

THE BRAIN, BIOLOGY AND COGNITION

Top-down vs. Bottom-up Processing and Visual Illusions

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What is Perception?

“Acquisition and processing of sensory information in order to see objects in the world...” Sekuler & Blake (2002), p. 621.

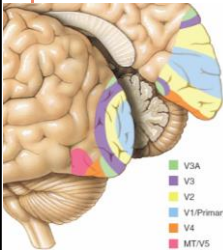
- Information received through senses
- “Raw” material for perception
- Data driven processing
- Attend to selective aspects
- Perception:
 - Connects selected data to higher cognitive processes
 - I.e., what we ‘perceive’ as reality



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Visual Functional Specialisation

• Different cortical areas in brain are specialised for processing different visual attributes/functions.



- V1 and V2: Early stage/initial processing of items
- V3 and V3a: Cells respond to form (especially shape)
- V4: Cells respond to colour and some to line orientation
- V5/MT: Processes visual motion

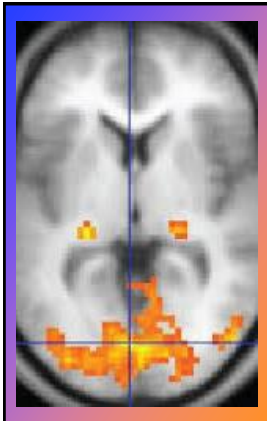
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Visual Functional Specialisation theory

- Lots of research by Zeki (1991, 1993, 2001, 2005) and Zeki et al. (1991).
- Examined brain of macaque monkeys then applied findings to humans
- Research utilises brain imaging
 - E.g., PET to measure regional cerebral blood flow when different stimuli are presented (colour vs. greyscale display).
- Zeki et al. propose V1/V2 and V4 are active during colour vision stimulation, while V1/V2 and V5 are active during motion stimulation.

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Visual Functional Specialisation theory

- Other research supports this theory with fMRI:
- E.g., Goddard et al. (2011):
- Measured responsivity of V4 when participants viewed colour and greyscale versions of film 'Strictly ballroom'.
- Larger response (of voxels) observed in V4 during chromatic cycle of the film.

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HOWEVER!!!

- Visual Functional Specialisation raises interesting question:
 - If different cortical areas are specialised for processing different visual attributes/functions, how do these combine and integrate to produce coherent perception?
- This is known as the **Binding Problem**



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The Binding Problem



- What does functional specialisation theory mean for visual cognition?
- Property binding involves distinct object attributes being coded (bound) together, allowing them to be distinguished from other objects.
- The brain must have way of synchronising all separate elements being processed into a coherent perceivable image (Revonsuo, 1999).

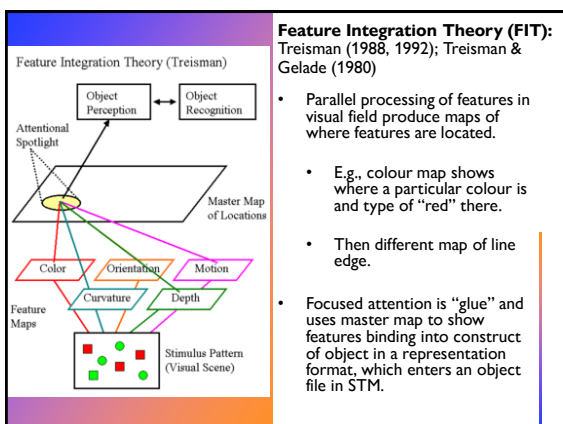
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Explanation from Cognitive Psychology

- Feature-Integration Theory (FIT)
 - Scalable 'window of attention' scans 'master map' of locations selecting features currently active in corresponding locations of various specialised feature maps
 - Selected features are assembled to form an 'object token' and compared to stored representations.
 - Distinction between Features of objects (e.g., size, shape, colour) vs. Whole objects
 - Parallel processing of features (fast) to begin, then....
 - Serial process to combine features (slow)
 - Stored knowledge influences combinations (e.g., we know oranges are orange in colour)



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Binding

- Treisman (1996): at least 7 types of binding:
 1. Property: shape, colour, etc. must be bound to an object
 2. Part: objects must be segregated from the background
 3. Range: values on a dimension (e.g., purple on a colour dimension)
 4. Hierarchical: shape and surface binding
 5. Conditional: one property (e.g., motion) depends on another (e.g., depth)
 6. Temporal: binding of successive states of an object
 7. Location: object being bound to its location

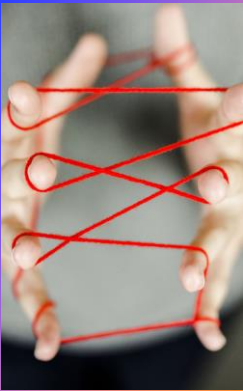
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IS THERE JUST ONE TYPE OF BINDING PROBLEM?



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The Binding Problem(s)

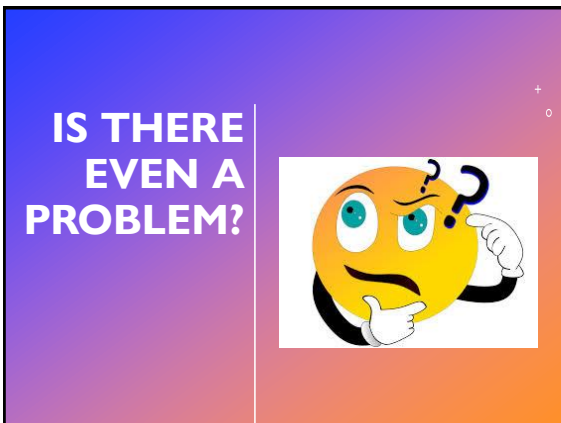
- Feldman (2013): there are four binding problems:
 1. General coordination (*temporal synchrony*): Co-occurrence in time is central to neural functioning.
 2. Visual Feature binding: Work of Treisman and work on attention
 3. Variable binding: relates to language and symbolic thought
 4. Subjective Unity of Perception: the mystery of subjective personal experience.

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Possible solution?

- **Binding by synchrony hypothesis** (Singer & Gray, 1995)
 - Detectors responding to features of single object fire together (*in synchrony*), while detectors responding to features of separate objects do not.
- Links to understanding conscious visual awareness:
 - Widespread neural activity enables us to understand/make sense/be aware of what we are seeing.
- However, because processing of an object occurs across many areas of the brain and goes through several stages, it would be difficult for precise synchrony to occur.
- Perhaps patterns of neural activity over time better explains perception (Guttmann et al., 2007).

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Is there a Binding Problem?

- DiLollo (2012): binding is an ill-posed problem
 - Why?
 - Modules can code jointly for multiple features
 - Neurons can respond/deal with more than one type of property.
- Research evidence:
 - E.g., form and colour are processed in modules that concurrently select both features (Mandelli & Kiper, 2005).
- Also, communication between brain regions is seldom one-way:
 - a target area can send signals back to a source area through *re-entrant* pathways.

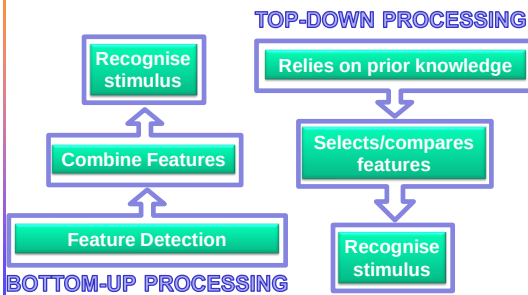
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Wolfe's Rebuttal to DiLollo

- Wolfe (2012): suggests DiLollo misunderstood the problem and incorrectly mapped the problem to the brain.
- Di Lollo challenges an early neurophysiological account of binding, which held that features (e.g., colour, orientation, etc.) were processed in geographically separate areas of the cortex.
- Thus separated, the features needed to be 'bound' together in order to see coherent objects.
- For Wolfe, the binding issue is not about where it takes place, but the capacity to do it and the need for attention.

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Links to direction of processing?

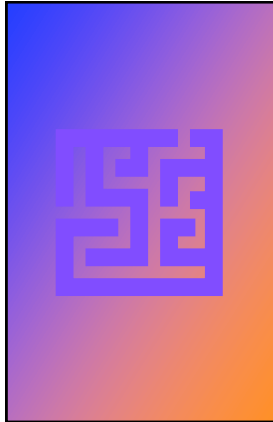


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Direction of processing

- Top-down theories (concept driven)
 - Mind **interprets** signals it receives in a rich, elaborative way (Gregory, 1970)
- Bottom-up theories (ecological/data driven)
 - Visual system has evolved to derive what it needs **from the environment** (Gibson, 1966)

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Top-down perception

- Sensory input is chaotic, unstable, and distorted
- Perceiver generates predictions (hypotheses) about sensory info
- Perception is constructed
 - **High level concepts** (knowledge of world) or representations shape **low level percepts**.
- Visual illusions provide support
 - 'Errors' show our hypotheses can be inaccurate (Gregory, 1963).
- For example,.....

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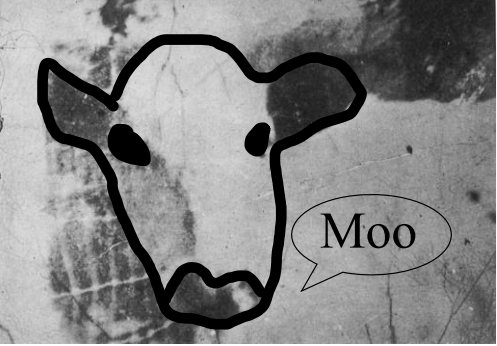
What can you see?



Dallenbach 1951

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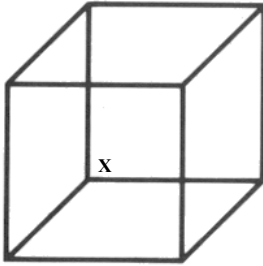
What can you see?



Dallenbach (1951)

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Is the X in the back or the front of the cube?



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Gregory: Illusions

- Necker cube shows we can derive two mutually exclusive percepts from single visual input - one sensation but two possible outcomes.
- Gregory argues Bottom-Up theories cannot explain this.
- Bottom-Up theories would suggest we should always perceive same thing from same input.

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VISUAL ILLUSIONS

<https://michaelbach.de/ot/>

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Ecological approach Gibson (1950)

- Gibson suggests Gregory's view of bottom-up processing is incorrect
- Visual system has **evolved** to detect what is important to survive/operate
- No need for inferences - all we need is present **in visual array**
- Ecological theory
 - Perception evolved in way that support survival of the species
 - Involves interpreting information as you move
 - Cannot separate perception from movement and context

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Ecological approach Gibson (1950)

- Gibson explained perception by how it relates to properties of world around us:
- Perception of **movement and change** within visual field provide crucial information about the world and our place within it (egocentric perspective)
 - Distance
 - Speed
 - Location
- **Surfaces** are important in deriving this information

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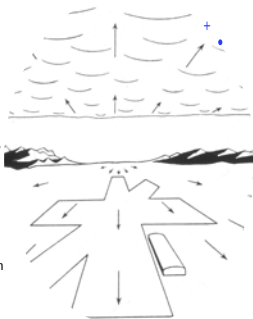
Movement

- Patterns of light reaching retina consist of information about texture and gradients of objects.
- 'Optic flow' is one of our main sources of visual information (Gibson).
- When we move, our visual environment **seems** to flow past at different rates (apparent movement)
 - Closer a thing is to us, the faster it seems to move past – e.g., when on a train vs. viewing a train.
- Shifts in flow indicate direction changes
 - Inflow and outflow

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Optic flow

- Diagram shows outflow from plane landing strip perspective
 - When moving towards an object the scene flows out from point of reference
- Opposite is inflow where we move away from a point (move backwards) – arrows flow the opposite way
- In real life, the scene is not as sparse as this – flow is achieved by objects moving forwards or backwards in our line of vision relative to our movement.
- This is environmental information (data) not hypotheses which provides invaluable information about direction, speed, and distance of objects from us etc (all useful in landing a plane!), from an egocentric perspective (our perspective)



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Ecological approach Gibson (1950)

- Optic flow demonstrates richness of environmental information
- Experiments involving illusions ignore complexity of natural world
 - 'air theory'
- With such a rich array of environmental data we do not need to make hypotheses about what we are 'perceiving'
- Instead, our brains have evolved mechanisms to pick up this rich data and compute meaning without needing to guess what we are seeing

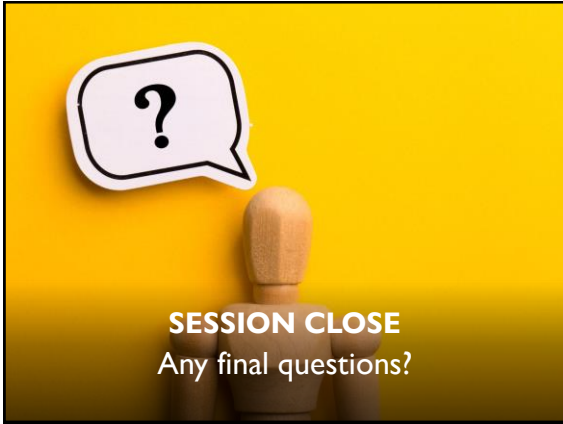


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Comparing both approaches

- Gregory – concept driven
 - We use conceptual theories to make sense of what we are seeing – does not necessarily mean we do so consciously (top-down)
- Gibson – data driven
 - We use data from the environment to make meaning – how we do this is by relying on mental processes which have evolved to do this job (bottom-up)
- Essentially both rely on internal processing of some kind

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