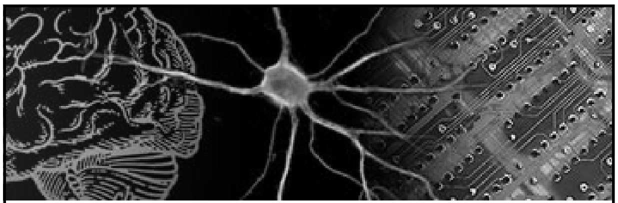

PSYC305-08A

Applied Cognition & Neuroscience

Mātai hinengaro whaipainga

Neuroscience
Neurological disorders (Lect. 14)

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Psychology Dept.
The University of Waikato

Topics:

1. Visual processing stream
   ‘what’ and ‘where’.
2. Specialized neural responding
3. Recognizing objects
4. Failures of object recognition
   - Visual Agnosias

Useful reading: Goldstein (6th Ed or 7th Ed. Chapter 4).
Some extra figures from: Gazzaniga, Ivry & Mangun. Cognitive Neuroscience. The Biology of the mind. (2nd Ed.).

In order to understand certain neurological disorders (e.g., Prosopagnosia) we need to have an understanding of where and how ‘normal’ visual processing (e.g., face and object recognition) occurs in the brain.

Review from Lect. 13:
Continuation of the magno and parvo subdivisions in visual area 1 (Primary visual cortex, V1)

Cells in magnocellular geniculate layers project to layer 4cα which then projects to 4B and then onto V2 and cortical area MT (Middle Temporal).

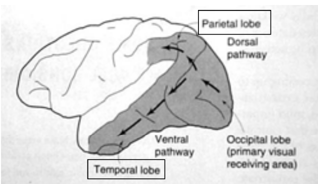
Magno ➡ 4Cα ➡ 4B

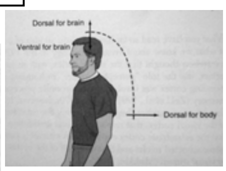
Parvocellular project to different layers of V1 and then onto V2.

Parvo ➡ 4Cβ ➡ layers 2 and 3 (blobs and interblobs)

Until now we have mainly studied the ‘lower level’ aspects of the visual system (the eye, the LGN, primary visual cortex).
We now look at the ‘extrastriate’ areas of the brain that respond to visual stimulation.

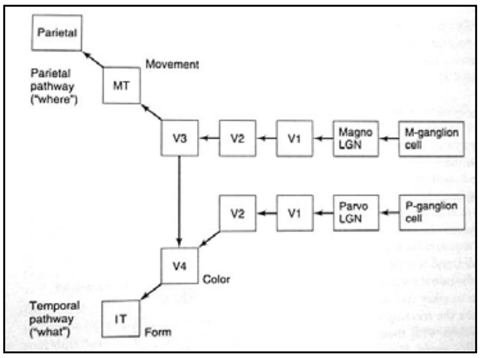
1. Visual processing streams





Dorsal fin

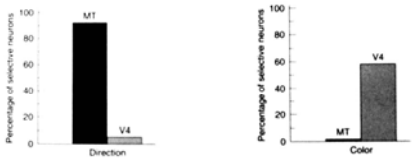
- The dorsal pathway is crucial for locating objects (the ‘where’ pathway).
- The ventral pathway is important for identifying objects (the ‘what’ pathway).



Simplified diagram of the visual pathways.

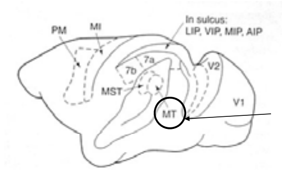
Modularity demonstrated by specialized neural responding

Certain cortical areas are processing information about specific visual qualities.



Most of the neurons in area MT (Middle temporal) are directionally selective (see next slides).

Direction selectivity in MT neurons

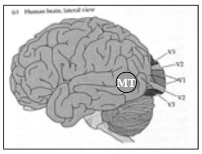


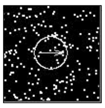
Specialized motion processing area in the primate brain

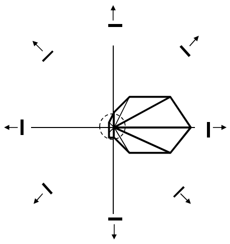
Middle Temporal (MT)

From Lect. 4

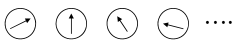
Motion sensitive neurons in MT





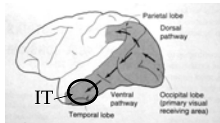


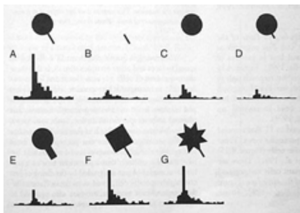
Direction tuning within MT (e.g., Albright, 1984)



Modularity demonstrated by specialized neural responding Continued.

Inferotemporal cortex (IT)
A module for Form



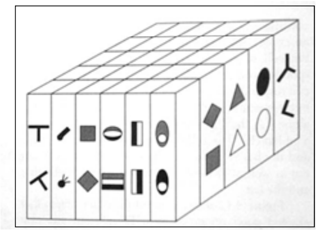


Example of a neuron that responds to complex stimuli (circular disk with a thin bar protruding from it).

(data from Tanaka et al., 1991)

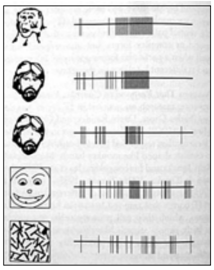
Tanaka et al., called cells in IT that responded best to simple stimuli (e.g., slits, spots, ellipses and squares) <u>primary cells.</u>

Other cells which respond best to more complex stimuli (specific shapes combined with colour or texture) they called <u>elaborate</u> cells.

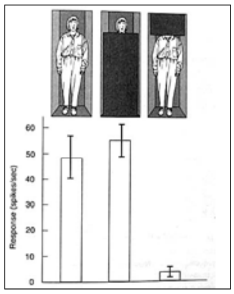


Neurons in the same column of IT cortex tend to respond to similar stimuli (compare to orientation tuning in V1).

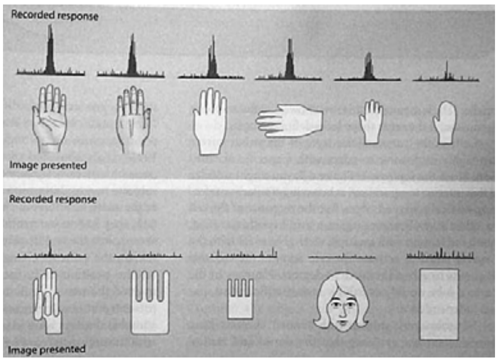
Neurons in IT that respond to faces and parts of the body:



This neuron responds best to a full face.
(Data from Bruce, Desimone & Gross, 1981).



An IT neuron that responds only to the head.
(Wachsmuth, Oram & Perrett, 1994).



Cell in IT that responds to a hand (Desimone et al., 1984).

Lesioning or Ablation Experiments

- First, an animal is trained to indicate perceptual capacities
- Second, a specific part of the brain is removed or destroyed
- Third, the animal is retrained to determine which perceptual abilities remain
- The results reveal which portions of the brain are responsible for specific behaviors

What and Where Pathways

- Ungerleider and Mishkin experiment
  - Object discrimination problem
    - Monkey is shown an object
    - Then presented with two choice task
    - Reward given for detecting the target object
  - Landmark discrimination problem
    - Monkey is trained to pick the food well next to a cylinder

What and Where Pathways - continued

- Ungerleider and Mishkin (cont.)
  - Using ablation, part of the parietal lobe was removed from half the monkeys and part of the temporal lobe was removed from the other half
  - Retesting the monkeys showed that:
    - Removal of temporal lobe tissue resulted in problems with the landmark discrimination task - What pathway
    - Removal of parietal lobe tissue resulted in problems with the object discrimination task - Where pathway

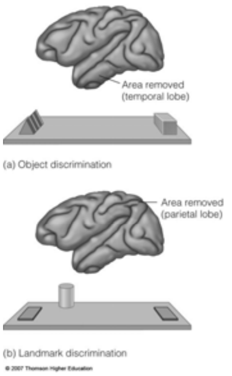


Figure 4.12 The two types of discrimination tasks used by Ungerleider and Mishkin. (a) Object discrimination: Pick the correct shape. Lesioning the temporal lobe (shaded area) makes this task difficult. (b) Landmark discrimination: Pick the food well closer to the cylinder. Lesioning the parietal lobe makes this task difficult. (*From "Object Vision and Spatial Vision: Two Central Pathways," by M. Mishkin, L. G. Ungerleider & K. A. Macko, 1983,* Trends in Neuroscience, 6, 414-417, *figure 2. Copyright © 1983 Elsevier Science Publishers B. V. Reprinted by permission.)*

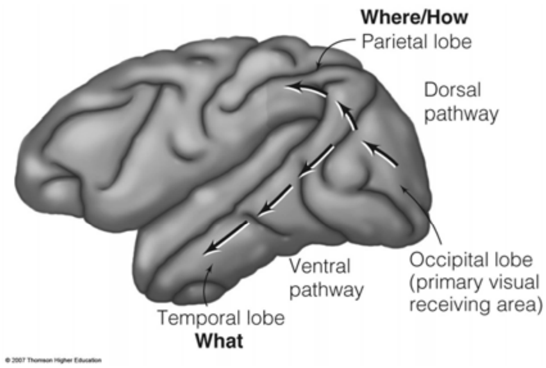


Figure 4.13 The monkey cortex, showing the *what*, or *ventral* pathway from the occipital lobe to the temporal lobe, and the *where*, or *dorsal* pathway from the occipital lobe to the parietal lobe. The *where* pathway is also called the *how* pathway (see page 81). The sequences of arrows indicate that there are a number of synapses along each of these pathways. (*From "Object Vision and Spatial Vision: Two Central Pathways," by M. Mishkin, L. G. Ungerleider & K. A. Macko, 1983,* Trends in Neuroscience, 6, 414-417, *figure 1. Copyright © 1983 Elsevier Science Publishers B. V. Reprinted by permission.*)

What and Where Pathways - continued

- What pathway also called dorsal pathway
- Where pathway also called ventral pathway
- Both pathways originate in retina
  - Ventral pathway begins in small or medium ganglion cells
    - Called P-cells
    - Axons synapse in layers 3, 4, 5, & 6 of LGN
    - Called parvocellular layers

What and Where Pathways - continued

- Dorsal pathway begins in large ganglion cells
  - Called M-cells
  - Axons synapse in layers 1 & 2 of LGN
  - Called magnocellular layers
- Ablation research with monkeys shows:
  - Parvo channels send color, texture, shape and depth information
  - Magno channels send motion information

See previous lecture and Hubel & Livingstone article

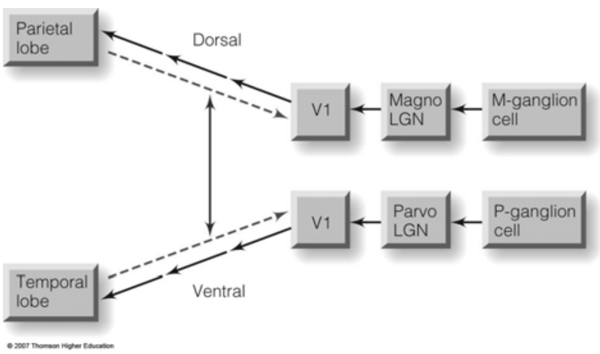


Figure 4.15 The dorsal and ventral streams in the cortex originate with the magno and parvo ganglion cells and the magno and parvo layers of the LGN. The red arrow represents connections between the streams. The dashed blue arrows represent feedback - signals that flow "backward."

What and Where Pathways - continued

- Where pathway may actually be "How" pathway
  - Dorsal stream shows function for both location and for action
  - Evidence from neuropsychology
    - Single dissociations: two functions involve different mechanisms
    - Double dissociations: two functions involve different mechanisms and operate independently

(see later slides on this topic)

2. Specialized neural responding

Modularity: Structures for Faces, Places, and Bodies

- Module - a brain structure that processes information about specific stimuli
  - Inferotemporal (IT) cortex in monkeys
    - One part responds best to faces while another responds best to heads
    - Results have led to proposal that IT cortex is a form perception module
  - Temporal lobe damage in humans results in prosopagnosia

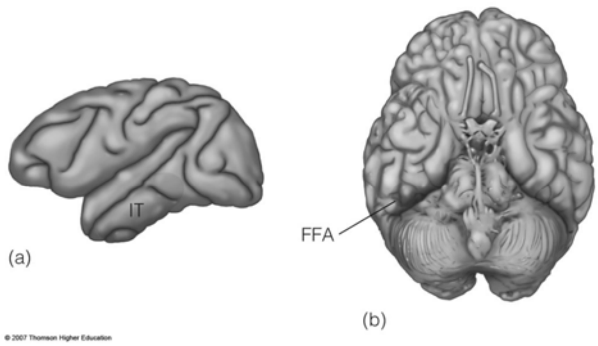


Figure 4.18 (a) Monkey brain showing location of the inferotemporal cortex (IT) in the lower part of the temporal lobe. (b) Human brain showing location of the fusiform face area (FFA) in the fusiform gyrus, which is located under the temporal lobe.

Figure 4.20 Response of a neuron in the IT cortex for which the person's head is an important part of the stimulus because firing stops when the head is covered. (*From "Recognition of Objects and Their Components Parts: Responses of Single Units in the Temporal Cortex of the Macaque," by E. Washmuth, M. W. Oram, and D. I. Perrett, 1994,* Cerebral Cortex, 4, *Copyright © 1994 by Oxford University Press.)*

Modularity: Structures for Faces, Places, and Bodies - continued

- Evidence from humans using fMRI and the subtraction technique show:
  - Fusiform face area (FFA) responds best to faces as well as when context implies a face
  - Parahippocampal place area (PPA) responds best to spatial layout
  - Extrastriate body area (EBA) responds best to pictures of full bodies and body parts

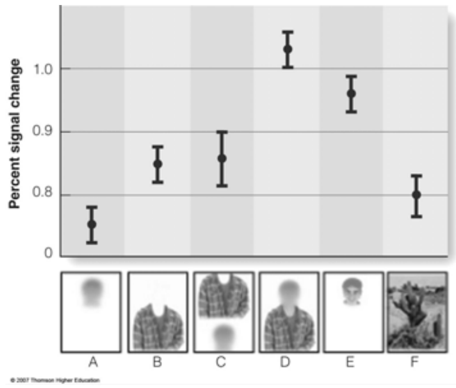


Figure 4.21 fMRI response of the human fusiform face area. Activation occurs when a face is present (E) or is implied (D) but is lower when other stimuli are presented (A,B,C,F). (*Reprinted with permission from Cox, D., Meyers, E., Sinha, P. (2004). Contextually evoked object-specific responses in human visual cortex,* Science, 304, *115-117.*

Evolution and Plasticity: Neural Specialization

- Evolution is partially responsible for shaping sensory responses:
  - Newborn monkeys respond to direction of movement and depth of objects
  - Babies prefer looking at pictures of assembled parts of faces
  - Thus "hardwiring" of neurons plays a part in sensory systems

Evolution and Plasticity: Neural Specialization - continued

- Plasticity of neurons also shapes sensory responses
  - Experience-dependent plasticity in animals
    - Monkeys trained to recognize specific view of unfamiliar object
    - Other views of object showed decline in recognition as object rotated from trained view
    - Neurons in the IT cortex showed maximal response to the trained orientation

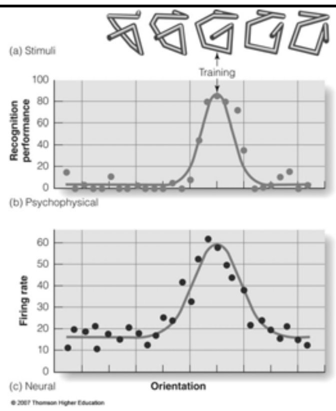


Figure 4.23 (a) Stimuli like those used by Logothetis & Pauls (1995). (b) Monkey's ability to recognize the training shape and rotated views of the shape that were not seen during training. (c) Response of neurons in the IT cortex of the trained monkey to the training shape and the rotated shape.

Evolution and Plasticity: Neural Specialization - continued

– Experience-dependent plasticity in humans
  - Brain imaging experiments show areas that respond best to letters and words
  - fMRI experiments show that training results in areas of the FFA responding best to:
    – Greeble stimuli
    – Cars and birds for experts in these areas

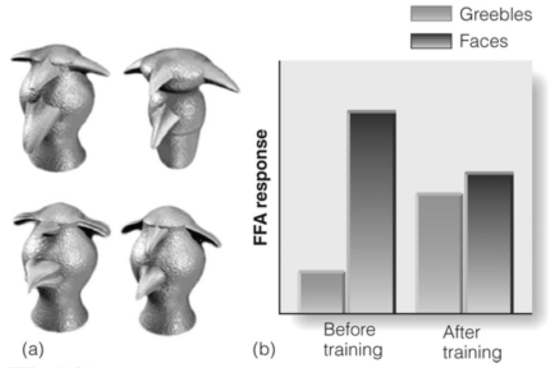


Figure 4.24 (a) Greeble stimuli used by Gauthier. Participants were trained to name each different Greeble. (b) Brain responses to Greebles and faces before and after Greeble training. (*a: From Figure 1a, p. 569, from Gauthier, I., Tarr, M. J., Anderson, A. W., Skudlarski, P. L., & Gore, J. C. (1999). Activation of the middle fusiform "face area" increases with experience in recognizing novel objects.* Nature Neuroscience, 2, *568-573.)*

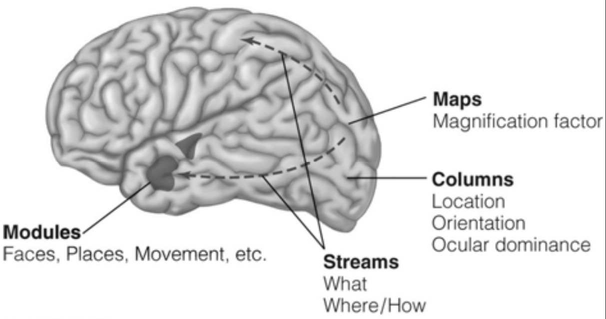


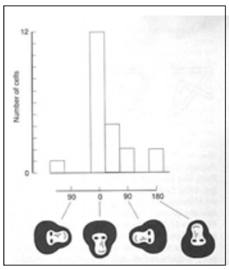
Figure 4.25 Ways that the brain is organized.

3. Recognizing objects

Object Perception: Why is it so hard?

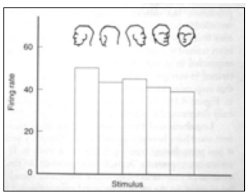
Despite large changes in viewpoint, colours, time of day etc., we can still recognize objects.

Some cells in IT respond best to faces seen in a particular view, others respond to different views of the face.



View-specific cells

(Tanaka et al., 1991)



View-invariant cells (respond equally well to different views of the same face). Perrett & Oram, 1993.

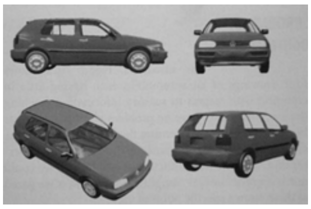
General findings on IT neurons:

Two classes of cells can be found:

(1) size-, location-, and view-*invariant* neurons.
The respond to a stimulus even when its size, location, or viewing angle is changed.

(2) size-, location-, and view-*specific* neurons.
These respond only to specific sizes, locations, and views.

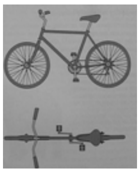
It is unlikely that a particular face or a particular complex object is signaled by the firing of just one highly specific cell (our perception of faces is determined by the firing of a number of neurons).



Different images on the retina but
still recognizable as the same object.

Shadows Occlusion

Object 'constancy' must be achieved in spite of many sources of variation in the sensory input.



Different viewpoints

Object recognition (quick overview)

View-dependent or view-invariant recognition?

(1) View-dependent theories:
Perception is assumed to depend on recognizing an object from a certain viewpoint.

The theory argues that we have many different specific representations in memory.

The stored representation for recognizing the bike from the side is different from the one used to recognize the bike from the top.

Problem with view-dependent theories?

Too much perceptual memory required.

But.. system could use interpolation

Recognition of an object seen from a novel viewpoint occurs by comparing the stimulus information to the stored representations and choosing the best match.

(2) View-invariant frame of reference theories.

Recognition does not happen by simply analyzing the stimulus information. Rather, sensor input defines basic properties; the object's other properties are defined with respect to these properties.

e.g., David Marr's theory.

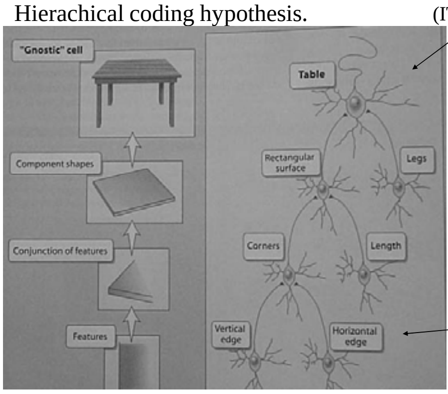
Critical property for recognition is establishing the major and minor axes inherent to the object.
A bike has a major axis running along its length. The handlebars can be represented as the minor axis (two appendages arranged perpendicular to the primary axis).

The properties will generally hold across different vantage points.

Object recognition in the brain:

Hierachical coding hypothesis.

Inferotemporal (IT) neuron



Edge detectors (Simple cells in V1)

Does this mean we have a 'grandmother cell' ?

There might be gnostic cells which only become active when one's grandmother is seen, another for the Golden Gate bridge etc etc.

But we need to consider:

(1) The idea of a grandmother cell rests on the assumption that the final percept of an object is coded by a single cell. Since cells are in a constant state of spontaneous firing, a 'single cell' coding scheme would be highly susceptible to error. If a gnostic unit were to die, we would experience a sudden loss for an object.

(2) The grandmother cell hypothesis cannot adequately account for the fact that we perceive novel objects, a perception whose mechanism is unexplained.

Alternative theory: Ensemble coding hypothesis.

Object recognition results from activation across complex feature detectors.

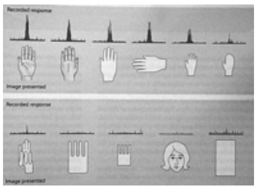
Grandmother is recognized by the co-occurrence of her glasses, facial shape, hair colour, etc.

Single-cell studies of temporal lobe neurons are in accord with ensemble theories of object recognition.

Some cells are selective for complex objects (like gnostic cells) but… the selectivity is almost always relative, not absolute.

The cells in the inferotemporal cortex prefer certain stimuli over others, but they are also activated by visually similar stimuli.

e.g., No cells respond to a particular individual's hand.
In contrast, our perceptual abilities demonstrate that we make much finer discriminations.



Goldstein (Ch. 4) refers to these two theories of object recognition as:

Specificity Coding: Representing of specific stimuli by the firing of neurons that are specialized to respond to just these stimuli. (= heirachical coding)

Distributed Coding: Representation of specific stimuli by the pattern of firing of many neurons. (= ensemble coding)

See next slide for face recognition example.

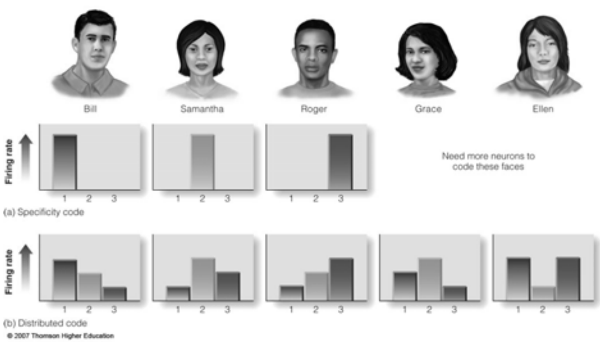


Figure 4.26 How faces could be coded according to (a) specificity coding and (b) distributed coding. The height of the bars indicates the response of neurons 1, 2, and 3 to each stimulus face. See text for explanation.

4. Failures of object recognition

- •Apperceptive Agnosia
- •Associative Agnosia
- •Prosopagnosia

+ Goldstein (6th & 7th Ed), Chapters 4, 5
Material and figures from:
Cognitive Neuroscience: The biology of the mind
M.S. Gazzaniga, R.B. Ivery & G.R. Mangun.

Visual agnosias: Seeing without recognizing.
(failures of object recognition).

See Goldstein textbook

Some definitions:

•Neuropsychology: Understanding the behaviour of patients with cortical damage.

What are Visual Agnosias?

The History of Agnosias

Although relatively rare, agnosias have been recognized at least since the time of classical Greek civilization. Thucydides suggested that agnosias develop because of the plague as early as 430 BC. Hippocrates also mentioned symptoms of agnosias in his writings "On Sacred Disease." The term *agnosia* is derived from the Greek "a" meaning not, and "gnosis" meaning to know. Broadly, the term refers to the failure to know or recognize an object or scene despite good basic vision. Systematic experimental research on visual agnosias began with Monk's 1877 observation of the effects of certain brain lesion on dogs. Although able to walk without bumping into objects, the dogs behaved abnormally when presented with food, or a whip. This suggested that the dogs were able to see but not recognize objects, an effect that Monk termed "seelenblindsheit".

Freud coined the term "visual agnosia" in 1891, using it to distinguish between perception and recognition. Freud's term is still used today to refer to a neurologically based inability to recognize or identify familiar objects in the absence of a primary visual problem (i.e., acuity, brightness discrimination and visual fields are all intact), a psychiatric disorder, or other serious cognitive or intellectual loss (e.g., aphasia, alexia). Typically, agnosias are acquired disorders due to brain lesions (e.g., trauma, stroke, tumor, or carbon monoxide poisoning) that impair functioning of one or more higher order visual centers .

From:
http://www.psych.ucalgary.ca/PACE/VA-Lab/Visual%20Agnosias/what%20are.html

Studying dissociations. One function is absent while another is is present. (e.g., consider a broken television set. It can lose its colour but still have a picture).

•Single dissociation: One function is absent and the other is present. It indicates that the two functions involve different mechanisms although they may not operate totally independently of one another.

•Double dissociation: One function is absent and the other is present *and* the opposite can also occur.

e.g., TV analogy (see Goldstein Table 4.1).

	Function 1 Sound	Function 2 Picture
Broken TV set #1	OK	No
Broken TV set #2	No	OK

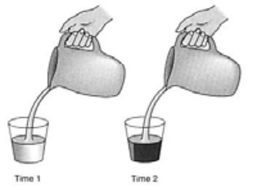
When double dissociation occurs, it means the two functions involve different mechanisms that operate independently of one another.

e.g., Double dissociations for people with brain damage.

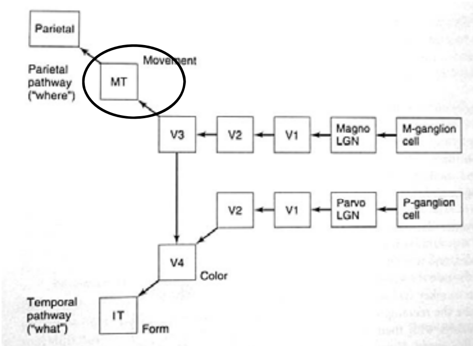
	Function 1 Visual-motor orientation	Function 2 Judging visual orientation
Ventral stream damage	OK	No
Dorsal stream damage	No	OK

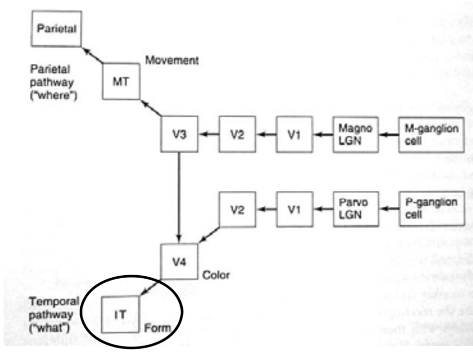
From Lect. 4
Motion information is very important for survival.

See description of patient with motion agnosia (p. 270, Goldstein).



Patient with motion agnosia (Zihl et al., 1991) perceived no change in the level of water being poured into a cup. People suddenly appeared and disappeared.

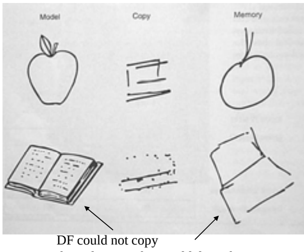




Person (DF) with damage to ventral processing stream (CO_2 poisoning accident). Milner & Goodale, 1995 study.

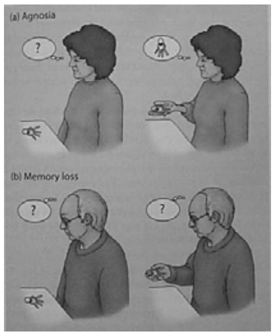
She had good colour and detail vision, but was unable to recognize simple geometric forms and was unable to identify objects pictured in line drawings.

A picture of a screwdriver was described as being 'long, black and thin', but she knew what a screwdriver was and could identify one by feeling it with her hand.



DF could not copy these drawings but could draw them from memory.

The inability to recognize common objects even though they can be seen is called <u>visual form agnosia.</u>



To diagnose agnosic disorder, it is essential to rule out general memory problems.

(a) Patient with agnosia is unable to recognize the keys by vision alone, but immediately recognizes the keys when she picks them up.

(b) Patient with memory disorder is unable to recognize the keys even when he picks them up.

<u>Visual agnosia</u> is when patients have difficulty recognizing visually presented objects, despite the fact that the visual information continues to be registered at the cortical level.

Two subtypes

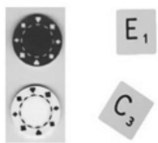
<u>Apperceptive agnosia</u>

Failures in object recognition linked to problems in perceptual processing.

<u>Associative agnosia</u>

Occurs in patients who derive normal visual representations but cannot use this information to recognize things.

Apperceptive agnosics are unable to distinguish visual shapes and so have trouble recognizing, copying, or discriminating between different visual stimuli. When patients are able to identify objects, they do so based on inferences using colour, size, texture and/or reflective cues to piece it together. For example, in the image below, an apperceptive patient may not be able to distinguish a poker chip from a scrabble tile despite their clear difference in shape and surface features.



Apperceptive Agnosia

e.g., Patient with widespread bilateral cortical damage (carbon monoxide poisoning).

The poisoning did not produce any scotomas (region of the visual field that is completely blind) and the patient could distinguish small differences in brightness and colour.
However:
•He could not distinguish between even the simplest shapes,

•He could not read letters (except simple vertical ones like ‘I’).
•He could not copy drawings
•face perception was impossible for him
(he failed to recognize his own face in a mirror).

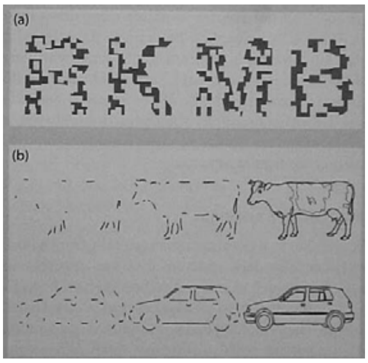
Apperceptive Agnosia (continued)

•Perceptual problems are subtle. Often standard clinical evaluations may fail to reveal any visual problems.

•A patient may perform normally on shape discrimination tasks yet make many mistakes when asked to recognize line drawings or photographs of objects.

To demonstrate that an agnosia is truly of the apperceptive subtype and not an associative agnosia, it is necessary to devise refined tests of perceptual acuity:

e.g. see next slide.



Incomplete Letters Task
(Harder for patients with agnosia following right hemisphere lesions)

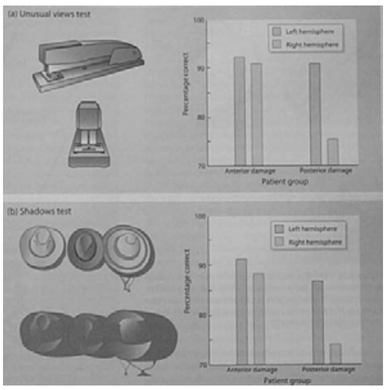
Gollin Picture Task

Patients with right-hemisphere lesions require more complete drawings in order to correctly identify the objects.

Elizabeth Warrington (National Hospital, London) has studied perceptual disabilities extensively.

She hypothesised that perceptual categorization is impaired in patients with apperceptive agnosia arising from right-hemisphere damage.

To test this hypothesis Warrington designed the Unusual Views Test and the Shadows Test (see next slide).



Patients with right-hemisphere lesions (especially in the posterior area) did much worse than controls (not shown) and patients with left hemisphere lesions.

Associative Agnosia

A failure of visual object recognition that cannot be attributed to perceptual abilities.

These patients rarely perform normally on perceptual tests, but their perceptual deficiencies are not proportional to their recognition problems.

Associative agnosias are also known as *visual object agnosias*. Although they can present with a variety of symptoms, the main impairment is failure to recognize visually presented objects despite having intact perception of that object. A patient with an associative agnosia may be able to replicate a drawing of the object but still fail to recognize it. Errors in misidentifying an object as one that looks similar are common.

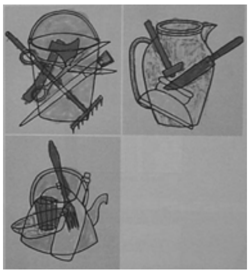
Associative agnosias are also known as *visual object agnosias*. Although they can present with a variety of symptoms, the main impairment is failure to recognize visually presented objects despite having intact perception of that object. A patient with an associative agnosia may be able to replicate a drawing of the object but still fail to recognize it. Errors in misidentifying an object as one that looks similar are common. Three specific criteria are associated with a diagnosis of associative agnosia (Farah,1990):

1) Difficulty recognizing a variety of visually presented objects (e.g., naming or grouping objects together according to their semantic categories).
2) Normal recognition of objects from a verbal description of it or when using a sense other than vision such as touch, smell, or taste.
3) Elementary visual perception intact sufficient to copy an object.

Overall, this loss can be thought of as "recognition without meaning".

e.g., Patient, F.R.A. awoke one morning and found that he could not read his newspaper (acquired dyslexia).
He had a lesion primarily in the occipital region of the left-hemisphere.

He could copy geometrical shapes with ease and could point to objects when they were named. He could also segment complex drawings into parts (Apperceptive agnosia patients cannot do this at all).



However he could not name the objects he had coloured.

•When shown line drawings of common objects, F.R.A could name or describe the function of only half of them.
(But if he was given the name verbally, he could readily generate a verbal description).

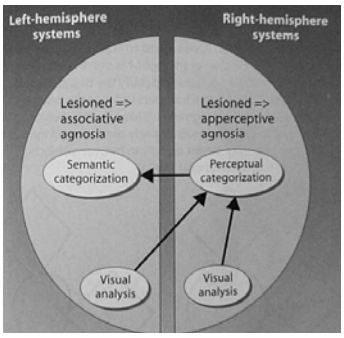
•If shown pictures of two animals (e.g., a mouse and a dog), and asked to point to the largest, he could not do it.
(but if the two animal names were said aloud, he could do it perfectly).

Therefore the problem was clearly restricted to the visual modality.

•The ability to recognize the meaning of visually presented objects was compromised by the stroke.

In both types of agnosias, the deficits are subtle and hard to detect. Strokes often go unnoticed until the patient discovers an inability to perform a task.

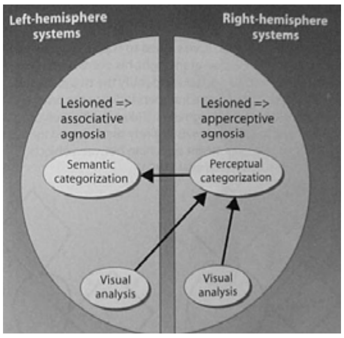
An example of a model that attempts to explain problems in object recognition:



Warrington's (1985) two-stage model of object recognition.

Visual analysis occurs in both hemi-spheres, at least when we look directly at an object.

An example of a model that attempts to explain problems in object recognition:

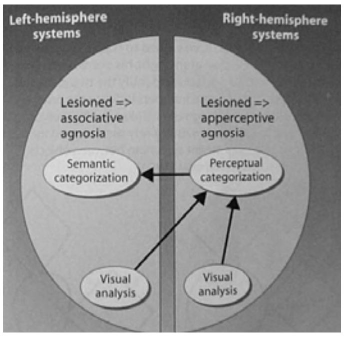


Warrington's two-stage model of object recognition.

1) The 1st stage of object categorization is perceptual, the processes required to overcome the perceptual variability in the stimulus (e.g., shadowing, different views).

Depends on right hemisphere

An example of a model that attempts to explain problems in object recognition:



Warrington's two-stage model of object recognition.
2) The 2nd stage involves semantic categorization in which the perceptual representation is linked to semantic knowledge.
The visual input is linked with knowledge in long-term memory concerning the name and functions of that input.

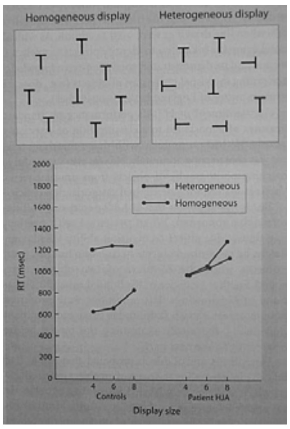
Depends on left hemisphere.

The Warrington model is a simple look at how we go about recognizing objects. However it requires elaboration:

•Neuropathological findings have not always proved a correspondence between associative agnosia and left-hemisphere lesions (patients usually have bilateral lesions).

•Unilateral right-hemisphere lesions in the occipitotemporal region can produce an agnosia more similar to the associative subtype than the apperceptive subtype.

•The model fails to capture the integration problems faced by some patients, i.e., the inability to synthesize parts into a coherent whole (see next slide).



Patients with <u>integrative agnosia</u> have difficulty grouping common elements together. Normal subjects find the upside down T much faster when all of the distractors are upright T's. Their reaction times are much slower when the distractors are heterogeneous.

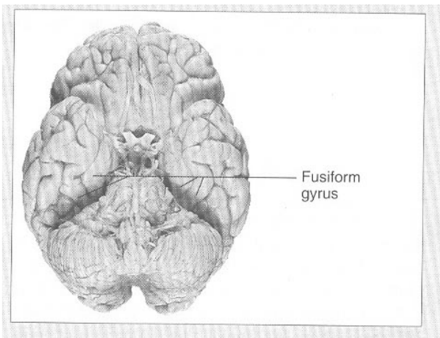
Patient H.J.A. presumably could not group the common elements and had the same RT's in both conditions.

Prosopagnosia: The inability to recognize faces.

Person with prosopagnosia have difficulty recognizing faces of familiar people. Even very familiar faces are affected (close friends, members of family and even one's own face in the mirror).

Implies damage to the temporal lobe.

http://www.prosopagnosia.com/main/stones/index.asp



The fusiform face area (FFA) is located in the fusiform gyrus.

FMRI techniques have revealed areas of the brain selective for face perception.

Note: There are many other types of agnosias and specific visual deficits.

The main point is that an understanding of basic visual processing and neural functioning is key to discovering what is causing these problems.