Lectures 5 & 6
Modularity in the visual pathways

Reading

Additional reading

“What” and “Where” systems in the cortex

Primary visual pathways

Visual pathways
cortical and sub-cortical functions

Schneider (1969)

Task 1
Position of reward
left right
Impaired by lesions of superior colliculus

Task 2
Visual discrimination
Impaired by lesions of visual cortex

Traditional approaches to vision in animals and humans
the type of motor response is irrelevant
animal discrimination learning
human psychophysics

Different motor responses required in an operant chamber, jumping stand or WGTA

The common assumption is that any response can equally be selected on the basis of task requirements and internal representations of the visual stimuli
Preferential access of specific motor output to specific visual input not considered
Visuo-motor control in water beetles (Shone, 1962)

Larvae will swim towards light if in need of air and away from light when air supply has been replenished. Reflexes can be flexibly modulated by internal drive. Similar control of behaviour in single-cell organisms (e.g., *Euglena*) reinforce the notion of non-representational visuo-motor reflexes.


Unilateral removal of tectum

Projections from retina to intact (ipsilateral) tectum

What does a rewired frog “see”?

Has the evolution of more sophisticated visual systems in mammals resulted in a radical re-organisation of the visual brain?

Visuo-motor modules in mammals

- mostly ignored
- at sub-cortical level similar to amphibia

superior colliculus (equivalent of frog’s tectum)

fibres to contralateral brain stem

two “group” reflex elicited by stimulation

eye movements in primates

fovea vision

orienting responses in rodents

feeding, predation?

fibres to ipsilateral brain stem

escape responses

Ellard and Goodale, 1986

Micro-stimulation of superior colliculus in Mongolian gerbil

A) Orienting response

Smooth head and body turns in direction opposite that of electrical stimulation

B) Escape response

Rapid running movements in direction ipsilateral to the stimulation site (and with little head turning)

Ipsilateral fibres from SC to brain stem – escape response to black rectangular target introduced in visual field

SH Sham Operation

D lesion of contralateral fibres from Superior Colliculus

LT lesion of ipsilateral fibres from Superior Colliculus

SC lesion of Superior Colliculus itself
Pretectal Nuclei barrier avoidance

Primate superior colliculus
preserved archaic circuit
regulation of involuntary eye movements

Evolution of complex forms of visuo-motor control
e.g. required by emergence of prehensile hand
expansion of visuo-motor systems in the cortex

Lesion studies in monkeys

1860s Ferrier
lesions of (what we now call) dorsal system
mis-reach for food items

1980s Glickstein et al.
lesions of dorsal stream
inability to reach for food in slots of different orientation

Electrophysiological studies in monkeys

1970s Mountcastle & Hyvarinen
electrophysiological recordings from dorsal stream neurons
neurons that fire during reaching
neurons firing during saccades towards stationary objects
neurons responding to moving objects if followed by gaze

Visuo-motor control in humans

The visual brain areas of monkeys and humans are remarkably similar

In both humans and non-human primates:

- the coordination of saccadic movements, pursuit eye movements, grasping with the hand and body locomotion is computationally complex if carried out by a single central system
- As such different specialised circuits may have evolved with a certain degree of autonomy
- There is evidence for separate modules in posterior parietal cortex and circuits linking the parietal cortex with the pre-frontal cortex and non-cortical archaic structures such as the superior colliculus and the cerebellum
Modularity in the parietal cortex

Activity in Lateral Intraparietal area traditionally attributed to shifts of attention and updating of spatial information

Snyder Batista & Andersen (1997)
- monkeys trained (conditional response to colour cue) to respond to the same stimuli with different responses
- double dissociation
- LIP activated by eye movements
- PPR activated by arm movements
- response requirements are just as important as shifts of spatial attention

IMRI studies in humans reveal similar functions (Culham et al., 2003; 2004)

Blindsight

Monkeys with V1 removed (Gross, 1973)
- no discrimination of visual patterns
- no activity in ventral stream

Weiskrantz et al. (1974); Weiskrantz (1986)
- residual ability to detect items of food and reach for them
- residual ability to guess locations in patients with cortical blindness

Cortical blindness in neuropsychological patients

Damage to V1 causing blindness in corresponding portion of visual field
- Scotoma: blind regions of visual field
- Left visual cortex

Typically assessed by perceptual report
- e.g. Can you see this light?

Weiskrantz et al. (1974; 1986; 1987)
- Patient D.B. (hemianopsia)
  - Unable to report light in blind visual field
  - High correlation of saccade position to "guessed" target positions within blind visual field
  - No evidence of systematic response location in control trials with no target or target presented in blind spot

Weiskrantz et al. (1974); Perry and Cowey (1984)
- visual ability in “blindsight” attributed to functions of superior colliculus
- Accuracy and latency of blindsight affected by nature of response (e.g. Marcel 1993; Zihl & von Cramon 1986)
  - Some patients can scale grip and rotate wrist when reaching for objects in blind field
  - Patients show performance and longer latency
  - Verbal (more arbitrary?) poor performance and long latency
  - Sticks, finger movements (less arbitrary?) faster and more accurate response
Evidence of modularisation in the ventral stream?

Specialised cells and brain areas for recognition of specific category of objects (as reviewed in Lectures 1&2)

e.g.

- face cells in the ventral stream

Some high level cells will respond to particular stimuli irrespective of variations in size, orientation, colour, luminosity etc.

e.g. Perrett et al. (1984; 1991)
cells in Superior Temporal Sulcus
category specific (e.g. faces)
some are “object centred” useful for object recognition

For very salient and biological important categories of objects such as faces, there may be specialised high order cells

For other objects it is likely that specialisation and categorisation is supported by the columnar organisation of cells sensitive to similar features

cells with similar but slightly different selectivity cluster in columns in the Inferior Temporal cortex
stimulus equivalence is obtained at the column level

fMRI evidence for specialised modules on the ventral system

- Fusiform Face Area (FFA) activated by faces not by objects, buildings or scrambled faces
- Parahippocampal Place Area (PPA) activated by pictures of buildings and scenes not by faces
- Lateral Occipital area (LO) activated by common objects not by faces or buildings

Clinical evidence of modularity in the ventral system

although often overlapping, prosopagnosia and agnosia for objects can dissociate

case C.K.
agnosia for objects but not for faces
“topographical agnosia” inability to navigate in familiar environment (e.g. home town) loss of recognition of landmarks can dissociate from other forms of agnosia

Summary

- Visuo-motor modules in lower vertebrates
- Visuo-motor modules in mammals?
- Blindsight
- Evidence for modularity in the dorsal system
- Evidence for modularity in the ventral system