INF1-CG 2015
Lecture 19

Memory: Computational issues

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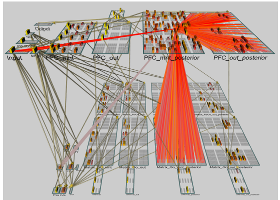
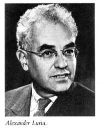
Today's goals



We will look at some of the computational aspects of long- and short-term memories.

Readings for the memory lectures

Luria, A. R., & Solotaroff, L. T. (1987). *The mind of a mnemonist: A little book about a vast memory*. Harvard University Press. (obtained by Googling A.R.Luria-The Mind of a Mnemonist-OCRd.pdf)



Anderson, J. R., & Schooler, L. J. (1991). Reflections of the environment in memory. *Psychological Science*, *2*(6), 396-408.

The story so far

Distinctions (abstractions) have been made concerning different types of memory.

Differential impairment has been the strongest argument for distinctions within memory.

We can look at memory from the perspective of the whole life of the individual.

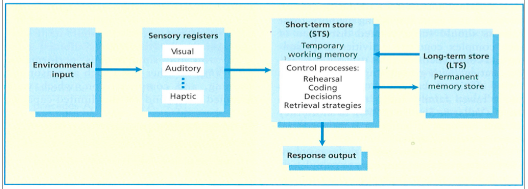
The Modal model of memory

Atkinson & Shiffrin (1968)

1. Information enters from the environment.
2. Brief processing in sensory systems.
3. Information goes to a short-term store (STS).
   – Passes information in and out of LTM
   – Workspace to perform operations, select and rehearse information.
   – Items are learned if held in this store.
4. Information is output or goes into long–term store (LTS).

The Modal model of memory

Atkinson & Shiffrin (1968)



We can specify stages of processing – *ordered relations* between these abstractions.
The model clarifies our thoughts; implementing it on a computer may do the same, but we want more than a redescription of the data.

Evidence from a dissociation

However, there is contradictory lesion evidence:

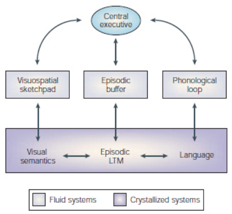
Shallice and Warrington (1970) reported a patient with severe STS-type deficits, but with an unimpaired LTS.

Shallice and Vallar (1990) report a patient with impaired STS, but able to drive a taxi or run a business.

The *ordering* of these abstract stages had to be amended.

Types of short-term memory

Baddeley and Hitch (1974, *etc.*)

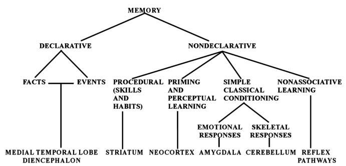


Different types of short-term memory have been postulated, modelled and experimented upon.

Remembering a list of words is a paradigm task.

Types of longterm memory

Squire (2004)



We can make qualitative distinctions between types of memory, aligned with crude anatomical distinctions, based on similarities over many real instances.

Such abstractions are always liable to defeat by new data, however …

"Personal Semantics" …

Renoult *et al.* (2012)

	Autobiographical facts	Self-knowledge	Repeated events	AS concepts[a]
Examples	My brother's name is Nicholas	I am a stubborn person	I brought my brother to school every day	Knowledge that Barack Obama is President + Recollection of an argument with my brother as to whether he should be re-elected
Typical neural correlates	MPFC, retrosplenial cortex, temporal pole, posterior temporal cortex	MPFC, retrosplenial cortex, precuneus, middle and inferior temporal gyri, inferior parietal lobe	MPFC, hippocampus, para-hippocampal gyrus, temporo-parietal junction, fusiform gyrus, inferior temporal cortex	MTL, temporo-parietal junction, ventrolateral prefrontal cortex, fusiform gyrus
Neuropsychological patterns	Similar to GS	Different from GS and EM	Similar to EM	Similar to EM

[a]Abbreviations: AS concepts, autobiographically significant concepts; GS, general semantic memory; EM, episodic memory; MPFC, medial prefrontal cortex; MTL, medial temporal lobe.

… "a personal pool of generalized knowledge" between general semantic memory and episodic memory.

There are deep difficulties in making categorical distinctions between different types of memory

Making distinctions

… These difficulties arise because we are dealing with abstract generalizations and we struggle to find any material content that distinguishes them categorically.

We talk in *spatial-metaphor terms* of perspectives, inclusion, extent, vantage-point, division …

(*This analysis will really help you make sense of box-and-arrow diagrams.*)

Sensory memories

Sperling (1960)

Iconic memory: immediate 100–250 msec visual stores, including afterimages, as shown by a "partial report paradigm."

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a j l
p d m
y f x
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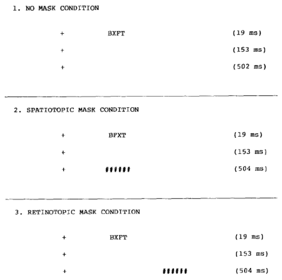
Sensory memories

McRae *et al.* (1987)



There are both retinotopic and spatiotopic components.

Inspecting iconic memories

Vlassova & Pearson (2013)

Sampling from a decaying memory trace; in the absence of different incoming data (e.g. masking). Simply waiting and accessing the memory can dramatically improve accuracy of responding.

Accessing memory can be as good as viewing the object.

So even though iconic storage looks very specific and isolated at the sensory periphery, there are complexities.

Category specific impairments

Warrington & Shallice (1984)

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Naming a picture or recognizing a printed word are functions of memory. Such behaviours can be very specifically impaired by insults such as encephalitis: living things, foods, concrete words, nouns …

Are memories *essentially* organized in terms of these categories? Could a model of memory capture such breakdowns *emergently*?

Types of memory

So we can try to define types of memory in terms of (a) their content, (b) patterns of impairment (typically, in humans, because of stroke or disease, rather than development), and (c) their possible anatomical locations.

Animal experiments can give us data, but animal memory has limited dimensionality.

All these criteria are problematic.

Simplicity and complexity

In selecting a model (*i.e.* an explanation) there is a choice between complexity and simplicity.

We can try and capture all the (possibly noisy) data points or we can try and make the best predictions.

We can value having the fewest parameters in a model. We can value having the fewest types of thing in the world.

(This is a philosophical issue not decidable by any new mathematical algorithm. See the *SEP* for pointers.)

Dissolving distinctions

One goal of modellers has been to show that some distinctions can *emerge* from computational architectures that don't seem to have such distinctions built into them.

Or we might try to show that the same principles can account for data in different types of memory (*e.g.* in short and long periods of time).

Retrieving and forgetting

The strength of a memory trace might determine retrieval. Perhaps it fades over time.

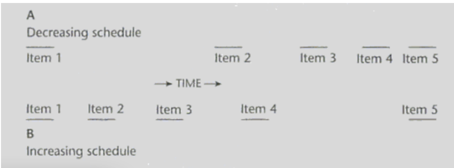
The context in which an event happened might let us reconstruct, infer the details, and retrieve.

Perhaps explicit pairwise relations between events are stored.

The temporal recency of an event might determine how easily it can be retrieved.

Retrieving and forgetting

Neath & Crowder (1996)

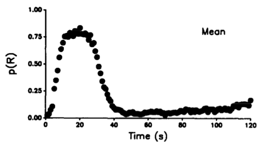


We can distinguish experimentally between timing, order and position. Temporally close events are confused, not ordinally or positionally close events.

Animals can judge time

Church & Broadbent (1990)

The rat is required to wait for 20s before responding in the "peak procedure" task. *Some* sort of internal representation of time is required. This might be important for optimizing foraging.



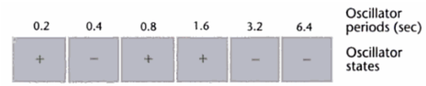
Judging time

A central clock-like pulse could store up pulses in working memory: large number = long time.

The basal ganglia may be implicated: Harrington, Haarland and Hermanowitz (1998) looked at the estimation of time, and at timing tasks, in patients with Parkinsonism. Such patients are impaired.

Oscillators

Church & Broadbent (1990)



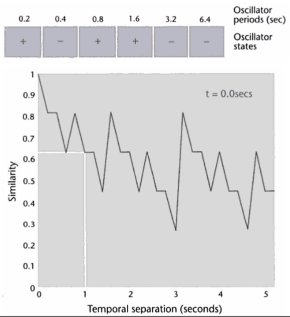
The brain contains pervasive recurrent connectivity and rhythmic activity.

A set of oscillators of different frequency can provide a snapshot of when an individual event occurs.

Such snapshots might be a way of "time-stamping" events. Pick a time and run the clock to retrieve.

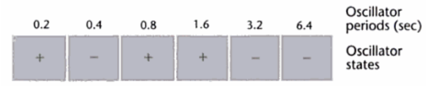
Oscillators

Church & Broadbent (1990)



Oscillators

Brown, Preece & Hulme (2000)

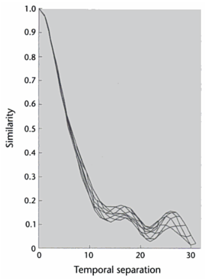


The frequencies of the oscillators can be changed to capture qualitative and quantitative effects of grouping and timescale.

Movement ordering and movement timing may have very similar underlying mechanisms (Rosenbaum, 1985).

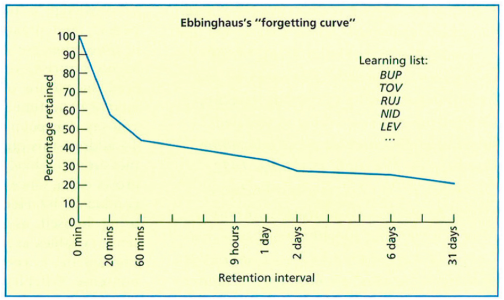
Oscillators

Brown, Preece & Hulme (2000)



Two events in the past will be more similar to each other than will two more recent events.

Forgetting over time



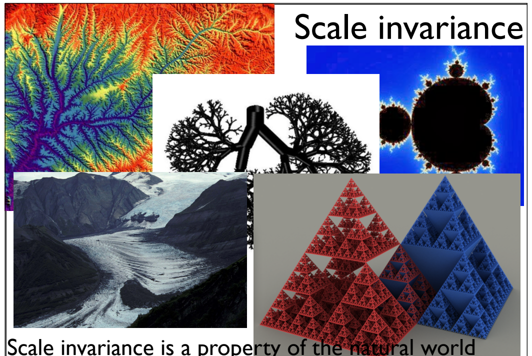
Less and less is remembered with the passage of time.

A spatial metaphor

Crowder (1976)

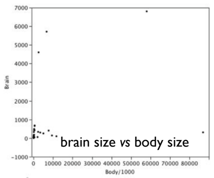
Telegraph poles go past at a steady rate. As they recede in the distance they become less discriminable. Time and space are closely analogous in psychological terms.

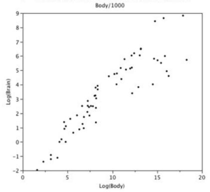
Scale invariance



Scale invariance is a property of the natural world with which we might expect cognition to resonate

Log transform





X	Log$_{10}$(X)
1	0
10	1
100	2

Turning quantities into their logs makes distributions appear more linear.

The brain often seems to do this.

(There may be a deeper understanding of this, grounded in probability.)

The SIMPLE model

Brown, Neath & Chater (2007)

"Scale-invariant Memory, Perception and Learning"

It assumes a psychological space corresponding to a log-transformation of time elapsed since memory formation.

Two retrieval cues become exponentially similar the closer together they are along that dimension.

Retrieval of one entry is interfered with by its neighbours.

The SIMPLE model

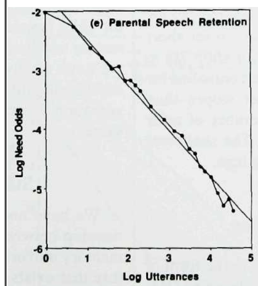
Brown, Neath & Chater (2007)

This retrieval mechanism closely resembles claims for mechanisms governing categorization, perception and learning.

It is an argument against forgetting due to fading.

The rational modelling approach

Anderson (1990), Anderson & Schooler (1991)



Cognition adaptively reflects the statistical structure of the environment.

How likely are we to need a particular piece of information at any one time? – its "need probability".

Foraging

What does an animal need to be able to do to forage for food successfully?

It needs to be sensitive to time of day, time of year, distance, rewards from food, costs of travel, recency, familiarity, …

Such requirements may underlie human memory (without reducing human capacities to animal ones).

How monolithic is memory?

If the same principles can be employed across apparently different types of memory, do we need to say there is a qualitative difference between them?

What about distinguishing between memory, perception, categorisation and learning?

How are these general principles instantiated?

Principles

Time passed is important, particularly in the short term. It is arguably the *essence* of memory phenomena.

Other dimensions can be important, particularly over longer times and more complex environments; e.g. hierarchical organization, as in confusions between the contents of the last place in different lists.

Challenges

Think about how the processes we have talked about might apply in the case of Luria's Shereshevsky, but also in normal everyday tasks.

How might we have memory specific to modality, to certain forms of content, *etc.* but also with more general mechanisms involved?

Think about the status of the role of elapsed time in a model. It is a *real material thing*; it mediates everything else in the model.

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