of basic geometric components known as 'geons' (geometric ions) – e.g., blocks, cylinders.

36 different types of geons make up all objects –

- e.g., arc connected to side of cylinder represents a cup, whereas same 2 geons but with arc connected to top of cylinder represents a bucket.



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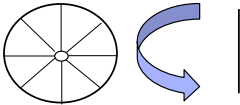
Biederman: Recognition-by-components

- Once components of geons and their relationships are established, the image can be matched against stored object representations.
- We then recognize an object based on whichever stored representation fits best with the information from the visual version of the object.
- In the RBC model edge extraction is the first step in object recognition.

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Viewpoint invariance vs. viewpoint dependent

- Some edges are considered invariant
 - Object can be recognized from many different viewing angles.
- In RBC model this relies on non-accidental properties
 - But: Imagine a bicycle wheel....what does it look like?



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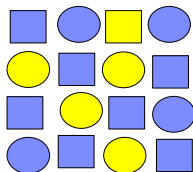
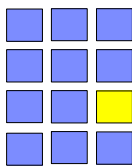
Previous example shows what happens when external stimuli guides attention.

What about searching our visual environment?

How does our vision and attention interact to enable us to successfully find something?



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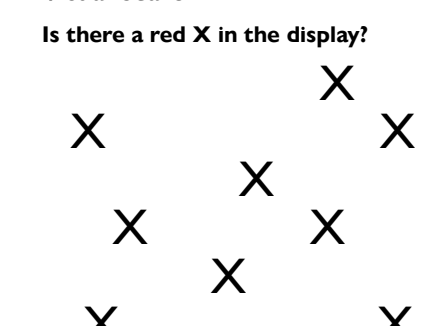


- If target differs from distractors on two dimensions (e.g., shape and colour) it takes longer to find target than if it only differed on one dimension (e.g., colour).
- Links to Feature Integration Theory (Treisman)

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Visual Search

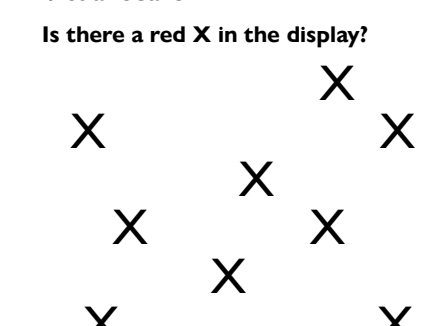
Is there a red X in the display?



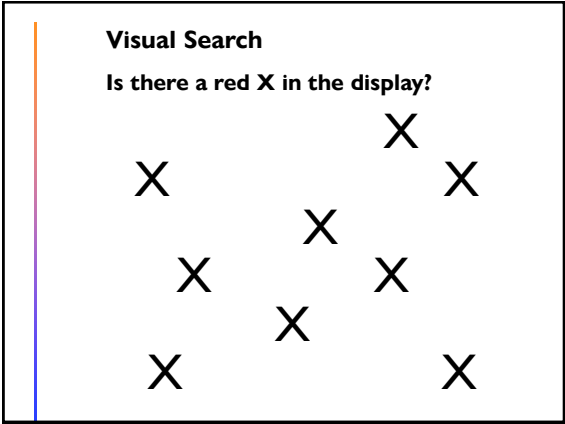
Row \ Column	1	2	3	4
1	X		X	
2		X		X
3	X		X	
4		X		X

Visual Search

Is there a red X in the display?



X		X	
	X		X
X		X	
	X		X



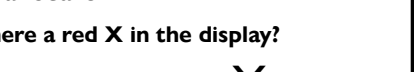
Visual Search

Is there a red X in the display?



Visual Search

Is there a red X in the display?



Visual Search

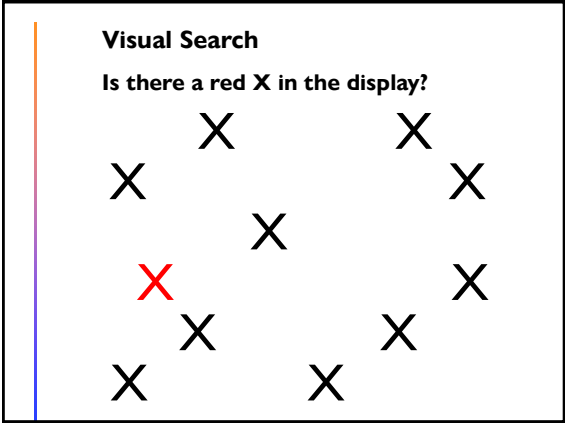
Is there a red X in the display?

	X		

Visual Search

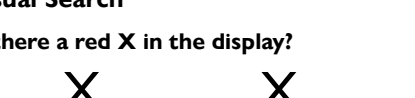
Is there a red X in the display?

	X		



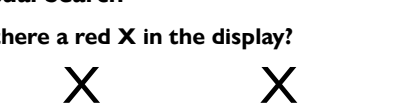
Visual Search

Is there a red X in the display?



Visual Search

Is there a red X in the display?



Visual Search

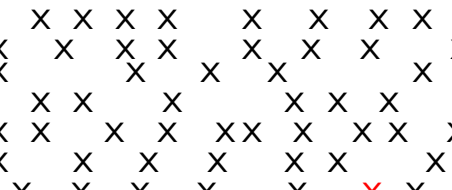
Is there a red X in the display?

A 10x10 grid of black 'X' marks. One 'X' is red, located at row 7, column 8 (counting from the top-left corner). The grid is as follows:

X		X		X		X		X	X
	X	X	X	X		X		X	
X		X	X	X		X		X	X
X			X		X				
X		X		X		X		X	
X	X	X		X			X	X	X
X	X		X	X	X	X	X	X	X
X		X	X		X		X	X	X
X	X		X		X	X	X	X	X
X		X	X	X	X		X		X

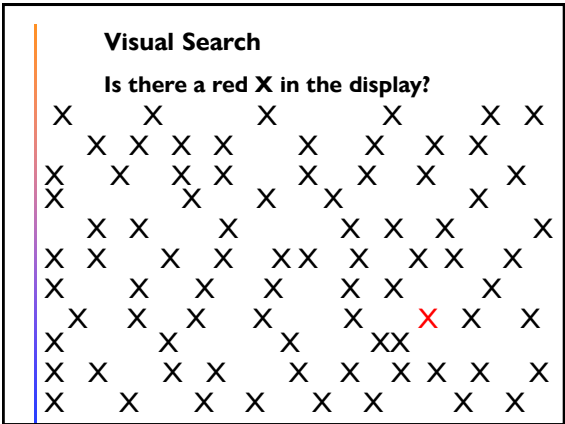
Visual Search

Is there a red X in the display?



A 10x10 grid of black Xs. One X, located at row 7, column 8 (counting from the top-left), is red. The grid is as follows:

X		X		X		X		X	X
	X	X	X	X		X		X	X
X		X	X	X		X		X	
X			X		X		X		X
X		X		X		X		X	
X	X	X		X			X	X	X
X	X		X	X	X	X	X	X	X
X		X		X		X	X	X	X
X		X	X		X		X	X	X
X	X		X	X		X		X	X



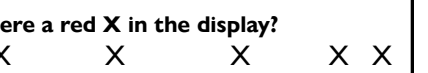
Visual Search

Is there a red X in the display?



Visual Search

Is there a red X in the display?



Visual Search

Is there a red X in the display?

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Visual Search

Is there a red X in the display?

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Visual Search

•Why was the last slide difficult?
 •Features vs. Conjunctions

- Features: 1 dimension – shape (X,O) or colour (black, red)
- Conjunctions: 2 dimensions – X, O, X, O

How does this affect (RT)?

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Damage to Primary Visual Cortex



Scotomas

- Areas of blindness in contralateral visual field.
- Detected by perimetry test: patient stares at fixation point – dot flashes on various parts of screen & patient presses button to record when they see it (each eye examined separately).
- Many are not consciously aware of their deficits. Why? Due to..

Completion

- Possibly from residual visual capacities in the scotoma
- Can also occur when a patient is hemianopsic (scotoma covers whole half of visual field).



The completion of a migraine-induced scotoma as described by Karl Lashley (1941) – notice the lines behind the scotoma remain.

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Damage to Primary Visual Cortex



We assume if someone has seen something, they will be consciously aware of it and acknowledge it.

This conscious awareness is inferred from their ability to verbally describe what they see.

However, some people can see perfectly clearly, but are not consciously aware of what they are directly looking at.....

Blindsight: Respond to visual stimuli in scotoma, but not consciously aware of “seeing”.

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Damage to Primary Visual Cortex



Two neurological interpretations of “Blindsight”:

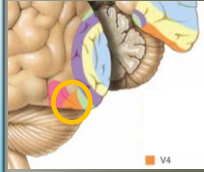
1. Striate cortex not completely destroyed & remaining islands of functional cells capable of mediating visual abilities in absence of conscious awareness.
 2. Visual pathways that ascend directly to secondary visual cortex from subcortical visual structures without passing through primary visual cortex capable of maintaining some visual ability in absence of cognitive awareness.
- Evidence for both but not enough conclusive evidence for one over other and perhaps a mechanism that involves both.

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Neuropsychological disorders of vision

Achromatopsia

- Inability to perceive colour.
- Associated with damage to V4
- Form and motion processing remain relatively intact.
 - However, some patients also have deficits in spatial vision
- Sometimes loss of colour vision is only partial.
 - Could suggest other areas involved in colour processing

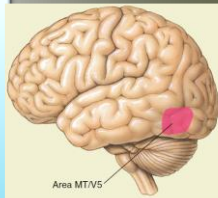


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Neuropsychological disorders of vision

Akinetopsia

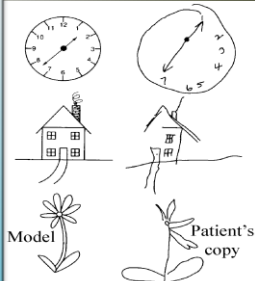
- Deficiency in ability to see movement progress in smooth fashion
- Can be induced by high dose of certain antidepressants
- Associated with damage to the middle temporal (MT) area of the cortex
- MT called V5 or MT/V5 because researchers studying brain in different species use different terminology



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Visual Neglect

- Lack of awareness of stimuli presented to side of space on opposite side to brain damage (contralateral side).
- Usually involves right hemisphere damage.
- Leads to inability to:
 - detect left side of objects (known as object-centred or allocentric neglect)
 - and/or detect all objects presented in left visual field (known as subject-centred or egocentric neglect).



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Visual Form Agnosia



- Severe problems with object recognition despite visual information reaching visual cortex.
- Most studied patient = DF.
 - Could not identify drawings of common objects
 - No greater activity in the ventral pathways.
 - Could reach out and grasp objects even at differing angles
 - High activation in the dorsal stream
- Suggests difference between visual perception and visually guided action

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Recognising faces



- Ability to recognise faces is important.
- It differs from other forms of object recognition.
- Face recognition involves more holistic processing
- Important because specific features of a face may be shared by different individuals or subject to change.
- However, some people cannot recognise faces
- See Heather Sellers clip
<https://www.youtube.com/watch?v=Gx0kOu-LoGs>
- See link to prosopagnosia site:
<https://prosopagnosiaresearch.org/index/information>

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Neuropsychological disorders of vision



Prosopagnosia

- Inability to distinguish faces – an agnosia for faces.
 - Can recognize a face as a face but not who it is.
- Report seeing jumble of facial parts never fused in a recognizable whole
 - See Stephan & Caine (2009)
- In some cases, they cannot recognise themselves.
 - However, some have a general problem recognizing specific objects, not just faces (Behrmann et al., 2005).

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Neuropsychological disorders of vision



Prosopagnosia

- In contrast, other case studies have failed to find recognition deficits unrelated to faces.
 - I.e., the patients only showed deficits in face recognition ability and not to other objects (De Renzi, 1997; Duchaine & Nakayama, 2005; Farah, 1990)
- According to Duchaine and Nakayama (2006), it is not a unitary disorder – only some patients have pattern recognition deficits restricted to facial recognition.
- Why? – Possibly because the condition can be caused by
 - Brain-damage: Acquired prosopagnosia, or
 - In the absence of brain-damage: Developmental prosopagnosia

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Neuropsychological disorders of vision



Prosopagnosia

- Associated with damage to the ventral stream between the occipital and temporal lobes:
 - Fusiform face area (FFA).
- Parts of FFA are selectively activated by human faces (Kanwisher, 2006; Pourtois et al., 2005).
 - However, parts also respond to other visual stimuli (Grill-Spector et al., 2006).
- Face perception plays a major role in human social behaviours, thus it makes sense for a specialized mechanism to perceive faces to have evolved in our brain (Pascalis & Kelly, 2009).

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Neuropsychological disorders of vision



Prosopagnosia

- May recognize faces without conscious awareness
 - Why? Because dorsal-stream function is intact.
- **Tranel & Damasio (1985):**
 - Presented patients with familiar and unfamiliar faces.
 - Patients claimed not to recognize any of the faces.
 - However, they exhibited large skin conductance response when familiar faces presented compared to unfamiliar faces.
 - Suggests faces were being unconsciously recognized by undamaged parts of the brain.
 - See Simon et al. (2011) for similar study on activity levels in FFA for familiar vs. unfamiliar faces.

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Face processing theories

- Explanation of face processing and recognition based on findings from research with prosopagnosiacs
- However, there is theoretical controversy as to whether Fusiform-Face Area (FFA) is face-selective.
- Brain mechanisms for face recognition are also involved in recognising any object categories for which we possess expertise (Gauthier & Tarr, 2002).
 - Expertise Hypothesis

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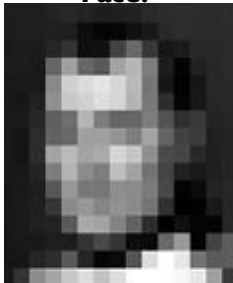
Are faces special?

Could you recognise this cow if you saw its face again?

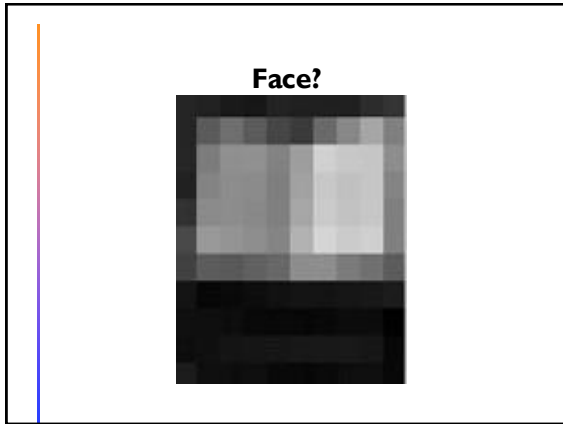


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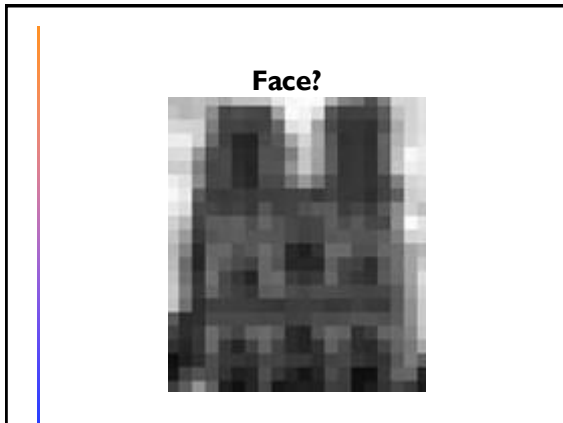
Face?



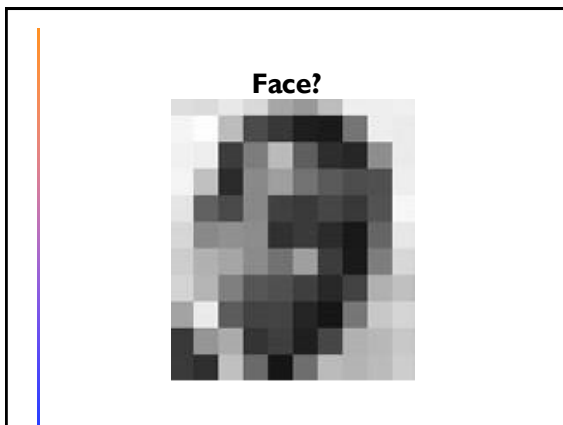
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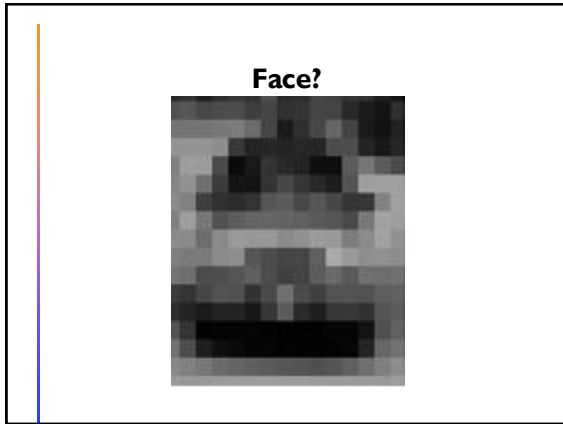
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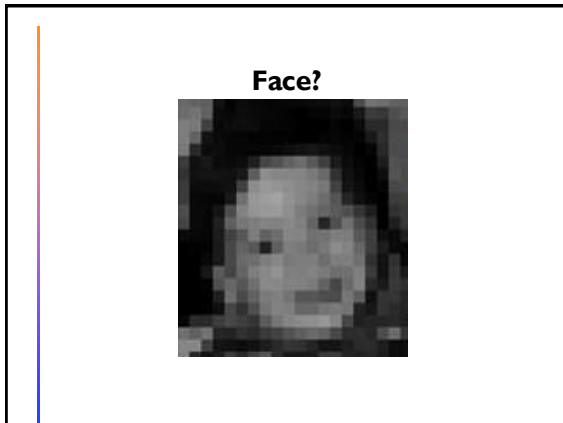
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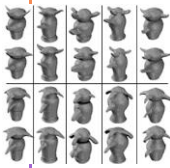
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Face processing theories

- Four predictions follow from this:
 1. Holistic processing occurs for any object category for which observers possess expertise.
 2. The FFA should be activated for any object category for which observers possess expertise.
 3. Young children should show less evidence of holistic processing of faces than older children and adults.
 4. If processing of faces and objects of expertise involves similar processes, then objects of expertise should interfere with face processing.

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Face processing theories



- Gauthier et al. found support for these predictions in studies involving recognition of "Greebles".
- "CK, a neuropsychological patient exhibiting severe visual object agnosia and dyslexia but intact face processing, tested with Greebles.
- CK performed poorly on Greebles, indicating intact face-specific abilities do not extend to include Greebles.
- Suggests CK is relying on face-specific visual processes, these processes do not a priori treat Greebles as faces." Pg 1961, 2004

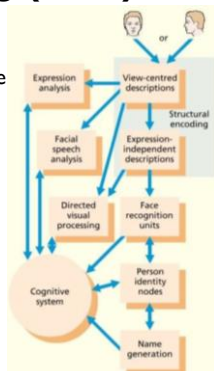
- Suggests faces have special and unique characteristics not shared by other objects.
- However, degree of "specialness" remains controversial.

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Bruce and Young (1986)

Model predicts that:

- Familiar and unfamiliar faces are processed differently;
- Facial identity and facial expression are processed separately;
- For a familiar face, familiarity information is accessed before information about identity or name.

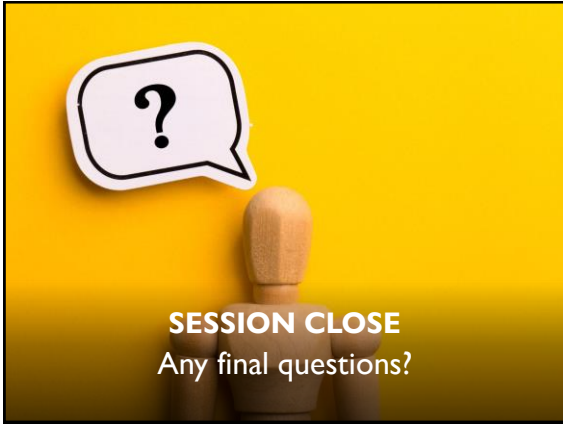


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EVALUATION OF MODEL

Strengths	Limitations
Emphasised wide range of information that can be extracted from faces	Oversimplified and incorrect proposal that facial expressions and facial identity are processed separately
Identified the major processes and structures involved in face processing and recognition	The expression analysis stage is much more complex than proposed by the model
Highlighted the differences in processing familiar vs. unfamiliar faces	Assumption that name processing always occurs after processing of other personal information may be too rigid

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