Clinical and Experimental Neuropsychology

Temporal Lobe Function and Dysfunction
Anatomy and connectivity of the temporal lobes

- **Temporal Lobe**: that area of the brain anterior to the occipital (visual) cortex and bounded by the lateral sulcus (Sylvian fissure) dorsally.
Gross anatomy is typically divided into:

- Superior temporal gyrus
- Middle temporal gyrus
- Inferior temporal gyrus
Cytoarchitectonically divided into 10 Brodmann’s Areas but there are likely to be more

Key subcortical regions:
Limbic cortex
Amygdala
Hippocampal formation
Four distinct types of cortical-cortical connections in the temporal lobe

Give clues to the function of the temporal lobe

1. Ventral Sensory Pathway
2. Dorsal auditory pathway
3. Visual and auditory projections to polymodal temporal regions
4. Medial temporal projections
5. Frontal lobe projections
1. **Ventral Sensory Pathway**

Hierarchical connections from primary and secondary auditory and visual areas

*Auditory Stream*

*Visual Stream*
2. Dorsal auditory pathway

Projects to posterior parietal cortex and analogous to dorsal visual stream
3. Polymodal Projections

Parallel projections from visual and auditory association areas to polymodal areas of the superior temporal sulcus (stimulus categorisation)
4. Medial Projections

Auditory and visual projections into medial temporal regions (MTL), finally arriving in the hippocampus (perforant pathway, long-term memory) and/or amygdala (emotional tone)
5. Prefrontal Projections

Projections to the frontal lobe (movement control, emotion, short-term memory).
Core functions

Role in Language (Wernicke’s aphasia)

Three core sensory functions: processing auditory information, visual object recognition, memory

The temporal lobe consists of a variety of areas which are particularly important for learning and memory
Primary dysfunctions of the temporal lobes

Specific visual/auditory deficits, Memory disturbance, language comprehension, changes in affect and personality

Specific Deficits:

- **Aphasia**: unable to recognise words or comprehend speech
- **Visual agnosia**: difficulty recognising objects
- **Prosopagnosia**: inability to recognise people, faces etc.
Primary dysfunctions of the temporal lobes

3 most frequent dysfunctions:

• Temporal Lobe Epilepsy (TLE)

• Memory disorders

• Alzheimer’s Disease
Temporal Lobe Epilepsy

- Epilepsy - episodic disturbance of behaviour or perception arising from hyper-excitability and hyper-synchronous neuronal discharge

- TLE = Most common form of epilepsy (3-6 per 1000 of the population);

- Causes: presence of scarring, brain damage (from birth trauma or head injury), presence of a tumour, infections, metabolic disorder, CVA and many other conditions;
Temporal Lobe Epilepsy

• Tends to be localised to one hemisphere or the other, although there can be propagation of epileptiform activity from one temporal lobe to the other

• Genetic predisposition

• Overall cognitive functioning may decline depending on severity of the seizures - reflects degree of abnormal tissue present
TLE patients have a variety of characteristics differentiating them from other epilepsy types:

- irritability
- anger outbursts
- anxiety
- depression
- Pedantic speech, obsessions, egocentricity, perseveration in discussion (temporal-lobe personality)
- occasional psychotic episodes characterised by paranoid delusions and hallucinations.

- Intractable forms can be operated on - single largest group of elective neurosurgical patients
Memory and the Temporal Lobes

The case of Patient HM - Henry Gustav Molaison

- In 1953: surgery for epilepsy, aged 21

“a frankly experimental operation” (Scoville & Milner, 1957)

- Almost completely removed his Hippocampus and Amygdala bilaterally
Lesion is bilateral, right side left intact for comparison.

(A) Entorhinal cortex  Amygdala
(B) Collateral sulcus  Entorhinal cortex  Hippocampus
(C)  Hippocampus
NOTE THE RESULTS OF HIS BILATERAL MEDIAL TEMPORAL LOBE RESECTION AND THE REMOVAL OF THE HIPPOCAMPUS
Seizures reduced significantly, BUT, one of the most severe and pure global anterograde amnesias ever reported

Symptoms:
- Unable to remember new autobiographical information for rest of his life
- Primarily episodic deficits
- Some degree of retrograde amnesia (several years)

Preserved:
- Procedural Memory, Memory for pictures
- Short Term Memory (e.g. digit span)
- IQ
- Personality and Motivation
Assessment of temporal lobe dysfunction

- Word list learning (e.g. RAVLT)
- Figure reproduction (Rey Complex Figures task)
- Sequence tapping (Corsi Blocks)
- Spatial memory (route learning)
# The Rey Auditory Verbal Learning Test (RAVLT)

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Rey-Osterrieth Complex Figure Task – NonVerbal Memory
Corsi Blocks Finger Tapping Task
Mirror Drawing Task – Procedural Memory
Seizures reduced significantly, BUT, one of the most severe and pure global anterograde amnesias ever reported

Symptoms:
- Unable to remember new facts for rest of his life
- Primarily episodic deficits
- Some degree of retrograde amnesia (several years)

Preserved:
- Non-declarative and some semantic memory
- Short Term Memory (e.g. digit span)
- IQ
- Memory for pictures
- Personality and Motivation
Memory is not unitary

Memories come in different forms supported by distinct neural systems (versus early 20C e.g. Lashley):

• (i) **declarative**, explicit or relational memory (conscious recollection about facts and events);

• (ii) contrasted with **nondeclarative** or **procedural** memory (skills, habits, priming, some types of classical conditioning).
Larry Squire’s Taxonomy (1991)

Memory

Declarative (Explicit)
- Facts
- Semantic

Events
- Episodic

Non-Declarative (Implicit)
- Skills/Habits
- Priming

Classical Condit.

Non-Associative Learning

What’s missing?
Emotional Memory

Key temporal lobe structure = amygdala

Top-down and/or Bottom-up process?

Emotion provides a vital heuristic for learning

E.g. associative learning, Flash-bulb memories

Animal models indicate that amygdala is not necessary for long-term memory formation
Memory Disorders of the Temporal Cortex

Amnesia can be very specific – modularity/localisation of memory function – brain is not equipotential

Retrograde amnesia proportional to extent of damage – memory formation may still be intact

Retrieval versus Storage (isolated R.A.)

Functional Asymmetry (verbal vs non-verbal memory)
Anterograde amnesia at the movies:
Alzheimer’s Disease

- Characterised by the deposition of senile plaques, neurofibrillary proteins (neural filaments) and widespread neuronal loss, particularly in the temporal lobe

- Trigger appears to be environmental but unknown - probably some sort of interaction with a genetic predisposition

- Definitive assessment is only available postmortem, although combined MRI and neuropsychological assessment can provide indications
Alzheimer’s Disease - progression

• Hippocampus and Entorhinal Cortex amongst the first to show histological change

• Initial symptoms: anterograde amnesia, depression, irritability, language problems, memory retrieval problems. Deficits in explicit memory first, implicit later.

• Compromised sensorimotor and attentional function appear later]

• Ultimately, patients are severely demented, lose ambulation and are reduced to a behavioural repertoire consisting of a few basic reflexes
The Hippocampus

- Specific role in memory still unclear
- Reciprocal connections to the rest of the brain through the perifrontal (posterior) and fimbria-fornix pathways (anterior)
- Deep structure, difficult to dissociate from adjacent cortex (impossible in humans)
- Removal associated with prominent anterograde deficits and also retrograde amnesia for more recent events
- Episodic & autobiographical memories more affected than semantic
Lesion is bilateral, right side left intact for comparison.

(A) Entorhinal cortex, Amygdala
(B) Collateral sulcus, Entorhinal cortex, Hippocampus
(C) Hippocampus
Theories of Hippocampal Function

• Some claim that HF is a temporary store
  • Classic Consolidation Theory (Squire)

• Others claim it is part of the memory circuit but its involvement diminishes over time
  • Multiple Trace Theory (Nadel & Moscovitch)
  • Reconsolidation Theory (Tronson and Taylor)

Different perspectives on the temporal gradient of retrograde amnesia
HF and Spatial Memory

- **Taxi-Driver**s: Eleanor Maguire *et al.* (1997) spatial memory study with expert and novice London taxi-drivers. Experts found to have larger right hippocampi than novices and controls.

**FIGURE 2.** Reprise of the voxel-based morphometry (VBM) taxi driver result (originally reported in Maguire *et al.*, 2000). A: Increased grey matter volume in the posterior hippocampi in taxi drivers compared with control subjects. B: Area in the right posterior hippocampal region where the longer the time taxi driving, the greater the grey matter volume.
Two possibilities:
- became taxi-drivers because of their enlarged hippocampi
- the hippocampus grew due to repeated use and exposure to routes. Next evidence suggests the latter…
Maguire et al., 1996 – Left vs. Right HF surgery patients
Long-term Potentiation (LTP): enduring change in cell firing due to high-freq. stimulation (Bliss & Lomo, 1973)

- LTP most easily induced in Hippocampal Formation (but, visual and somatosensory cortex also)
- A form of Hebbian learning
- Blocking LTP prevents formation of spatial memories in mice
Summary – Temporal Lobe Function

• Adds categorisation and emotional tone to sensory information

• Forms and consolidates new episodic and possibly also semantic memories

• Medial temporal lobe = memory formation, temporal cortex = primarily retrieval and some storage

• Performs its memory operations in concert with other cortical and subcortical regions

• Uses spatial information to guide object recognition and memory of object location
Readings

Gazzaniga, Ivry & Mangun (Chapter 8)
Kolb & Whishaw (Chapters 15 and 19)

Sacks – “The man who mistook his wife for a hat”

Code et al – Classic Cases – HM