Review of Classes 3-6

Huge thank you to these peer tutors for the following review slides:

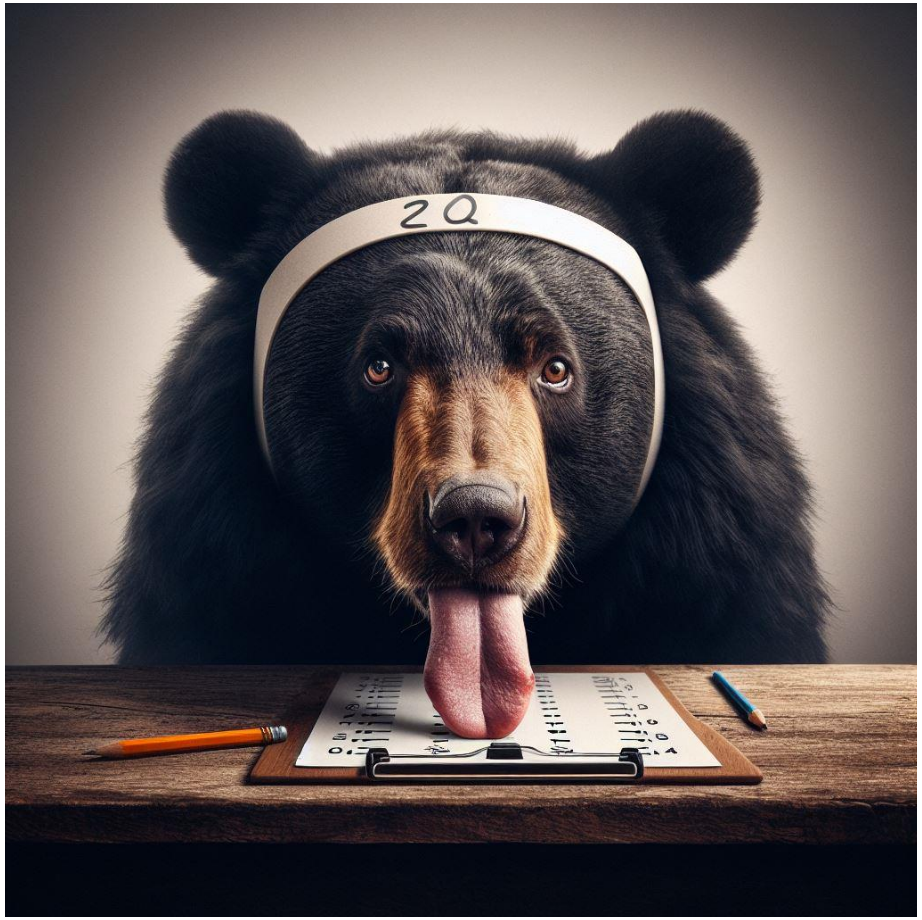
- **Giselle Mirfallah**
- **Ava Momeni**
- **Tishya Kumar**
- **Lochlan Walsh**

Methods of Cognitive Neuroscience

Classes 3 and 4

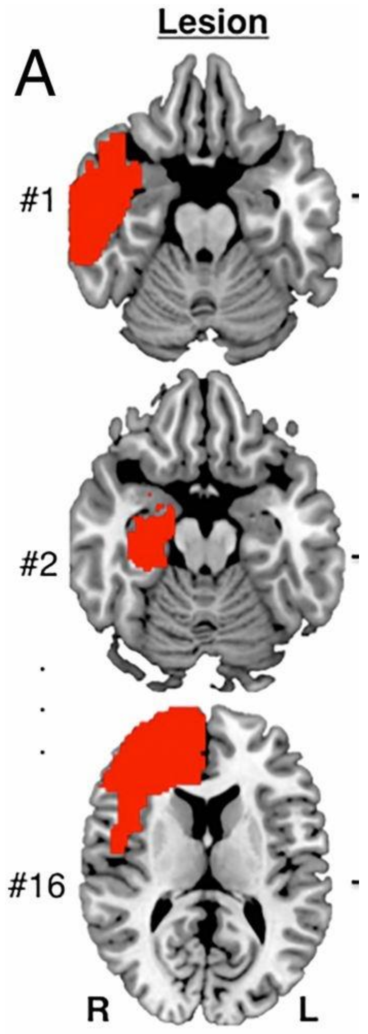
Lesion studies

- Examine the way damage or inactivation of specific brain areas →study the deficits in behaviours and specific cognitive processes.
- Causal relationship
- An approach where the brain changes while we measure behaviour

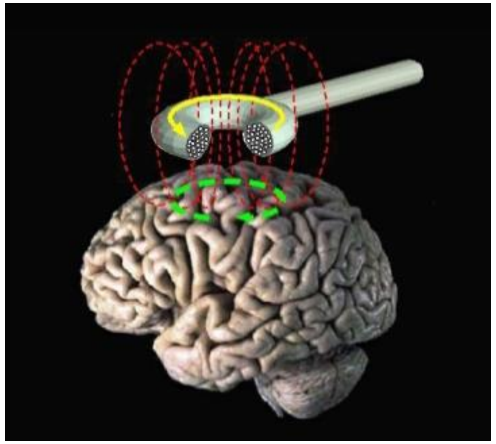


Lesion network mapping

- Find different lesion locations linked to problems w a given behaviour in different people
- Look for a single network they are all a part of
  - E.g., a “moral decisions making network” involved in morality value-based decisions making



NEUROMODULATION: Transcranial Magnetic (TMS) & Electric Brain Stimulation (TES)



- Uses an electromagnetic coil/electrodes to ramp up or damp down neuron activity
- Can activate or inhibit specific regions of cortex
- Test behaviour/cognitive processes

2 Kinds of Mechanistic Insight

Strength of Causal Evidence	Level of Mechanism			
	Molecules	Cells	Populations	Networks
Purely observational (no causality)				
Manipulate psychological processes & observe brain				
Manipulate brain and observe psychological effects			Focal Lesions Neuromodulation (TMS/TES)	Lesion Network Mapping

Poldrack & Farah, 2015

What are the strengths and disadvantages of these approaches?

Summary: Lesions Found or Created

- The brain is either damaged or manipulated
- Behaviour is used as the dependent measure
- Allows inference that a brain region is necessary for that function
  - … or the network it's part of

BRAIN IS CHANGED, MEASURE BEHAVIOUR

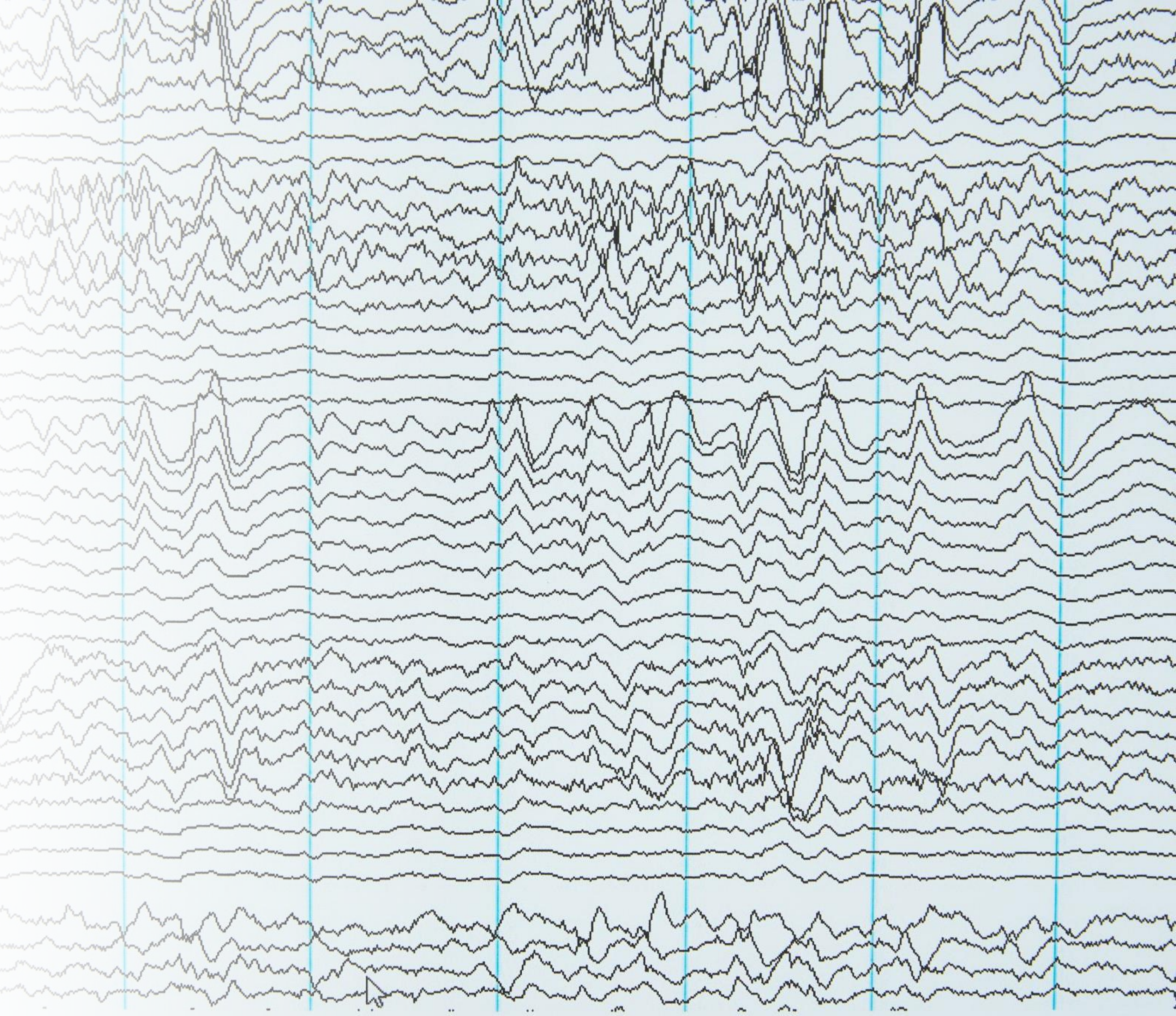
Methods looking directly at brain structure and activity

- EEG→ measured at the scalp
- MEG – measure at scalp, can model sources of activity
- ECoG/Stereo EEG→ electrode placed on the surface of or in the brain directly
- PET→ usually measuring neuromodulator activity
- MRI/DTI→ measures the structure of the brain
- fMRI→ measures the ration of oxygenated/de-oxygenated blood the brain

BEHAVIOUR IS CHANGED,
MEASURE BRAIN

EEG

- EEG measures cumulative electrical activity outside of columns of cortical cells
- EEG waves reflect the electrical output of columns of cortical neurons
- Poor spatial resolution→ hard to know where exactly the signal is coming from



EEG

Event-related potentials (ERPs)

- Averaged EEG signal following a stimulus or response
- Compare between groups and conditions
- ERP components→ linked to specific processes

Frequency domain analyses

- Frequency domain analysis → decomposes EEG signal into signals of different frequencies→
- Now we look at synchrony in oscillations between distant regions or over time
- By breaking down the EEG we can study how the populations of neurons in distant brain regions work together to produce cognition

MEG

- Like EEG, MEG picks up activity for a population of neurons
- EEG and MEG both have a good temporal resolution
- Uses magnetic detectors surrounding the had, these magnetic fluctuations are produced by the electrical activity of neurons
- Better spatial resolution than EEG→ since signals are not distorted by the scalp

Intracranial EEG (ECoG-Stereo EEG)

- When you put an electrode or grim of electrodes directly onto the brain
- Very invasive- needs a good medical reason- no control over where the electrode is placed- epileptic brains are different

PET

- Radioactive tracers mostly tag neurotransmitters
- Invasive – radioactive material injected
- Very slowwww→ poor temporal resolution

2 Kinds of Mechanistic Insight: The table so far

Strength of Causal Evidence	**Level of Mechanism**			
	Molecules	Cells	Populations	Networks
Purely observational (no causality)	Correlations of PET imaging with psychological traits			
Manipulate psychological processes & observe brain	Task modulation studies using PET with neurotransmitter ligands	Intracerebral recording in surgical patients	Task activation studies (EEG/MEG)	Task-based functional connectivity (EEG/MEG)
Manipulate brain and observe psychological effects		Direct brain stimulation in surgical patients	Focal Lesions Neuromodulation (TMS/TES)	Lesion Network Mapping

What are the strengths and disadvantages of these approaches?

MRI

- Protons in nuclei of H atoms in water naturally resonate when the direction of the magnetic field is suddenly changed
- Different tissues produce different images → you can distinguish between white and gray matter and CSF

fMRI

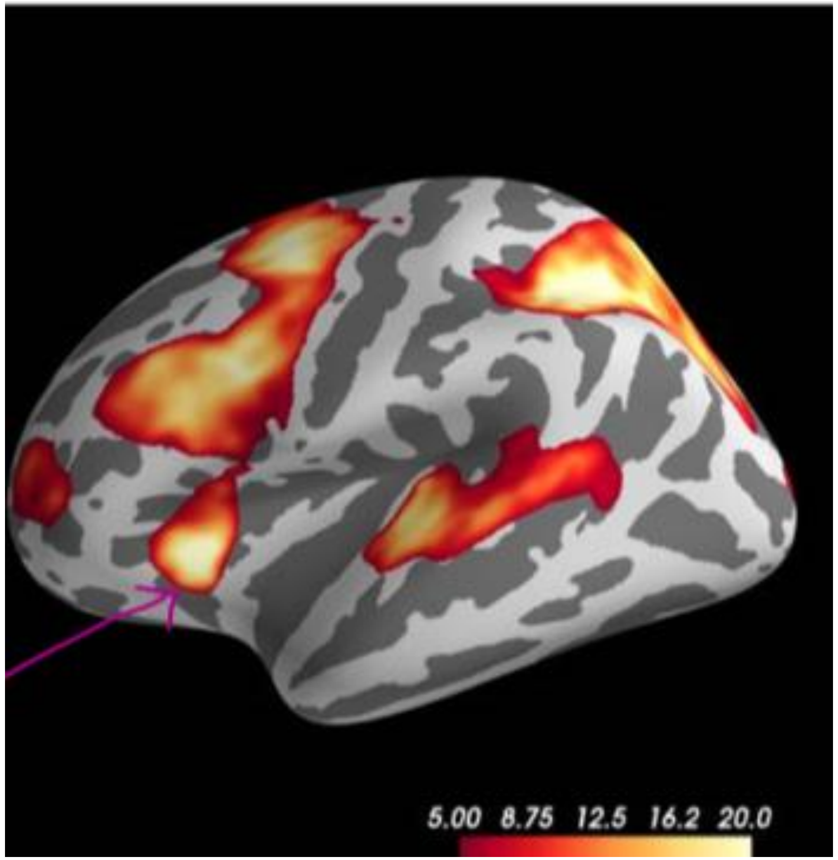
- Measures DIFFERENCE in activity between groups of experimental conditions → COMPARISON
- Does not directly measure neural activity → measures BOLD
- Oxygenated blood delivered to regions that need it will alter the brain’s magnetic signal
- DV→ BOLD response: changes in the ratio of oxygenated: deoxygenated blood

DV=Bold response

- Signal processing is done on fMRI signal
- The statistics produce blobs
- This is a statistical map →the red pattens are parts of the brain that are more active at a certain statistical threshold

→Colours =statistical threshold NOT brain or neural activity

- Voxel is the unit of measurement



Two approaches to analyzing the fMRI data

1) Encoding –standard
   - “brain mapping” → use a stimulus or experimental task and measure activity that is evoked

2) Decoding
   - Look at brain activity and predict or decode what stimulus or cognitive process is producing it

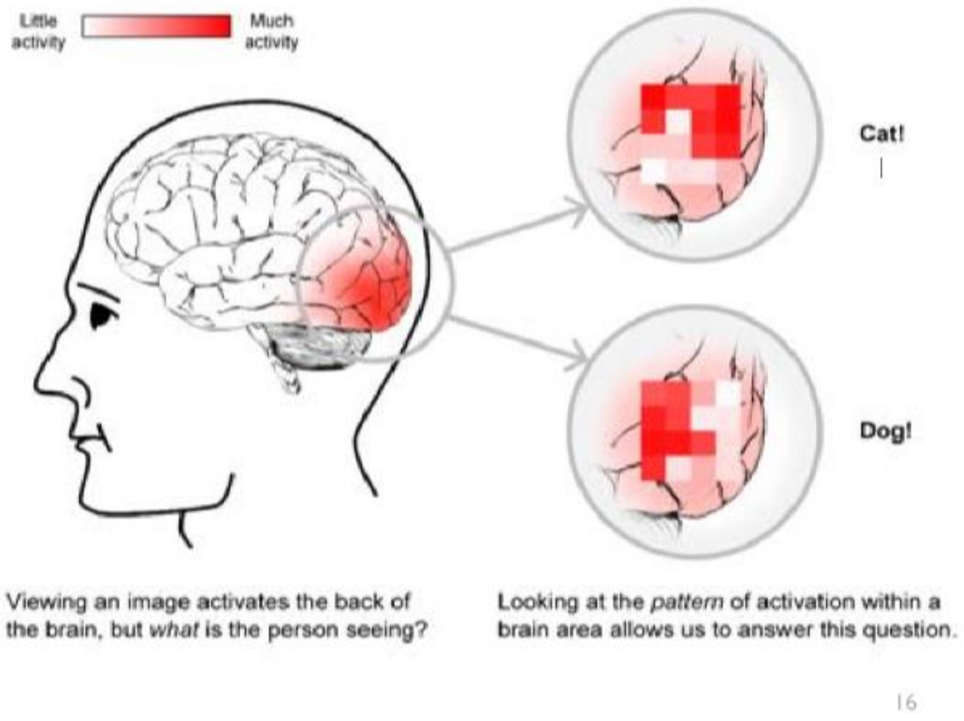
Standard (Encoding)

- Goal → brain mapping → discovering regions responsible for basic mental processes
- Identify regions active during on experimental condition vs another
- → Look at average activation for each individual voxel across trials in each condition and measure the difference between conditions

BUT maybe coding depends on pattern of high and low activation across voxels instead of in individual voxels → this is the idea behind representational approach

Multivoxel decoding appraoch

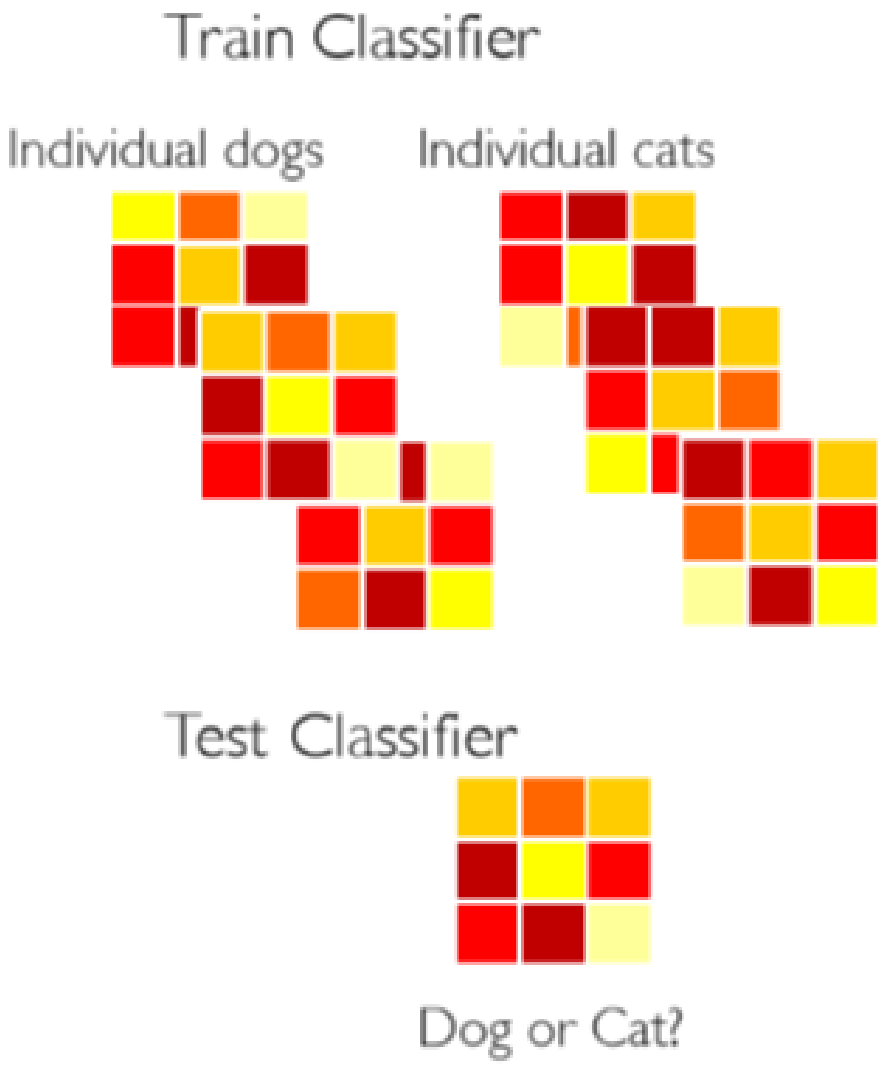
- Decoding→ look at brain activity to predict what the stimulus or cognitive process producing it is
- Two common multivoxel approaches are:
    1) Multivoxel pattern analysis (MVPA)
    2) Representational similarity analysis (RSA)



MVPA

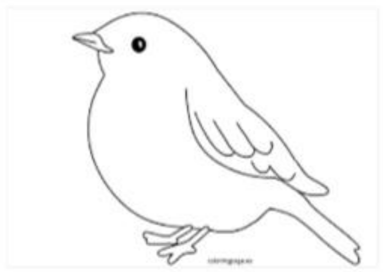
- How do PATTERNS of activation across voxels REPRESENT object categories or mental states?

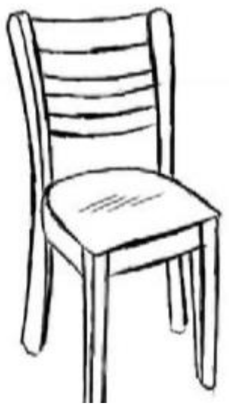
Dependent variable?



RSA

- How similar are brain representations to each other?
  - Does my brain represent a robin as more like a parrot or a chair?





Summary

Encoding	Decoding (Representational)
What parts of the brain lights up when you do something! INDIVIDUAL VOXELS	What does the brain activity tell us what you are doing?
Goal→ functional brain mapping	Goal→ mind reading

How do we measure connectivity?

1) Anatomical/structural connectivity:
   - Presence of axonal connections
   - Ex. DTI or myelin imaging

2) Functional connectivity
   - Correlation in activation between BOLD activity in different areas over time
   - Whether or not they are structurally connected is unimportant

   Examined while doing an experimental task for lying in the scanner “at rest” or watching movies (→ intrinsic network)

2 Kinds of Mechanistic Insight

Strength of Causal Evidence	**Level of Mechanism**			
	Molecules	Cells	Populations	Networks
Purely observational (no causality)	Correlations of PET imaging with psychological traits		Volume of brain regions (MRI) correlated with psychological traits	
Manipulate psychological processes & observe brain	Task modulation studies using PET with neurotransmitter ligands	Intracerebral recording in surgical patients	Task activation studies (fMRI/EEG/MEG) **Representational analysis (fMRI/EEG/MEG)**	Task-based functional connectivity (EEG/MEG)
Manipulate brain and observe psychological effects		Direct brain stimulation in surgical patients	Focal Lesions Neuromodulation (TMS/TES)	Lesion Network Mapping

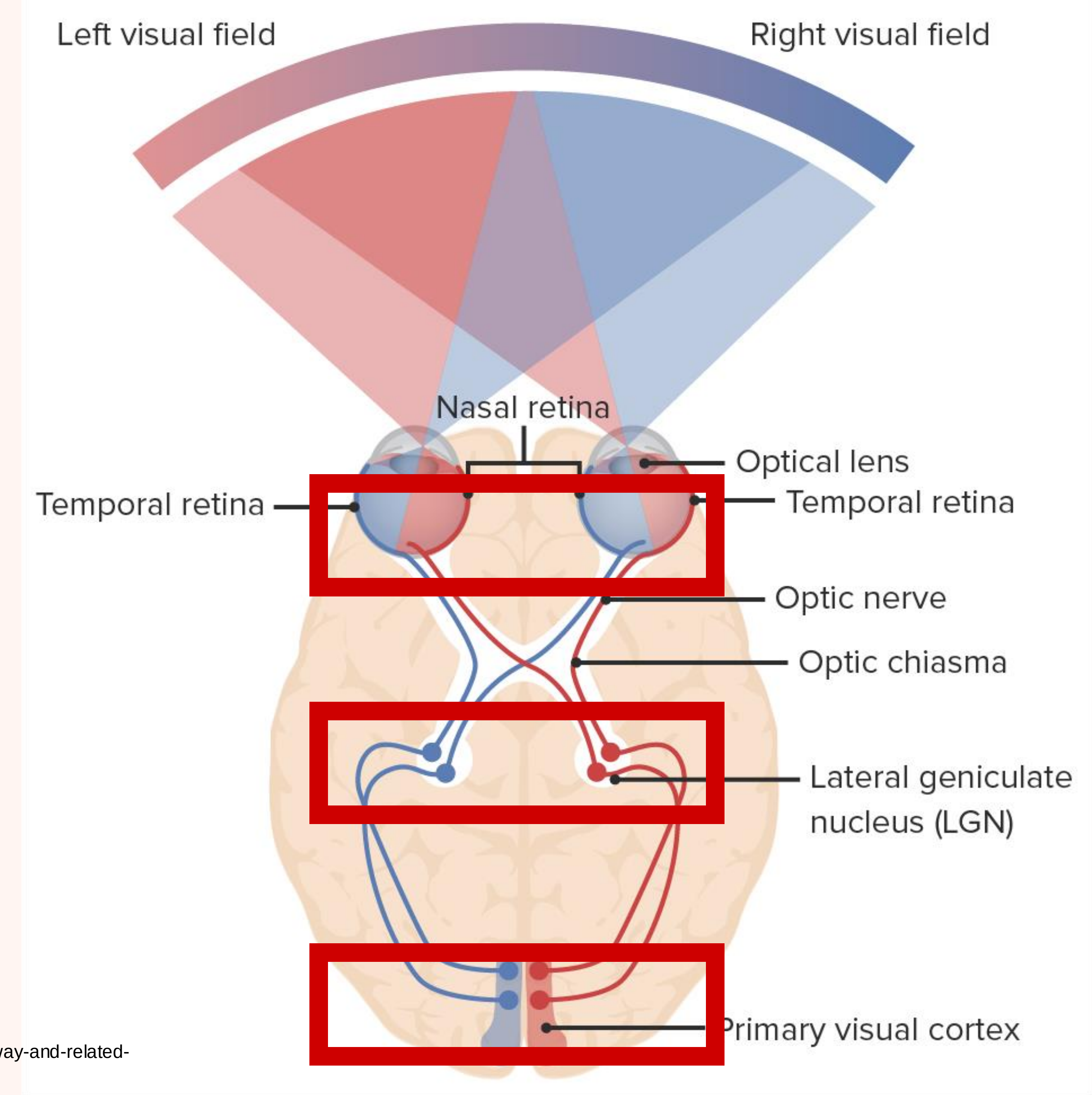
What are the strengths and disadvantages of these approaches?

Vision and Object Recognition (Part 1)

- Class 5

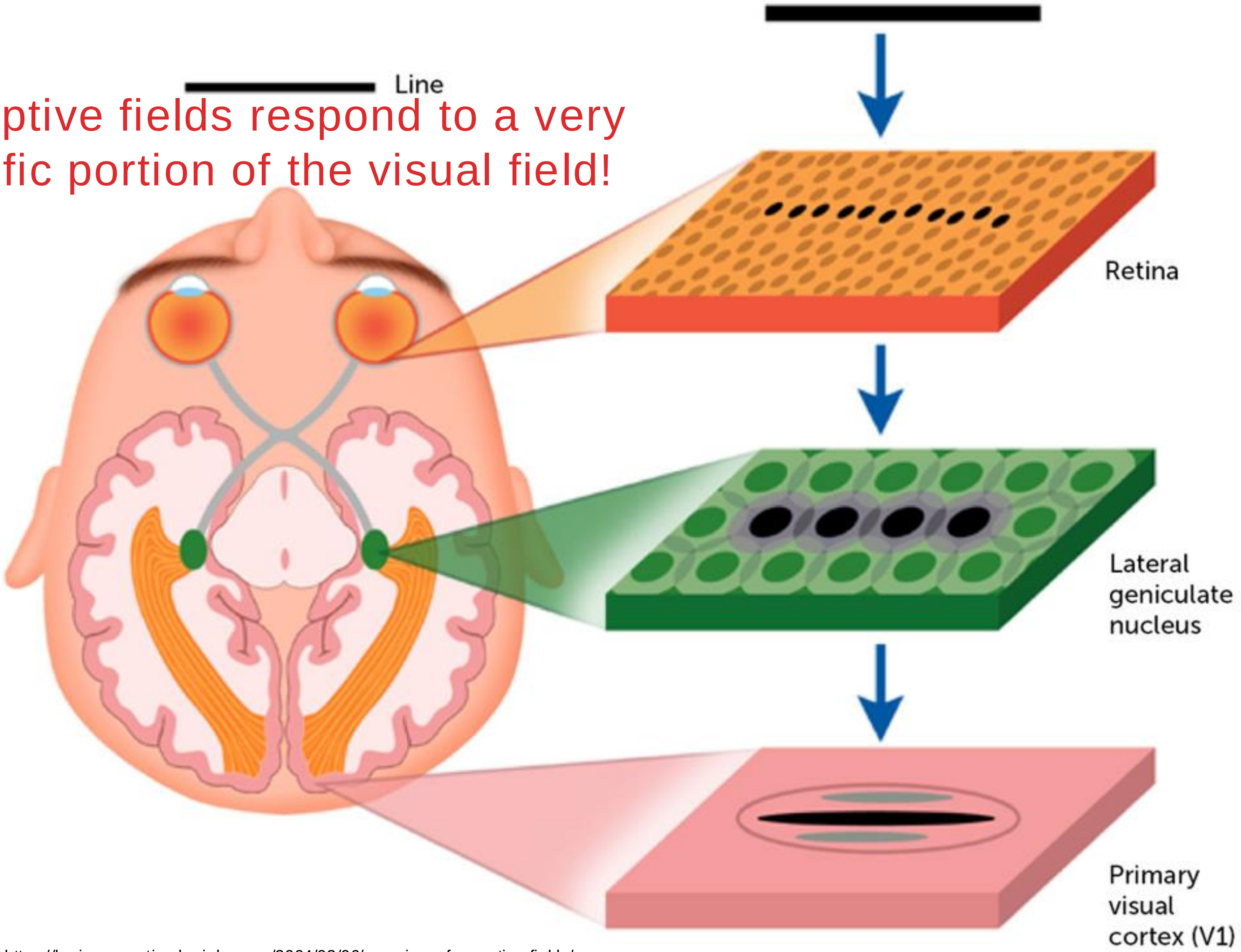
Learning Objectives (Part 1)

- Describe key structures in retina-geniculate-striate system
- Explain how neural signals arrive in both ipsilateral and contralateral cortex
- Describe receptive field properties of lateral geniculate nucleus (LGN) and V1 neurons



https://www.lecturio.com/concepts/the-visual-pathway-and-related-disorders/

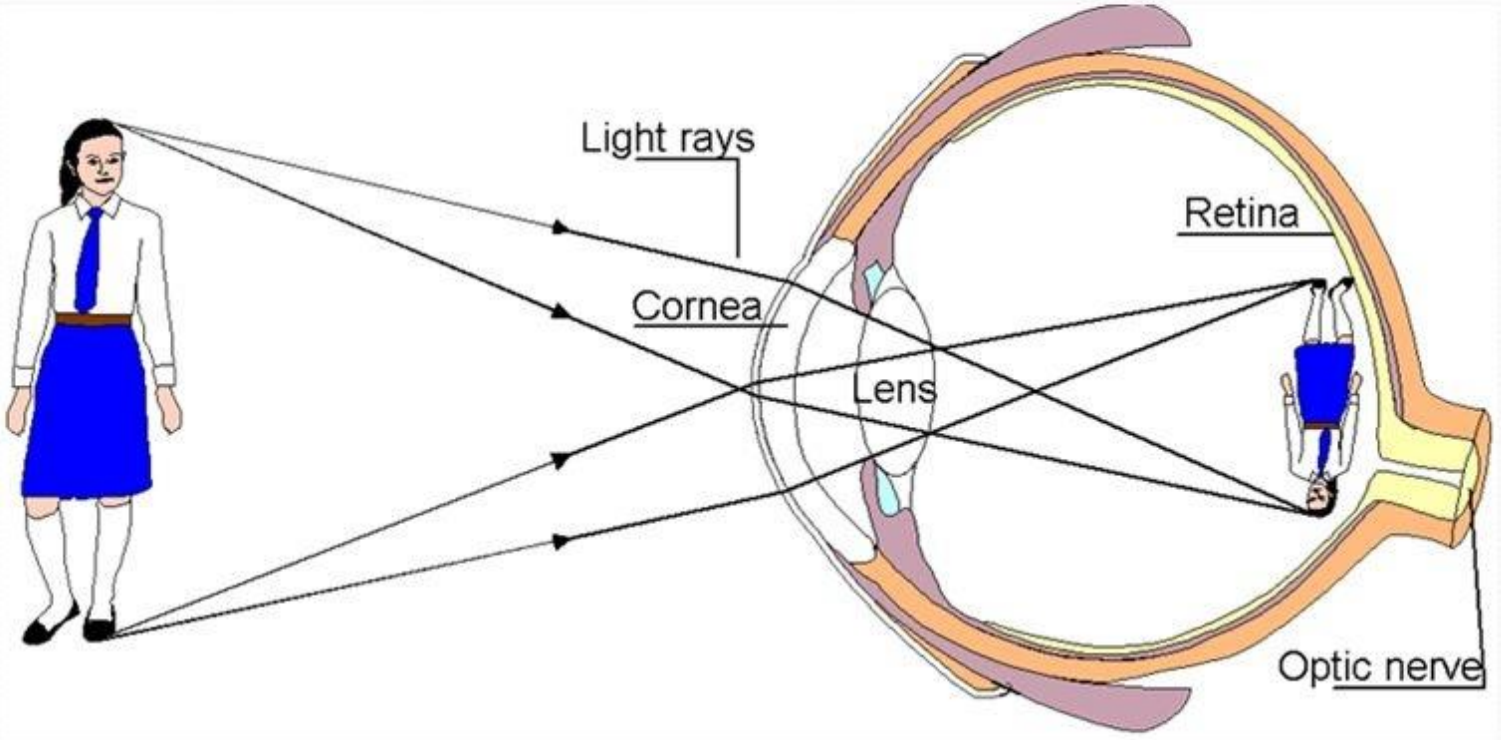
Receptive fields respond to a very specific portion of the visual field!



https://brainconnection.brainhq.com/2004/03/06/overview-of-receptive-fields/

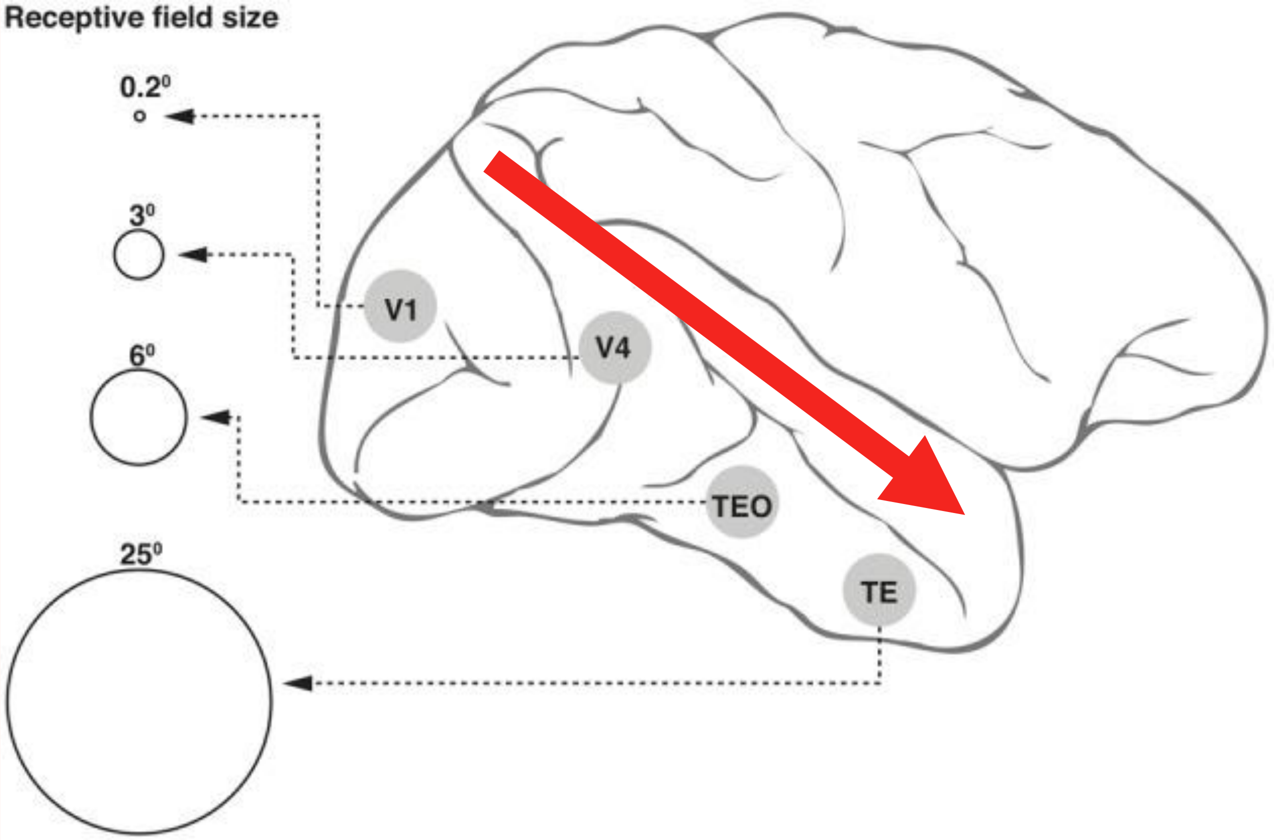
https://www.quora.com/When-we-see-an-object-is-the-image-formed-on-the-retina

Image formed by Retina



The image formed on the retina is inverted, but your brain interprets the image as being right side up.

The image is inverted <u>and</u> flipped L/R due to the lens shape



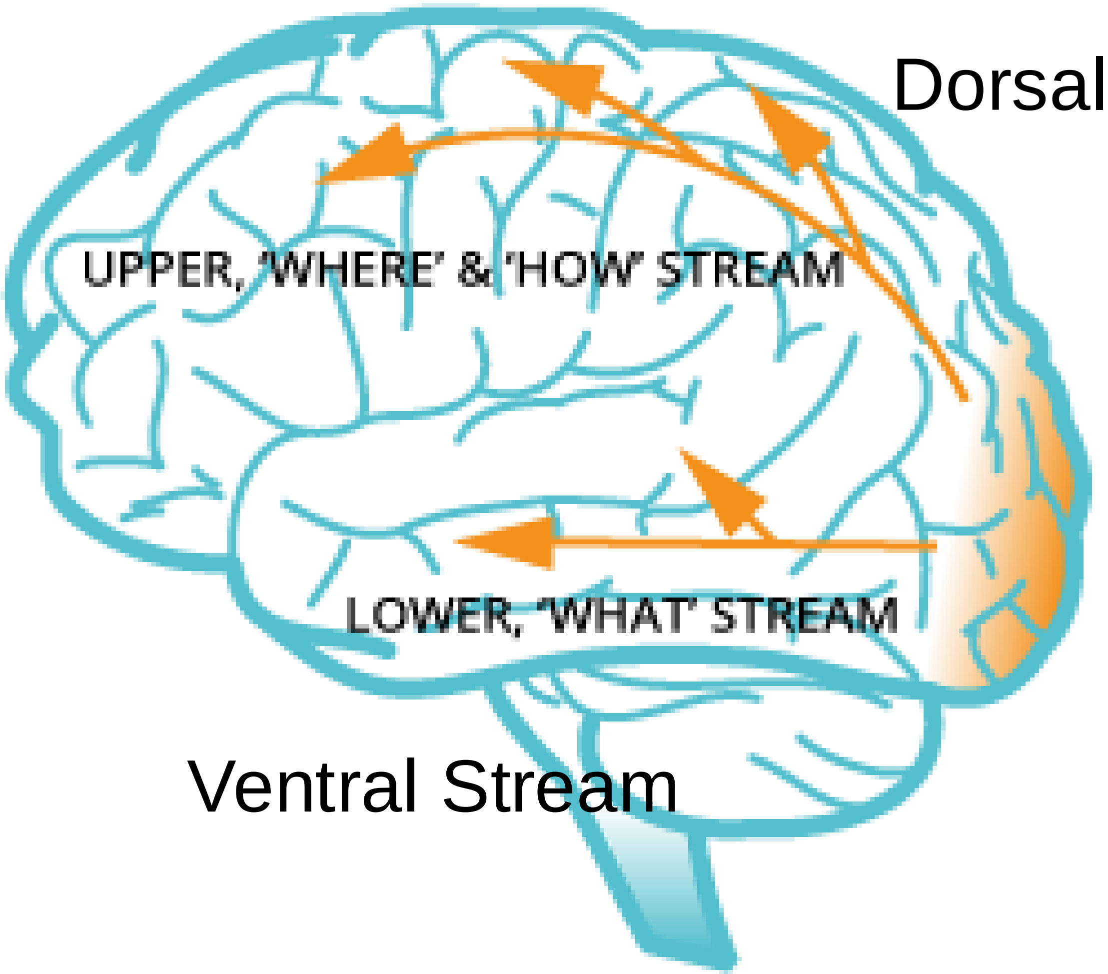
Feedforward sweep of processing

- As we go further down the ventral visual stream, receptive field size <u>increases</u> and more information is integrated at each area.

Downstream areas such as LOC and IT receive lots of small bits of information, integrating them into whole shapes and scenes.

https://www.researchgate.net/figure/Receptive-field-RF-sizes-along-the-ventral-cortical-stream-in-the-primate-While-the_fig1_259354359

Two Visual streams



Milner & Goodale

- Patient DF with bilateral ventral-stream lesions
- Visual form agnosia (trouble identifying visual forms) —> doesn't know what an object is, but knows how to use it
  - Can adjust grasp width and orientation between two objects, but can't discriminate between them (still knows how to act with the object)
- M&G argued that the difference in the two streams is not what information they carry, but how the information is used (parallel pathways for fast processing)
  - Dorsal stream produces visually-guided action, while the ventral stream mediates conscious perception of objects

Parallel pathway functions

- Dorsal Stream
  - Planned, object-oriented action
  - Guided action
  - Uses shape and orientation to guide the action of reaching out and grasping

- Ventral Stream
  - **LOC uses shape information to identify an object**
    - **Give names to things**
  - **Pieces bits of information from V1 to identify objects**

What are the characteristics of each type of agnosia?

Visual Agnosia

- Damage to the ventral stream
- Loss of ability to recognize objects, form shapes, etc. (without significant memory loss)
- Two types of agnosia:
  - Apperceptive
  - Associative

https://agnosia-ot.weebly.com/categories-of-agnosia.html

Summary

(Object Recognition Part 1)

- \- Retina-Geniculate-Striate pathway
- \- information representation at different levels of visual cortex (incl. receptive field sizes)
- \- What vs. Where pathway (how have lesion studies helped?)
- \- Apperceptive vs. Associative agnosia

Big Ideas

- Feedforward bottom-up feature-based sweep
- Challenges to human vision vs computer vision
- Contribution of fMRI to understanding of object processing stages in humans

Feedforward bottom-up feature-based sweep

FEEDFORWARD : V1 ———> Inferotemporal cortex (IT)

BOTTOM-UP : simple ———> complex

FEATURE-BASED: individual elements of an object come together to create a complete representation

- Like puzzle pieces to create a full puzzle where the “puzzle pieces”= colour, orientation, motion

The visual system detects features and then puts them together to a whole at increasing levels of abstraction till the object is matched to a mental template by passing information from V1 along the ventral stream

fMRI contributions

WHAT WE KNEW (1998)

- 2D upside-down retinotopic map to category-selective regions
- RF size increases forward in the ventral stream
- Beginning of ventral stream —> sensitive to parts of an object
  End of ventral stream —> sensitive to whole object

WHAT WE DIDN'T KNOW

- What happened in between the beginning and end stages of the ventral stream that allowed this feature-based sweep?

fMRI contributions

GRILL-SPECTOR fMRI STUDY

- Tested hemodynamic response to different degrees of scrambling in pictures by comparing HRF plateaus in the LOC (role —> detecting whole objects)

Results

- V1 = prefers scramble
- V4v = prefers partial objects (simpler, localized features)
- LOC = prefers whole objects (mostly true, some voxels behaved like V4v)

Demonstrated that as info moves from V1 along the ventral stream through the LOC, voxels go from responding to bits —> simple shapes —> whole objects on the path from processing features to whole objects and object categories, consistent with increasingly large RFs

Challenges to object recognition

3 MAIN CHALLENGES

1. objects can be occluded
2. differences in size/distance
3. an object can look very different from different angles

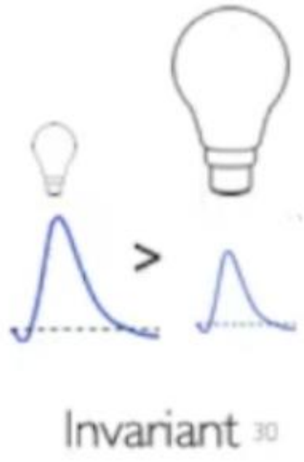
SIZE INVARIANCE —> ability to know an object is the same when it is at a different size on the retina

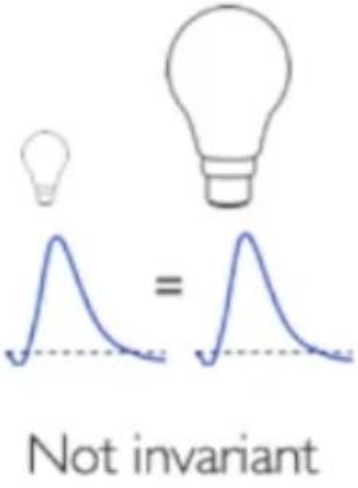
VIEWPOINT INVARIANCE —> ability to recognize objects from different viewpoints

- Childhood experiences teach us how objects look from different angles
- Earlier V1 neurons = see objects from one view, higher order regions = collect info from lower order neurons and can match that info to mental representations of objects through early experiences

Size invariance using adaptive suppression

- if voxel's activity is SIZE INVARIANT —> should treat different sizes of an object as the same object
  - should be SUPPRESSION in hemodynamic response
- if voxel's activity is NOT SIZE INVARIANT —> should treat different sizes of an object as different objects
  - should be NO SUPPRESSION in hemodynamic response





Size invariance using adaptive suppression

- EARLY VISUAL AREAS —> same HDR size for large and small objects
  - Treat images as different
- ANTERIOR LOC —> HDR reduced when shown a different sized image of the same object
  - Treat images as the same

Voxels in early visual areas are not size invariant

Voxels in anterior LOC are size invariant

Viewpoint invariance using adaptive suppression

- EV AREAS and POSTERIOR LOC —> no reduced HDR, not viewpoint invariant
- ANTERIOR LOC —> reduced HDR, viewpoint invariant

EV and earlier (posterior) LOC only recognize one size/viewpoint

Later (anterior) LOC regions only recognize objects from any angle/size

Things fMRI taught us!

1. ENCODING APPROACH —> responses to object parts and then whole objects moving along the occipital cortex from EV to LOC

2. ENCODING APPROACH —> more view and size invariant processing further along the ventral stream

Computer vision

- Convolutional Neural Networks —> computer program used to combine bits and features into whole objects
- Convolutional layers create maps similar to the LOC —> filters break down an image into different elements and each successive layer is more abstract and complex than the previous one

Why do Bowers et al.
say machines are not
just like us?

What problems do they
describe in using neural
network models for to
model human vision?