Long-term Memory

Semantic:
- multiple experience
- association of features

Episodic:
- single experience
- association with time/place

Conscious / 'Declarative'

Unconscious / 'Procedural'

Visual Memory
'Any neural or behavioural phenomenon implying storage of a past visual experience'.

Encoding

Semantic:
- multiple experience
- association of features

Episodic:
- single experience
- association with time/place

no associations

no context

imagination

Categories

Individual exemplars:
- e.g. Jeremy Corbyn
- e.g. Miley Cyrus
- e.g. The Crimea
- e.g. World Trade Centre

Visual 'events'
- 'snapshots' of scenes;
- groupings of recognised items/people & place.

'photographic' memory

'Recognition'

Familiarity

Recollection

Working Memory

Iconic Memory

Short-term Memory

Visual 'events'

‘deja vu’ = episodic false familiarity

Systems of categorisation:

Faces
- Animal
- Mammal
- Dog
- 'Scottie'

Facial identity

Facial expression

Colour
- red
- orange

Working Memory

Iconic Memory

Short-term Memory

Visual ‘events’

‘photographic’ memory

‘deja vu’ = episodic false familiarity

Visual Memory
‘Any neural or behavioural phenomenon implying storage of a past visual experience’.
e.g. Semantic familiarity; learning individual faces

AM patch:
View invariant
Subject specific latency = 124 msec

AL patch:
View symmetrical latency = 104 msec

ML/MF patches:
View selective
Subject specific latency = 88 msec

e.g. Friewald & Tsao (2010) Hierarchical model [Ref 3]

Area TE neurons learning ‘facial’ features

parametric ‘face-space’:
- eye height
- eye separation
- nose length
- mouth height

The categorisation depends on two features only

Mean response of recorded population:
best type of each feature: worst type of each feature:

- eye height
- eye separation
- nose length
- mouth height

e.g. Sigala & Logothetis (2002) [Ref 2]

Training stimuli of face category 1 (★)
1 2 3 4 5

Training stimuli of face category 2 (●)
1 2 3 4 5
Large stimulus set = 125

**Semantic & Episodic**

<table>
<thead>
<tr>
<th>SEMANTIC</th>
<th>EPISODIC</th>
</tr>
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<tbody>
<tr>
<td>X</td>
<td>familiarity</td>
</tr>
<tr>
<td></td>
<td>recollection</td>
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</table>

**Novel v. Familiar Stimulus Sets**

**Areas TEO & TE**
- known together as ‘IT cortex’ (inferior temporal)

**Woloszyn & Sheinberg (2012)** [Ref 4] 
**Neural encoding of familiarity v novelty**

**Graph:**
- Broad spike = excitatory neuron
- Narrow spike = inhibitory neuron

**Time (µs):**
- 500 to 2500

**Stimulus set = 125**
Woloszyn & Sheinberg (2012) [Ref 4] Neural encoding of familiarity v novelty

Familiar

Novel

broad spike = excitatory neuron

narrow spike = inhibitory neuron
**Semantic vs. Episodic**

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**Broad Spike = Excitatory Neurons**

![Familiar vs Novel Graph 1](image)

- **Familiar**
  - Neural population: Average response to best stimulus
  - Average response to all stimuli

- **Novel**
  - Neural population: Average response to all stimuli

**Narrow Spike = Inhibitory Neurons**

![Familiar vs Novel Graph 2](image)

- **Familiar**
  - Neural population: Average response to best stimulus
  - Average response to all stimuli

- **Novel**
  - Neural population: Average response to all stimuli

*Woloszyn & Sheinberg (2012) [Ref 4] Neural encoding of familiarity vs novelty*
Paired-associate task:
1. Learn the specific pairings for 12 pairs of unfamiliar complex patterns;
2. Observe a single cue stimulus (any one of the 24 items) e.g. item 5’;
3. Recall associated item (item 5);
4. Select correct item from a choice of two (e.g. 5 & 8').
Area TE
Inferotemporal cortex

Area 36
Area 35
Perirhinal cortex

ECECEC
Entorhinal cortex

Naya, Miyashita et al. (2003-10) ‘Paired-associate task’ – learning arbitrary associations [5-7]

‘MEANING’
transient representation of cue object
... sustained recall of target object

Pair recall

longer latency; sustained activity

‘MEANING’
representation of cue-target pair

Pair coding
Kasahara et al. (2011) [Ref 8] Colour or shape pair associates task

<table>
<thead>
<tr>
<th>n = 375</th>
<th>pair coding</th>
<th>pair recall</th>
</tr>
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<tbody>
<tr>
<td>colour</td>
<td>19%</td>
<td>11%</td>
</tr>
<tr>
<td>shape</td>
<td>30%</td>
<td>7.7%</td>
</tr>
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</table>

PAIR CODING

PAIR RECALL

Area 36

PAIR CODING

PAIR RECALL

best colour

paired assoc. colour

best shape

paired assoc. shape

LATERAL ↔ MEDIAL

colour shape

rs

sts

rs
Yamashita, Miyashita et al. (2009) Memory consolidation in IT cortex (human fMRI) [ref 9]

Subjects required to learn 2 sets of pairings:

‘remote learning’ = 8 weeks before scan
‘recent learning’ = 30 minutes before scan

Hippocampus
Anterior IT cortex

Remote > Recent
Recent > Remote

Average activation for group, n = 30
Pair associate recall – hypothetical neural mechanism

RECENT LEARNING

REMOTE LEARNING
(as observed in highly trained macaques)
Pair associate recall – hypothetical neural mechanism (including display)

learnt pair

cue

choice

ACHIEVES SELECTION
Ranganath et al. (2004) Pair Associate recall (human fMRI) [ref 10]

**Task:**
1. Pre scan: learn face-house pairs;
2. In scan: recall pair associate, OR Perform match to sample task.

<table>
<thead>
<tr>
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<th>probe</th>
<th>Delay period activation:</th>
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'pair associate' task

'match-to-sample' task

**Pair associates task v. Match-to-sample task**

- **Cue Delay Probe**
- **Time (sec)**: 0 2 4 6 8 10 12 14 16 18 20 22
- **% Signal change**: 0.0 0.1 0.2 0.3 0.4 0.5 0.6

- **Anterior Prefrontal Cortex**
- **Hippocampus**
- **Caudate Nucleus**

- **p**: 10^-3, 10^-4
**Quiroga et al. (2009)**  
Single unit recordings from human: [ref 11]

- left posterior hippocampus: ‘Jennifer Aniston’ cell

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![Graph showing single unit recordings](image-url)
**Quiroga et al. (2009)** Single unit recordings from human: [ref 11]

- left anterior hippocampus: ‘Oprah Winfrey’ cell

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- Oprah Winfrey
- Cameron Diaz
- Sandra Bullock
- Yoda
- Luke Skywalker
- Darth Vader
- Clint Eastwood
- Whoopi Goldberg
- Andrea Parker
- Luke Skywalker
- Cameron Diaz
- Oprah Winfrey

50 Hz
1s
Quiroga et al. (2009) Single unit recordings from human [ref 11]

- left amygdala: ‘Arne’ (one of the research team)
Quiroga et al. (2009) Single unit recordings from human entorhinal cortex [ref 11]
The hippocampus forms the curled-up, lateral rim of the cortical sheet.

**Hippocampal learning:**
- Arbitrary associations;
- Multimodal;
- One shot;

All episodic in character.

Hippocampus is Latin for ‘sea-horse’.
Coronal brain section in nonhuman primate (Macaque monkey)

Hippocampus
The Hippocampal Loop

- Entorhinal cortex
- Subiculum
- CA1, CA2, CA3
- Dentate gyrus
- Granule cells
- Pyramidal cells
- Perforant Path
The hippocampal loop: circuitry

ERC = Entorhinal Cortex
DG = Dentate Gyrus
CA = Cornu Ammonis
Sub = Subiculum
The hippocampal loop: circuitry

Ramon y Cajal (1911) ‘Histologie du système nerveux de l'homme et des vertébrés’
An auto-association (or attractor) neural network theory of memory.

Hebb’s Law: ‘Cells that fire together, wire together’

CA3

familiarity
recollection
An auto-association (or attractor) neural network theory of memory.
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