Retinotopy & Phase Mapping

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Retinotopy

- Visual Cortex organised in visual field maps:
- Nearby neurons have receptive fields at nearby locations in the image
- Receptive fields of neurons is a region of space in which the presence of a stimulus will alter the firing of that neuron. (identified in auditory, somatosensory and visual system)
- Retinotopy describes the spatial organisation of the neuronal responses to visual stimuli
Human Visual Cortex

- Human cortex spans a surface area on the order of 1000 cm²
- 2-4 mm in thickness
- 50,000 neurons per cubic millimeter => 25 billion neurons in both cortical hemispheres
- Much of the posterior human brain responds to visual stimulation
- Human visual cortex: Entire occipital lobe and extends significantly into the temporal and parietal lobes (20% of cortex) => 5 billion neurons
- Essential for vision: Calcarine sulcus, located on the medial aspect of the occipital lobe
Discovery of Visual Field Maps

- Observed strong correlations between visual field deficits and the location of lesions within human visual cortex (V1)
- V1 in each hemisphere encodes one half of visual space
- Cortical magnification: The central fovea is represented over a larger fraction of cortical surface than a comparable extern of the peripheral visual field
- Animal research: uncovered multiple maps
- Useful for many generations of clinicians
Motivations for Measuring Human Visual Fields

• Clinical Applications
• Differences between primate species
• Differences between human and non-human primates
• Relationship between maps and perceptual function
• Relationship between maps and behavior (stimulation of MT influences behavioural decisions about motion)
• Cortical organisation of visual function
• Quantitative measures of these maps are used for analyses of visual system pathology (plasticity-baseline measurements)
• Anatomical correspondence does not imply functional correspondence
Visual Field Maps versus Visual Areas

- Visual Areas:
  - Architecture
  - Connectivity
  - Visual Topography
  - Functional characteristics
  - These criteria may conflict
  - Architecture and connectivity are not easily accessible in-vivo
  - Small differences in experimental design and interpretation may lead to differences in area definition

- Visual Field Maps:
  - Relatively straightforward
  - Each visual field map contains no more than a single representation for each point in the visual field
  - A visual field map should represent a substantial portion of the visual field
  - A visual field map should generally be contiguous
  - The basic features of a visual field map should be consistent across subjects
Measuring Visual Field Maps
Travelling-Wave Method/
Phase Encoded Retinotopic Mapping

Effective Eccentricity

Effective Angle
Phase-encoded Retinotopic Mapping

- Differential measurement: for each cortical location, the most effective stimulus is estimated by comparing the responses to a set of stimuli.
- Presents an orderly series of visual field locations from which the most effective location can be interpolated using simple mathematical methods.
- The entire visual field layout is estimated.
- The visual field map description is not limited by the choice of certain critical visual field locations (horizontal and vertical meridians).
- Effective for measuring field maps with neurons that have small receptive fields that are mainly confined to one hemifield, such as V1.
Visual Field Maps in Humans and Animals

Visual Field Maps in Humans and Animals

Visual Field Maps in Human Visual Cortex
Limitations of the Phase-encoded Mapping

- Fails when measuring maps with large receptive fields
- Stimulus is poorly designed to measure neuronal populations whose receptive fields are centered on the fovea
- Eccentricity fields are nonlinearly distorted, particularly when cortical response regions overlap with the fovea
- Angular responses near the vertical midline are difficult to measure due to technical limitations
- Adjacent fields do not always have the opposite field sign (V3A and LO-1 has similar signs)
Organisation of Visual Field Maps

Diagram showing the organisation of visual field maps, including areas like Posterolateral Parietal Cortex, Dorsal Stream, V1+, LGNd, SC, Retina, and Inferotemporal Cortex.
Anatomical Organisation of Visual Field Maps

- Anatomical method
- Hierarchical graph
- Visual areas in macaque
- Connection are classified:
  - Ascending
  - Lateral
  - Descending
- Substantial uncertainties