The Parietal Cortex

The parietal lobe of the cortex is located towards the rear and at the top of the brain.

The parietal lobe contains four major separate cortical fields:

- Area 7a contains visual and eye position sensitive neurons and appears to be involved in transformations between different spatial representations.
- Area 7b contains somatosensory and reach related cells.
- Area MST (Medial Superior Temporal) contains visual motion neurons and neurons related to smooth pursuit eye movements.
- Area LIP (Lateral Intraparietal) contains visual neurons and neurons related to saccadic eye movements.

The parietal lobe has sensory input from four different modalities: visual, auditory, vestibular, and somatosensory.

It projects to several frontal and premotor areas, such as the superior colliculus.

Lesions of the (posterior) parietal cortex produce profound spatial deficits.

Hemineglect - difficulty in initiating eye or arm movements towards visual, auditory or somatosensory stimuli in one half of the spatial field.

For example, patients with parietal lesions will have problems with a line-cancellation task, where they must cross out short line segments spread out over a page. They will typically fail to cross out the lines on the side contralateral to the lesion.

Movements that are made to the affected areas are inaccurate and usually deviate to the side of the lesion. The movements are also altered kinematically: their duration is increased, their peak velocity is lower and deceleration takes longer.

Grasping and orientating of grasped objects is also impaired. Patients often open their hand too wide and exhibit little or no pre-shaping of the grasp.

Parietal lesions do not seem to affect conscious object recognition, but do affect object shape recognition as it relates to forming the hand for grasping of the object.

$\rightarrow$ A $WHAT$-$WHERE$ distinction.

The parietal lobe seems to be involved in the WHAT, or ACTION, stream of the cortical processing.

Parietal Lobe Cortex and Coordinate Transformations

The parietal cortex appears to combine eye position signals with retinotopic visual input to generate head-centred representations of the visual input.

One approach to obtaining a head-centred representation would be to shift a neuron's receptive field on the retina as the eye moved, thereby keeping the receptive field fixed relative to the head.

Andersen and his colleagues carried out experiments which suggest that another approach to constructing head-centred representations is being used in the brain.

In their model, cells in area 7a of the posterior parietal cortex have visual receptive fields that are fixed relative to the retina, but whose responses to visual stimuli are *modulated* by eye position.

(Andersen, R.A., Essick, G.K. and Siegel, R.M., "Encoding of spatial location by posterior parietal neurons", *Science*, Vol. 230, pp 456-458)

The modulation was measured to be linear in the x and y coordinates of the eye position, hence Andersen *et al* referred to the modulated receptive fields as *planar gain fields*.

Taken individually, these neurons do not form a head-centred representation, as their receptive fields are fixed relative to the retina.

Taken as a *distributed* representation, these neurons can form a head-centred representation.

Recall that distributed representation of space appears to be used in the superior colliculus as well. This seems to be a common aspect of spatial representations in the central nervous system.

There may not be an actual explicit head-centred representation anywhere in the brain Instead, it is likely that the distributed head-centred representation is an intermediate stage in the transformation from visual to motor coordinates.

Other Coordinate Systems

Recent experiments suggest that there are head-centred representations with also include the third dimension of the distance from the head. The method of encoding distance is in the form of gain fields.

The LIP (Lateral-Intraparietal) area has neurons in which the vergence angle of the eyes modulates the magnitude of the visual responses. The vergence angle is related to the distance to an object being foveally fixated by the two eyes.

About half of the cells with eye position gain fields in areas 7a and LIP were found to have similar gain fields with respect to head position. These may form body-centred spatial representations.

Neurons have been found that have gain fields for eye position and body rotation (presumably controlled by vestibular signals). These may form a world-centred representation of space.

Neural Network Model of Parietal Cortex

(Zipser, D. and Andersen, R.A., "A back-propagation programmed network that simulates response properties of a subset of posterior parietal neurons", *Nature*, Vol. 331, pp 679-684)

Zipser and Andersen implemented a neural network model of the neurons in the posterior parietal (i.e. area 7a).

This model was a standard three layer network (input layer, hidden layer, and output layer).

A back-propagation procedure was used to learn the weights of synapes on the output layer and hidden layer units. This has been criticized as being non-biological, so they later repeated their modelling using a reinforcement learning technique, which is more plausible biologically. Similar results were obtained.

The input layer cells are of two types: visual cells and eye position cells.

The visual inputs consist of cells with Gaussian receptive fields distributed spatially in a retinotopic map.

The eye position cells have piece-wise linear receptive fields. The reponse of these neurons are zero up to a given eye position and then increase linearly from that position on. There are four sets of these cells, two groups of two each, corresponding to positive and negative slopes, for vertical and horizontal eye positions.

Two different output representations were used in the training:

Gaussian receptive fields in a head-centred coordinate system.

Monotonic receptive fields where neuron firing rates are linear in the position of the stimulus in head coordinates.

The network was trained using randomly selected pairs of input eye positions and retinal stimuli corresponding to a visual feature at some location in space. The true output (teacher signal) was the spatial location in head coordinates corresponding to the inputs, and was represented in either the gaussian or monotonic format.

The hidden layers of the trained neural network exhibit responses very similar to those observed in the parietal cortex. In particular, responses similar to gain fields are seen.