PSYC 10004-6 – FOUNDATIONS OF PSYCHOLOGY
Introduction to Cognitive Psychology

Lecture 4 – Higher-level Perception: Making contact with meaning

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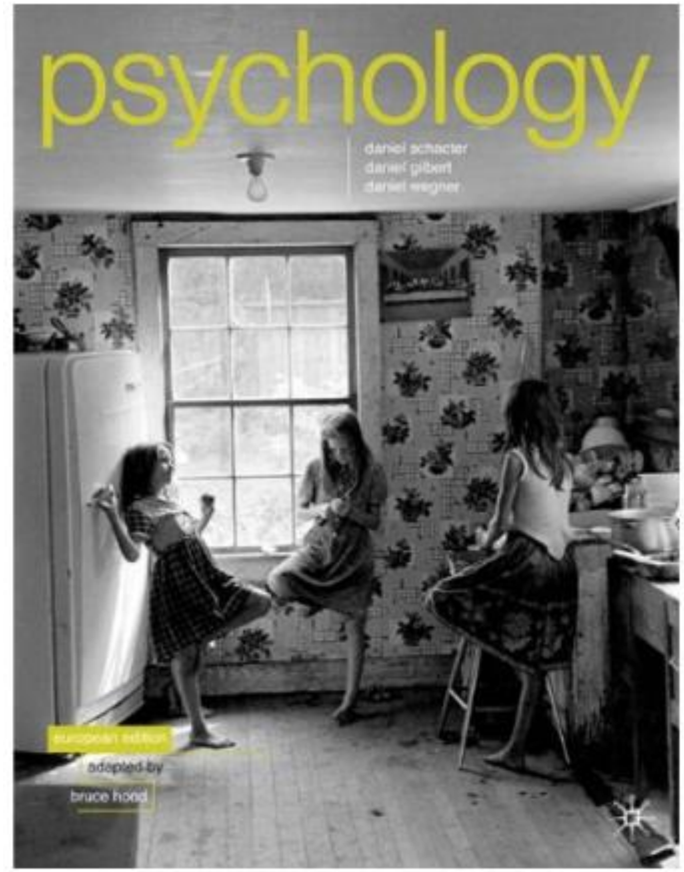
Additional reading

- Schacter, Gilbert, Wegner & Hood (2011), Psychology. New York: Worth
  - Chapter 4 (“Sensation and Perception”), pp. 130-151 (“Vision: more than meets the eye”)
- Also: any recent textbook on Cognitive Psychology, such as Ashcraft & Radvansky (2010)



High-level perception

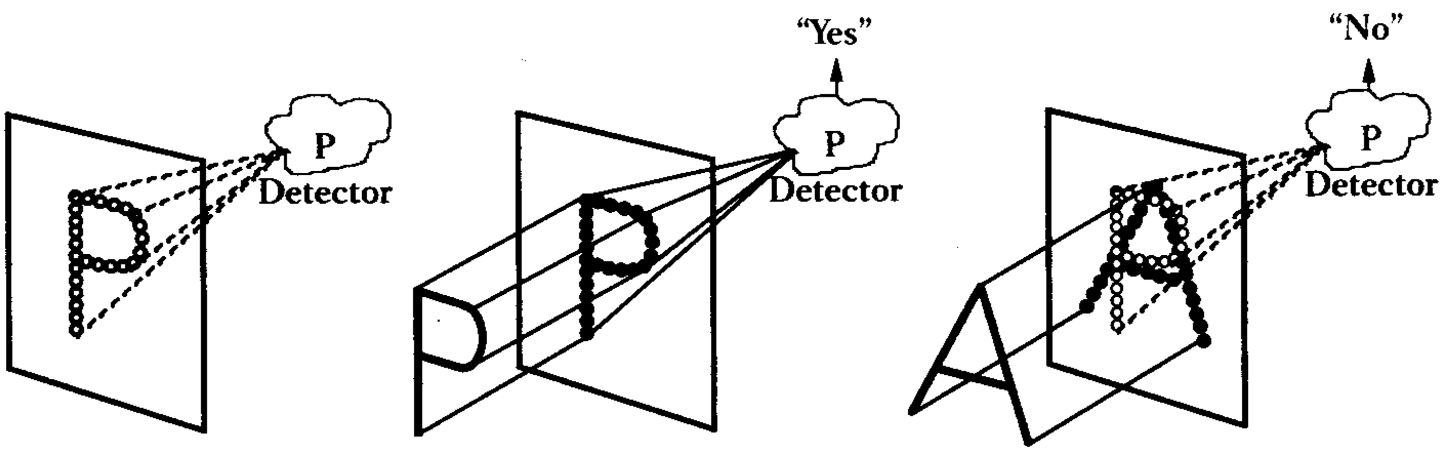
- In everyday cognition, perceptual information makes contact with meaning, e.g.,
  - identifying objects
  - recognising faces
  - reading printed words
  - comprehending spoken words
- identification of complex arrangement of sensorial input, and matching up with visual or conceptual knowledge stored in memory
- typically extremely rapid and efficient (e.g., visual object recognition within 200 or so msec)
- difficult because of variability in the sensory input

Aims of lecture

- Three possible approaches to object recognition:
  - template matching
  - feature matching
  - structural analysis
- all three can be implemented as computer models – some based on simulated neural networks
  - demonstrates validity of approach (fully specified theories)
  - ...and highlights unsolved problems
- conceptual analysis guides interpretation of neurological disorders of object recognition ("visual agnosias")

Template theories (e.g., Neisser, 1967)

- templates are fixed models for classifying objects
- pattern recognition based on global similarity match between sensory input and templates stored in memory
- best match is output of recognition process
  - e.g. letter recognition

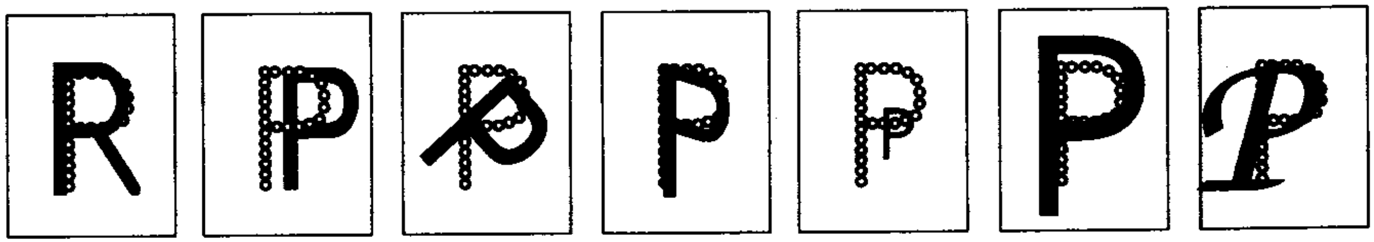


Template theories – arguments in favour

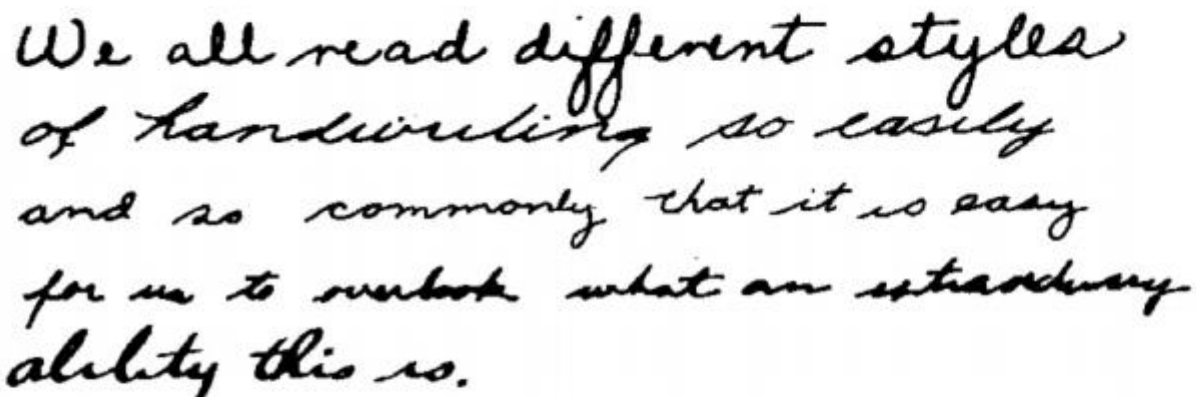
- theory is intuitive and computationally simple – works for some machine recognition systems, but...

- need to specify measures of similarity/dissimilarity between templates and sensory input templates and sensory input
- variability in position, size, orientation etc. is problematic

Template theories – arguments against

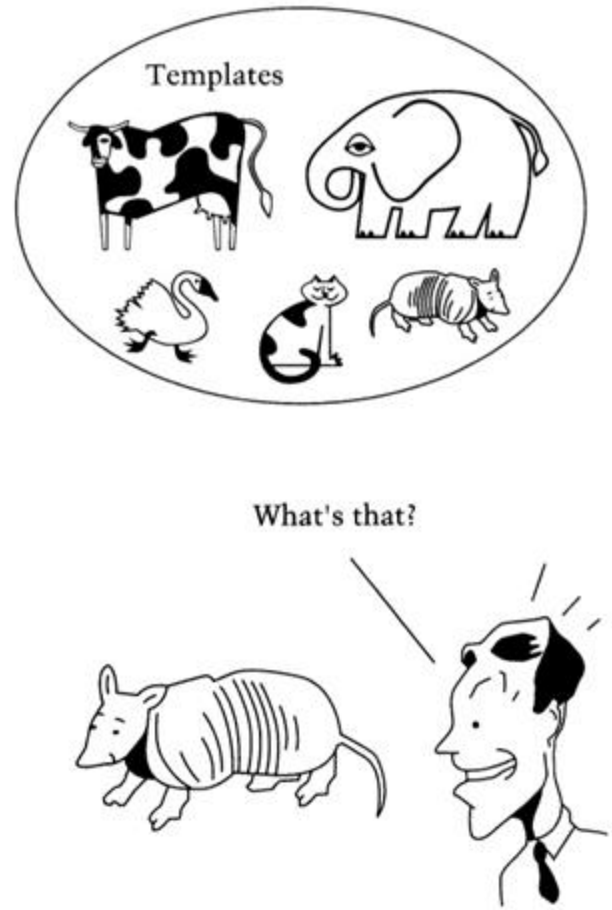


- completeness issue ("R" recognised as "P"?), position, rotation, slant, size, differences in font etc.
  - partially resolved by preprocessing ("normalisation") of the visual image
  - but problematic for handwriting



Template theories – arguments against

- complex objects – dealing with changes in viewpoint, quantification of “similarity”



Template matching - conclusions

- works in some (very restricted) environments
- raises (but does not answer) important questions – i.e. identifies problems that must be addressed
- doesn’t look promising as a general theory of human pattern recognition

Feature matching theories

- object recognition is based on identification of features in the visual array
- "features" are fragments or elementary components of a larger pattern
- for recognition purposes, objects can be defined in terms of their component features, e.g.

A consists of the features / - \

Feature matching

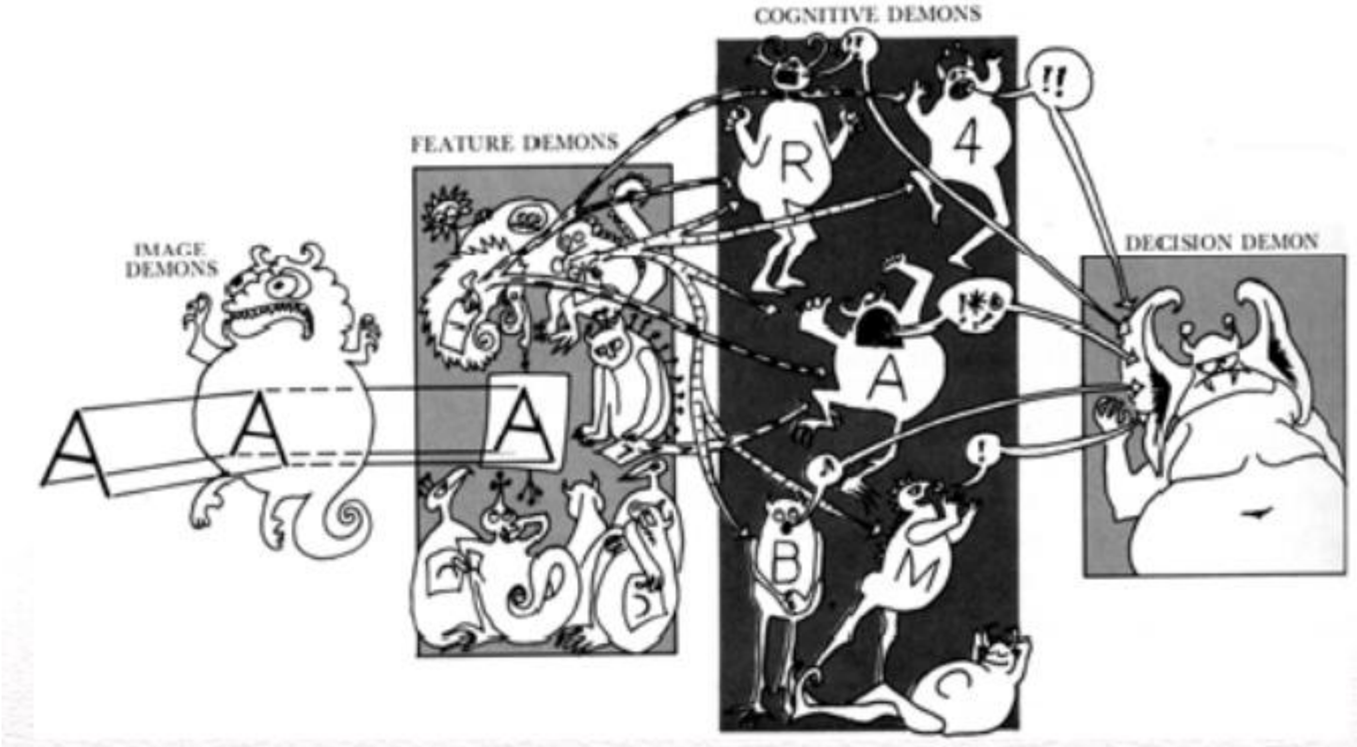
- object recognition involves matching visual features to known patterns
- advantage is that a limited number of features can be used to represent a very large number of objects
- what kind of visual features will be most efficient? Some desirable characteristics: (Gibson, 1969)
  - should discriminate effectively between possible alternatives
  - should not be redundant with other features
  - satisfaction of these requirements ensures minimal feature set, with maximum efficiency

Possible set of features for capital letters (Gibson, 1969)

Features	A	E	F	H	I	L	T	K	M	N	V	W	X	Y	Z	B	C	D	G	J	O	P	R	Q	S	U
Straight	●	●	●	●		●	●								●				●							
horizontal		●	●	●	●	●	●	●	●	●				●		●		●				●	●			
vertical	●							●	●		●	●	●	●	●											
diagonal/	●							●	●	●	●	●	●	●									●	●		
diagonal\																										
Curve																										
closed																●		●			●	●	●	●		
open vertical																				●						●
open horizontal																	●		●	●					●	
Intersection	●	●	●	●			●	●					●			●						●	●	●		
Redundancy																										
cyclic change		●							●			●				●									●	
symmetry	●	●		●	●		●	●	●		●	●	●	●		●	●	●			●					●
Discontinuity																										
vertical	●		●	●	●		●	●	●	●				●								●	●			
horizontal		●	●			●	●								●											

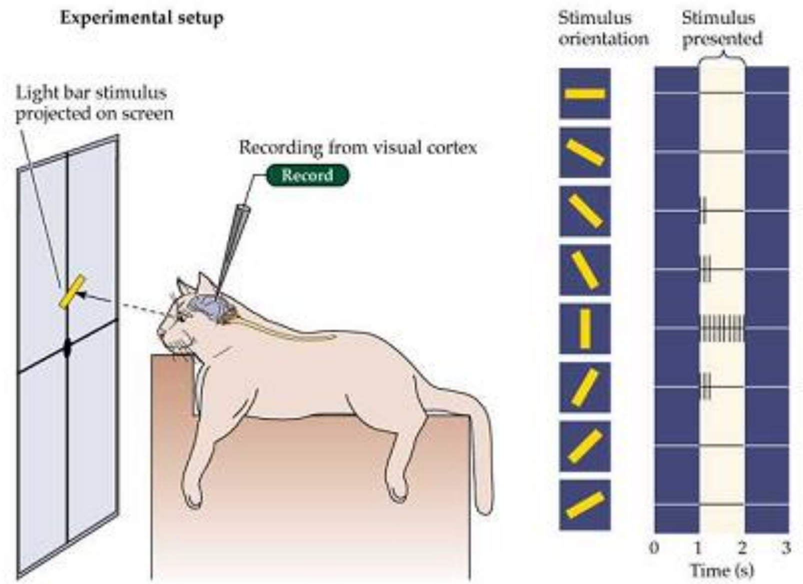
Models of feature-based recognition

- Selfridge's (1958) Pandemonium: a paradigm for learning in mechanisation of thought processes



Feature matching theories – arguments in favour

- physiological evidence for low-level visual feature analysis:
- Hubel and Wiesel (1962) conducted single cell recording in the visual cortex of anaesthetised cats
- specific cells respond only to certain kinds of stimuli (e.g., a line, at particular width, at particular angle, located in the right position) – simple feature detectors are "wired in"



Feature matching theories – arguments against

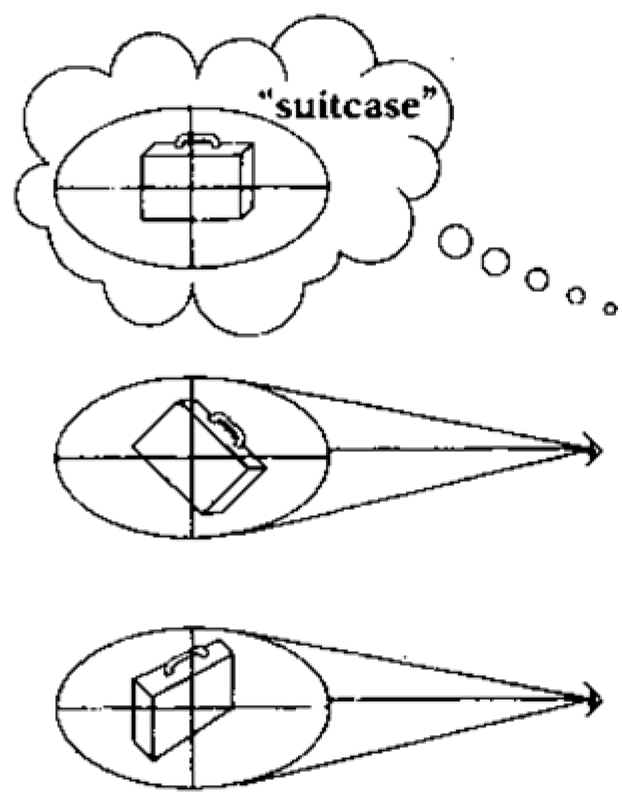
- feasibility for complex object recognition?
  - description of a cat or a shirt in terms of low-level visual features?
  - can break down even for letters

Viewpoints and object representations

- one potential problem is that both template- and feature matching theories assume that objects are stored in a viewer-centred representation ("what it looks like"):

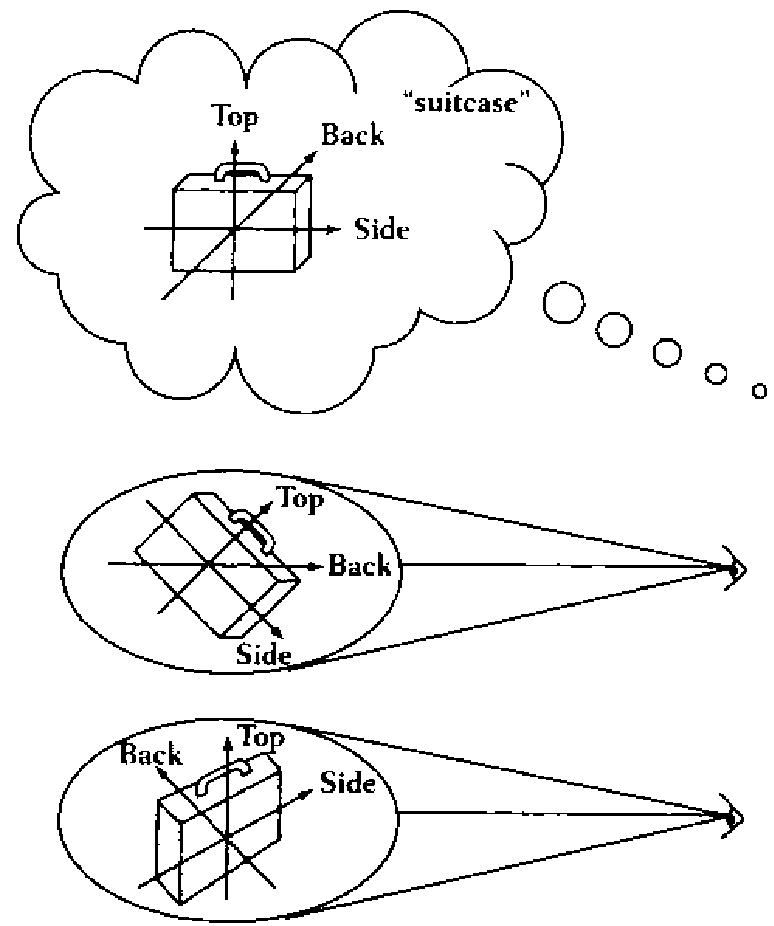
template

viewer-centred perspectives



A potential solution

- represent objects in object-centred fashion:
  - object is perceived in a coordinate system centered on the *object*, not the viewer
  - brain aligns a reference frame, using object's axes of elongation and symmetry
  - uses that reference frame to measure relative positions of object components

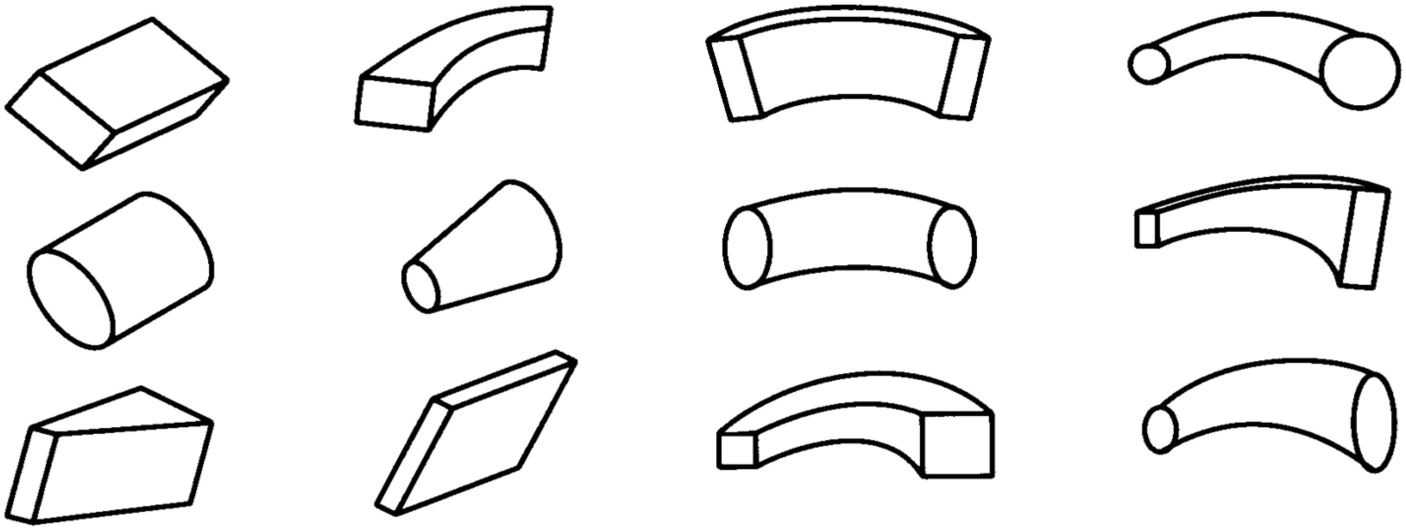


Structural theories of object recognition

- representation of a pattern includes a description of
  - individual features
  - the relations among them
- *object-centred* relations between features provide crucial information for pattern recognition

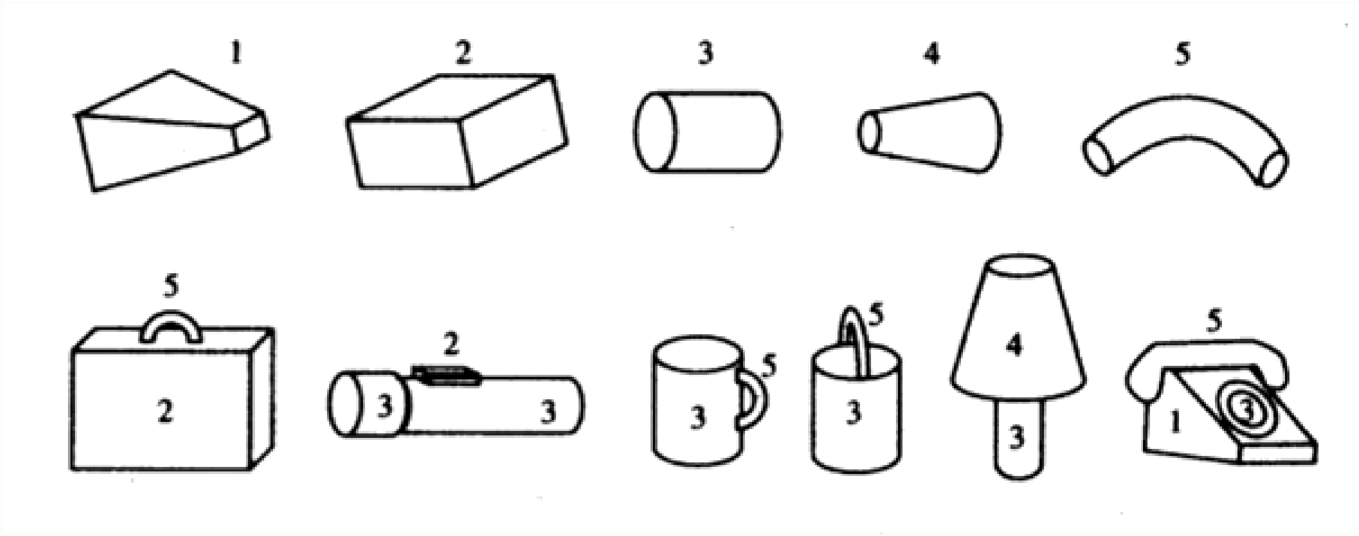
Recognition by components (Biederman, 1987)

- objects can be described in terms of small set of geometrical parts named <u>geons</u> - about 24
- geons are simple 3D shapes: cylinders, cones, wedges, etc., each in ~ 15 sizes and builds

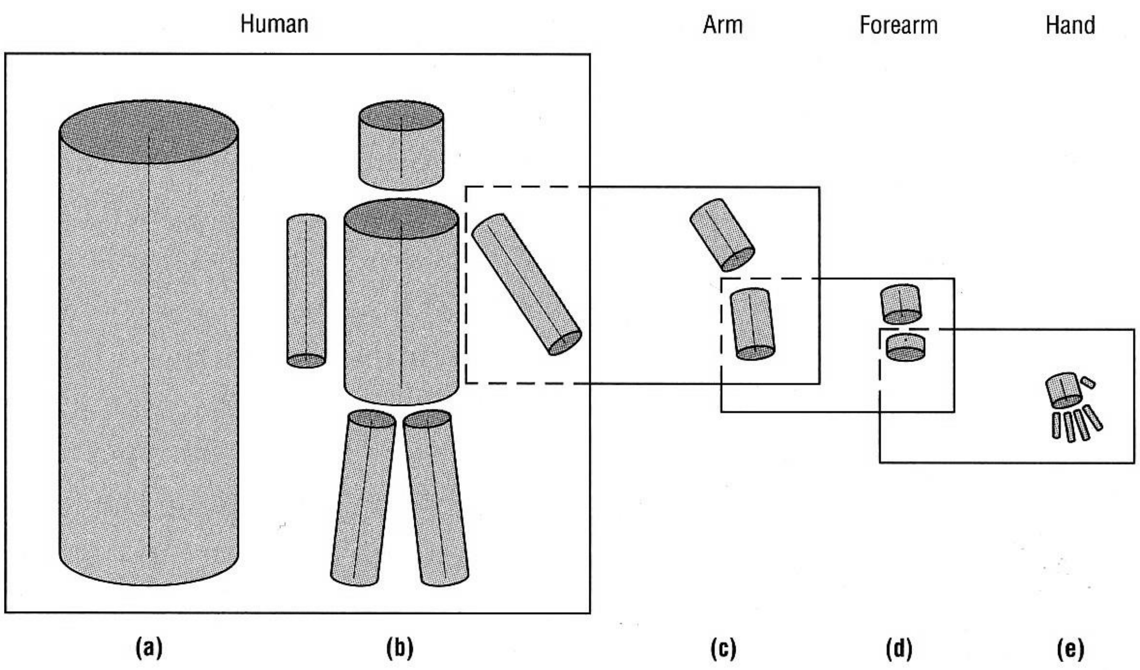


How objects might be represented by geons

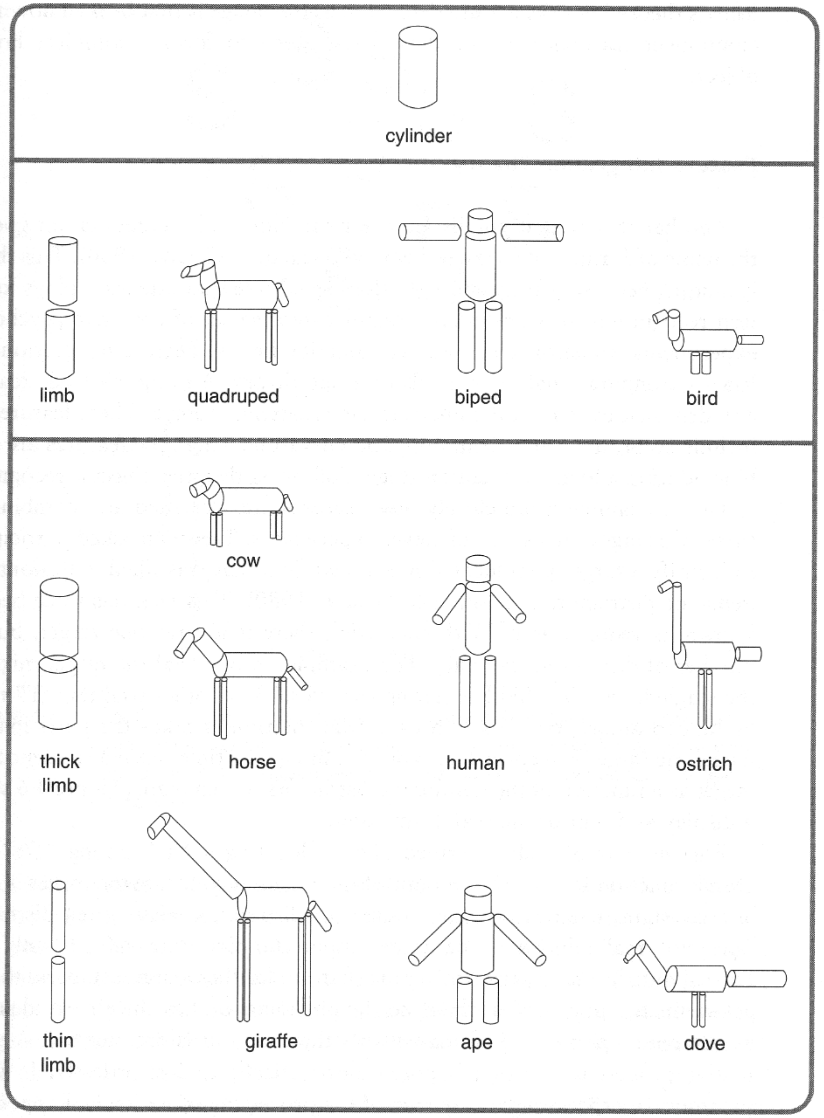
- mental representation of an object consists of array of constituent geons, along with description of spatial relations among them ("attachment relations")
- many everyday objects can be built out of 2 or 3 geons



More complex objects



Complex objects



From: Marr & Nishihara (1978)

Geons

- limited number of geons and “attachment relations” can be combined into an astronomical number of objects:
- 24 geons x 15 sizes/builds x 81 ways to join them = 10,497,600 possible objects
- many everyday objects can be built out of two or three geons into instantly recognisable shapes
- demands on the visual system are not unrealistic: object recognition implies carving up objects into shapes, and ascertaining their arrangement

Evidence from behavioural studies - Biederman (1987)

- if object recognition critically relies on attachments between geons, then deleting info about attachments should make recognition more difficult!
- brief (100 msec) presentation of images with 65% deletion of contour:

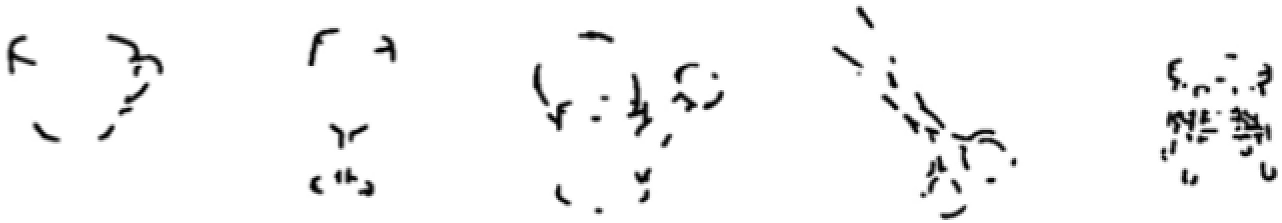
  (A) deletion from middles of segments, (less diagnostic of geon structure)

  (B) deletion at vertices (critical for identifying geon structure)
- Results: correct identification
  - condition A: 70%
  - condition B: 45%
- interpreted as support for RBC

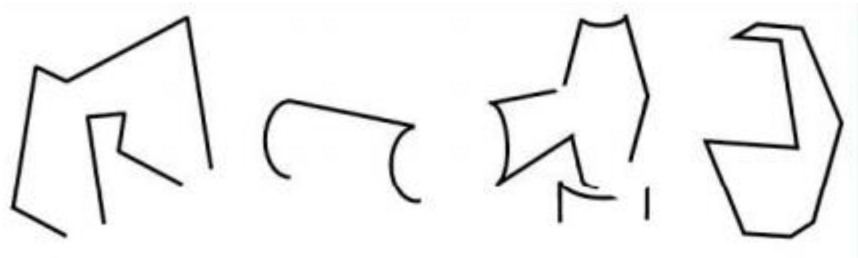
Some problems with geon theory

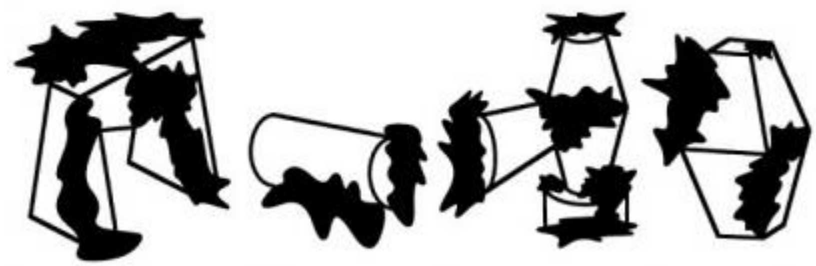
- difficult to distinguish between objects with identical (or very similar) geon structure, e.g., horse and cow?
- recognition of specific individuals (e.g. faces) - if there is a generic geon construct of face, how does the visual system distinguish between different faces?
- works well for artefacts, but less so for natural objects (mountains, trees, etc.) – what is the geon representation of a puddle?

Critique of Biederman (1997) experiment



- RBC hypothesis relies on *bottom-up* perceptual processes to interpret these fragments as 3-D volumetric shapes
- but doesn't work for unfamiliar objects
- unless additional cues are added to account for missing segments
- suggests that interpretation in both cases is based on *top-down* hypotheses about the objects (Moore & Cavanagh 1998)



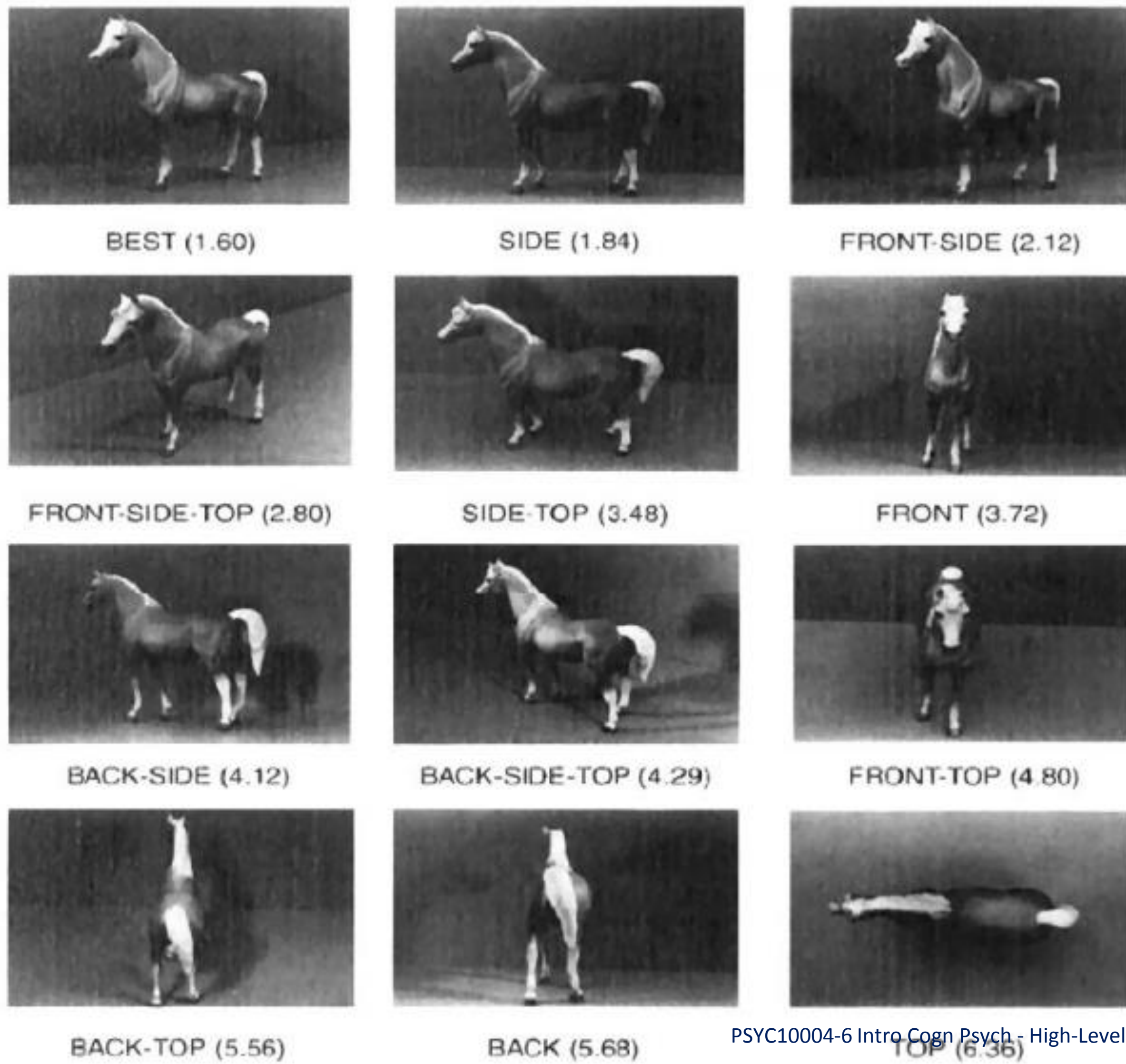


Alternatives to structural theories

- structural theories combine elements of template matching and of feature matching theories
- features and their relationship to each other are both important, but structural theories with object-centred descriptions are still inadequate
- alternative theories return to viewer-centred approach
  - object recognition based on mental representations that include multiple viewpoints
  - centred on canonical forms ("normative" view); objects are more easily recognised when seen from this viewpoint

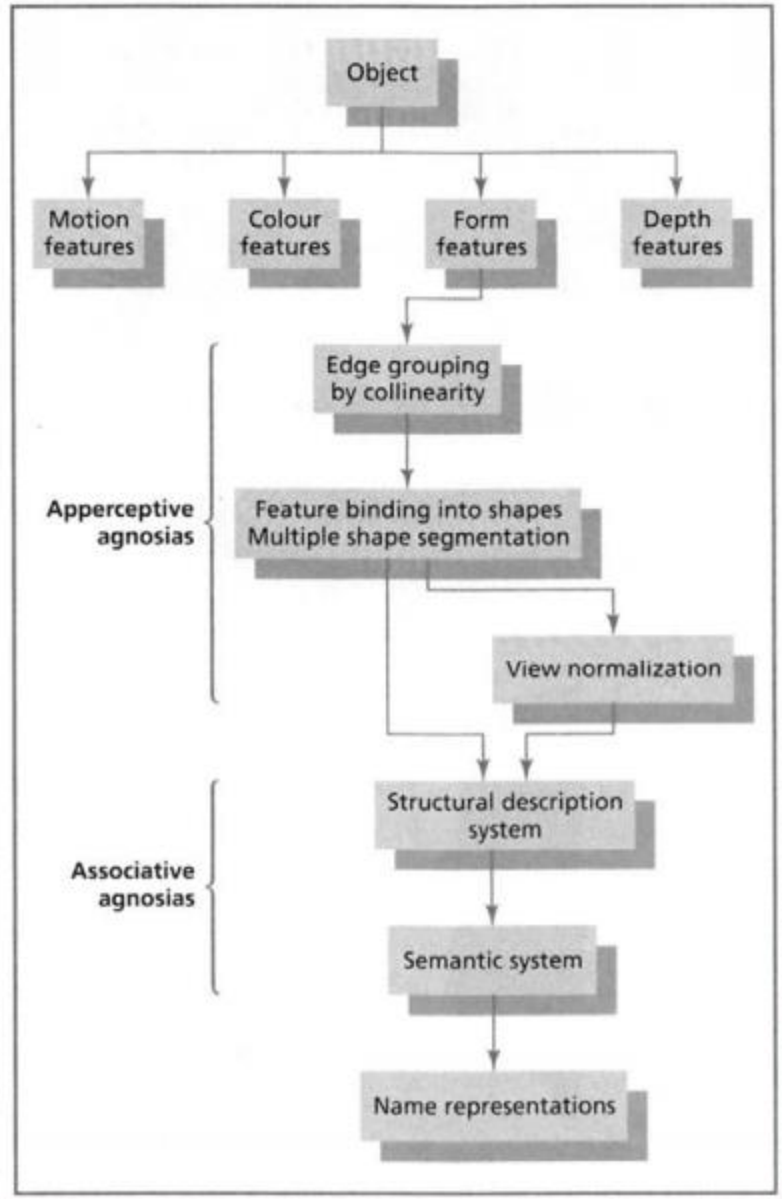
“Canonical forms” - normative object views

- rated “goodness” of images (Palmer et al., 1981):



Putting it all together (Riddoch & Humphreys, 2001)

- first stage involves basic elements – edges, bars etc.
- later stages group these elements
  - coding depth cues
  - figure/ground segregation
  - viewer-centred representation
- matching to object-centred structural descriptions in long-term memory
- access to meaning object naming



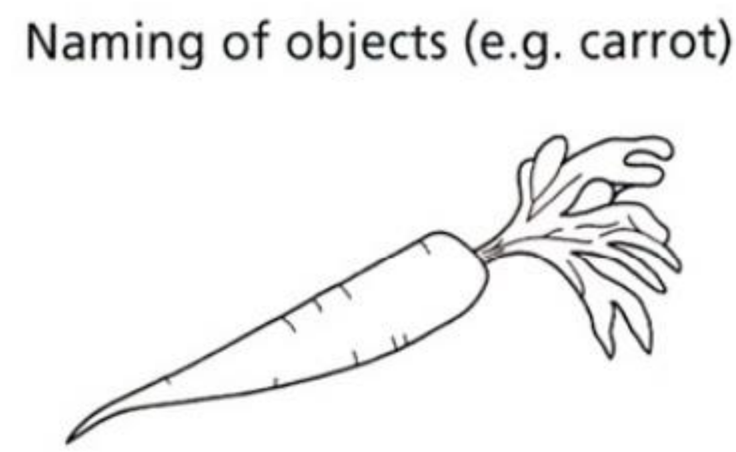
A clinical case study – apperceptive agnosia

- traditional distinction (Lissauer, 1890) between:
  - *apperceptive* agnosia - deficit in perceptual processing
  - *associative* agnosia - problem with access to stored memory representations
- a case of apperceptive agnosia - HJA (Riddoch et al., 1999)
- visual problems following bilateral stroke:
  - preserved sensory discrimination of length, orientation and position
  - severe difficulties in recognising objects
- symptoms suggest difficulty in integrating parts of an object to recognise the whole

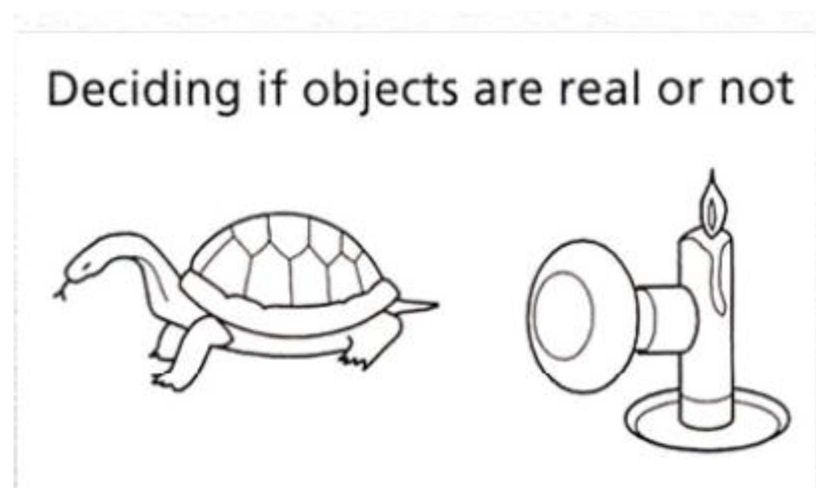
HJA’s impairments

- unable to identify pictures but can describe parts, e.g. a carrot:

“The bottom points seems solid and the other bits are feathery. It does not seem logical unless it is some sort of brush.”



- poor performance on *object decision task* when non-objects are created by recombining parts of real objects



HJA's preserved abilities

- able to copy drawings of objects he cannot recognise (i.e. low-level vision functions normally)
- can draw objects from memory – so can access structural descriptions from memory, but not from vision
- can recognise objects using other senses

Copying from a picture

Drawing from memory (e.g. owl)

Object recognition in a patient with visual agnosia

From Oliver Sacks (1998), “The man who mistook his wife for a hat”

> “About six inches in length”, he commented. “A convoluted red form with a linear green attachment.”
>
> “Yes” I said encouragingly, “and what do you think it is, Dr. P.?”
>
> “Not easy to say....”
>
> “Smell it ” I suggested.
>
> “Beautiful!” he exclaimed. “An early rose. What a heavenly smell!”

(pp 13-14)

Summary and key points

- pattern recognition is a non-trivial problem
- three different approaches to pattern recognition:
  - template matching
  - feature analysis
  - structural theories
- structural theories combine feature analysis with "holistic” processing – requires integration of feature sets as an initial stage
- mechanisms of pattern recognition are still poorly understood, but experimental evidence and clinical case studies are consistent with this conceptual analysis

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